Traffic Modelling

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Cellular Concepts

- Mobile telephone service
- Distributed network of transmitters
- Use multiple low-power transmitters (100 W or less)

Cellular Network Organization

- Areas divided into cells
  - Each served by its own antenna(s)
  - Band of frequencies allocated
  - Cells set up such that antennas of all neighbors are equidistant (hexagonal pattern)
- Architecture
  - PSTN
  - MTSO
  - Base Station and Antenna

Handoff Performance Metrics

- Cell blocking probability – probability of a new call being blocked
- Call dropping probability – probability that a call is terminated due to a handoff
- Call completion probability – probability that an admitted call is not dropped before it terminates
- Probability of unsuccessful handoff – probability that a handoff is executed while the reception conditions are inadequate

Blocking System Performance Questions

- Probability that call request is blocked?
- What capacity is needed to achieve a certain upper bound on probability of blocking?
- What is the average delay?
- What capacity is needed to achieve a certain average delay?

Traffic Intensity

- Load presented to a system:

$$A = \lambda h$$

  - λ = mean rate of calls attempted per unit time
  - h = mean holding time per successful call
  - A = average number of calls arriving during average holding period, for normalized λ

Problem 5!

Factors that Determine the Nature of the Traffic Model

- Manner in which blocked calls are handled
  - Lost calls delayed (LCD) – blocked calls put in a queue awaiting a free channel
  - Blocked calls rejected and dropped
    - Lost calls cleared (LCC) – user waits before another attempt
    - Lost calls held (LCH) – user repeatedly attempts calling
- Number of traffic sources
  - Whether number of users is assumed to be finite or infinite

First-Generation Analog

- Advanced Mobile Phone Service (AMPS)
  - In North America, two 25-MHz bands allocated to AMPS (pg 304)
    - One for transmission from base to mobile unit
    - One for transmission from mobile unit to base
  - Each band split in two to encourage competition
  - Frequency reuse exploited
- Each carrier could support
  - 395 / 2 voice calls per cell
  - 21 control channels (10kbps)
  - Required creative splitting of busy cells!

AMPS Operation – 1G

- Subscriber initiates call by keying in phone number and presses send key
- MTSO verifies number and authorizes user
- MTSO issues message to user's cell phone indicating send and receive traffic channels
- MTSO sends ringing signal to called party
- Party answers; MTSO establishes circuit and initiates billing information
- Either party hangs up; MTSO releases circuit, frees channels, completes billing

Differences Between First and Second Generation Systems

- Digital traffic channels – first-generation systems are almost purely analog; second-generation systems are digital
- Encryption – all second generation systems provide encryption to prevent eavesdropping
- Error detection and correction – second-generation digital traffic allows for detection and correction, giving clear voice reception (digital / dsp)
- Channel access – second-generation systems allow channels to be dynamically shared by a number of users (TDM and CDMA)

AMPS Frequency reuse

- Mobile station transmission frequencies
  - 824.04 ~ 848.97 MHz
- Base stations transmission frequencies
  - 869.04 ~ 893.97 MHz
- 45 MHz separation between transmit and receive channels
- AMPS uses 832 channels that are each 30 kHz wide

MSC		Receives call from PSTN. Sends the requested MIN to all base stations			Verifies that the mobile has a vaild MIN, ESN pair.	Requests BS to move mobile to unused voice channel pair.		Connects the mobile with the calling party on the PSTN.
Base Station	FCC		Transmits page (MIN) for specified user.				Transmits data message for mobile to move to specific voice channel.	
	RCC			Receives MIN, ESN, Station Class Mark and passes to MSC.				
	FVC							Begin voice transmission.
	RVC							Begin voice reception.
Mobile	FCC		Receives page and matches the MIN with its own MIN.				Receives data messages to move to specified voice channel.	
	RCC			Acknowledges receipt of MIN and sends ESN and Station Class Mark.				
	FVC							Begin voice reception.
	RVC							Begin voice transmission.

time ⟶

Figure 1.6
Timing diagram illustrating how a call to a mobile user initiated by a landline subscriber is established.

2G and Beyond - Standards

- Purposes – Allow interoperation of equipment
- Allows many vendors to compete
- Less risk for implementers
- Based on technologies (from ch2-8)

2G - TDMA Basics

- Used TDM with FDM (same 30kHz channels)
- TD multiplexed 3 users per channel
- Voice encoding
  - PCM is 64kbps – TOO BIG
  - Used technique to make 12kbps
- Cingular and many ATT phones use this!

