CDMA System

Contents

- *The characteristics of mobile communications*
- *CDMA migration from 2G to 3G*
- *CDMA spectrum usage*
- *CDMA Codes*
- *CDMA Channels*
- *The advantage of CDMA*
- *cdma2000 -1x*

Characteristics of Mobile Communication

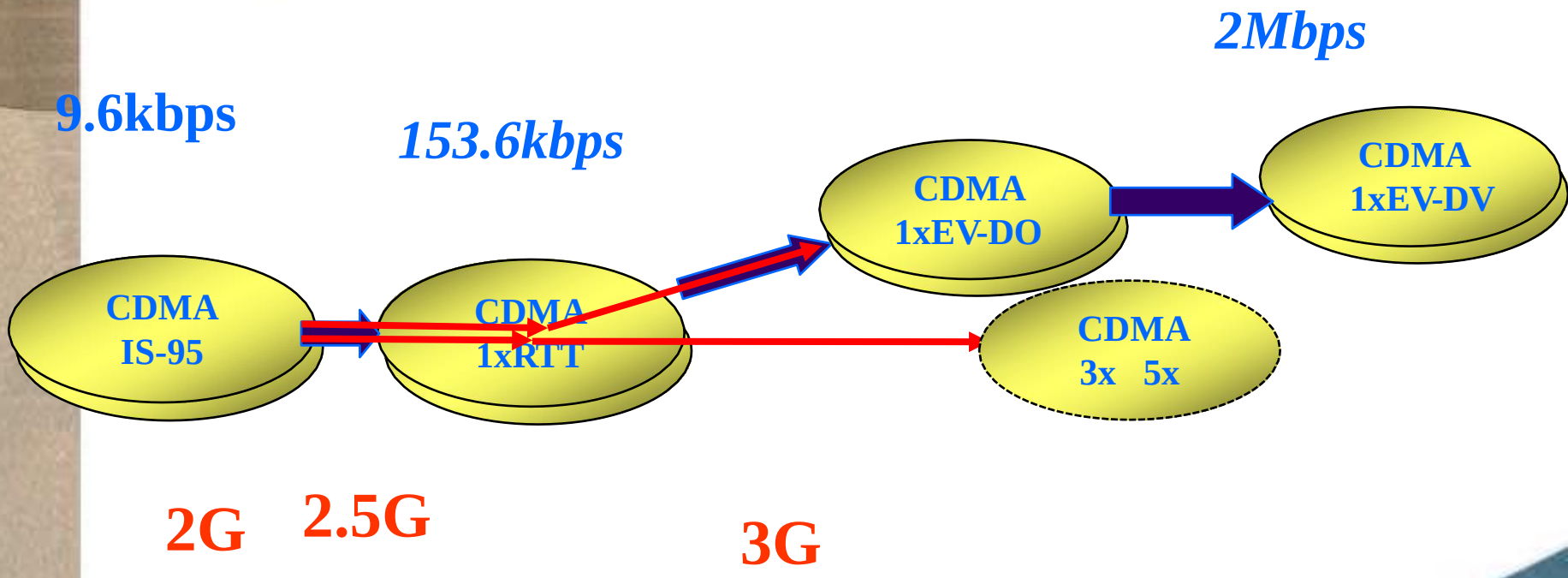
- Mobility :
  - **flexible and convenient , global personal communication**
- Poor environment and conditions :
  - **Co-channel interference, multi-path(space and time)shadow effect and delay, power change and other noise**
- Multiple MS and channels :
  - **Interference, near and far effect**
- Limit of frequency resources
- Reliability is important
  - **registration, handoff, switching**

Communications System

1G	2G	3G
Analog cellular	Digital cellular	Digital cellular
Voice	Voice /data	Vioce / high speed data
AMPS	CDMA 1XRtt	CDMA2000
TACS	GSM GPRS	W_CDMA
80’	1992 1999	2001 2003

AMPS: Advanced Mobile Phone System
TACS: Total Access Communication System
GPRS: General Packet Radio Services

CDMA Evolution Paths

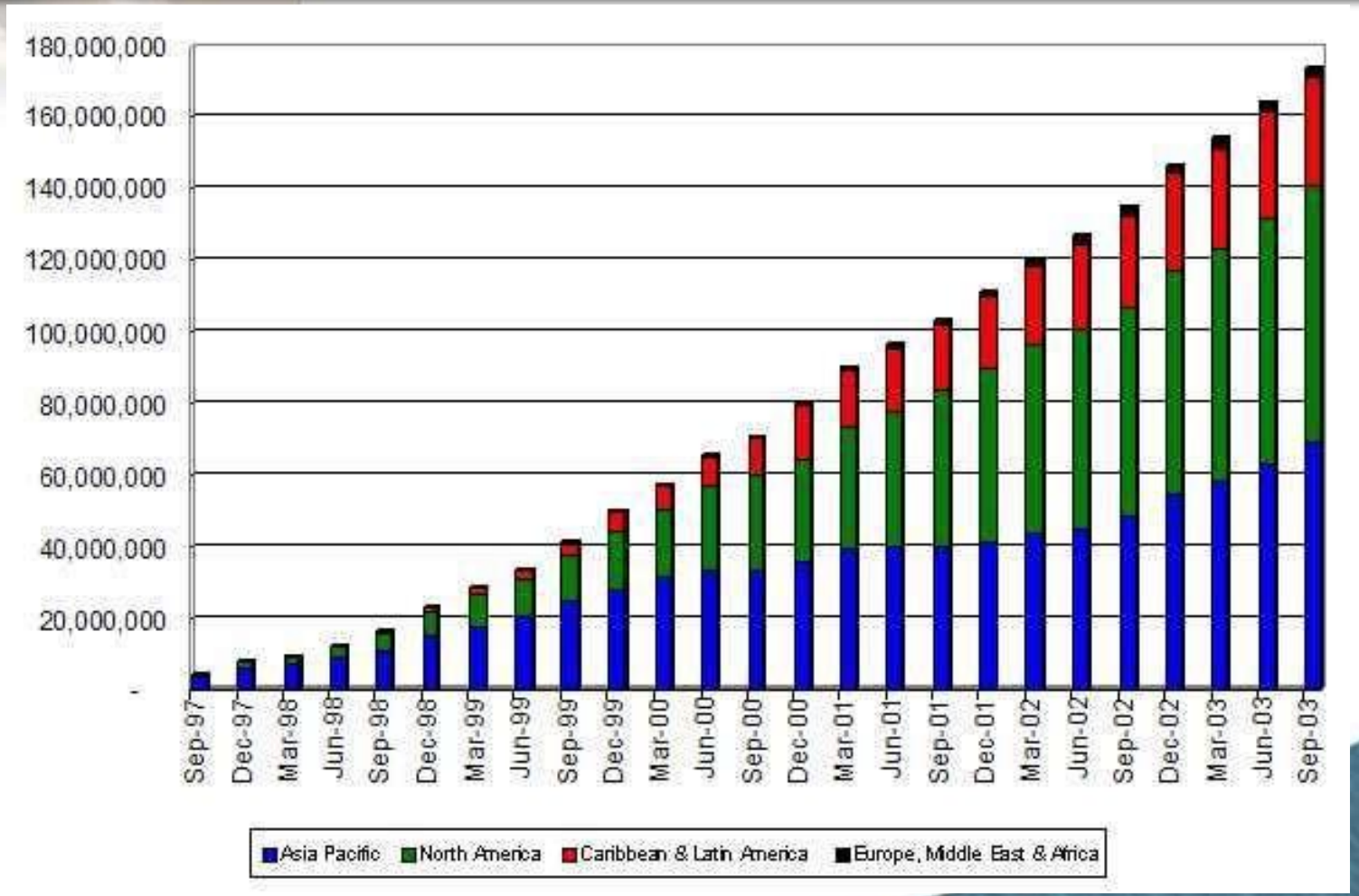


CDMA-Its History & Status

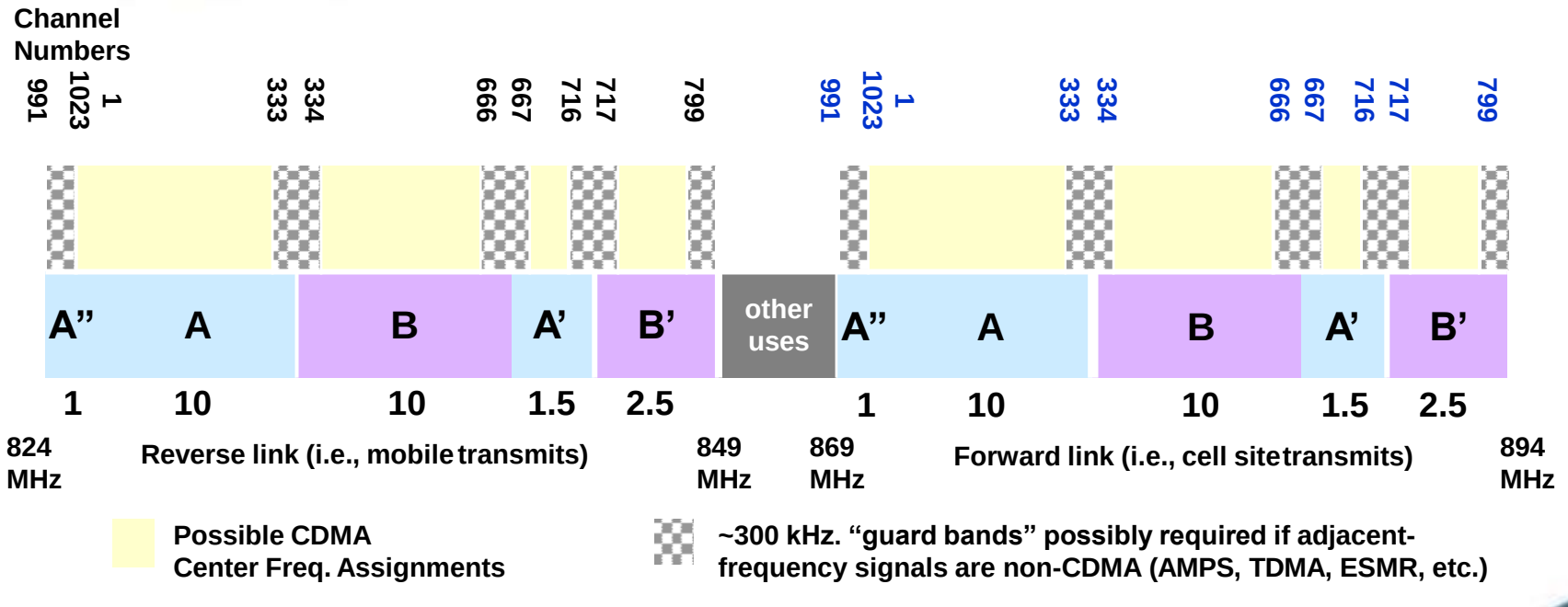
CDMA-Its History & Status

- 1993, the first CDMA standard IS-95 was issued;
- In 1995, CDMA technology was put into commercialization in Hong Kong and America on large scale;
- In April, 2001, China Unicom began to construct CDMA networks—the largest in the world (about 70Million line now);
- At present, CDMA commercial networks are established in about 40 countries or area, almost 20% of all users in the world.

