CDMA 101

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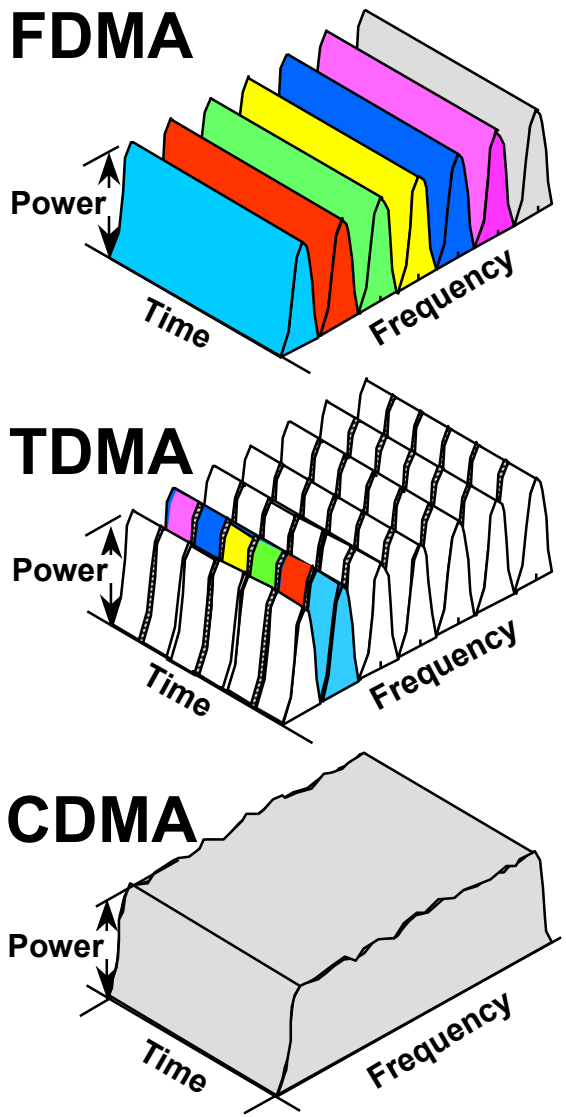
CDMA 101 Outline

- **CDMA Basics**
  - **Multiple Access Technology Survey**
  - **CDMA coding principles**
  - **Spread Spectrum principles**
  - **Forward and Reverse Channel Structure**
- **Nortel CDMA System Architecture**
  - **MTX BSC BSM BTS**
- **CDMA Details and Operation**
  - **Power Control**
  - **Handoff mechanics**
  - **Optimization concepts**

CDMA Basics

Multiple Access Technologies

- **FDMA** (example: AMPS)
  - **Frequency Division Multiple Access**
    - each user has a private frequency
- **TDMA** (examples: IS-54/136, GSM)
  - **Time Division Multiple Access**
    - each user has a private time on a private frequency
- **CDMA** (IS-95, J-Std. 008)
  - **Code Division Multiple Access**
    - users co-mingle in time and frequency but each user has a private code



Other Technologies: Avoiding Interference

- **AMPS, TDMA and GSM depend on physical distance separation to keep interference at low levels**
- **Co-channel users are kept at a safe distance by careful frequency planning**
- **Nearby users and cells must use different frequencies to avoid interference**

AMPS-TDMA-GSM

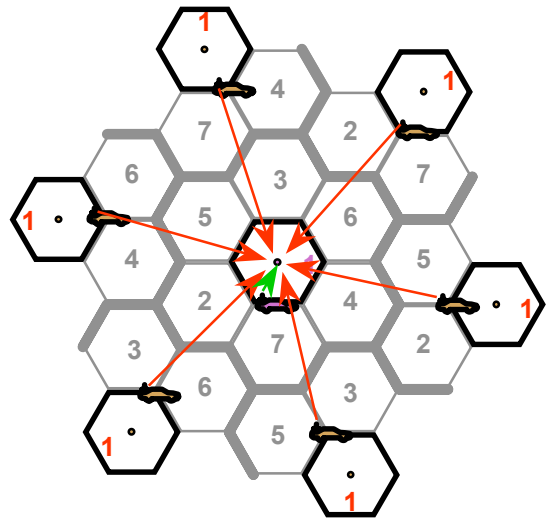


Figure of Merit: C/I
(carrier/interference ratio)
AMPS: +17 dB
TDMA: +14 to 17 dB
GSM: +7 to 9 dB.

CDMA: Using A New Dimension

- All CDMA users occupy the same frequency at the same time! Time and frequency are not used as discriminators
- CDMA interference comes mainly from nearby users
- CDMA operates by using CODING to discriminate between users
- Each user is a small voice in a roaring crowd -- but with a uniquely recoverable code

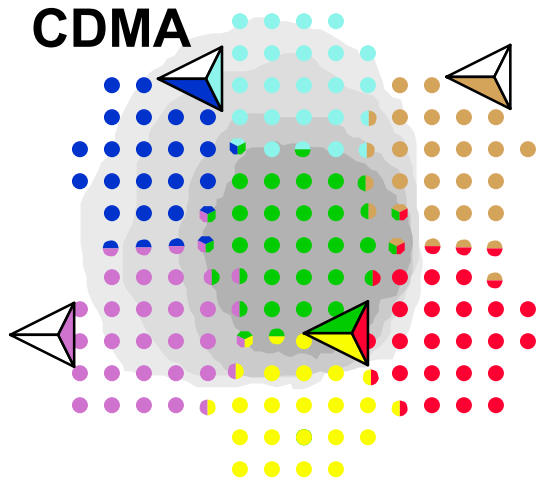
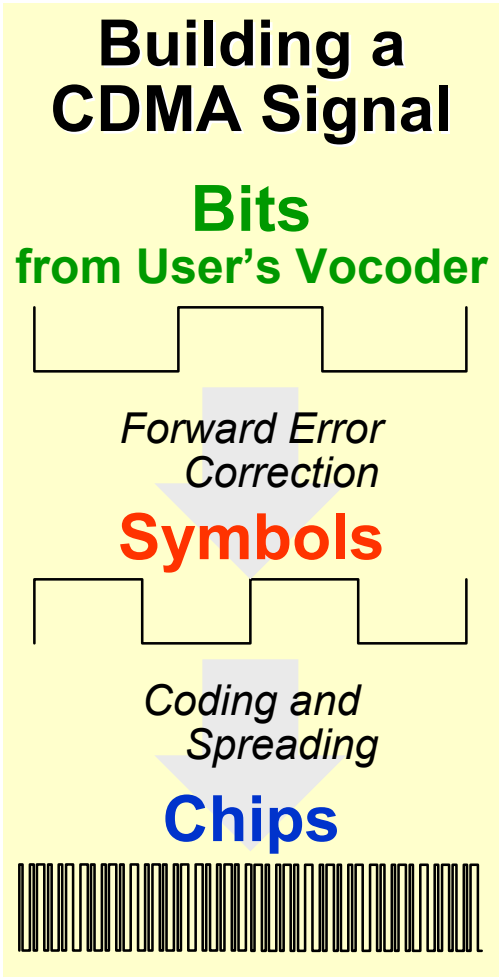


Figure of Merit: C/I
(carrier/interference ratio)
AMPS: +17 dB
TDMA: +14 to +17 dB
GSM: +7 to 9 dB.
CDMA: -10 to -17 dB.
CDMA: E_b/N_o ~+6 dB.

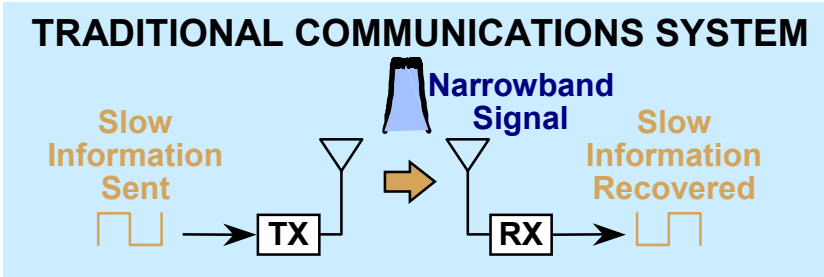
CDMA Uses Code Channels

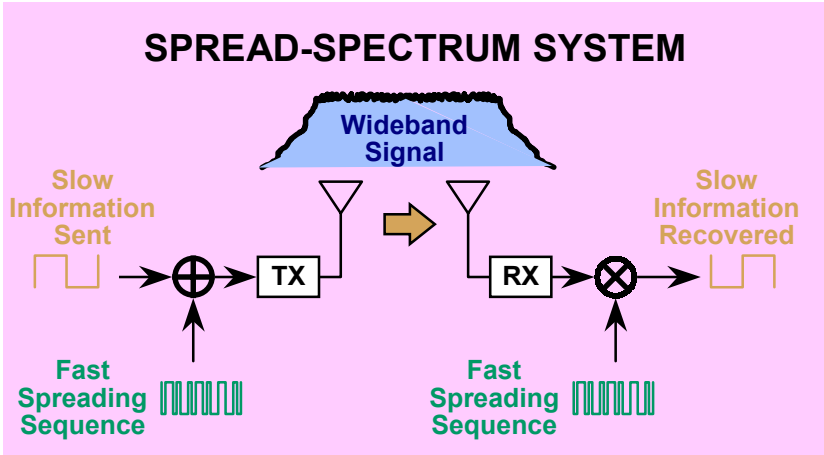
- A CDMA signal uses many chips to convey just one bit of information
- Each user has a unique chip pattern, in effect a code channel
- To recover a bit, integrate a large number of chips interpreted by the user's known code pattern
- Other users' code patterns appear random and integrate toward low values, hence don't disturb the bit decoding decision