Voice Coding Algorithms

Algorithm	Rate (kb/s)	MOS /5	MIPS
PCM (G.711)	64	4.3	.01
ADPCM (G.721)	32	4.1	2
LD-CELP (G.728)	16	4	19
RPE-LTP (GSM)	13	3.47	6
Skyphone-MPLP	9.6	3.4	11
VSELP (IS-54)	8	3.45	13.5
CELP (IS-95)	4.8	3.2	16

TDMA - Design Considerations

- Number of logical channels (number of time slots in TDMA frame): 8
- Maximum cell radius (R): 35 km
- Frequency: region around 900 MHz
- Maximum vehicle speed (V_m):250 km/hr
- Maximum coding delay: approx. 20 ms
- Maximum delay spread (Δ_m): 10 μs
- Bandwidth: Not to exceed 200 kHz (25 kHz per channel)

2G- GSM

- Uses TDMA with 8 users per channel
- Based on European standards
- T-Mobile!

Base Station Subsystem (BSS)

- BSS consists of base station controller and one or more base transceiver stations (BTS)
- Each BTS defines a single cell
  - Includes radio antenna, radio transceiver and a link to a base station controller (BSC)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging

Network Subsystem (NS)

- NS provides link between cellular network and public switched telecommunications networks
  - Controls handoffs between cells in different BSSs
  - Authenticates users and validates accounts
  - Enables worldwide roaming of mobile users
- Central element of NS is the mobile switching center (MSC)

Mobile Switching Center (MSC) Databases

- Home location register (HLR) database – stores information about each subscriber that belongs to it
- Visitor location register (VLR) database – maintains information about subscribers currently physically in the region
- Authentication center database (AuC) – used for authentication activities, holds encryption keys
- Equipment identity register database (EIR) – keeps track of the type of equipment that exists at the mobile station

TDMA Format – Time Slot Fields

- Trail bits – allow synchronization of transmissions from mobile units
- Encrypted bits – encrypted data
- Stealing bit - indicates whether block contains data or is "stolen"
- Training sequence – used to adapt parameters of receiver to the current path propagation characteristics
  - Strongest signal selected in case of multipath propagation
- Guard bits – used to avoid overlapping with other bursts