CDMA Subscriber Growth History: Sept.1997 through Sept.2003

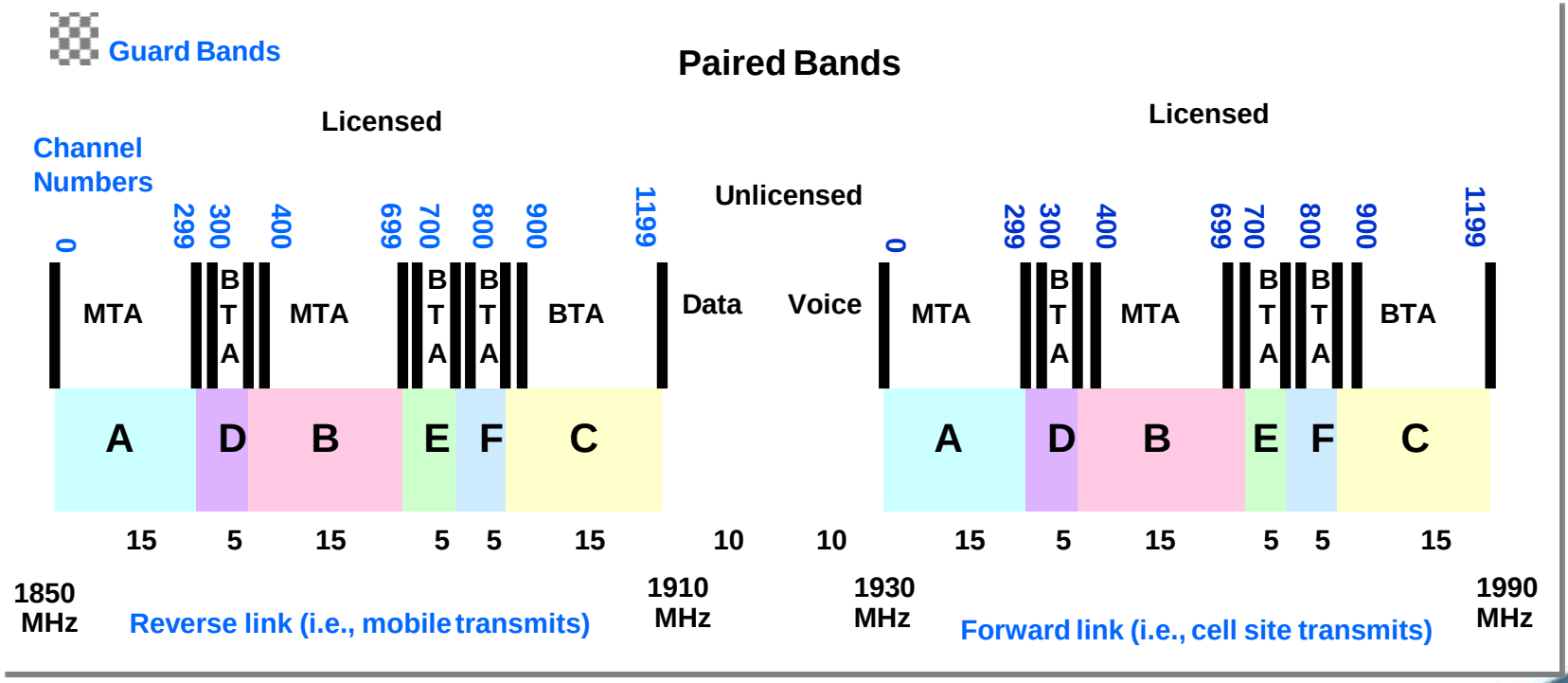


CDMA 800 MHz Cellular Spectrum Usage

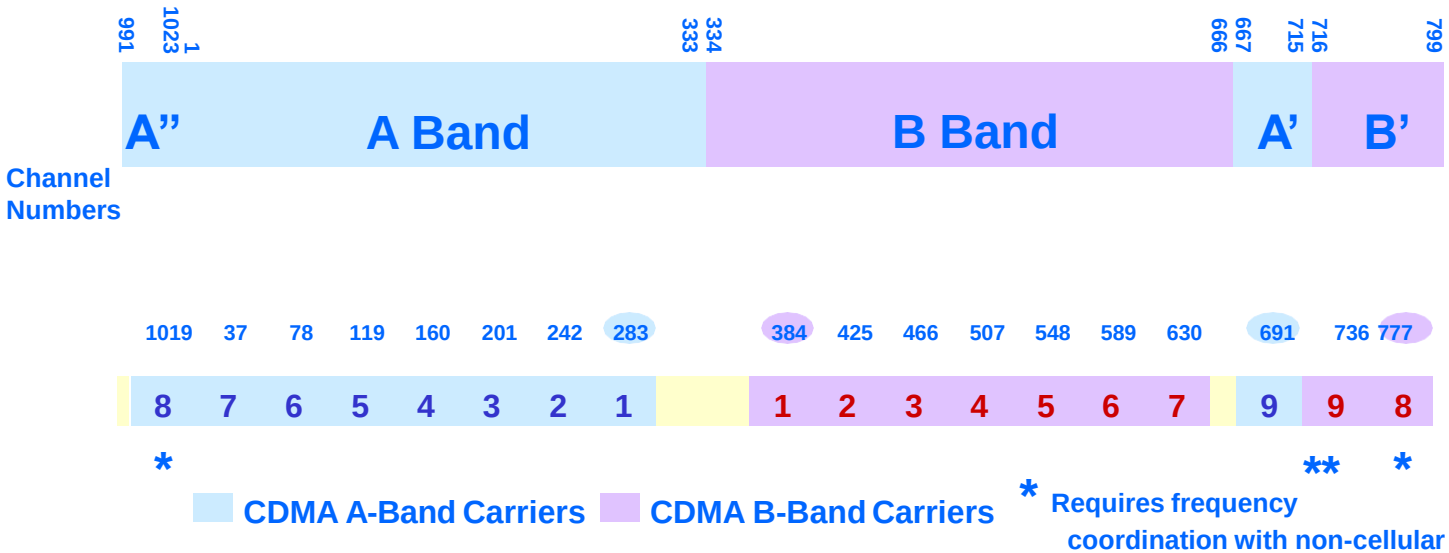


- All CDMA RF carriers are 1.25 MHz. wide
  - Can serve ~20 users /8 kb vocoder

CDMA PCS 1900 MHz Spectrum Usage



CDMA Frequency Channel Assignment at 800 MHz Cellular



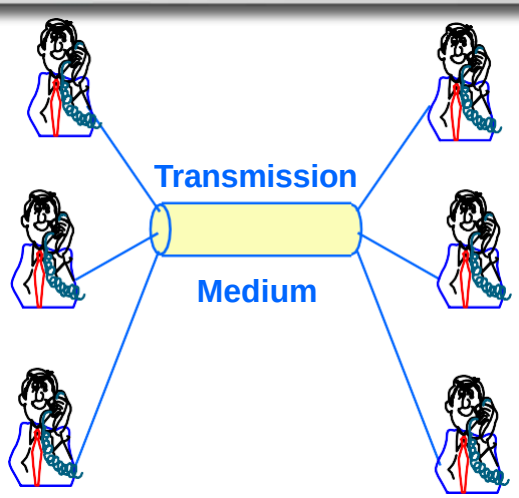
A Band Primary Channel	283 B Band Primary Channel	384
A Band Secondary Channel	691 B Band Secondary Channel	777

Multiple Access

Since the beginning of telephony and radio, system operators have tried to squeeze the maximum amount of traffic over each circuit.