CDMA is a Spread-Spectrum System

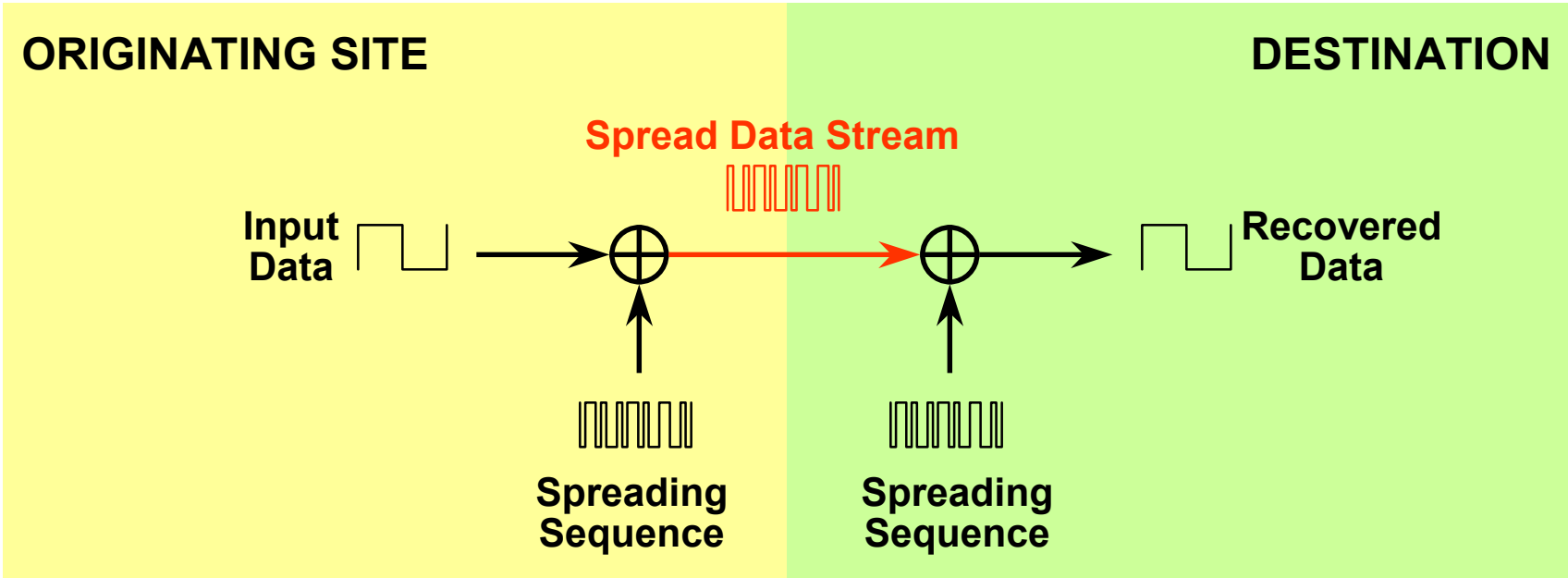
- **Traditional technologies try to squeeze signal into minimum required bandwidth**
- **CDMA uses larger bandwidth but uses resulting processing gain to increase capacity**





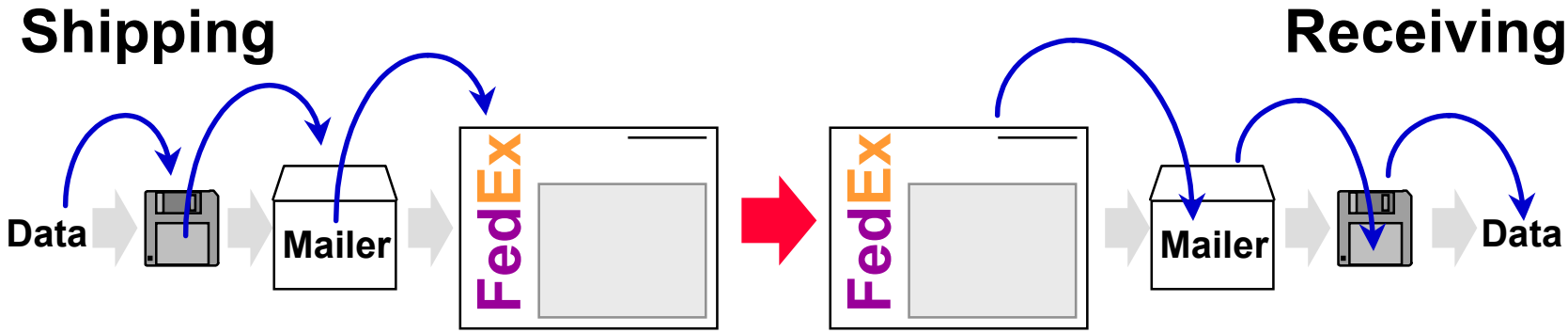
Spread Spectrum Payoff: Processing Gain

Spreading: What we do, we can undo



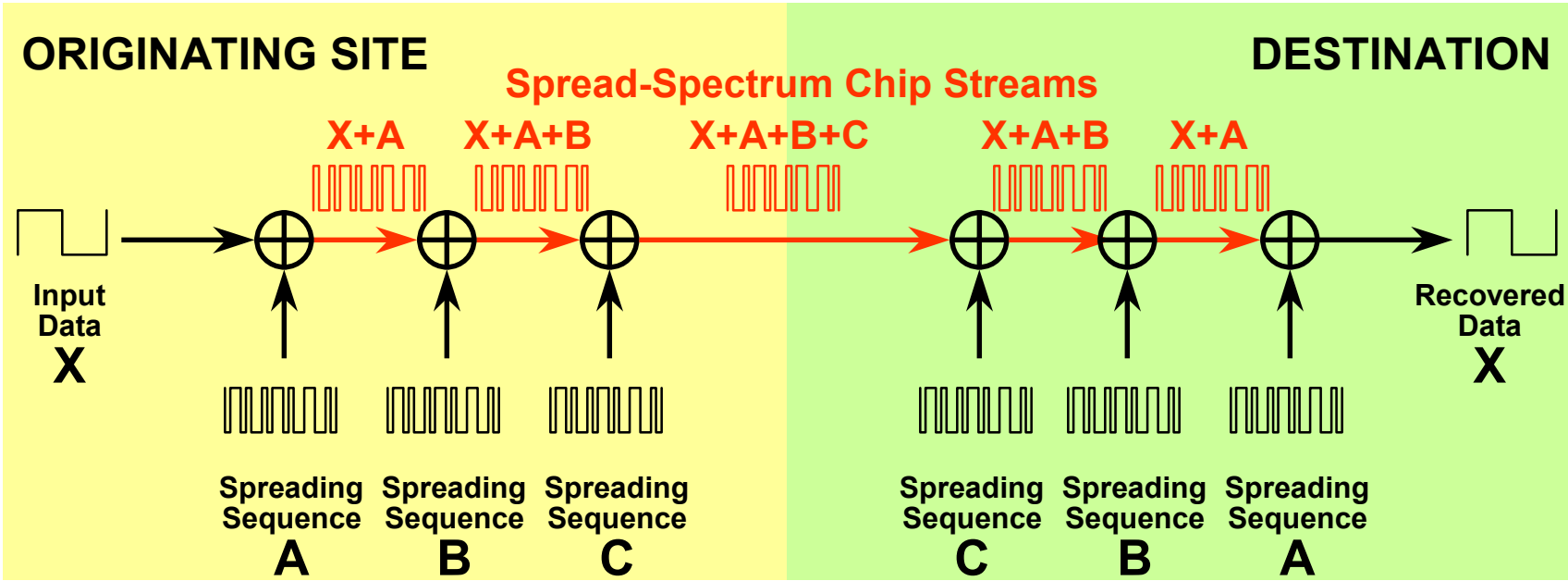
- Sender combines data with a fast spreading sequence, transmits spread data stream
- Receiver intercepts the stream, uses same spreading sequence to extract original data