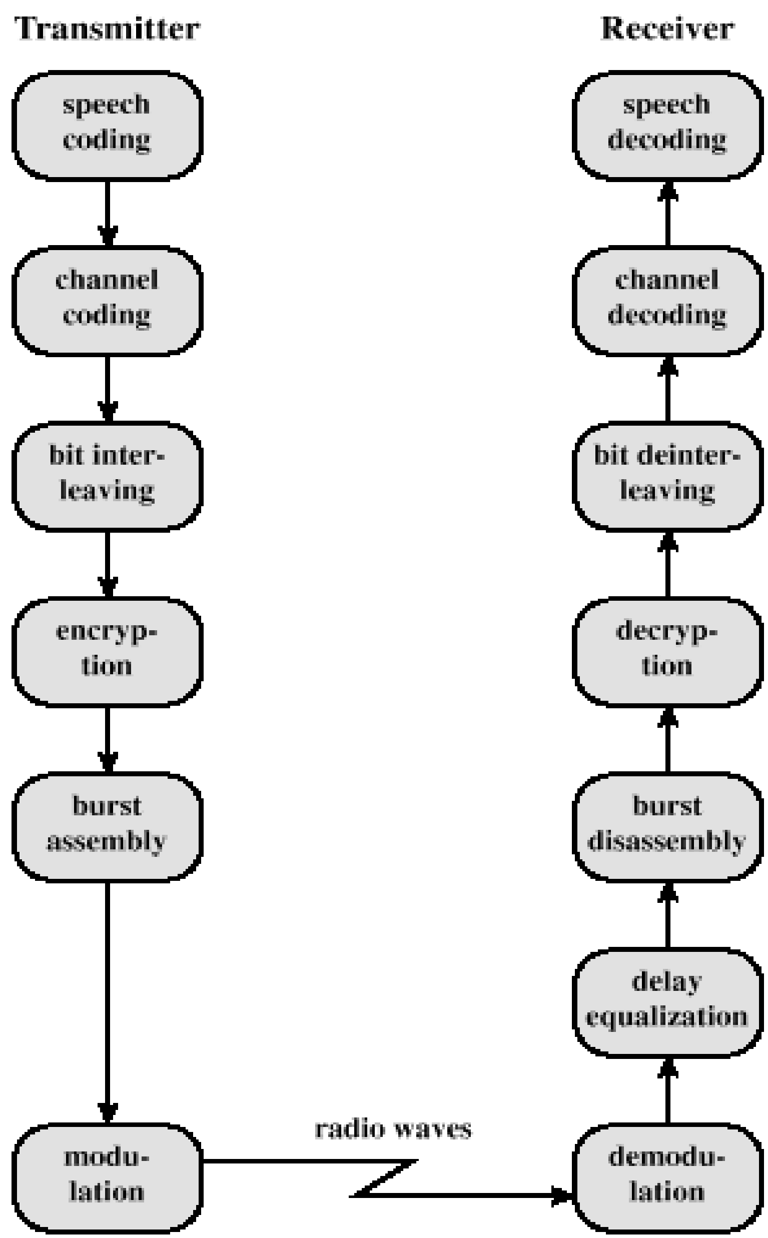
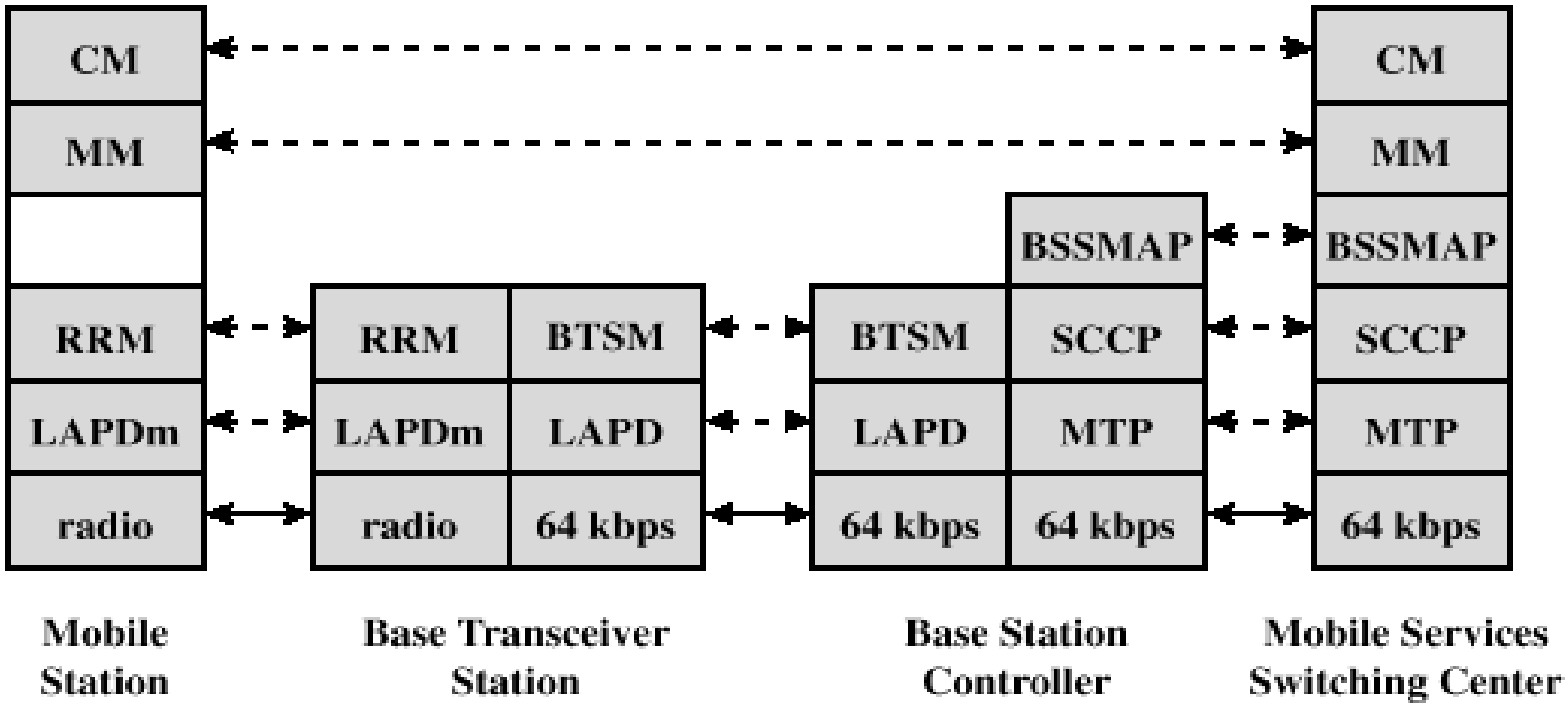