- Types of Media -- Examples:
  - Twisted pair - copper
  - Coaxial cable
  - Fiber optic cable
  - **Air interface (radio signals)**

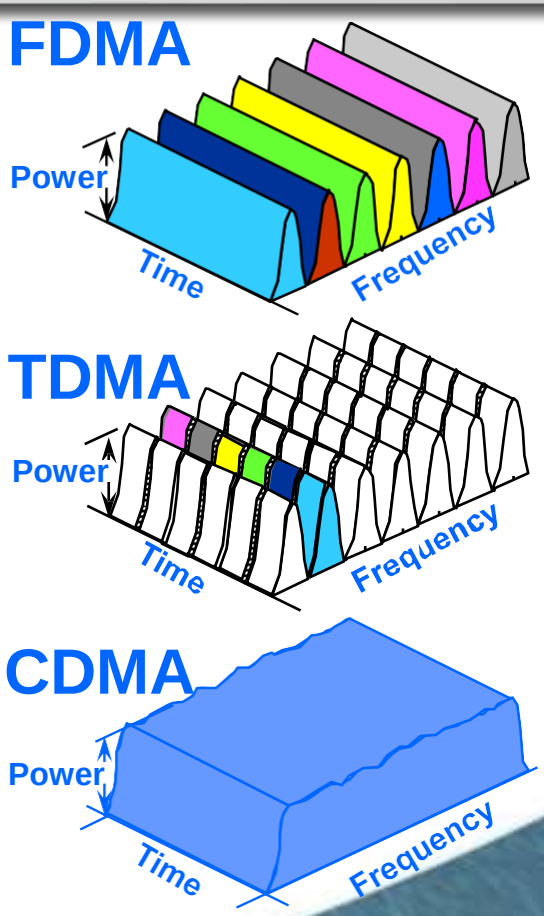
- **Advantages of Multiple Access**
  - Increased capacity: serve more users
  - fewer media can carry the trafficReduced capital requirements since
  - Decreased per-user expense
  - Easier to manage and administer



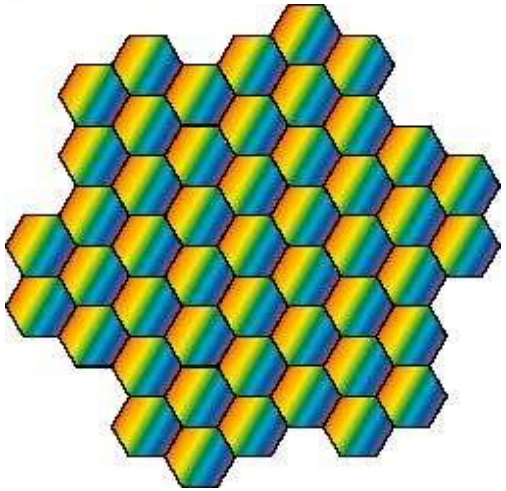
Each pair of users enjoys a dedicated, private circuit through the transmission medium, unaware that the other users exist.

Multiple Access Schemes

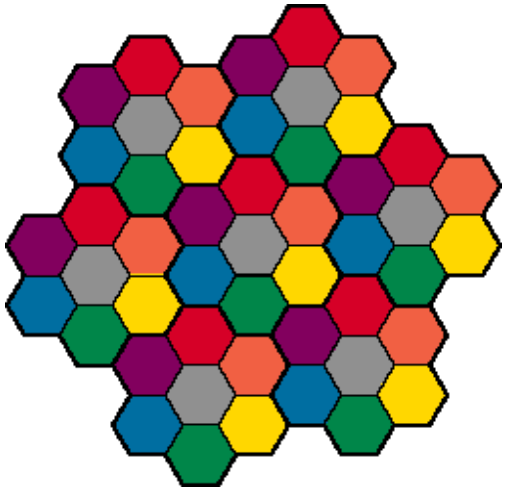
- ***FDMA Frequency Division Multiple Access***
  - Each user on a different frequency
  - A channel is a frequency
- ***TDMA Time Division Multiple Access***
  - Each user on a different window period in time (“time slot”)
  - A channel is a specific time slot on a specific frequency
- ***CDMA Code Division Multiple Access***
  - A channel is a unique code pattern
  - Each user uses the same frequency all the time, but mixed with different distinguishing code patterns



Frequency Reuse



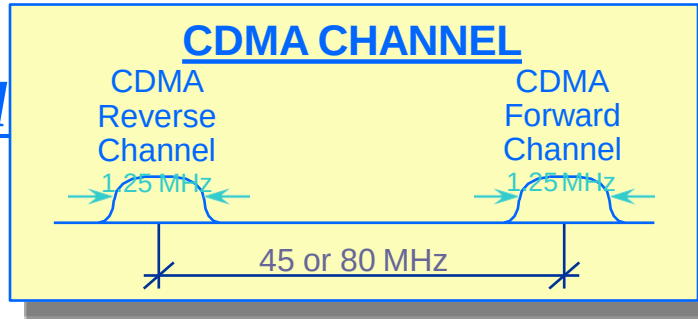
CDMA (IS-95)
frequency reuse = 1



TDMA (IS-136)
frequency reuse = 7

Terms & Definitions

- ***CDMA Channel* or *CDMA Carrier* or *CDMA Frequency***
  - Duplex channel made of two 1.25 MHz-wide bands of electromagnetic spectrum, one for Base Station to Mobile Station communication (called the FORWARD LINK or the DOWNLINK) and another for Mobile Station to Base Station communication (called the REVERSE LINK or the UPLINK)
  - In 800 Cellular these two simplex 1.25 MHz bands are 45 MHz apart
  - In 1900 MHz PCS they are 80 MHz apart



- ***CDMA Forward & Reverse Channel***
  - 1.25 MHz Forward / Reverse Link
- ***CDMA Code Channel***
  - Each individual stream of 0's and 1's contained in either the CDMA Forward Channel or in the CDMA Reverse Channel
  - Code Channels are characterized (made unique) by mathematical codes
  - Code channels in the forward link: Pilot, Sync, Paging and Forward Traffic channels
  - Code channels in the reverse link: Access and Reverse Traffic channels

Walsh Codes

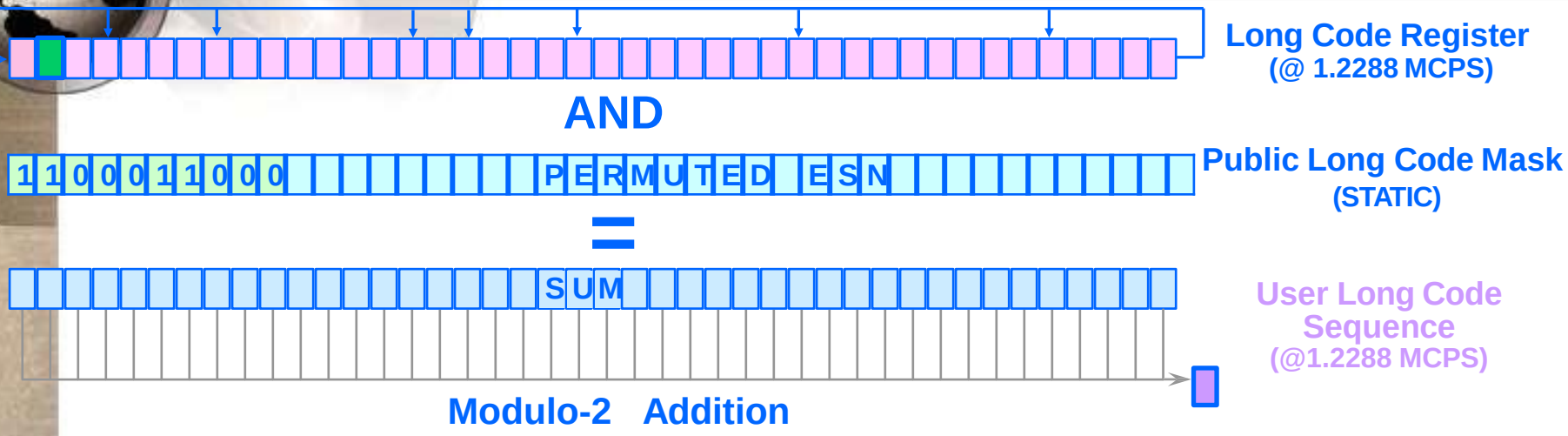
- 64 Sequences, each 64 chips long
  - A chip is a binary digit (0 or 1)
- Each Walsh Code is Orthogonal to all other Walsh Codes
  - This means that it is possible to recognize and therefore extract a particular Walsh code from a mixture of other Walsh codes which are “filtered out” in the process
  - Two same-length binary strings are orthogonal if the result of XORing them has the same number of 0s as 1s

Short PN Sequences

- The two Short PN Sequences, I and Q, are 32,768 chips long

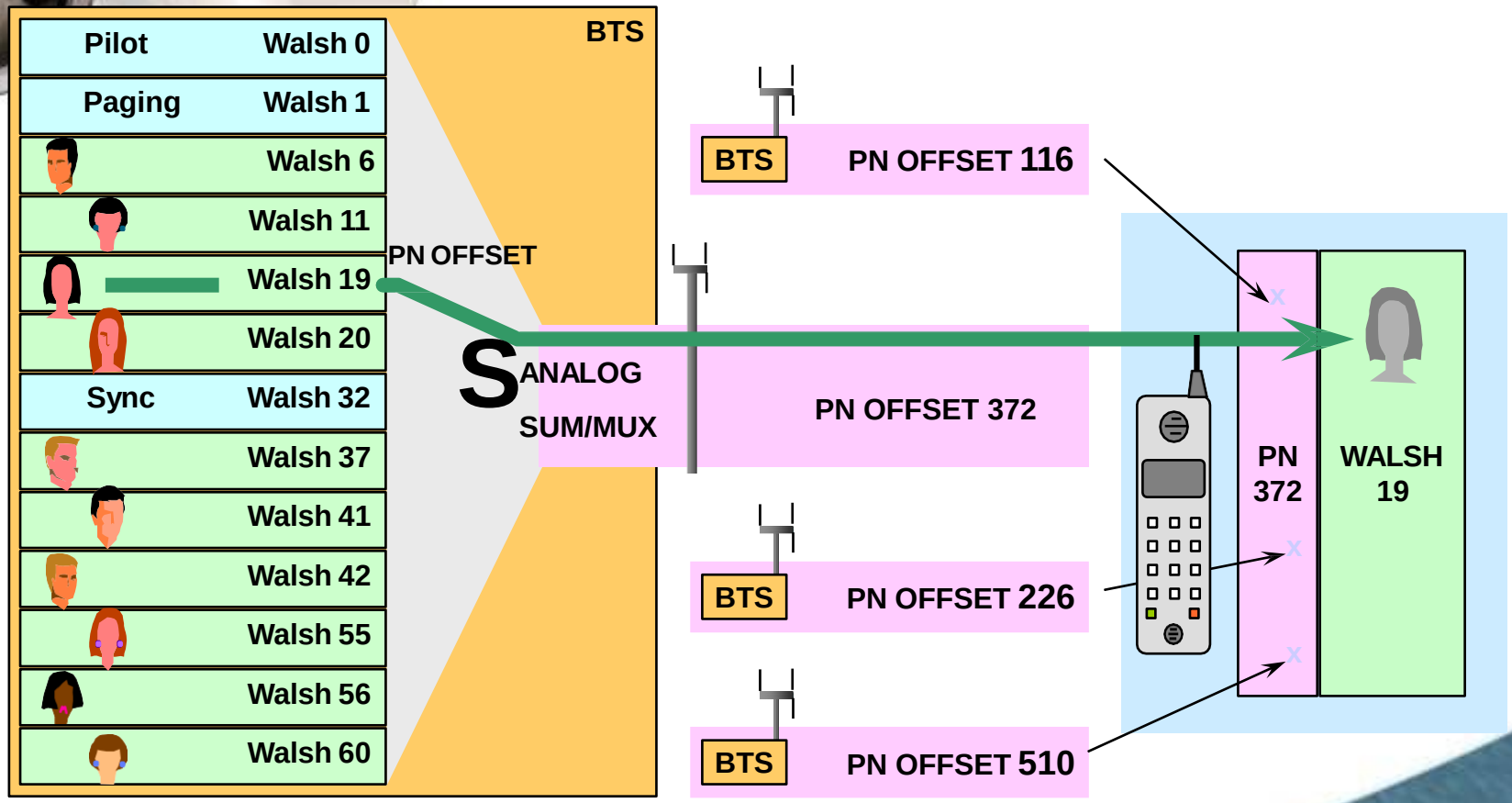
- Together, they can be considered a two-dimensional binary "vector" with distinct I and Q component sequences, each 32,768 chips long
- Each Short PN Sequence (and, as a matter of fact, any sequence) correlates with itself perfectly if compared at a timing offset of 0 chips
- Each Short PN Sequence is special: Orthogonal to a copy of itself that has been offset by any number of chips (other than 0)

