Integrated Technical Education Cluster
At AlAmeeria

E-716-A
Mobile Communications Systems

Lecture #8
2G CDMA Mobile Systems

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Agenda

2G in Egypt

Second Generation CDMA

- Introduction to CDMA
- IS-95 system

2G IN EGYPT

2G in Egypt

- Mobinil
  - 1998, Buy the 1st mobile license in Egypt from Telecom Egypt.
  - Contributors: Orascom Telecom Egypt &France Telecom Orange .
  - First announcement of EDGE Technology.
  - First usage of Micro BTS to cover El-Azhar tunnels and Metro/Subway stations.
- Vodafone
  - 1998, got the 2nd mobile license in Egypt.
  - Known as (misr phone/ Click GSM)
  - Contributors: Vodafone, air touch and some local & International partners.
  - 2002, Vodafone Egypt instead of Click GSM.
  - 2007, 54.93% for Vodafone & 44.94% Telecom Egypt & 0.13 % free
- Etisalat
  - In 2007, got the 3rd mobile license in Egypt.
  - Contributors: Etisalat Emirates , Egypt Post, NBE bank & others.
  - The first 3G (3.5 G) services (video call, mobile TV, ..) in Egypt.
  - 1 million subscriber in 50 days !
  - Currently provide 2G & 3G services.

2G CDMA

2G CDMA

- Higher quality signals
- Higher data rates
- Support of digital services
- Greater capacity
- Digital traffic channels
  - Support digital data
  - Voice traffic digitized
  - User traffic (data or digitized voice) converted to analog signal for transmission
- Encryption
  - Simple to encrypt digital traffic
- Error detection and correction
  - Very clear voice reception
- Channel access
  - Channel dynamically shared by users via Time division multiple access (TDMA) or code division multiple access (CDMA)
- Each cell allocated frequency bandwidth
  - Split in two
    - Half for reverse, half for forward
    - Direct-sequence spread spectrum (DSSS)

CDMA Advantages

- Frequency diversity
  - Frequency-dependent transmission impairments (noise bursts, selective fading) have less effect
- Multipath resistance
  - DSSS overcomes multipath fading by frequency diversity
  - Also, chipping codes used only exhibit low cross correlation and low autocorrelation
  - Version of signal delayed more than one chip interval does not interfere with the dominant signal as much
- Privacy
  - From spread spectrum (see chapter 9)
- Graceful degradation
  - With FDMA or TDMA, fixed number of users can access system simultaneously
  - With CDMA, as more users access the system simultaneously, noise level and hence error rate increases
  - Gradually system degrades