Figure 10.16 GSM Speech Signal Processing



BSSMAP = BSS mobile application part
BTSM = BTS management
CM = connection management
LAPD = link access protocol, D channel
MM = mobility management
MTP = message transfer part
RRM = radio resources management
SCCP = signal connection control part

Figure 10.17 GSM Signaling Protocol Architecture

Functions Provided by Protocols

- Protocols above the link layer of the GSM signaling protocol architecture provide specific functions:
  - Radio resource management
  - Mobility management
  - Connection management
  - Mobile application part (MAP)
  - BTS management

2G – CDMA - Advantages

- Frequency diversity – frequency-dependent transmission impairments have less effect on signal
- Multipath resistance – chipping codes used for CDMA exhibit low cross correlation and low autocorrelation
- Privacy – privacy is inherent since spread spectrum is obtained by use of noise-like signals
- Graceful degradation – system only gradually degrades as more users access the system

Drawbacks of CDMA Cellular

- Self-jamming – arriving transmissions from multiple users not aligned on chip boundaries unless users are perfectly synchronized
- Near-far problem – signals closer to the receiver are received with less attenuation than signals farther away
- Soft handoff – requires that the mobile acquires the new cell before it relinquishes the old; this is more complex than hard handoff used in FDMA and TDMA schemes

Mobile Wireless CDMA Design Considerations

- RAKE receiver – when multiple versions of a signal arrive more than one chip interval apart, RAKE receiver attempts to recover signals from multiple paths and combine them
  - This method achieves better performance than simply recovering dominant signal and treating remaining signals as noise
- Soft Handoff – mobile station temporarily connected to more than one base station simultaneously