"Shipping and Receiving" via CDMA



- Whether in shipping and receiving, or in CDMA, packaging is extremely important!
- Cargo is placed inside "nested" containers for protection and to allow addressing
- The shipper packs in a certain order, and the receiver unpacks in the reverse order
- CDMA "containers" are spreading codes

CDMA's Nested Spreading Sequences

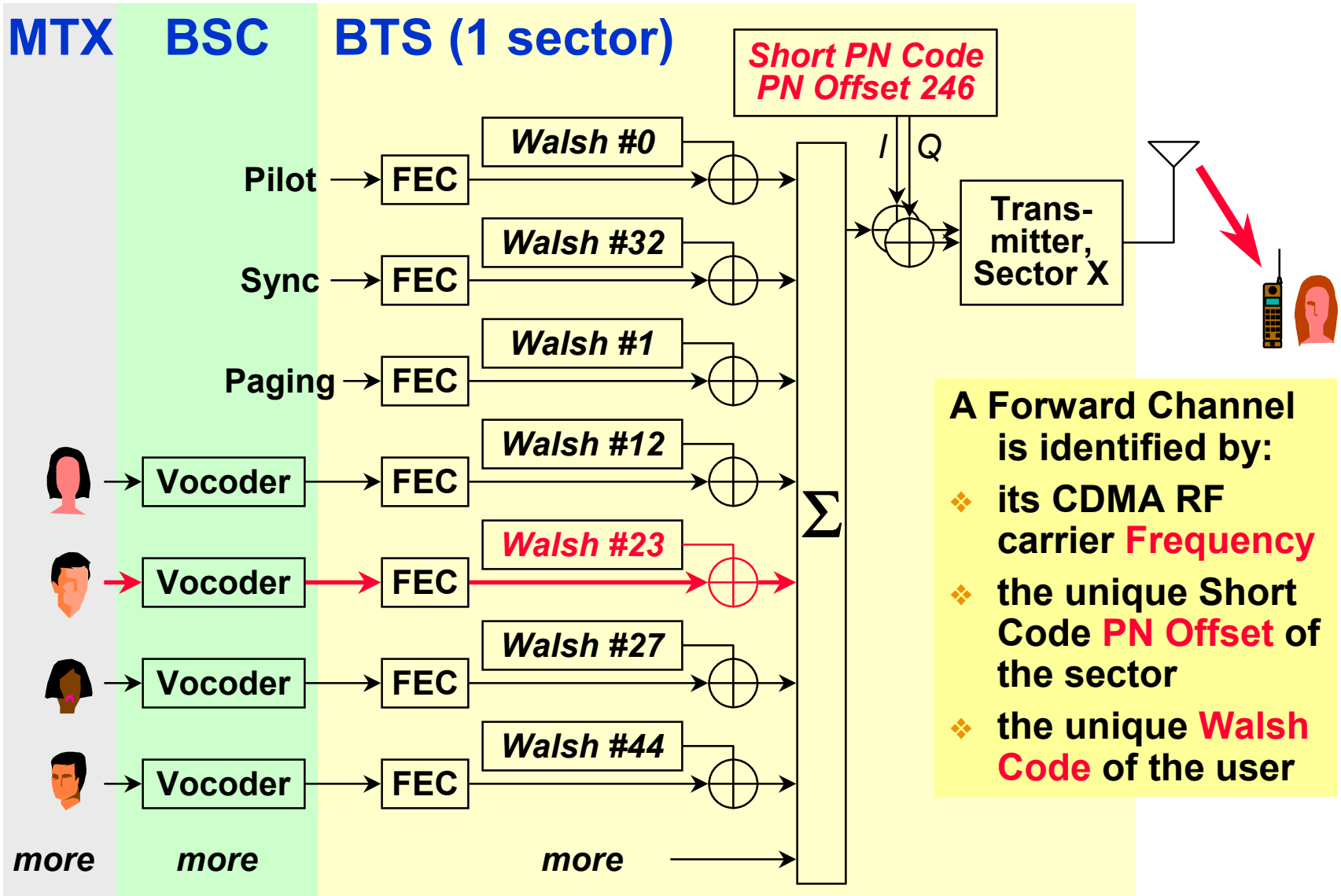


- CDMA combines three different spreading sequences to create unique, robust channels
- The sequences are easy to generate on both sending and receiving ends of each link
- "What we do, we can undo"

The Three CDMA Spreading Sequences

- **Walsh Codes:** *64 are available*
  - **64 chips long -- lasts 1/19200 sec**
  - **mutually orthogonal**
- **PN Short Code:** *one pair is used (I & Q)*
  - **32K long -- lasts 26-2/3 mS, repeats 75x in 2 sec.**
    - **generated in 15-bit tapped shift register**
  - **Nearly self-orthogonal if compared out-of-sync**
- **PN Long Code:** *only one is used*
  - **2^{42}-1 chips long -- lasts 40+ days!**
    - **generated in 42-bit tapped shift register**
  - **Any short sample is nearly orthogonal with any other short sample**

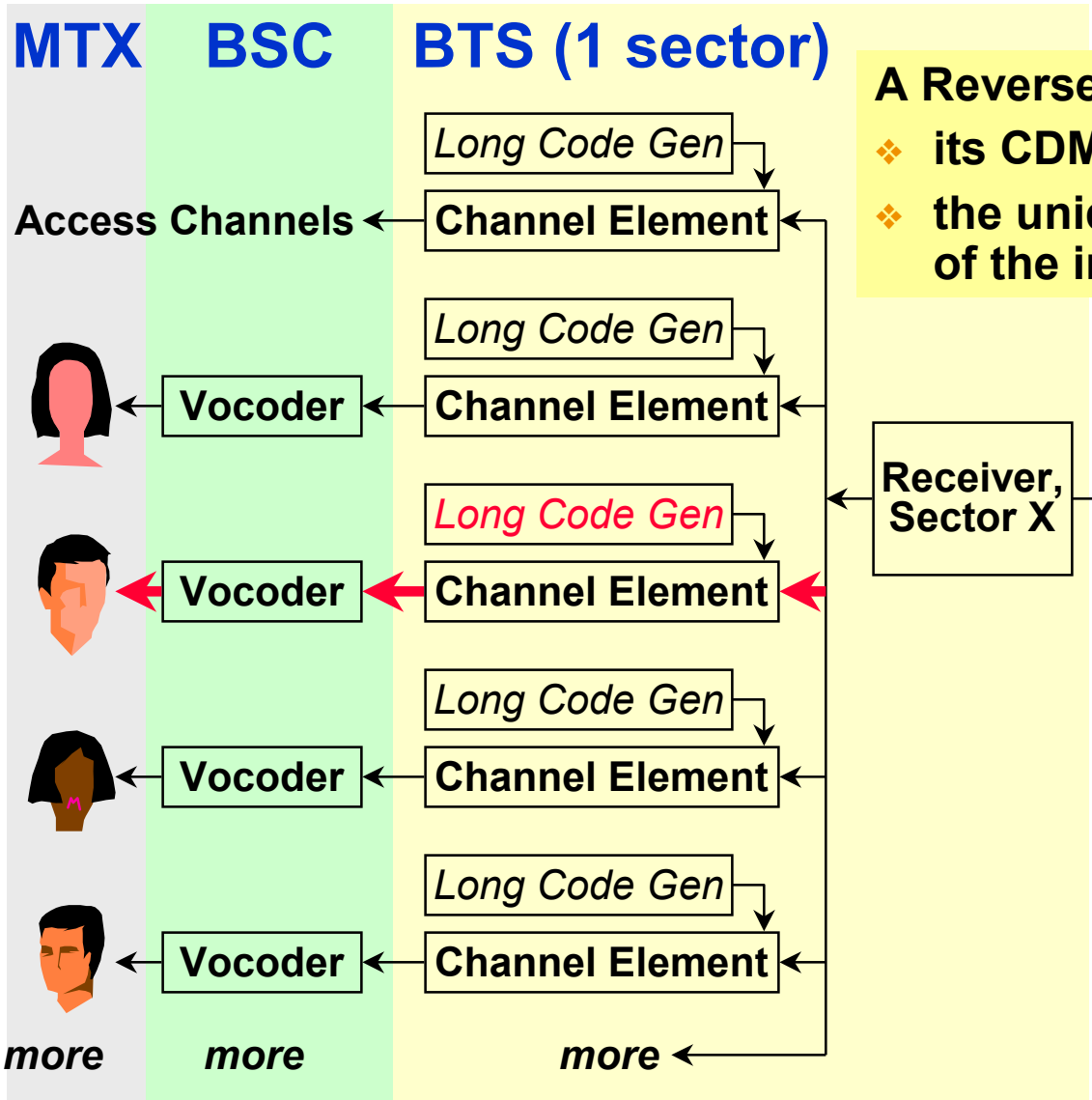
Code Channels in the Forward Direction



A Forward Channel is identified by:

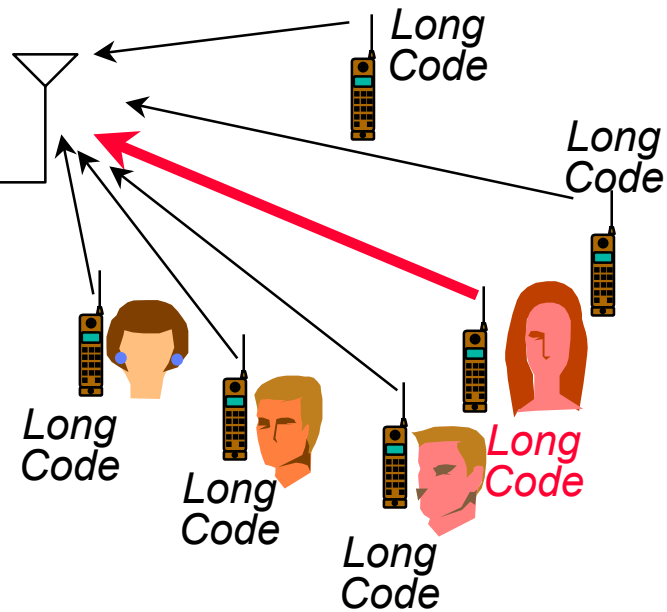
- its CDMA RF carrier Frequency
- the unique Short Code PN Offset of the sector
- the unique Walsh Code of the user

Code Channels in the Reverse Direction



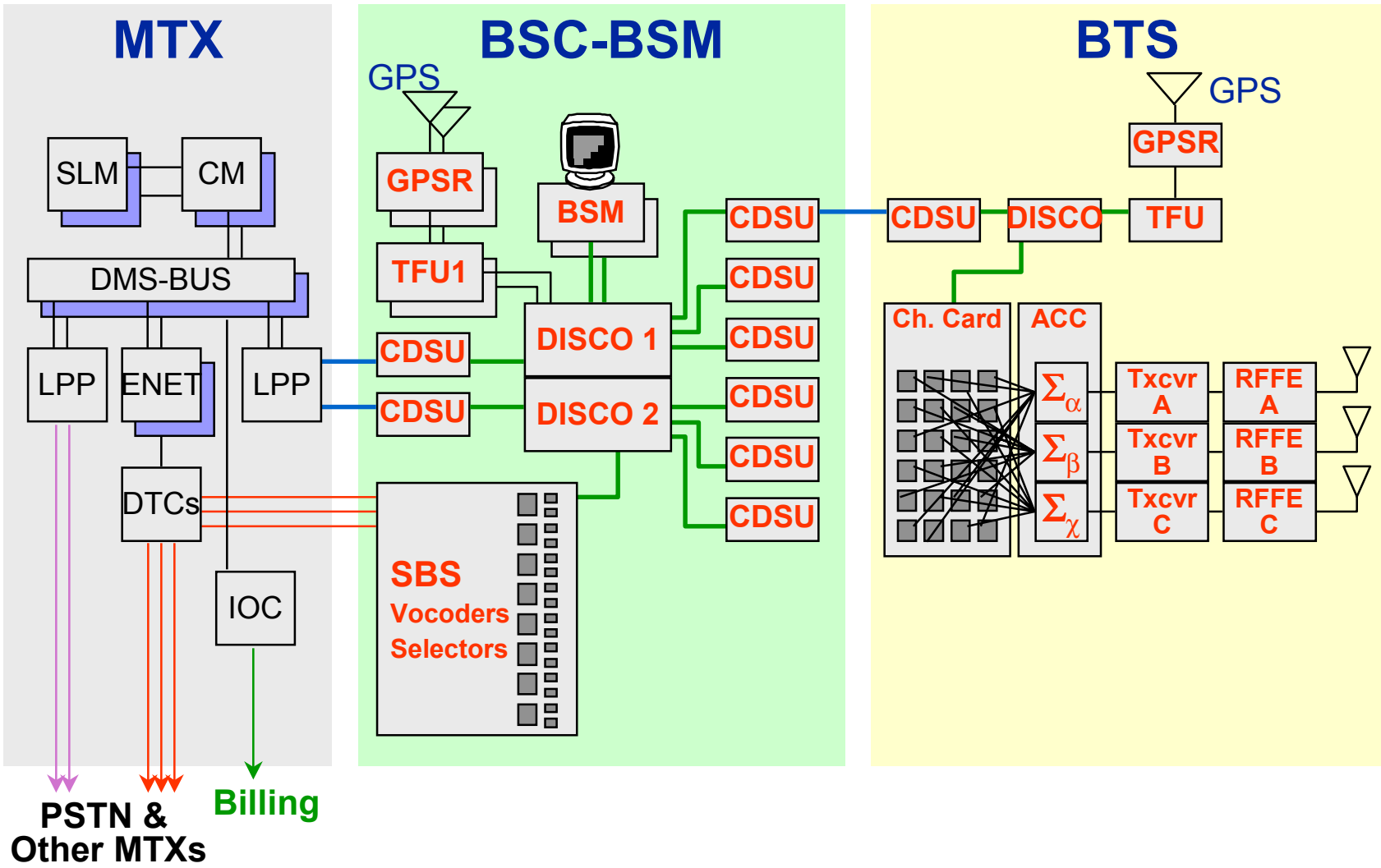
A Reverse Channel is identified by:

- its CDMA RF carrier **Frequency**
- the unique **Long Code PN Offset** of the individual handset