The Long PN Sequence



- Each mobile station uses a unique User Long Code Sequence generated by applying a mask, based on its 32-bit ESN, to the 42-bit Long Code Generator which was synchronized with the CDMA system during the mobile station initialization.
- Generated at 1.2288 Mcps, this sequence requires 41 days, 10 hours, 12 minutes and 19.4 seconds to complete.

Coding Process on CDMA Forward Channels



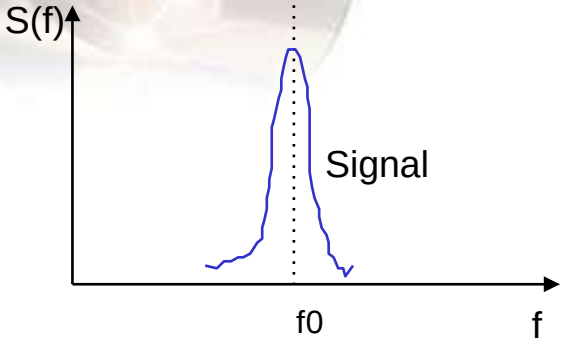
CDMA Code Summary

Type of Sequence	How Many	Length	Special Properties	Forward Link Function	Reverse Link Function
Walsh Codes	64	64 chips 1/19,200 sec.	Mutually Orthogonal	User identity within cell's signal	Orthogonal Modulation (information carrier)
Short PN Sequences	2	32,768 chips 26-2/3 ms 75x in 2 sec.	Orthogonal with itself at any time shift value except 0	Distinguish Cells & Sectors	Quadrature Spreading (Zero offset)
Long PN Sequences	1	2^{42} chips ~41 days	near-orthogonal if shifted	Data Scrambling to avoid strings of 1's or 0's	Distinguish users

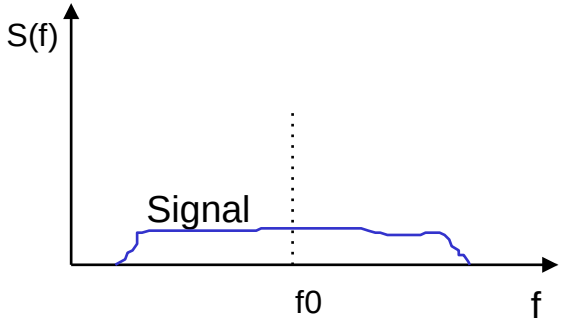
CDMA Advantages

- Spread Spectrum
- Soft & Softer Handoff
- Rake Receiver
- Variable Rate Vocoder
- High quality voice
- Power Control
- Coverage
- Simple Network Planning
- Green Handset
- Smooth migration to 3G and the operator's benefit is protected at the most

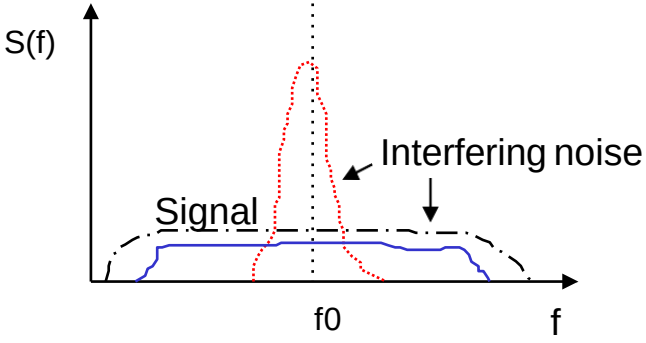
Spread Spectrum (1)