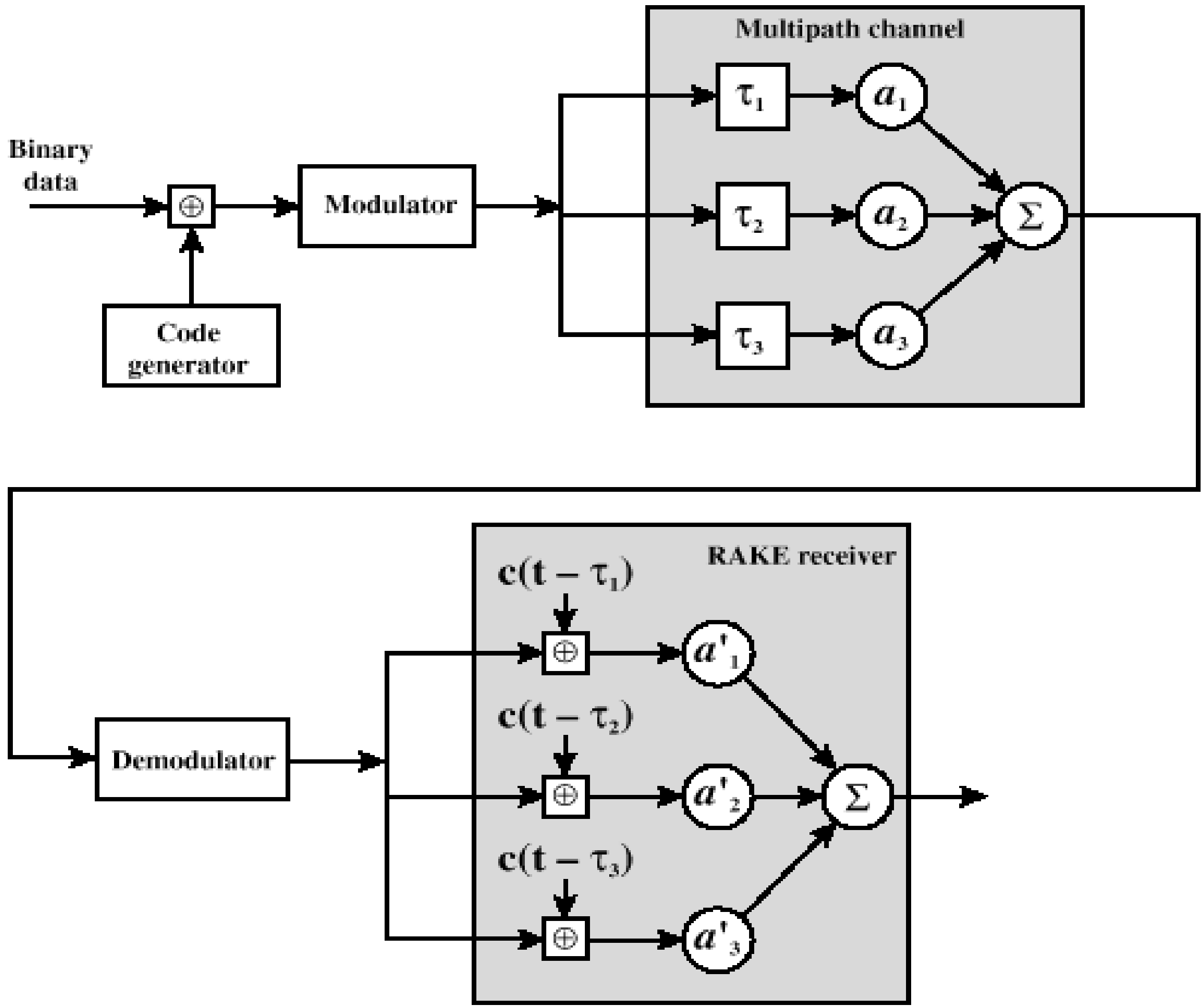


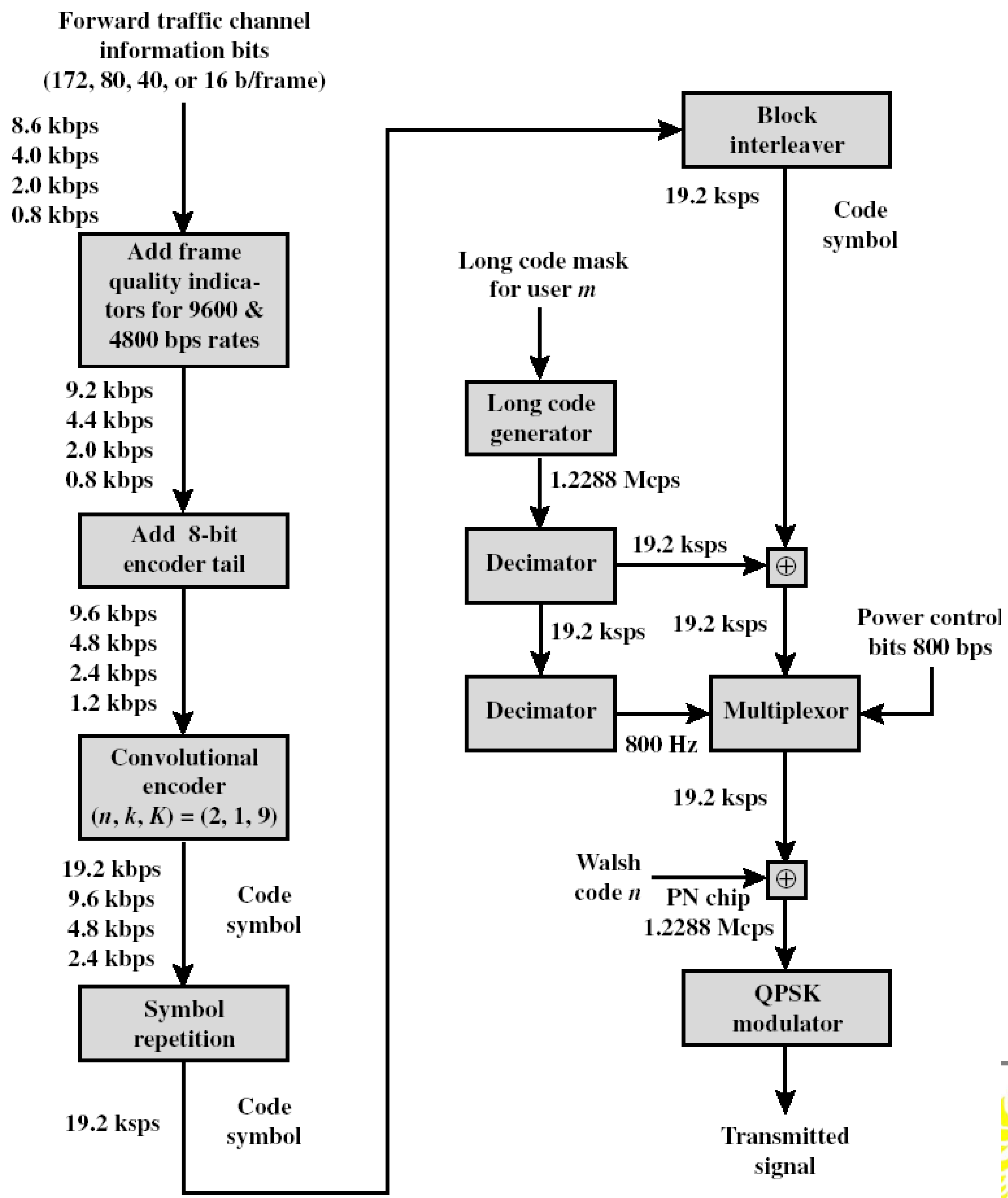
Figure 10.18 Principle of RAKE Receiver [PRAS98]