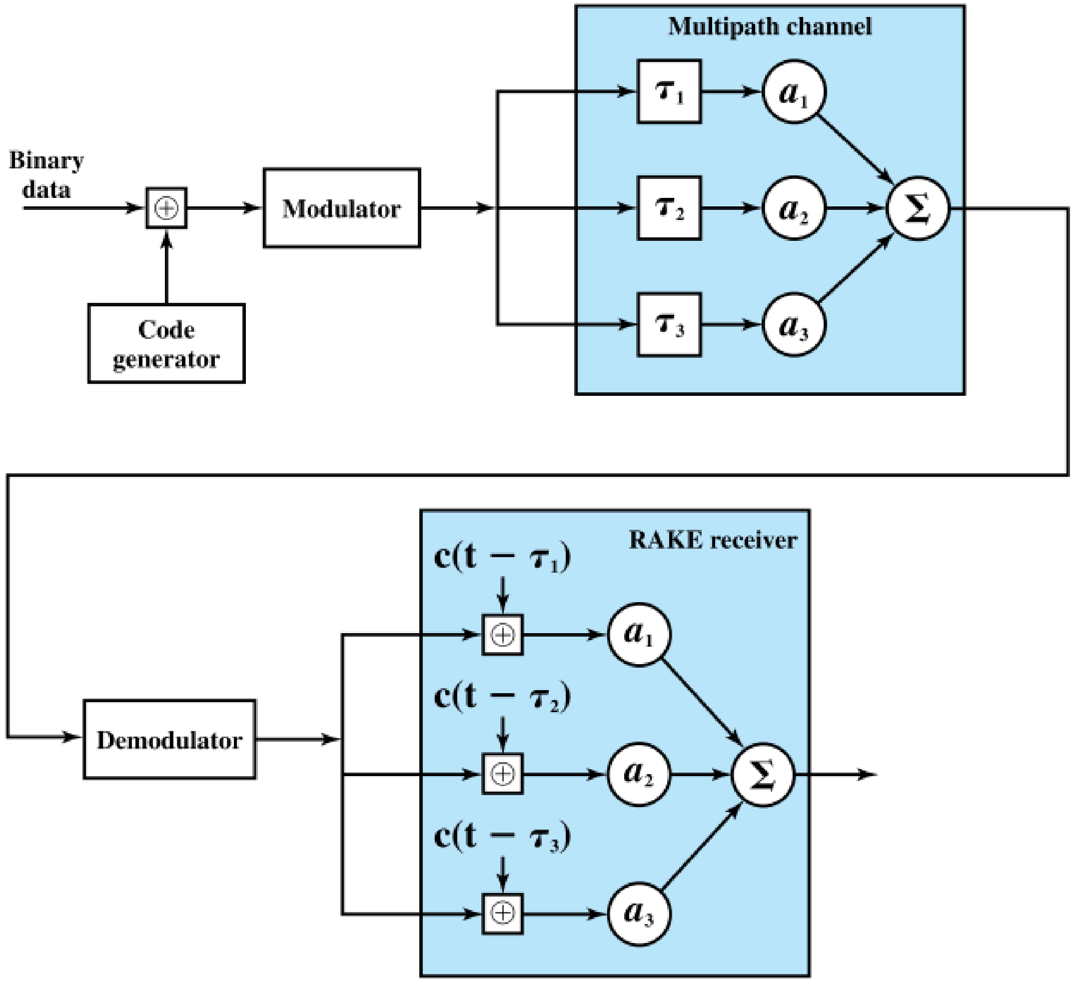
CDMA Disadvantages

- Self-jamming
  - Unless all mobile users are perfectly synchronized, arriving transmissions from multiple users will not be perfectly aligned on chip boundaries
  - Spreading sequences of different users not orthogonal
  - Some cross correlation
  - Distinct from either TDMA or FDMA
    - In which, for reasonable time or frequency guardbands, respectively, received signals are orthogonal or nearly so
- Near-far problem
  - Signals closer to receiver are received with less attenuation than signals farther away
  - Given lack of complete orthogonality, transmissions from more remote mobile units may be more difficult to recover

CDMA Design Consideration (RAKE Receiver)