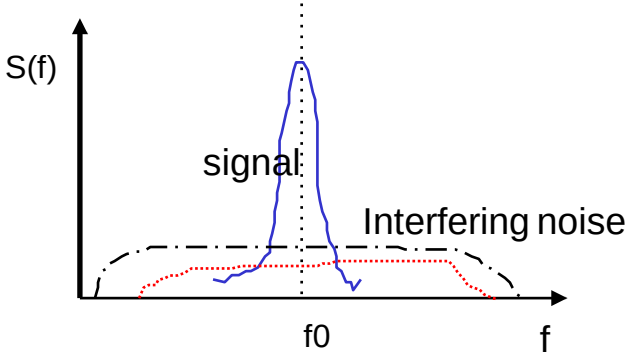
Before spreading



After spreading

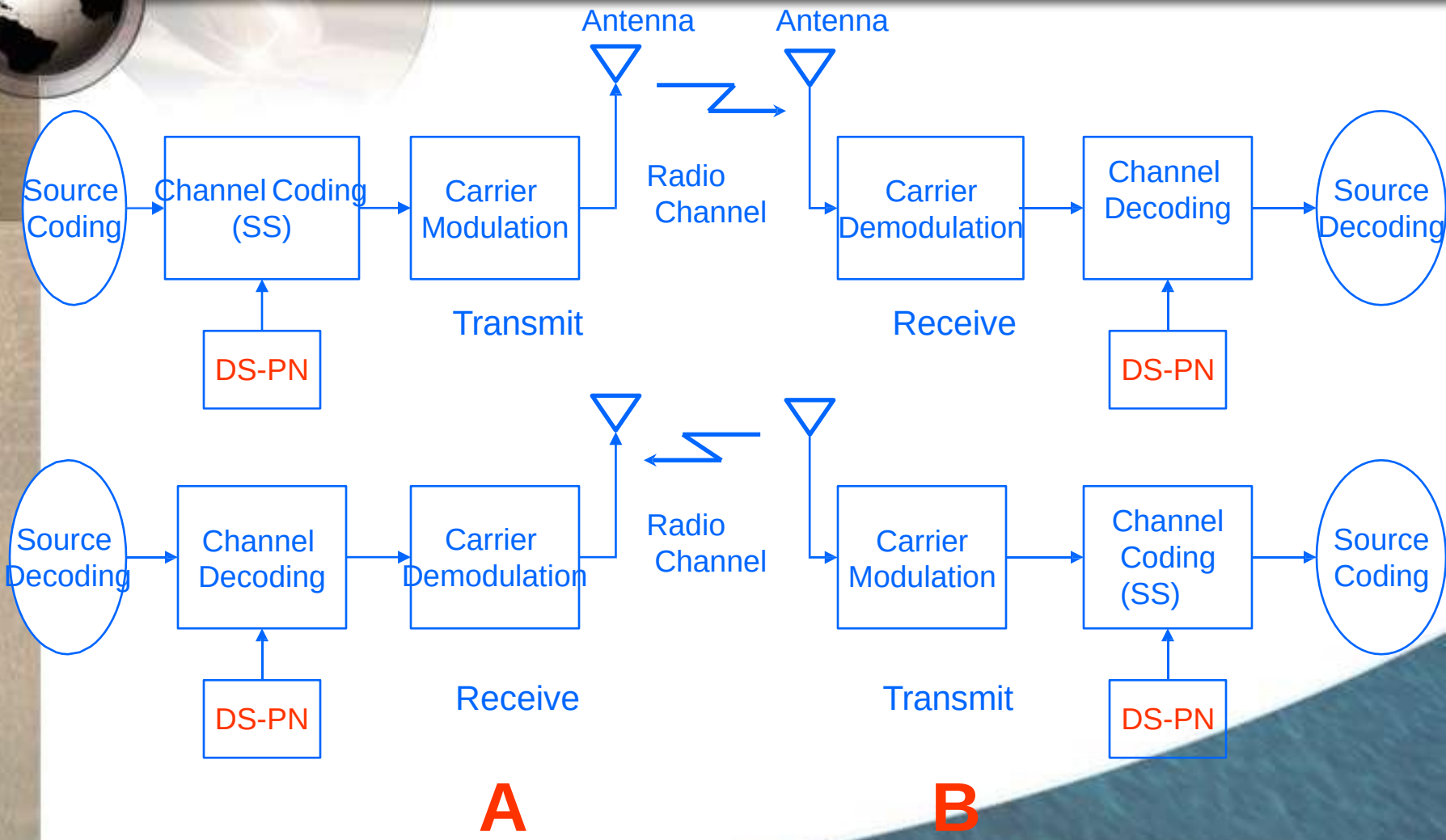


Before despreading

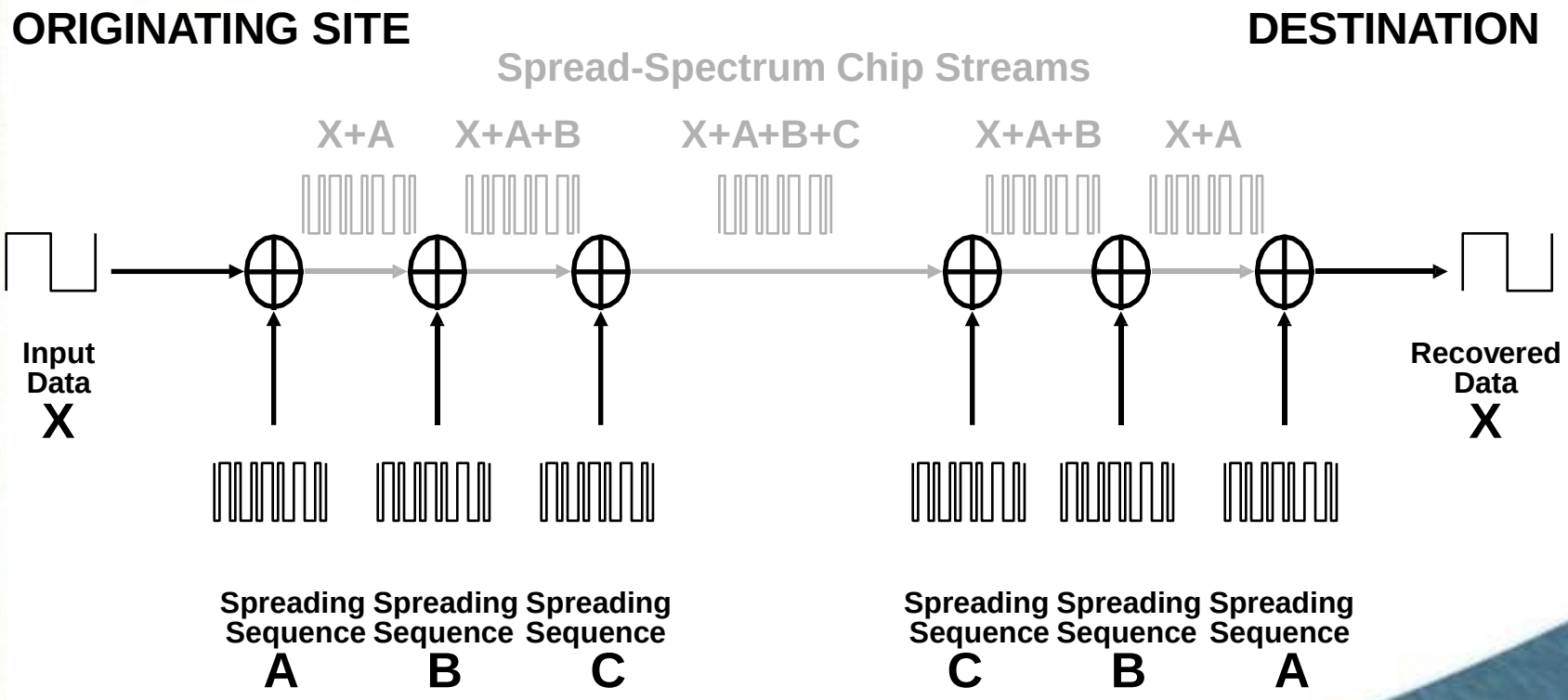


After despreading

Spread Spectrum(2)

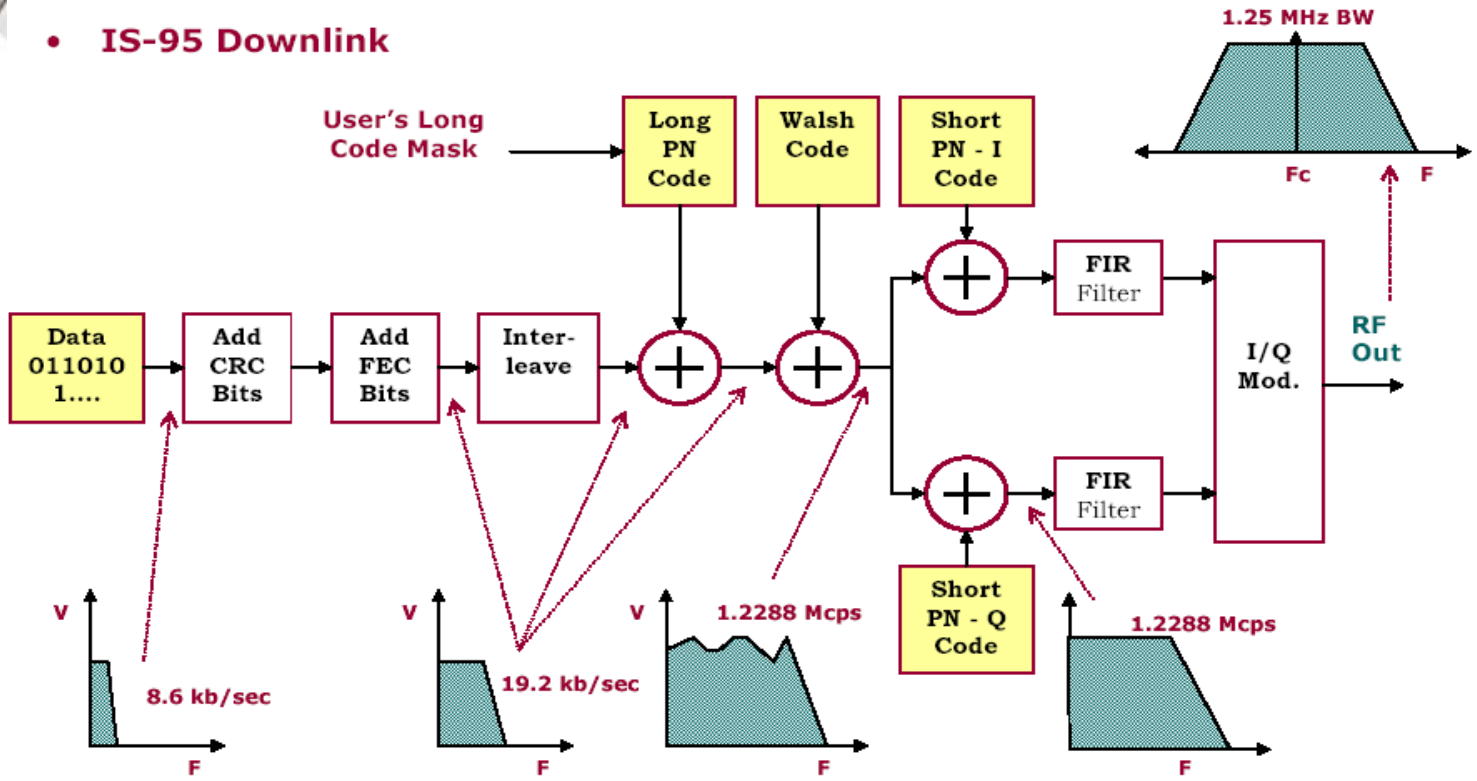


Spreading Spectrum (3)
"Principle of Using Multiple Codes"



Spread Spectrum (4)

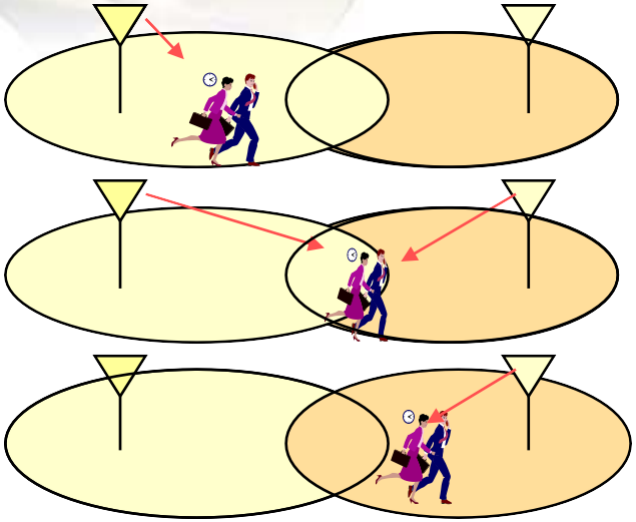
- IS-95 Downlink

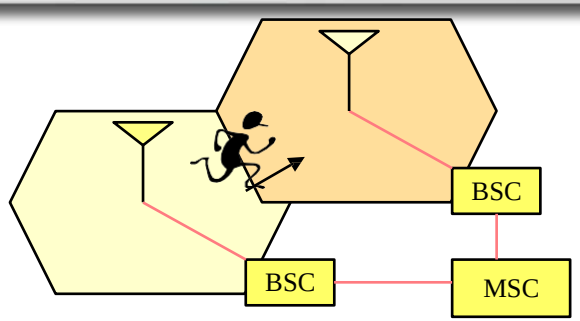


Advantages of Spread Spectrum

- ✓ Avoid interference arising from jamming signal or multi-path effects.
- ✓ Covert operation:Difficult to detect
- ✓ Achieve Privacy: Difficult to demodulate, Noise like signal.
- ✓ Impossible to Eavesdrops on the signal expect using the same PN sequence