Types of Channels Supported by Forward Link (BS to Mobile)

- Pilot (channel 0) - allows the mobile unit to acquire timing information, provides phase reference and provides means for signal strength comparison
- Synchronization (channel 32) - used by mobile station to obtain identification information about cellular system
- Paging (channels 1 to 7) - contain messages for one or more mobile stations
- Traffic (channels 8 to 31 and 33 to 63) – the forward channel supports 55 traffic channels

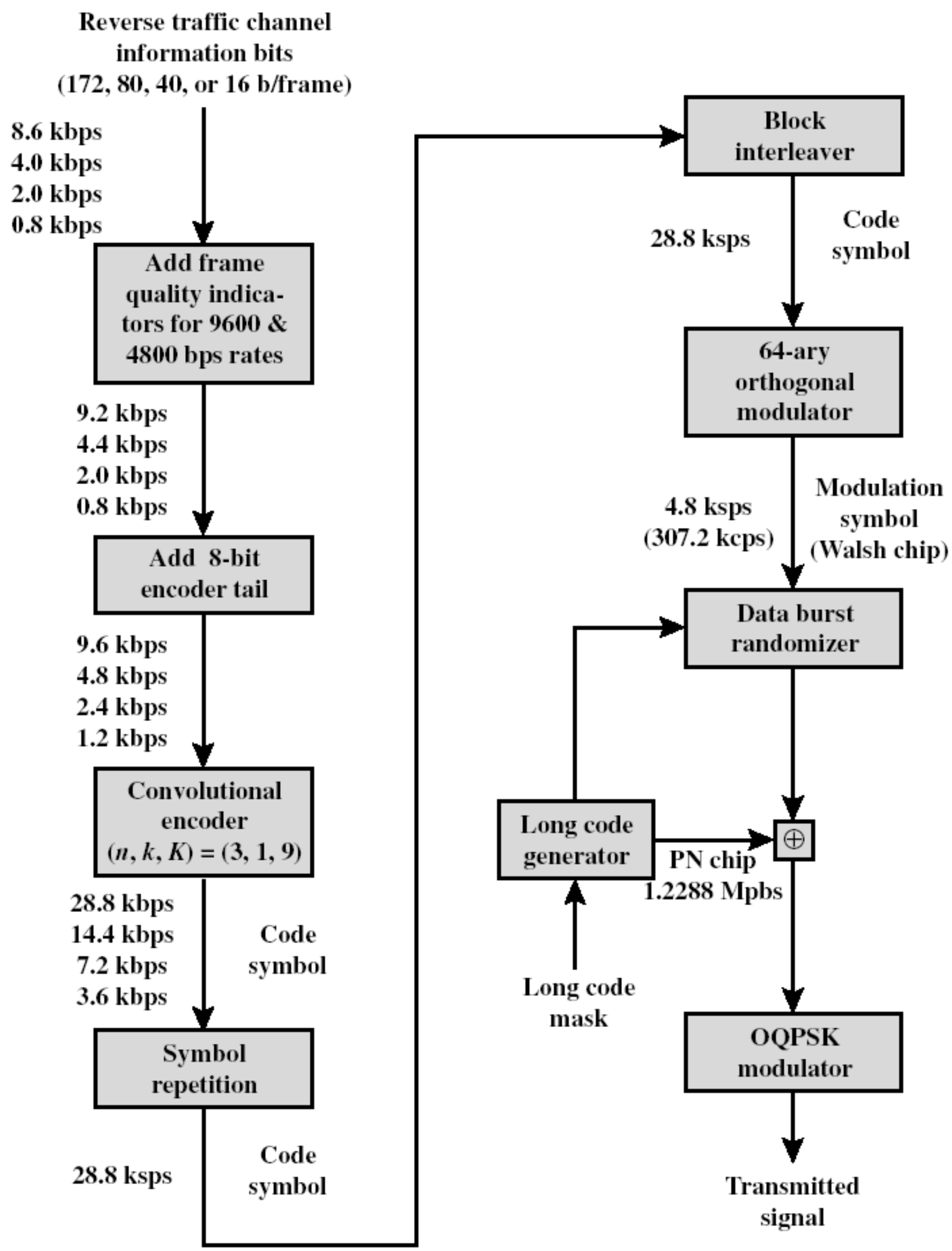
Forward Traffic Channel Processing Steps (Fig 10.20)