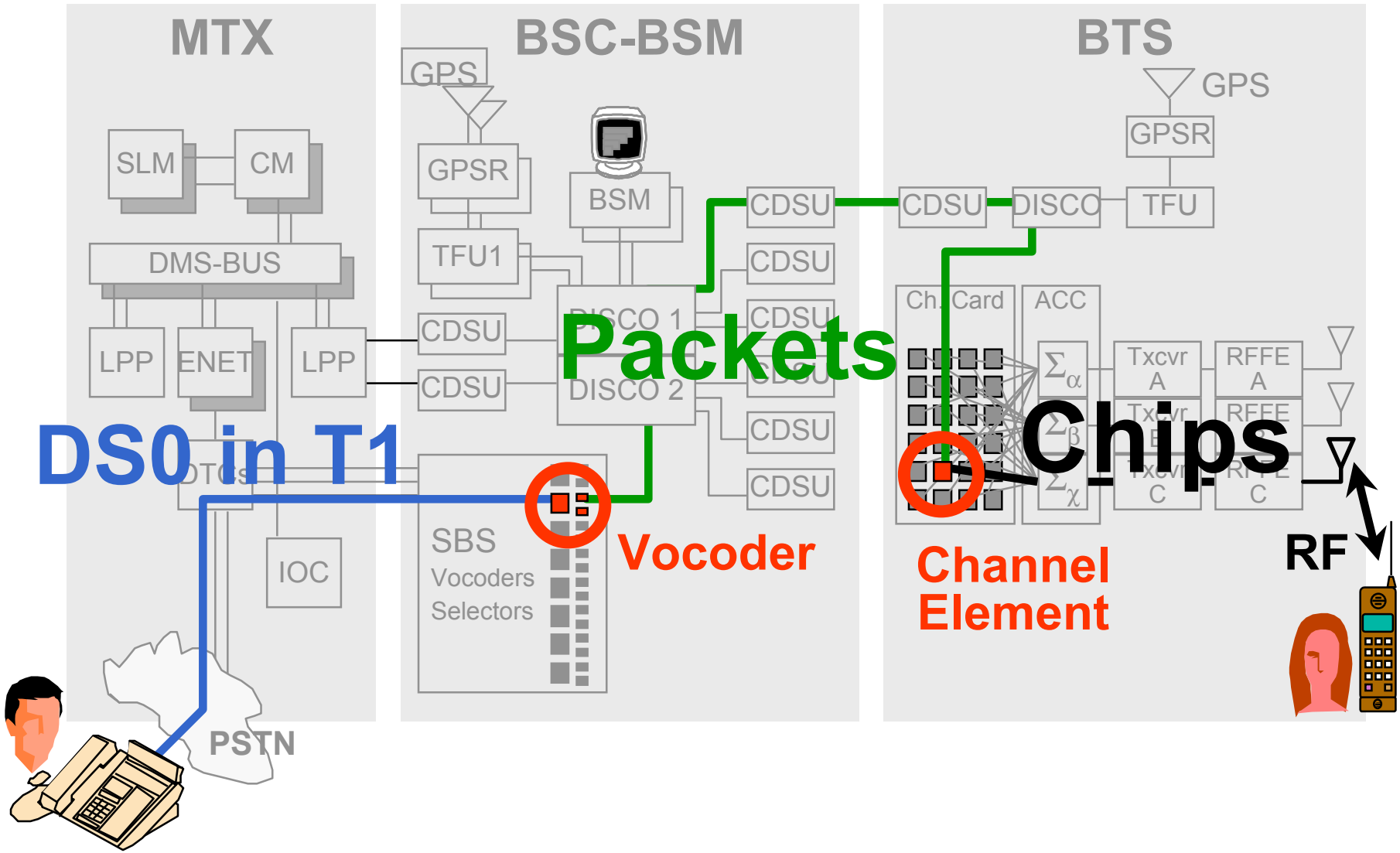


CDMA System Architecture

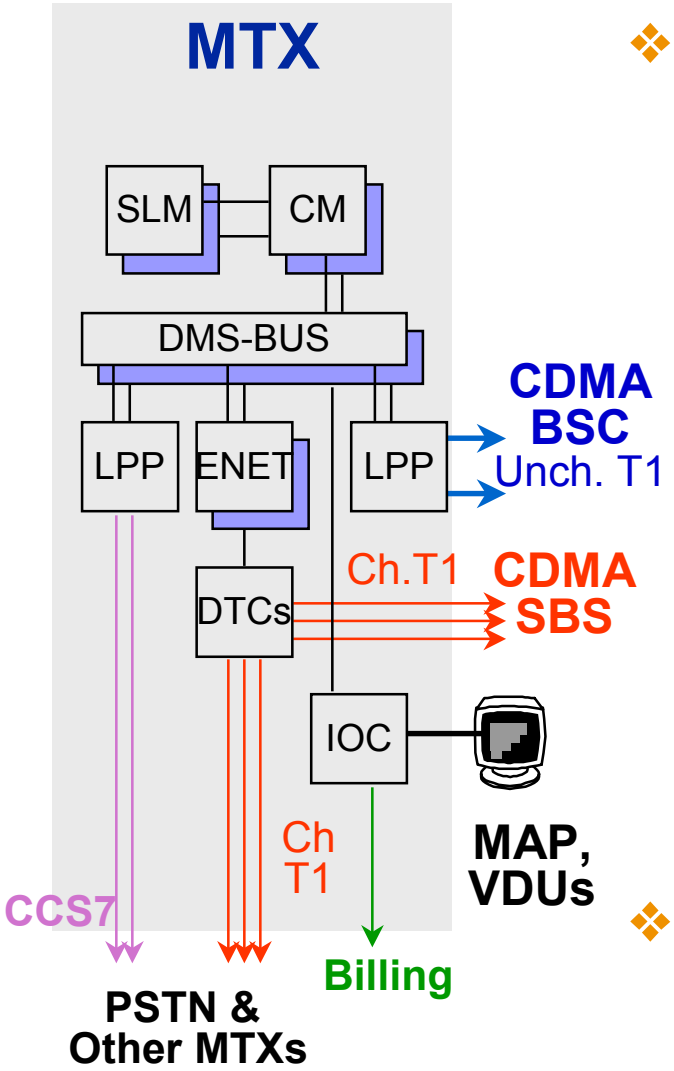
NORTEL CDMA System Architecture



Signal Flow: Two-Stage Metamorphosis

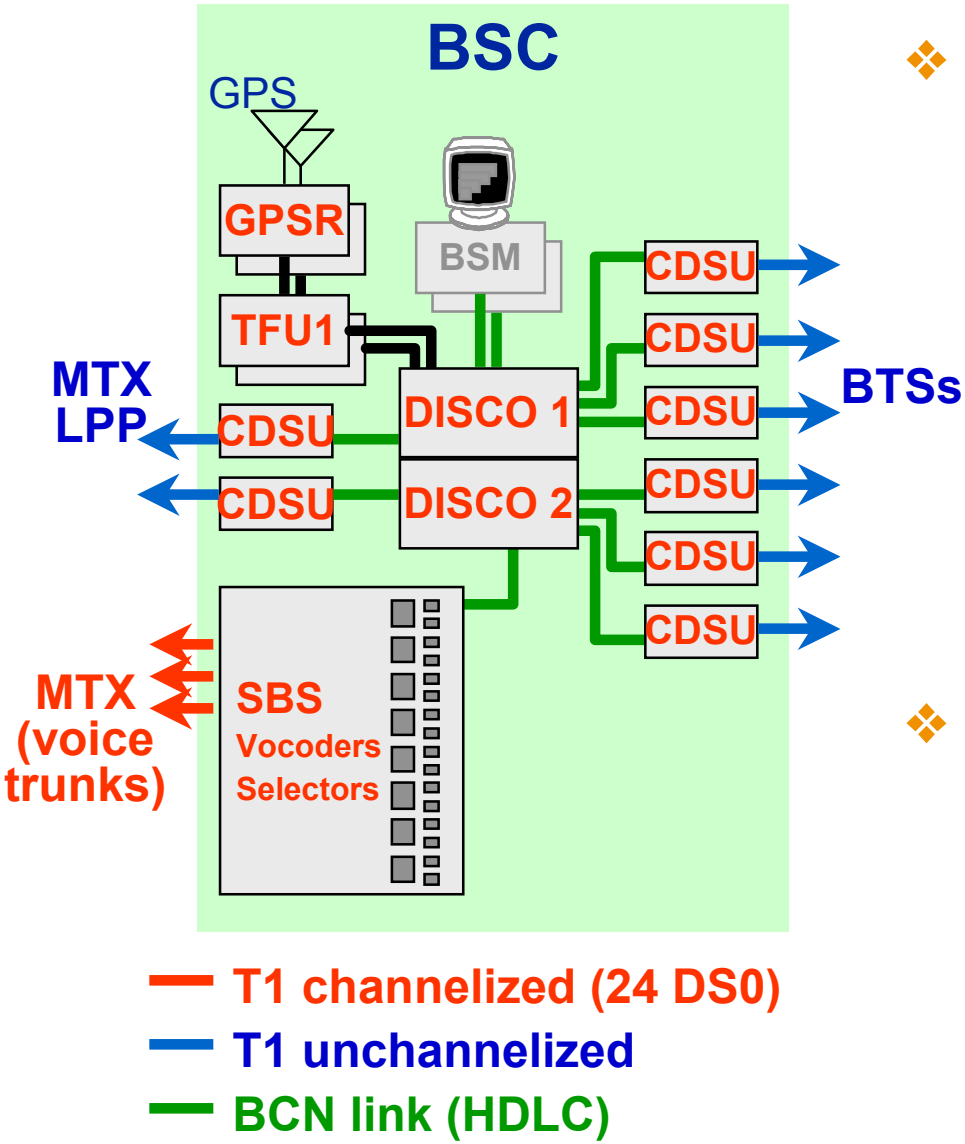


Architecture: The MTX



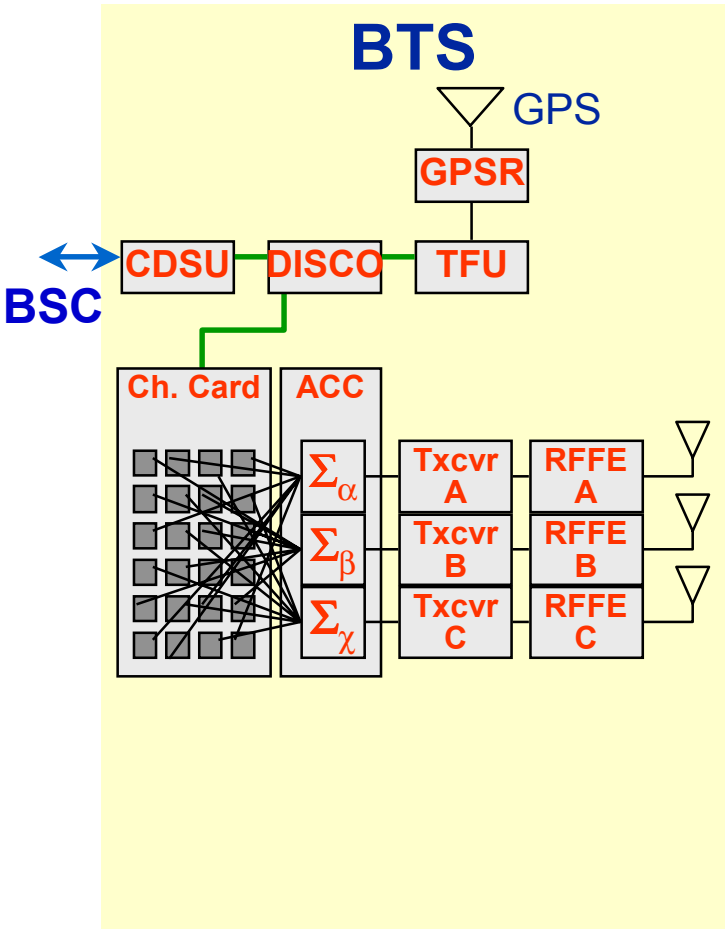
- **Primary functions**
  - **Call Processing**
  - **Mobility Management**
    - **HLR-VLR access**
    - **Intersystem call delivery (IS-41C)**
    - **Inter-MTX handover (IS-41C)**
  - **Billing Data Capture**
  - **Calling Features & Services**
  - **Collecting System OMs, Pegs**
- **High reliability, redundancy**