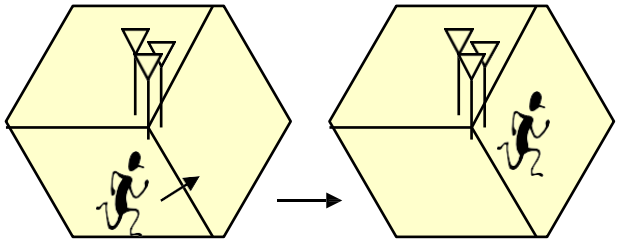
Soft & Softer Handoff





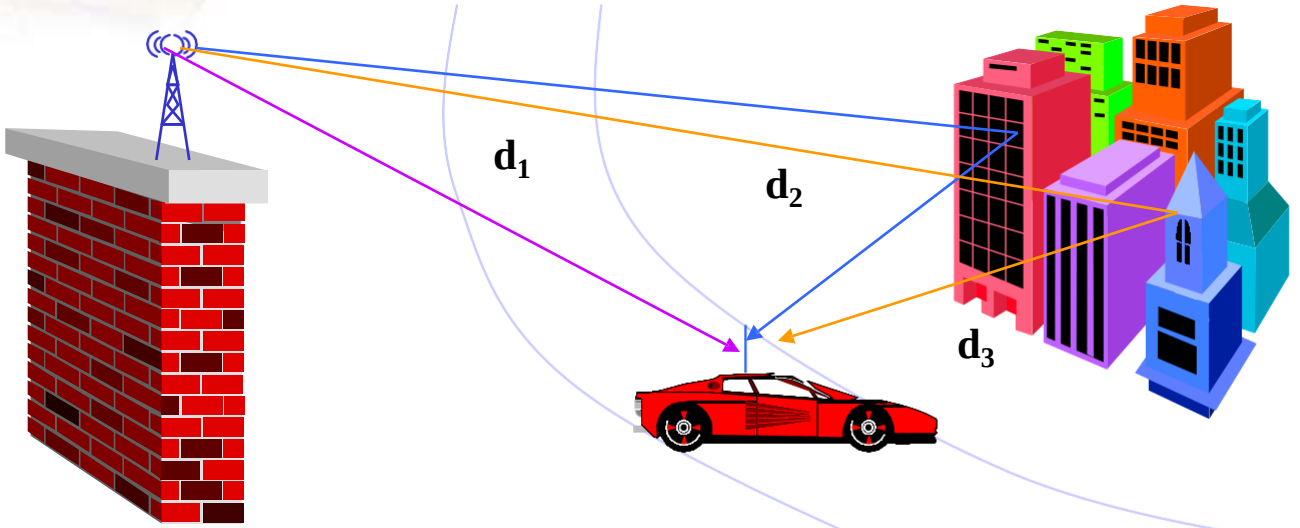
Soft handoff: adjacent cells of the same frequency.

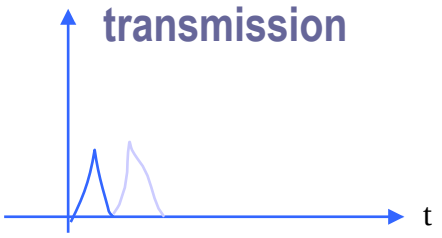
Connection first and disconnection afterwards in handoff.
High quality of service and effective reduction of call drops.

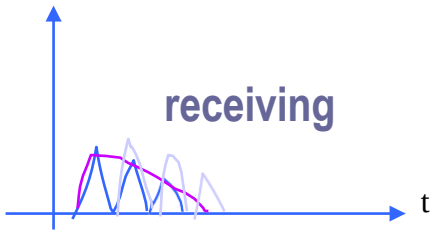


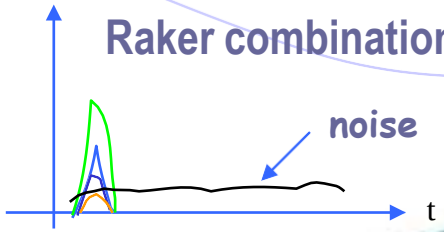
Softer handoff: same BS & frequency, between different sectors.

Rake Receiver (1)

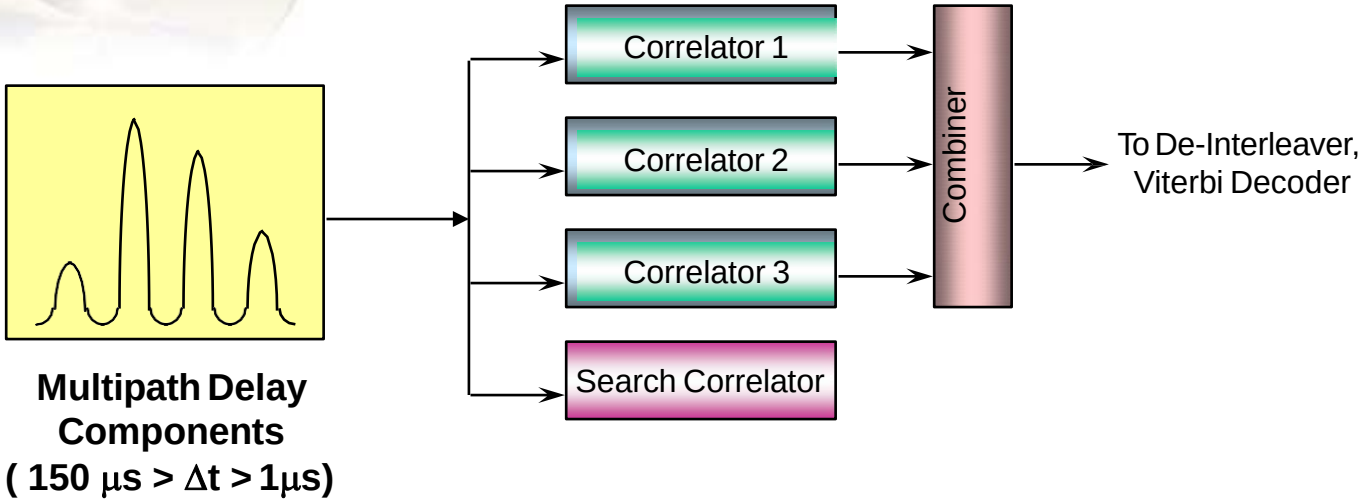








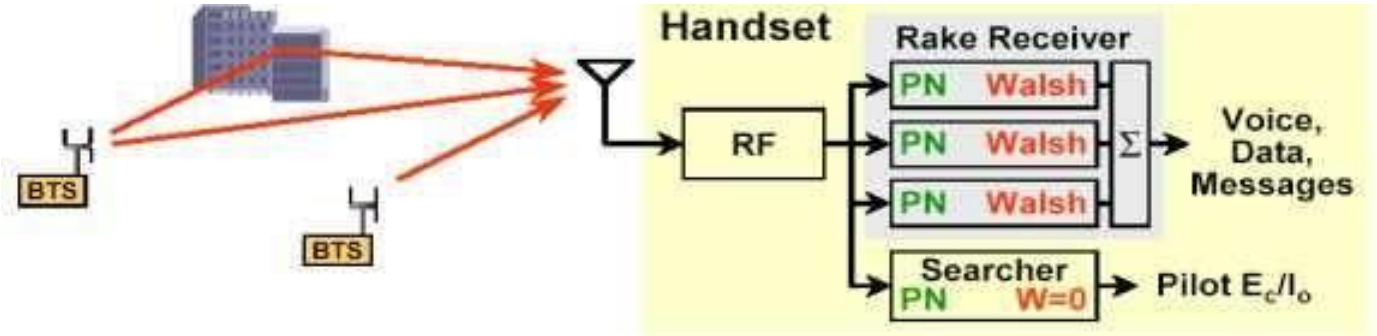
Rake Receiver (2)



Rake receiver can isolate multipath spaced > 1 chip length.

Rake Receiver (3)

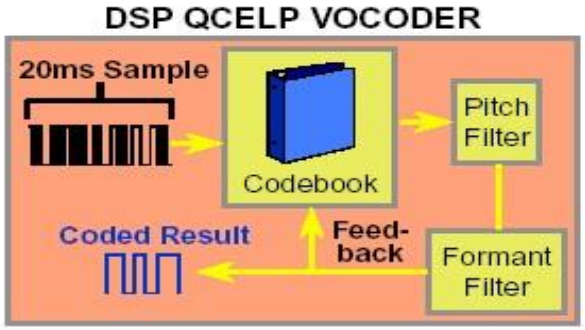
- Handset uses combined outputs of the three traffic correlators —rake fingers‖
- Each finger can independently recover a particular PN offset and Walsh code
- Fingers can targeted on delayed multipath reflections, or even on different BTSs
- Searcher continuously checks pilots



Intelligent Vocoder

Variable Rate Vocoding & Multiplexing

- Vocoders compress speech, reduce bit rate, greatly increasing capacity
- 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



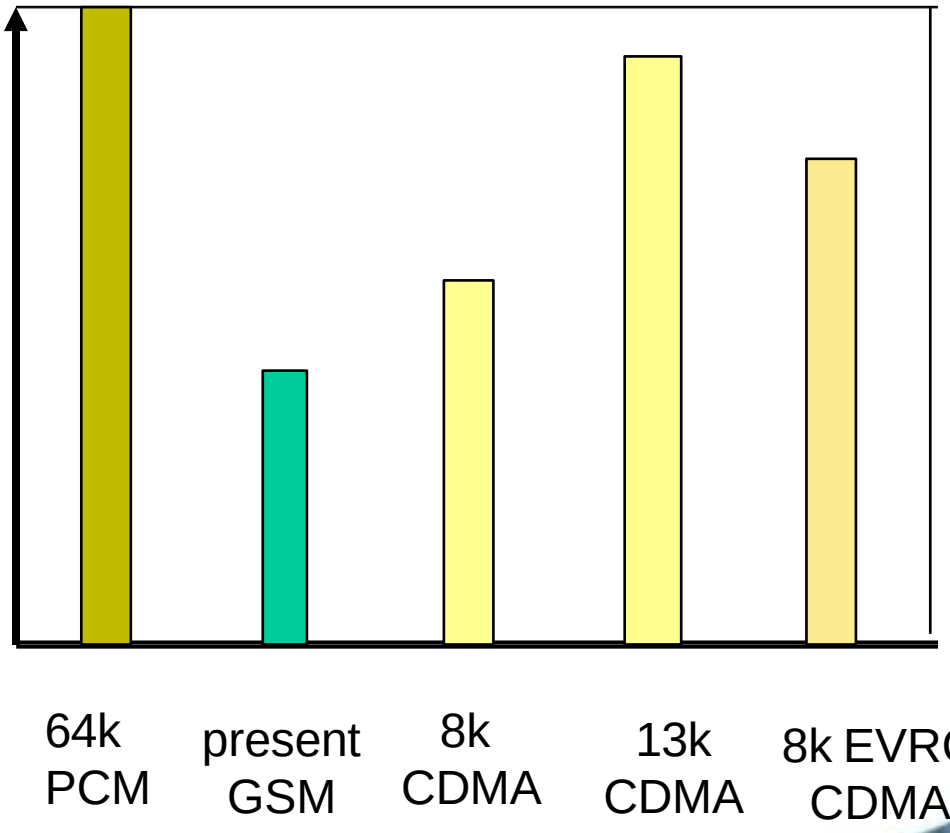
bits	Frame Sizes
288	Full Rate Frame
144	1/2 Rate Frame
72	1/4 Rt.
36	1/8