- Speech is encoded at a rate of 8550 bps
- Additional bits added for error detection
- Data transmitted in 2-ms blocks with forward error correction provided by a convolution encoder
- Data interleaved in blocks to reduce effects of errors
- Data bits are scrambled, serving as a privacy mask


Forward traffic channel information bits (172, 80, 40, or 16 b/frame)
8.6 kbps
4.0 kbps
2.0 kbps
0.8 kbps
Add frame quality indica-tors for 9600 & 4800 bps rates
9.2 kbps
4.4 kbps
2.0 kbps
0.8 kbps
Add 8-bit encoder tail
9.6 kbps
4.8 kbps
2.4 kbps
1.2 kbps
Convolutional encoder (n, k, K) = (2, 1, 9)
19.2 kbps
9.6 kbps
4.8 kbps
2.4 kbps
Code symbol
Symbol repetition
19.2 ksps
Code symbol
Block interleaver
19.2 ksps
Code symbol
Long code mask for user m
Long code generator
1.2288 Mcps
Decimator
19.2 ksps
19.2 ksps
19.2 ksps
Power control bits 800 bps
Decimator
Multiplexor
800 Hz
19.2 ksps
Walsh code n
PN chip 1.2288 Mcps
QPSK modulator
Transmitted signal

Forward Traffic Channel Processing Steps (cont.)

- Power control information inserted into traffic channel
- DS-SS function spreads the 19.2 kbps to a rate of 1.2288 Mbps using one row of 64 x 64 Walsh matrix
- Digital bit stream modulated onto the carrier using QPSK modulation scheme


Reverse traffic channel information bits (172, 80, 40, or 16 b/frame)
8.6 kbps
4.0 kbps
2.0 kbps
0.8 kbps
Add frame quality indica- tors for 9600 & 4800 bps rates
9.2 kbps
4.4 kbps
2.0 kbps
0.8 kbps
Add 8-bit encoder tail
9.6 kbps
4.8 kbps
2.4 kbps
1.2 kbps
Convolutional encoder (n, k, K) = (3, 1, 9)
28.8 kbps
14.4 kbps
7.2 kbps
3.6 kbps
Code symbol
Symbol repetition
28.8 ksps
Code symbol
Block interleaver
28.8 ksps
Code symbol
64-ary orthogonal modulator
4.8 ksps (307.2 kcps)
Modulation symbol (Walsh chip)
Data burst randomizer
Long code generator
PN chip 1.2288 Mpbs
Long code mask
OQPSK modulator
Transmitted signal

