Lecture #9

10/10/2016

Last Class

- Orthogonal Codes
- CDMA

Today

- CDMA
- Near-Far Problem
- Error Correcting Codes
- Convolutional Codes

Next Class

- Convolutional Codes

Announcements

- Homework #5 Due This week
- Exam #1 in 2 weeks (10/24/2016)

2G CDMA Standards

North America Standard IS-95 (cdmaone)

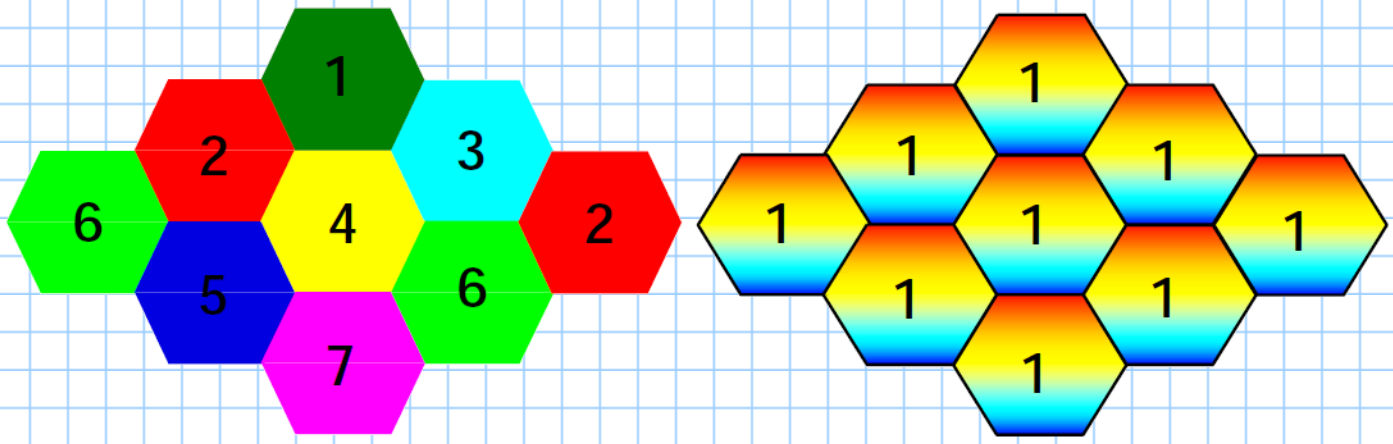
Developed by Qualcomm in Early 90s

Forward and Reverse Channels in
824 MHz – 849 MHz Band
869 MHz – 894 MHz Band

1.25 MHz Channels

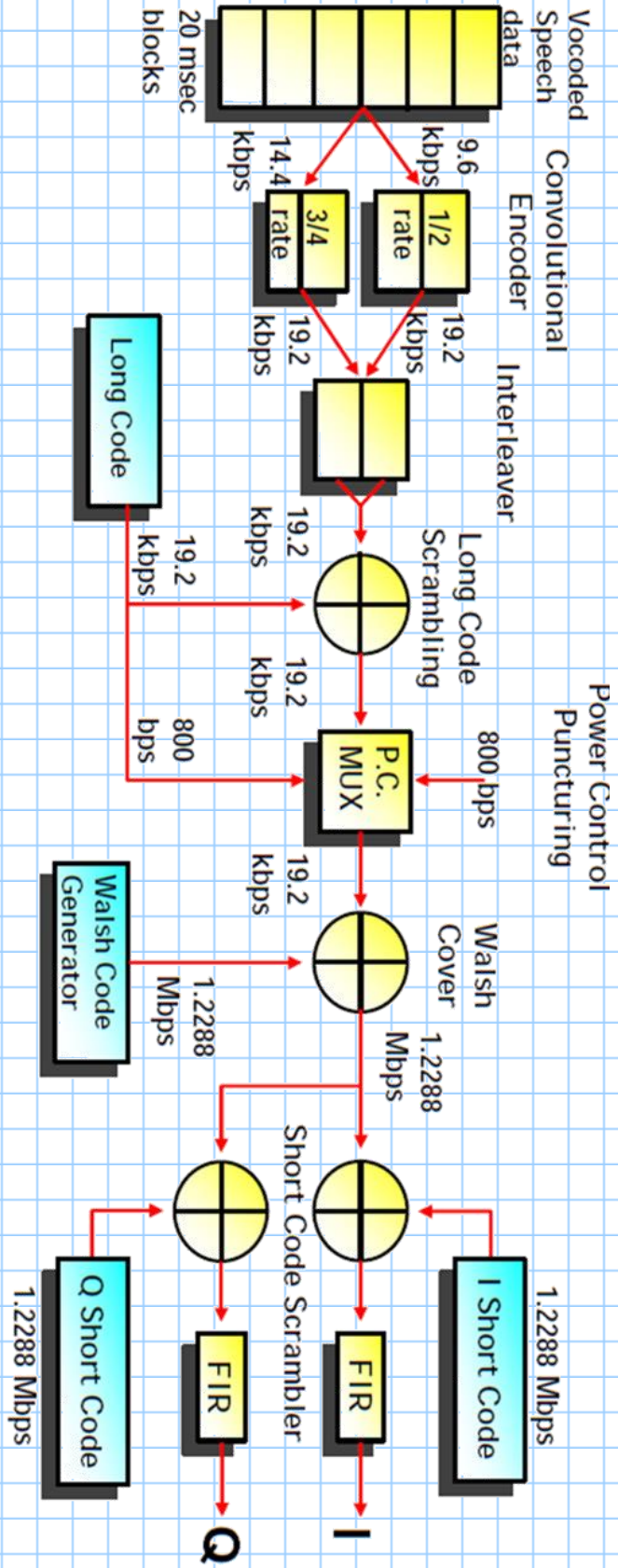
64 Walsh Spreading Codes per Channel

Universal Frequency Reuse



FDMA Reuse CDMA Reuse

IS-95 Forward Link Channel



IS-95 Error Correction Methods

Problem of transmission using a noisy wireless medium remains in 2G

Switch from analog to digital enables use of Channel Coding techniques to reduce error rate

The type of channel coding used in IS-95 (CDMA) is a Convolutional Error Correcting Code

Developed in the 1950's , still widely used in modern digital communications

Convolutional codes, similar to block codes, are *Forward Error Correction codes*

- **In block codes (Hamming) the information bits were followed by parity bits.**
- **In convolutional codes, only parity bits are transmitted**

Convolutional Codes

In Convolutional Codes, an encoder sequentially processes a sequence of bits and generates a corresponding output sequence

The output depends on the current and previous input bits