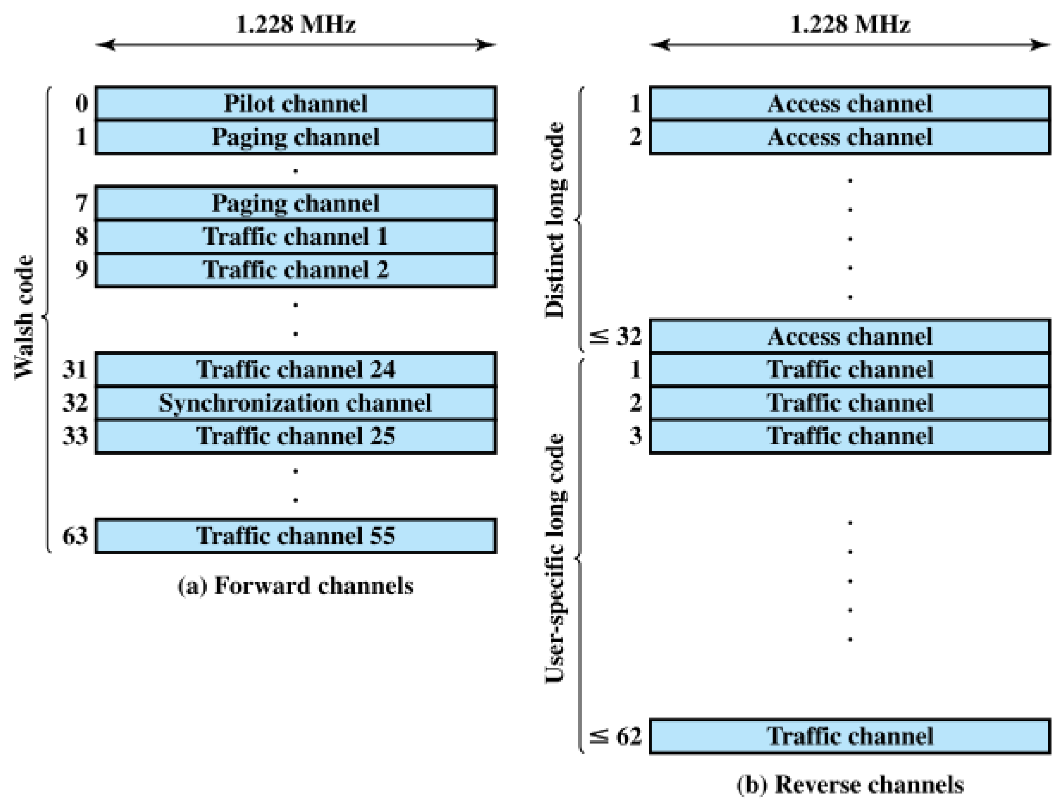
- If multiple versions of signal arrive more than one chip interval apart, receiver can recover signal by correlating chip sequence with dominant incoming signal
  - Remaining signals treated as noise
- Better performance if receiver attempts to recover signals from multiple paths and combine them, with suitable delays
- Original binary signal is spread by XOR operation with chipping code
- Spread sequence modulated for transmission over wireless channel
- Multipath effects generate multiple copies of signal
  - Each with a different amount of time delay ($\tau 1$, $\tau 2$, etc.)
  - Each with a different attenuation factors (a1, a2, etc.)
  - Receiver demodulates combined signal
  - Demodulated chip stream fed into multiple correlators, each delayed by different amount
  - Signals combined using weighting factors estimated from the channel

Principal of RAKE Receiver



IS-95 Channel Structure

- **IS-95**
  - Second generation CDMA scheme
  - Primarily deployed in North America
  - Transmission structures different on forward and reverse links



IS-95 Forward Link

- Up to 64 logical CDMA channels each occupying the same 1228-kHz bandwidth

- Four types of channels:
  - Pilot (channel 0)
    - Continuous signal on a single channel
    - Allows mobile unit to acquire timing information
    - Provides phase reference for demodulation process
    - Provides signal strength comparison for handoff determination
    - Consists of all zeros
  - Synchronization (channel 32)
    - 1200-bps channel used by mobile station to obtain identification information about the cellular system
    - System time, long code state, protocol revision, etc.

IS-95 Forward Link..

- Paging (channels 1 to 7)
  - Contain messages for one or more mobile stations
- Traffic (channels 8 to 31 and 33 to 63)
  - 55 traffic channels
  - Original specification supported data rates of up to 9600 bps
  - Revision added rates up to 14,400 bps
- All channels use same bandwidth
  - Chipping code distinguishes among channels
  - Chipping codes are the 64 orthogonal 64-bit codes derived from 64 × 64 Walsh matrix

Channel	Sync	Paging		Traffic Rate Set 1				Traffic Rate Set 2			
Data rate (bps)	1200	4800	9600	1200	2400	4800	9600	1800	3600	7200	14400
Code repetition	2	2	1	8	4	2	1	8	4	2	1
Modulation symbol rate (sps)	4800	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200
PN chips/modulation symbol	256	64	64	64	64	64	64	64	64	64	64
PN chips/bit	1024	256	128	1024	512	256	128	682.67	341.33	170.67	85.33

Forward Link Processing

- Voice traffic encoded at 8550 bps
- Additional bits added for error detection
  - Rate now 9600 bps
- Full capacity not used when user not speaking
- Quiet period data rate as low as 1200 bps
- 2400 bps rate used to transmit transients in background noise
- 4800 bps rate to mix digitized speech and signaling data
- Data transmitted in 20 ms blocks
- Forward error correction
  - Convolutional encoder with rate ½
  - Doubling effective data rate to 19.2 kbps
  - For lower data rates encoder output bits (called code symbols) replicated to yield 19.2-kbps
- Data interleaved in blocks to reduce effects of errors by spreading them