Architecture: The BSC



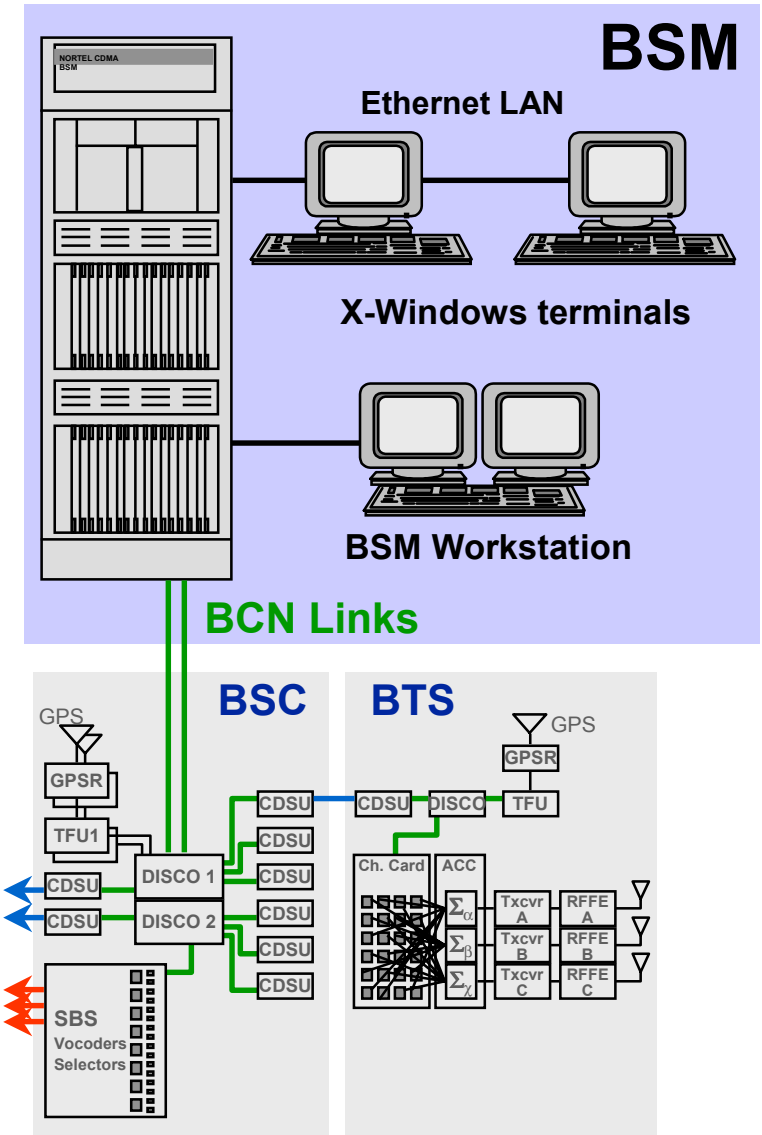
- Primary functions
  - vocoding
  - soft handoff management
  - FER-based power control
  - routing of all traffic and control packets
- Scaleable architecture
  - expand SBS to keep pace with traffic growth
  - expandable DISCO

Architecture: The BTS



- Primary function: Air link
  - generate, radiate, receive CDMA RF signal IS-95/J.Std. 8
  - high-efficiency T1 backhaul
  - test capabilities
- Configurations
  - 1, 2, or 3 sectors
  - 800 MHz.: indoor
  - 1900 MHz.: self-contained outdoor, remotable RFFEs
  - future: 1900 MHz. indoor, 800 & 1900 multi-carrier options

Architecture: The BSM

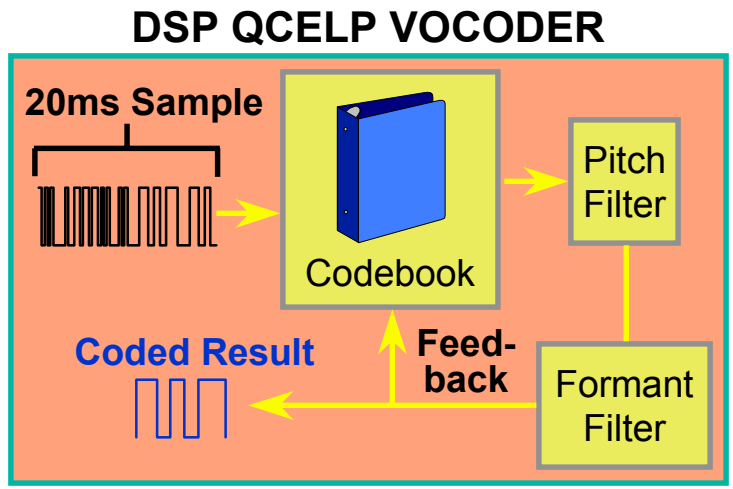


- Primary functions: OA&M for CDMA components
  - Configuration management
    - BSC, BTS configuration and parameters
  - Fault management
    - Alarm Reporting
  - Performance management
    - interface for CDMA statistics and peg counts collection
  - Security management
  - Unix-based

CDMA Details and Operation

Variable Rate Vocoding & Multiplexing

- Vocoders compress speech, reduce bit rate
- CDMA uses a superior Variable Rate Vocoder
  - full rate during speech
  - low rates in speech pauses
  - increased capacity
  - more natural sound
- Voice, signaling, and user secondary data may be mixed in CDMA frames