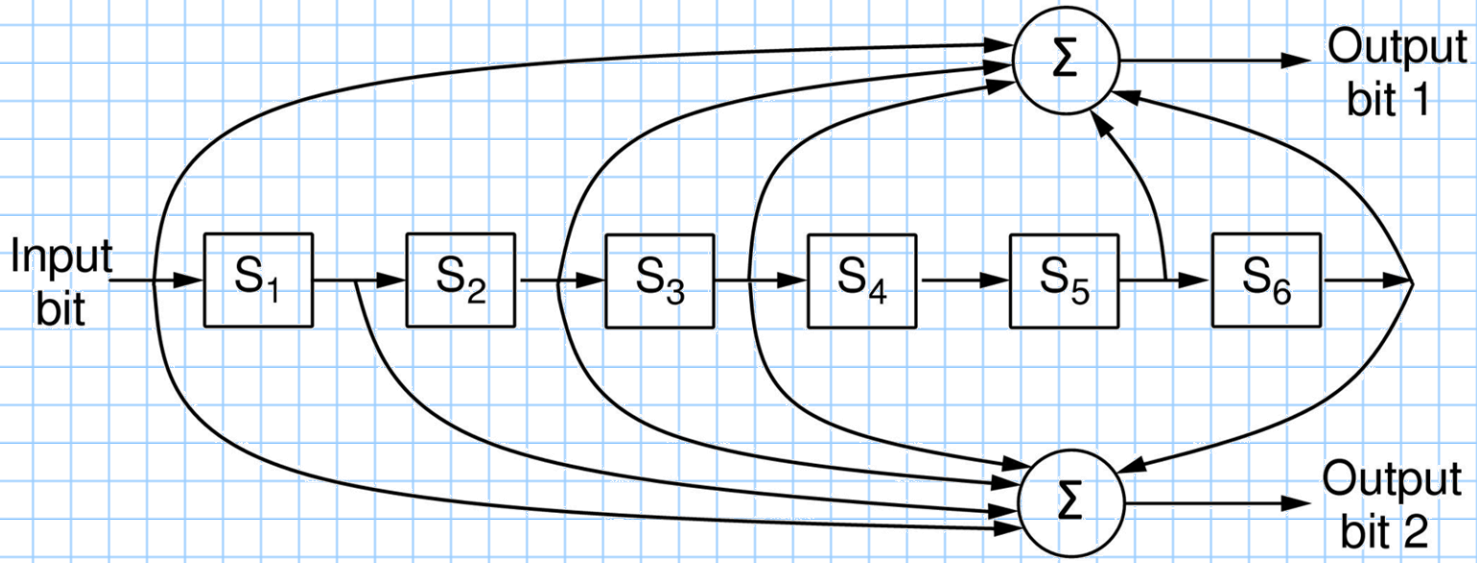
The number of previous bits on which the output depends is the *constraint length (k)*

The convolutional *code rate (r)* is the ratio of input bits to output bits

Convolutional Code Encoding

Convolutional codes are implemented using a series of delay and sum units

NASA Convolutional Code



Convolutional codes performance increases with decreasing code rate (r) and with increasing constraint length (k)

Convolutional Code Encoding

EX: Convolutional Code with k = 3 and r = 1/2

Implementation

Parity Equations

Output Sequence Given input sequence X [n] = [1, 0, 1, 1]

Convolutional Code Encoding

Alternative Finite State Machine Representation

Convolutional Code Decoding

Due to transmission errors, a 1 to 1 mapping between transmitted sequences and observed sequences not always possible

The receiver must determine the "best possible" sequence of message bits (i.e. transmitter states)

Decoders that infer the most likely sequence are known as *Maximum Likelihood Decoders*

The approach of working with uncertainty is known as *soft-decision decoding*.

Deciding whether each bit is a 0 or 1 is called *hard decision decoding*

The Viterbi algorithm is widely used to decode convolutional codes

- **Walk the received sequence**
- **For each state, keep track of possible input sequence that would have produced observed sequence**
- **Input sequence requiring fewest errors is most likely**