Scrambling

- After interleaver, data scrambled
- Privacy mask
- Prevent sending of repetitive patterns
  - Reduces probability of users sending at peak power at same time
- Scrambling done by long code
  - Pseudorandom number generated from 42-bit-long shift register
  - Shift register initialized with user's electronic serial number
  - Output of long code generator is at a rate of 1.2288 Mbps
    - 64 times 19.2 kbps
    - One bit in 64 selected (by the decimator function)
    - Resulting stream XORed with output of block interleaver

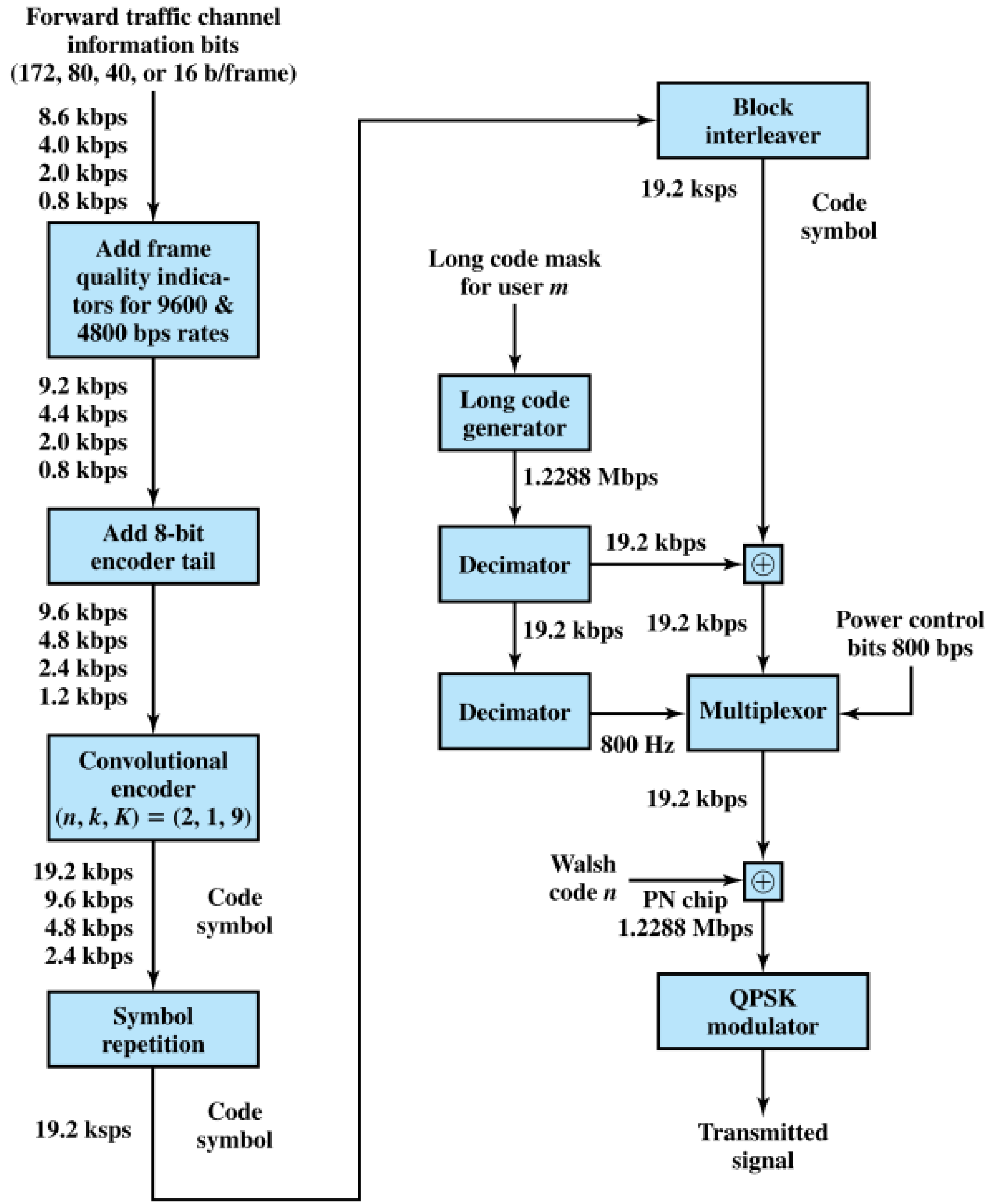
Power Control & DSSS

- Next step inserts power control information in traffic channel
  - To control the power output of antenna
  - Robs traffic channel of bits at rate of 800 bps by stealing code bits
  - 800-bps channel carries information directing mobile unit to change output level
  - Power control stream multiplexed into 19.2 kbps
    - Replace some code bits, using long code generator to encode bits

DSSS:

- Spreads 19.2 kbps to 1.2288 Mbps
- Using one row of Walsh matrix
  - Assigned to mobile station during call setup
  - If 0 presented to XOR, 64 bits of assigned row sent
  - If 1 presented, bitwise XOR of row sent
- Final bit rate 1.2288 Mbps
- Bit stream modulated onto carrier using QPSK
  - Data split into I and Q (in-phase and quadrature) channels
  - Data in each channel XORed with unique short code
    - Pseudorandom numbers from 15-bit-long shift register

Forward Link Transmission



Reverse Link

- Up to 94 logical CDMA channels
  - Each occupying same 1228-kHz bandwidth
  - Supports up to 32 access channels and 62 traffic channels