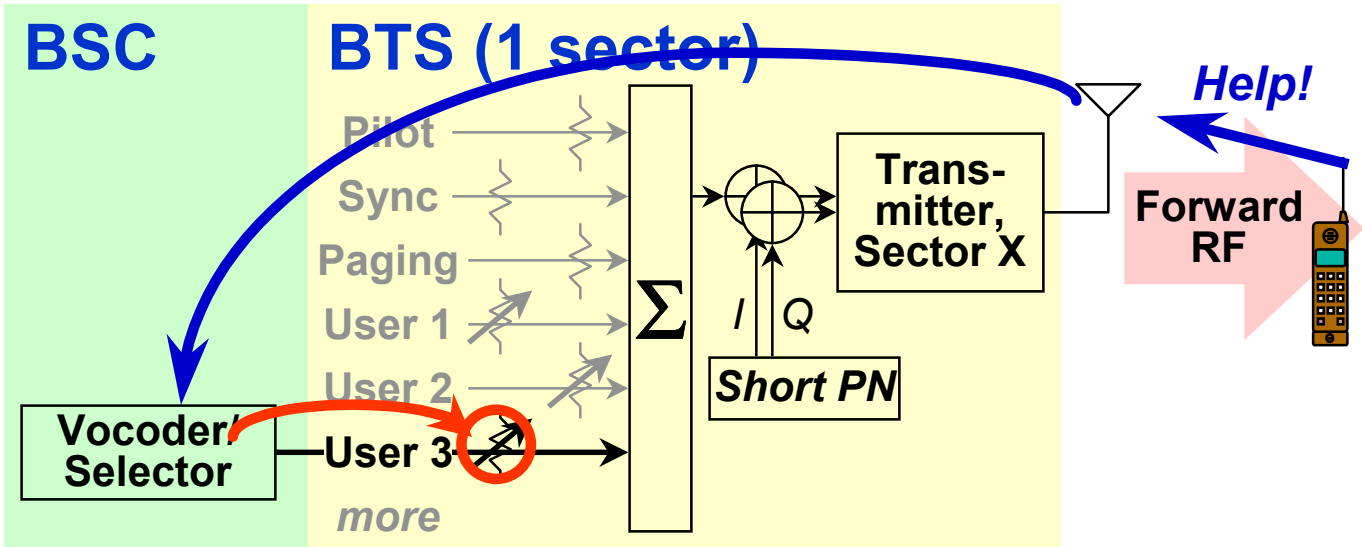


bits	Frame Sizes
288	Full Rate Frame
144	1/2 Rate Frame
72	1/4 Rt.
36	1/8

Frame Contents: can be a mixture of

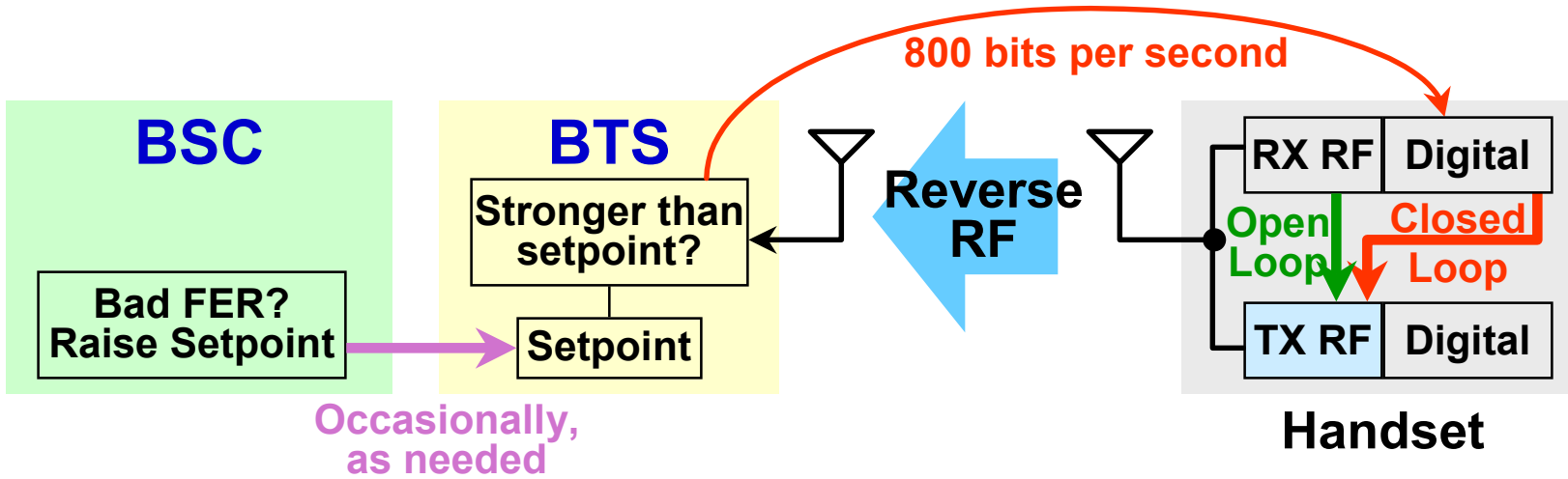
Voice | Signaling | Secondary

Forward Power Control



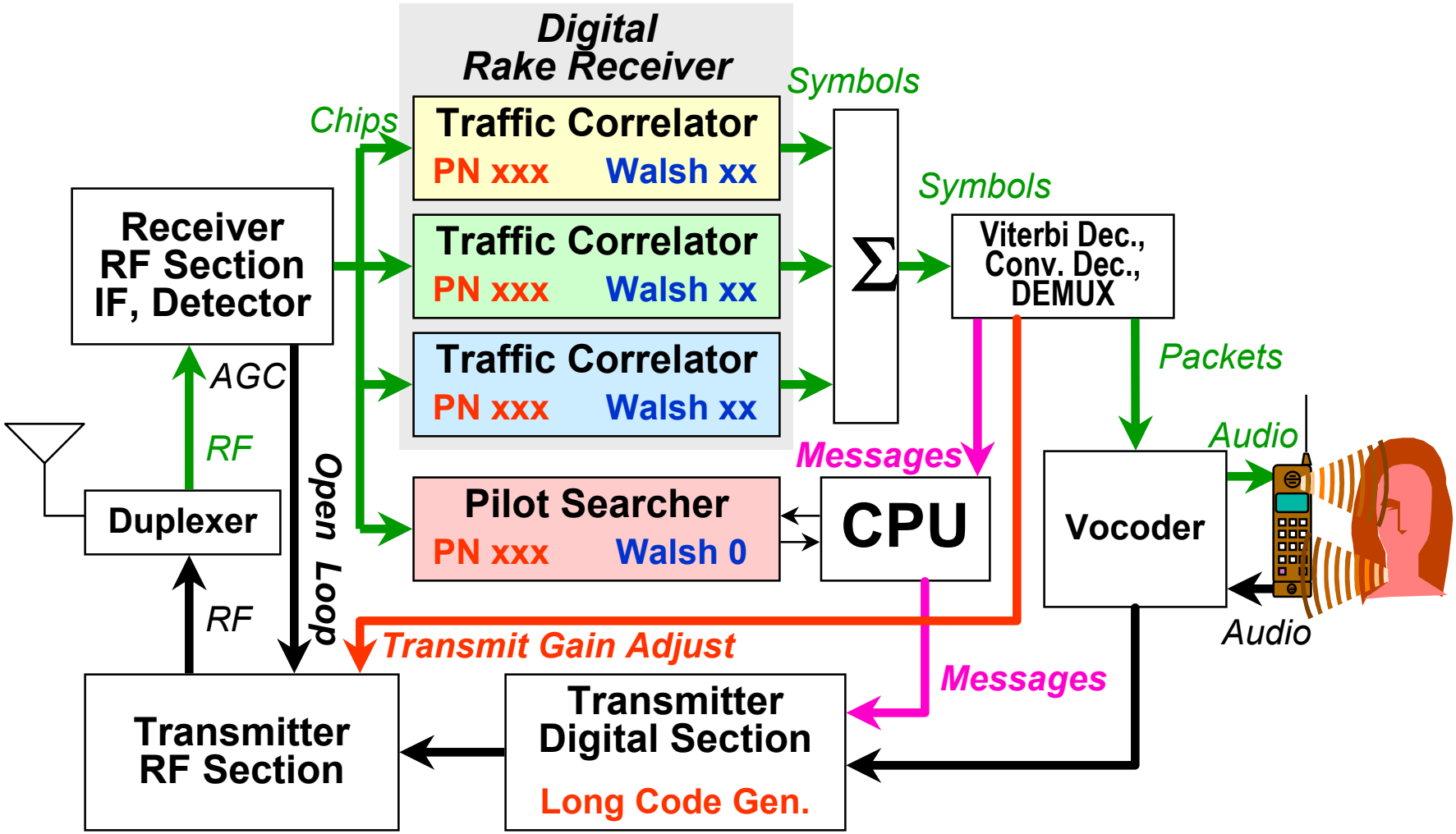
- The BTS continually reduces the strength of each user's forward baseband chip stream
- When a particular handset sees errors on the forward link, it requests more energy
- The complainer's chip stream gets a quick boost; afterward, continues to diminish

Reverse Power Control

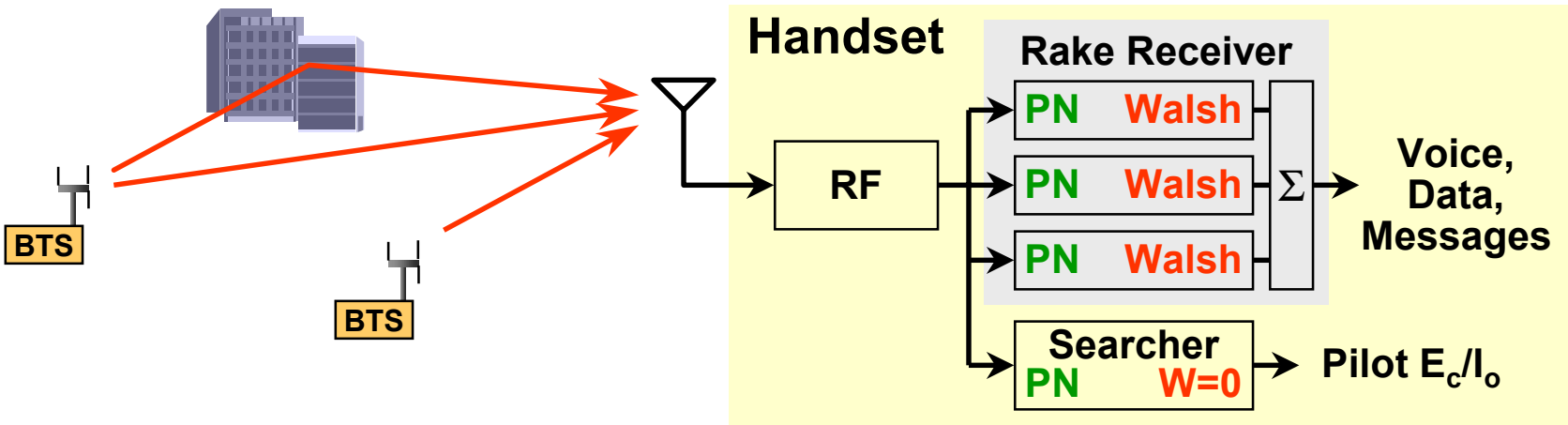


- Three methods work in tandem to equalize all handset signal levels at the BTS
  - Reverse *Open* Loop: handset adjusts power up or down based on received BTS signal (AGC)
  - Reverse *Closed* Loop: Is handset too strong? BTS tells up or down 1 db 800 times/second
  - Reverse *Outer* Loop: BSC has FER trouble hearing handset? BSC adjusts BTS setpoint

What's In a Handset?