3G - ITU's View of Capabilities

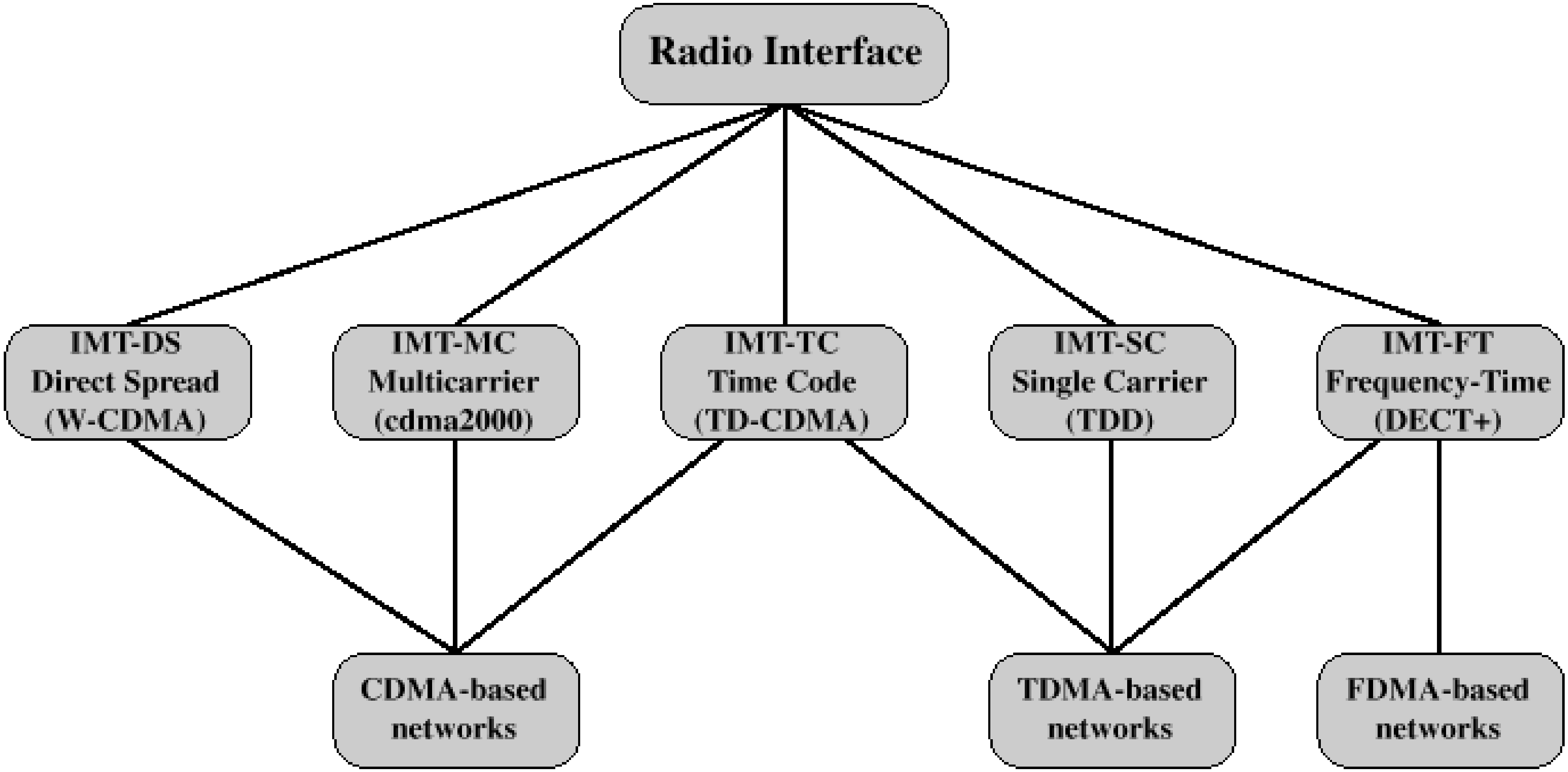
- Voice quality comparable to the public switched telephone network
- 144 kbps data rate available to users in high-speed motor vehicles over large areas
- 384 kbps available to pedestrians standing or moving slowly over small areas
- Support for 2.048 Mbps for office use
- Symmetrical / asymmetrical data transmission rates
- Support for both packet switched and circuit switched data services

3G - ITU's View of Capabilities

- An adaptive interface to the Internet to reflect efficiently the common asymmetry between inbound and outbound traffic
- More efficient use of the available spectrum in general
- Support for a wide variety of mobile equipment
- Flexibility to allow the introduction of new services and technologies

BIG GOALS

Alternative Interfaces



CDMA Design Considerations

- CDMA is dominant in 3G
- Bandwidth – limit channel usage to 5 MHz
- Chip rate – depends on desired data rate, need for error control, and bandwidth limitations; 3 Mcps or more is reasonable
- Multirate – advantage is that the system can flexibly support multiple simultaneous applications from a given user and can efficiently use available capacity by only providing the capacity required for each service