- Traffic channels mobile unique
  - Each station has unique long code mask based on serial number
    - 42-bit number, $2^{42} - 1$ different masks
    - Access channel used by mobile to initiate call, respond to paging channel message, and for location update

Channel	Access	Traffic-Rate Set 1				Traffic-Rate Set 2			
Data rate (bps)	4800	1200	2400	4800	9600	1800	3600	7200	14400
Code rate	1/3	1/3	1/3	1/3	1/3	1/2	1/2	1/2	1/2
Symbol rate before repetition (sps)	14,400	3600	7200	14,400	28,800	3600	7200	14,400	28,800
Symbol repetition	2	8	4	2	1	8	4	2	1
Symbol rate after repetition (sps)	28,800	28,800	28,800	28,800	28,800	28,800	28,800	28,800	28,800
Transmit duty cycle	1	1/8	1/4	1/2	1	1/8	1/4	1/2	1
Code symbols/ modulation symbol	6	6	6	6	6	6	6	6	6
PN chips/ modulation symbol	256	256	256	256	256	256	256	256	256
PN chips/bit	256	128	128	128	128	256/3	256/3	256/3	256/3

Reverse Link Processing and Spreading

- First steps same as forward channel
  - Convolutional encoder rate 1/3
  - Tripling effective data rate to max. 28.8 kbps
  - Data block interleaved
- Spreading using Walsh matrix
  - Use and purpose different from forward channel
  - Data from block interleaver grouped in units of 6 bits
  - Each 6-bit unit serves as index to select row of matrix ($2^6 = 64$)
  - Row is substituted for input
  - Data rate expanded by factor of 64/6 to 307.2 kbps
  - Done to improve reception at BS
  - Because possible codings orthogonal, block coding enhances decision-making algorithm at receiver
  - Also computationally efficient
  - Walsh modulation form of block error-correcting code
  - $(n, k) = (64, 6)$ and $d_{min} = 32$
  - In fact, all distances 32