Frame Contents: can be a mixture of

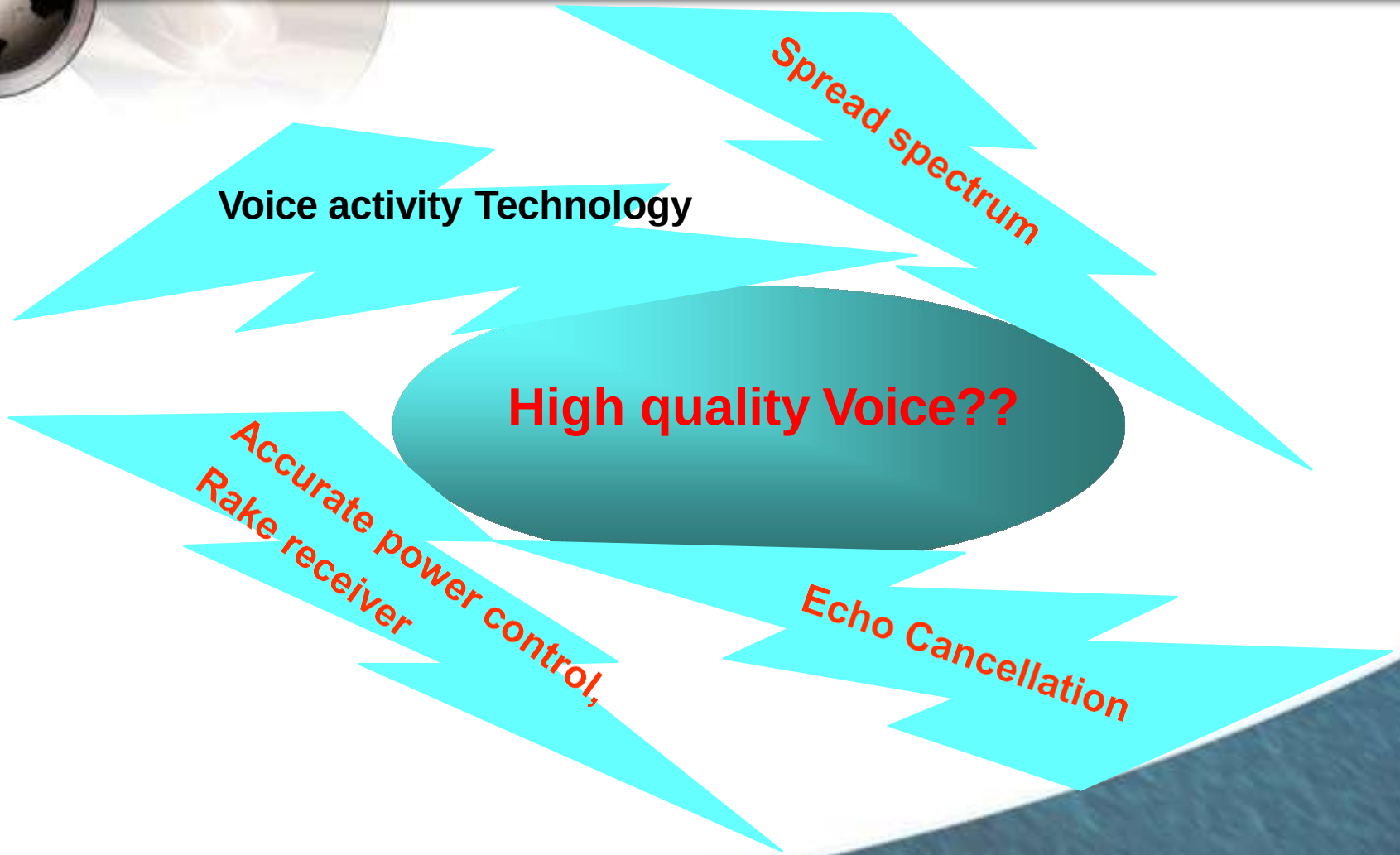
Primary Traffic (Voice or data)	Signaling (System Messaging)	Secondary (On-Air activation, etc)

High Quality Voice(1)

Voice quality



High Quality Voice(2)



Power Control

- ✓ Autonomous power control

On the **Uplink** tells the MS to vary it's transmitted power inversely with the power level it receive from the BS.

- ✓ Direct power control

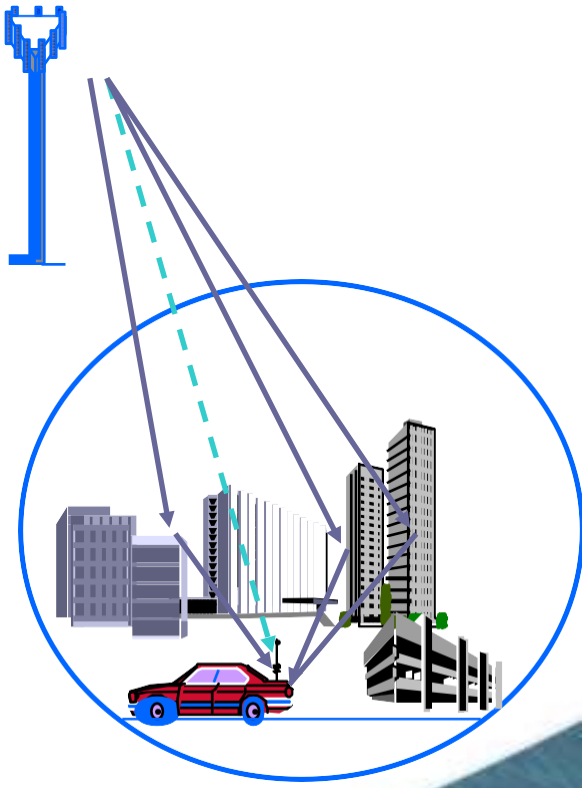
On the **Uplink** measures Eb/No at the base station and sends power Control Bits over the Downlink to the MS to instruct the MS to either increase or decrease its transmit power.

- ✓ Downlink power control

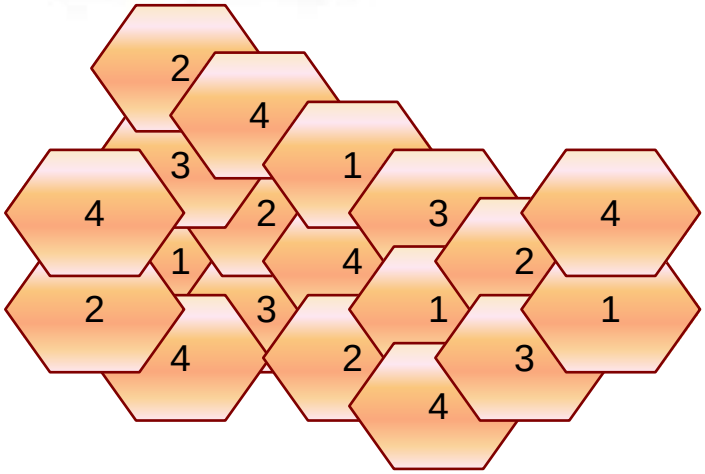
Attempts to use minimum power needed to meet to a Frame Error Rate **(FER)** threshold at the MS s.

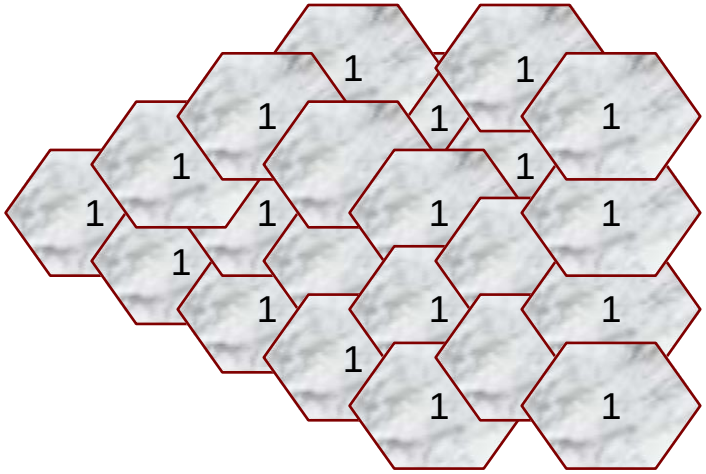
Coverage

- The coverage radius is 2 times of standard GSM.
- Coverage of 1000 km^2: GSM needs 200 BTS 's, while CDMA requires only 50.
- Under the same coverage conditions, the number of BTS 's is greatly decreased



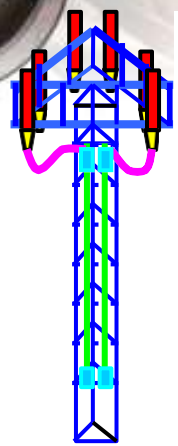
Simple Network Planning





Simple project design & convenient capacity expansion

Green Handset



Low transmission power:
Accurate power control, handoff control, voice activation

Systems	Mean transmission power	Max transmission power
GSM	125 mW	2W
CDMA	2 mW	200mW

Functions of the CDMA Reverse Channels

- There are two types of CDMA Reverse Channels:
  - ***TRAFFIC CHANNELS*** are used by individual users during their actual calls to transmit traffic to the BTS.
  - ***ACCESS CHANNELS*** are used by mobile stations not yet in a call to transmit registration requests, call setup requests, page responses, order responses, and other signaling information

Coding Process on CDMA Reverse Channels

- Each mobile is uniquely identified by the User Long Code, which it generates internally.
- All mobile stations transmit simultaneously on the same 1.25 MHz wide frequency band.
- Any nearby BTS can dedicate a channel element to the mobile station and successfully extract its signal.
- Mobile stations also use the other CDMA spreading sequences, but not for channel-identifying purposes.
- Short PN Sequences are used to achieve phase modulation.
- Walsh Codes are used as Orthogonal Modulation to give ultra-reliable communications recovery at the BTS.