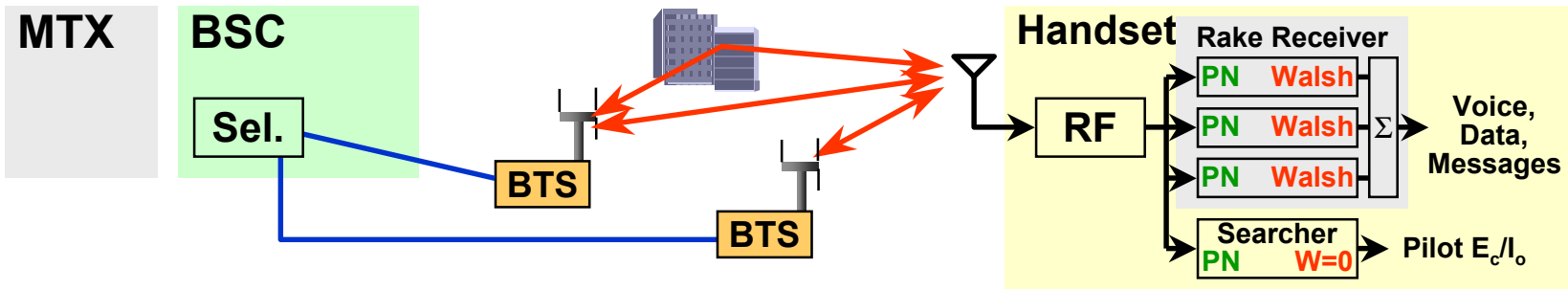


The Rake Receiver



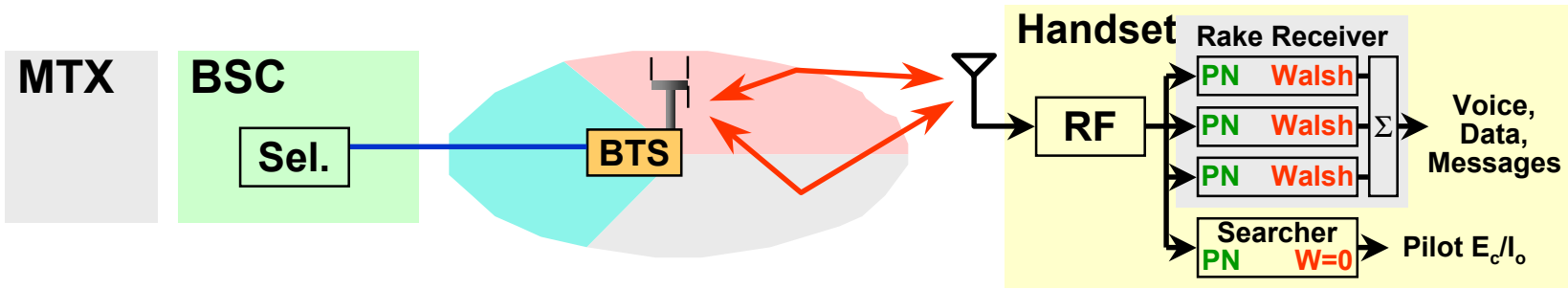
- Every frame, handset uses combined outputs of the three traffic correlators ("rake fingers")
- Each finger can independently recover a particular PN offset and Walsh code
- Fingers can be targeted on delayed multipath reflections, or even on different BTSs
- Searcher continuously checks pilots

CDMA Soft Handoff Mechanics



- CDMA soft handoff is driven by the handset
  - Handset continuously checks available pilots
  - Handset tells system pilots it currently sees
  - System assigns sectors (up to 6 max.), tells handset
  - Handset assigns its fingers accordingly
  - All messages sent by dim-and-burst, no muting!
- Each end of the link chooses what works best, on a frame-by-frame basis!
  - Users are totally unaware of handoff

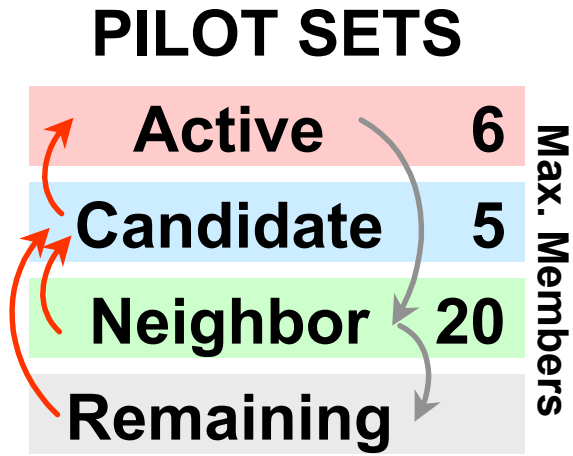
Softer Handoff



- Each BTS sector has unique PN offset & pilot
- Handset will ask for whatever pilots it wants
- If multiple sectors of one BTS simultaneously serve a handset, this is called Softer Handoff
- Handset is unaware, but softer handoff occurs in BTS in a single channel element
- Handset can even use combination soft-softer handoff on multiple BTS & sectors

Pilot Sets and Soft Handoff Parameters

- Handset views pilots in *sets*
- Handset sends message to system whenever:
  - It notices a pilot in neighbor or remaining set exceeds T_ADD
  - An active set pilot drops below T_DROP for T_TDROP time
  - A candidate pilot exceeds an active by T_COMP
- Handoff setup processing time usually <<1 second



HANDOFF PARAMETERS

T_ADD	T_DROP
T_TDROP	T_COMP

Overall Handoff Perspective

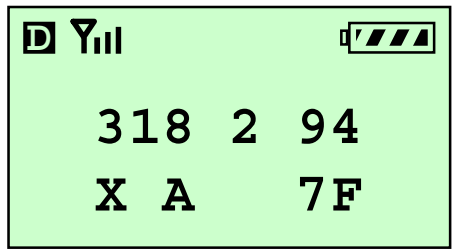
- **Soft & Softer Handoffs are the best**
  - **but a handset can receive BTS/sectors simultaneously only on *one* frequency**
  - **all involved BTS/sectors must connect to a *single BSC* (the BSC must choose packets each frame)**
  - ***frame timing* must be same on all BTS/sectors**
- **If above not possible, handoff still can occur but will be "hard" like AMPS/TDMA/GSM**
  - **intersystem handoff: hard**
  - **change-of-frequency handoff: hard**
  - **CDMA-to-AMPS handoff: hard, no handback**
    - Ð **auxiliary trigger mechanisms available**

CDMA Performance Optimization

- Key Performance Indicators and Objectives
  - Dropped Calls, Access Failures, system FER
  - Soft Handoff Percentage
  - Capacity
- Success comes from managing resources
  - Handoff: keep dynamics fast, delays short
    - Neighbor lists well-optimized
  - RF Coverage: holes vs. excessive overlap
  - PN Planning, optimum Search Window sizes
  - Per-Cell anomalies: watch parameters for clues

CDMA Mobile Analysis Tools

- Handset Maintenance Mode
- Real-Time Data Collection Tools
  - Qualcomm MDM
  - Grayson WMI, Surveyor
  - Grayson Invex3G
  - Agilent Nitro, Viper
  - Comarco



- Pilot Ec/Io
- Finger Information
- RX Level, TX Power output, TX Gain Adjust, Forward FER
- Temporal Analyzer
- Markov Call Statistics
- Messaging Activity
- Pilot Set Activity

CDMA Network Analysis Tools

- Post-Processing Tools
  - Actix Analyzer
  - Grayson Interpreter
  - Agilent OPAS
  - Nortel RFOptimizer
- OM Analysis Tools
  - Metrica Kingfisher

- Map Plots
  - Best Ec/Io, PN, FER, handset RX & TX Powers, Transmit Gain Adjust, Number of active pilots
- Charts, Tables & Graphs
  - Handoff statistics (per-neighbor tables), parameter distributions
  - Access, Drop Call rates
- Message Search/Analysis
- Analysis of Anomalies
  - Pre-drop parameters