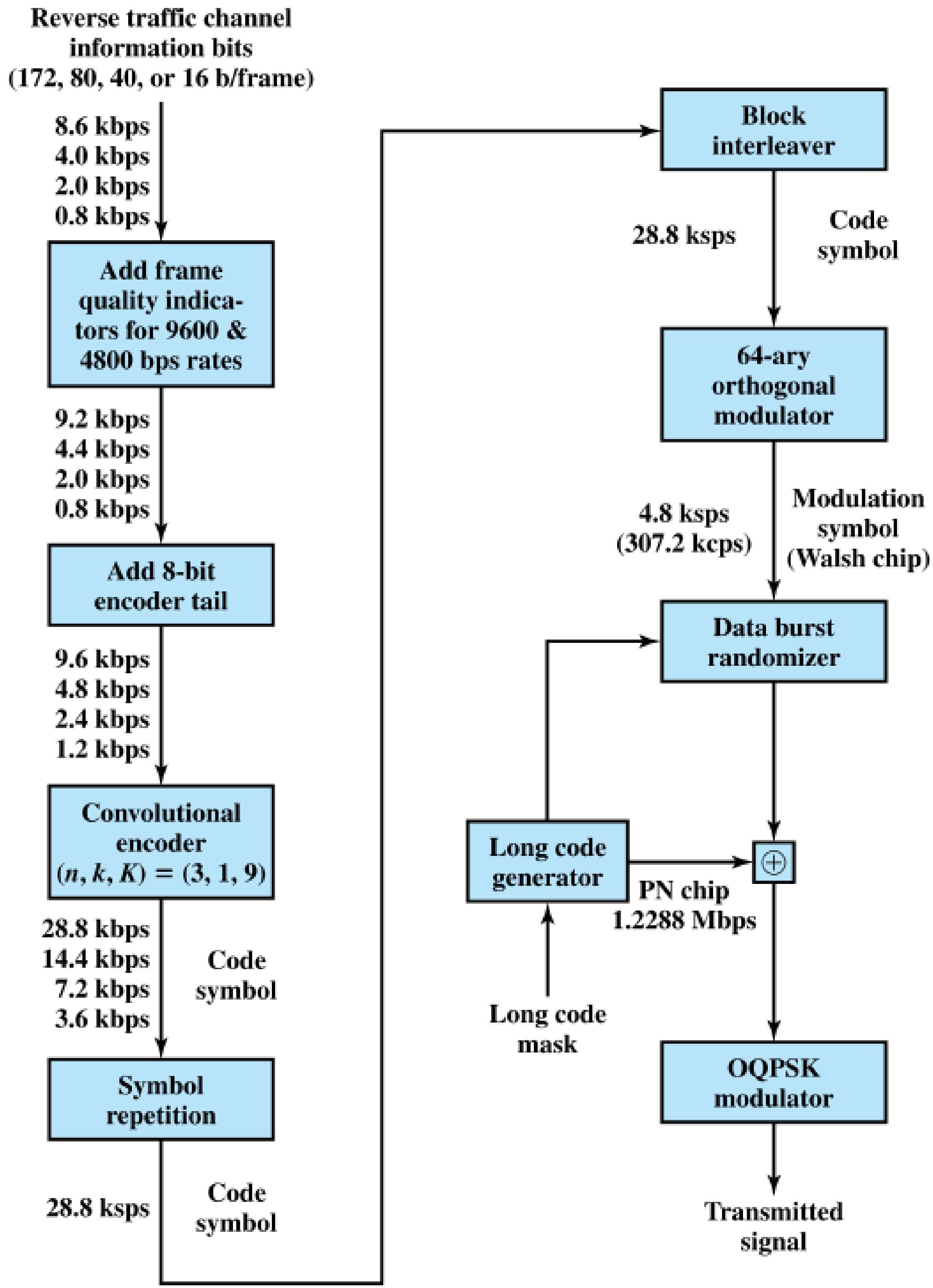
Data Burst Randomizer & DSSS

- Reduce interference from other mobile stations
- Using long code mask to smooth data out over 20 ms frame

DSSS:

- Long code unique to mobile XORed with output of randomizer
- 1.2288-Mbps final data stream
- Modulated using orthogonal QPSK modulation scheme
- Differs from forward channel in use of delay element in modulator to produce orthogonality
  - Forward channel, spreading codes orthogonal
    - Coming from Walsh matrix
  - Reverse channel orthogonality of spreading codes not guaranteed

Reverse Link Transmission



- For more details, refer to:
  - Chapter 4, J. Chiller, Mobile Communications, 2003.
  - Chapter 10, W. Stallings, Wireless Communications and Networks, 2005.
- The lecture is available online at:
  - https://speakerdeck.com/ahmad_elbanna
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