Benefits of the cdma2000 1x Standards

- Increased mobile standby battery life (via Quick Paging Channel)
- Total backward compatibility to reuse switch and call processing features
- 2-3 dB better coverage
- High speed 153.6 kbps packet data capabilities
- ***cdma2000 1x = 1.25 MHz Radio Transmission Technology***

Backward Compatible with IS-95 Air Interface

IS-95 mobiles are supported in the IS-2000 standard for 1xRTT:

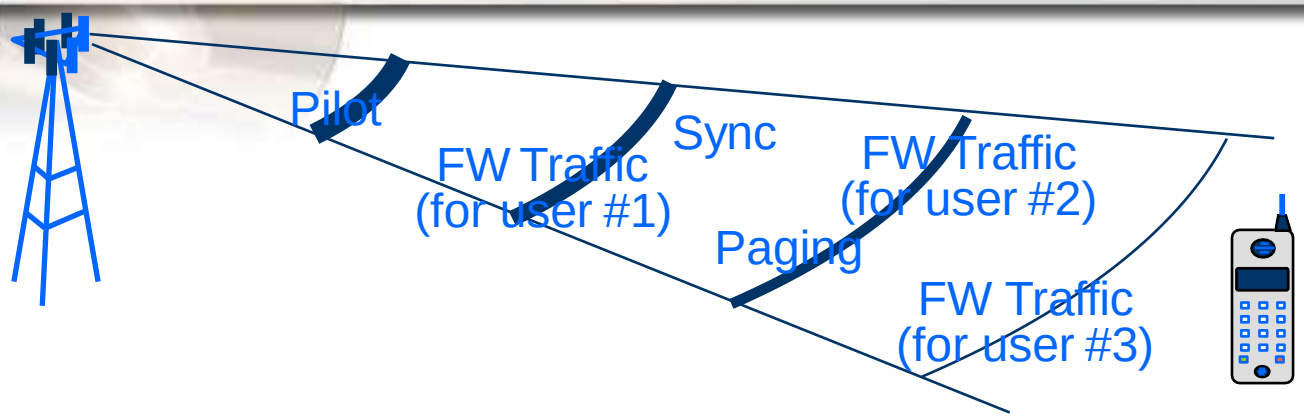
- *No need to change any RF infrastructure*
- *Capacity improvements will not be realized until most IS-95 subscribers disappear*

Channel List: 1xRTT vs. IS-95

- IS-95B built on the IS-95A channels, and introduced two new channels
  - Fundamental channel was the same as IS-9A traffic channel
  - Supplemental code channels assigned to support rates above 14.4Kbps
- IS-2000 1xRTT continue to build on the IS-95 channels
  - IS-95 channels continue to be supported in IS-2000 to support IS-95 mobiles

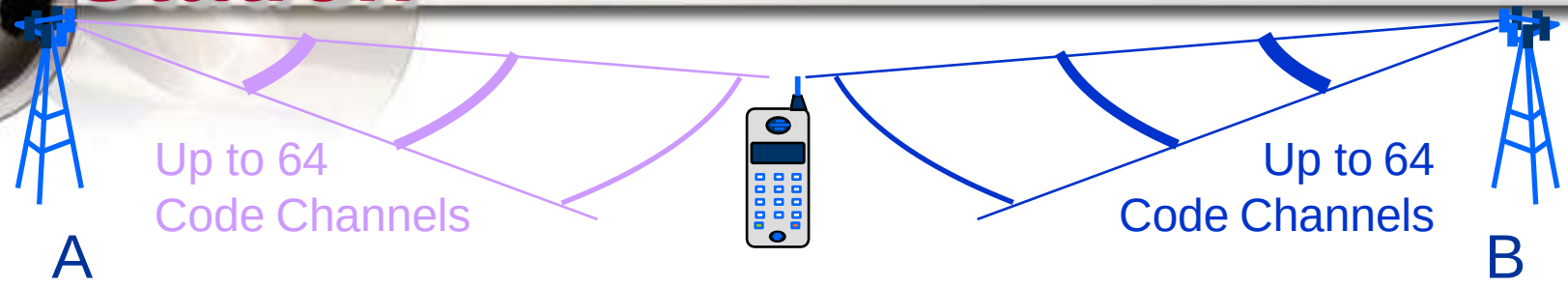
	Forward	Reverse
IS-95A	Pilot channel Sync channel Paging channel Forward Traffic Channel	 Access channel Reverse Traffic Channel
IS-95B	Fundamental channel Supplemental Code channel (F-SCCH)	Fundamental channel Supplemental Code channel (R-SCCH)
1xRTT	Supplemental channel (F-SCH) Quick Paging channel (F-QPCH)	Supplemental channel (R-SCH) Reverse Pilot channel (R-PICH)

Discriminating Among Forward Code Channels



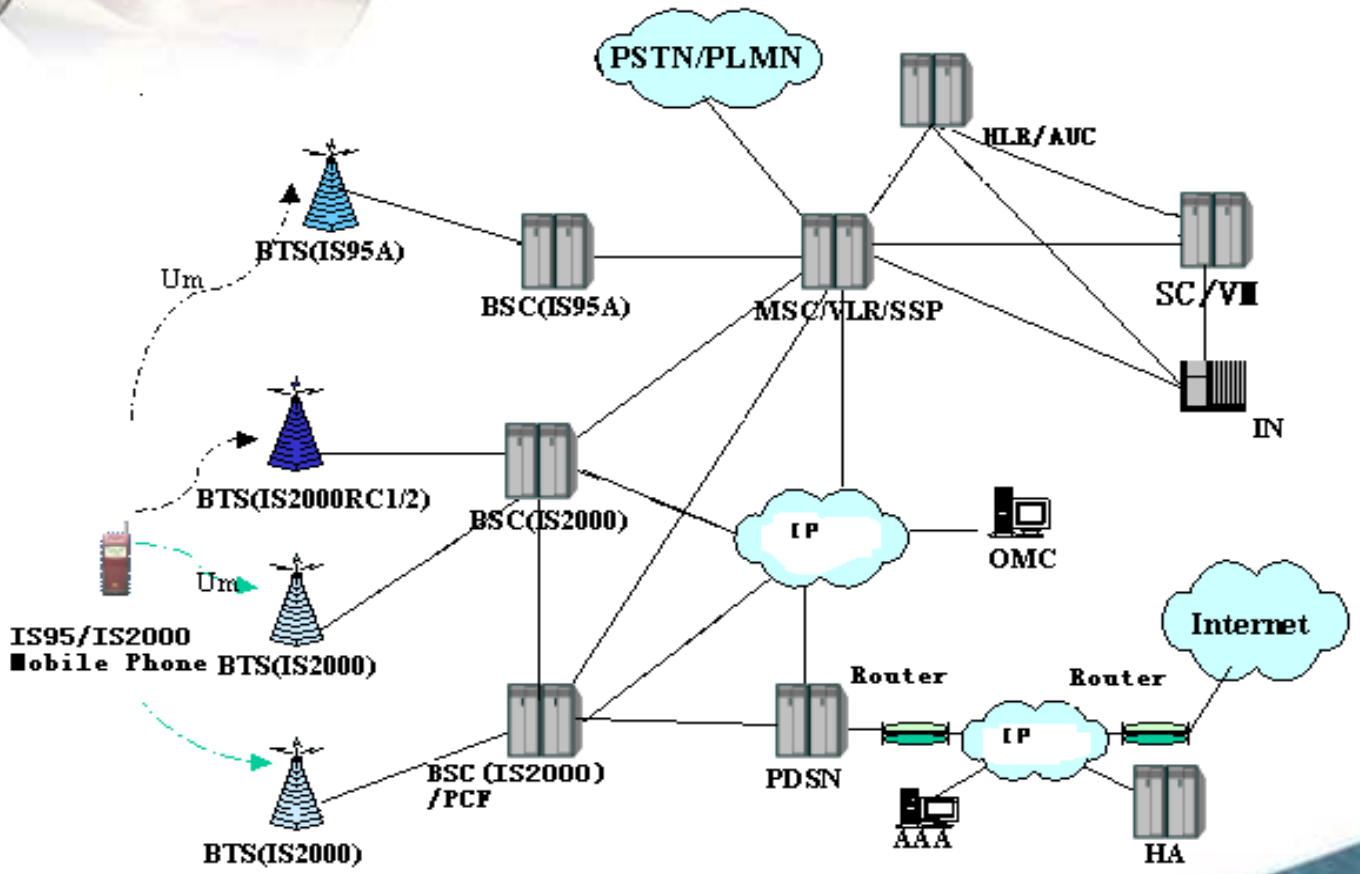
- A Mobile Station receives a Forward Channel from a sector in a Base Station.
- The Forward Channel carries a composite signal of up to 64 forward code channels.
- Some code channels are traffic channels and others are overhead channels.
- A set of 64 mathematical codes is needed to differentiate the 64 possible forward code channels.
  - The codes in this set are called “Walsh Codes”

Discriminating Among Base Station



- A mobile Station is surrounded by Base Stations, all of them transmitting on the same CDMA Frequency.
- Each Sector in each Base Station is transmitting a Forward Traffic Channel containing up to 64 forward code channels.
- A Mobile Station must be able to discriminate between different Sectors of different Base Stations.
- Two binary digit sequences called the I and Q Short PN Sequences (or Short PN Codes) are defined for the purpose of identifying sectors of different base stations.
- These Short PN Sequences can be used in 512 different ways in a CDMA system. Each one of them constitutes a mathematical code which can be used to identify a particular sector.

Example of cdma2000 1x Network



Structure of a Typical CDMA system