Chap. 1 Introduction & overview of wireless communication systems

I. Wireless Networks

1. Analog Networks
2. Digital Networks

   2.1 Cellular Systems

   2.2 Non-Cellular Systems

      2.2.1 Local area Networks

      2.2.2 personal area Networks

Example of Wireless Systems

Cellular	Voice; Data	3GPP 3GPP2	Cellular Band (800-900 MHz) PCS Band (2 GHz)
WMAN	Data, VoIP	802.16e	
WLAN	Data, VoIP	802.11	ISM Band
WPAN	Data,	802.15.3a Blue Tooth	UWB Band
Optical Wireless	Data,	WWRF	

II. Historical Introduction of mobile wireless communications.

1. propagation test in 1926 at 40MHz

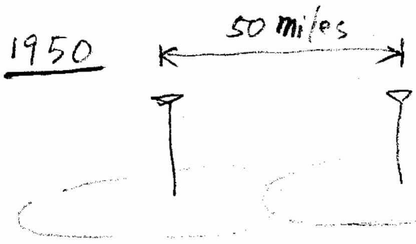
   1.1 propagation effects.

$$P_{av} \propto \frac{1}{(d)^n}$$ n is path loss exponent

   1.1.1 long-term fading (shadowing)

   1.1.2 short-term fading (due to mobile motion)

2. MacroCell systems in <u>1950</u>



2.1 40 channels/cell

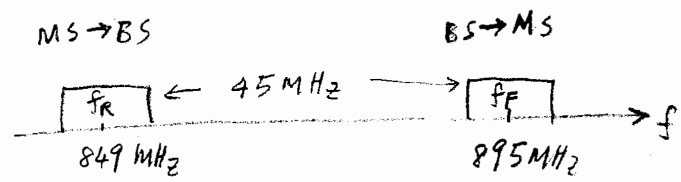
2.2 half-duplex

Notes: (1) Simplex: message go in one direction only (e.g., one-way pager)

(2) Half-duplex: Two way transmission but only one direction at a time (e.g., push to talk radio)

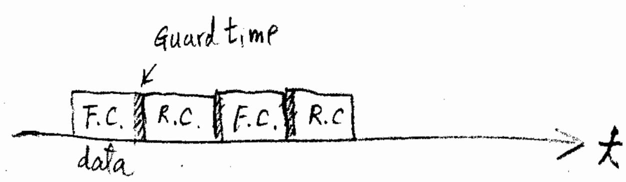
(3) Full-duplex: Two way simultaneous transmission (e.g., Cellular)

① FDD (Freq Division Duplex)



$$\frac{f_F}{f_R} > 1.05$$

② TDD (Time Division Duplex)



TDD scheme only apply to the systems

(i) Data must be digitized (i.e., only for digital systems)

(ii) Guard time must be used to account for variable propagation delays.

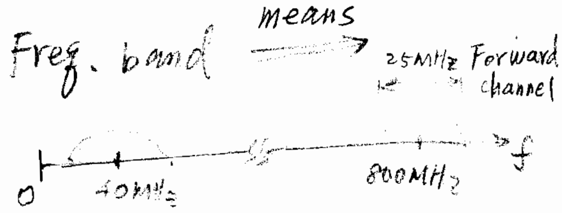
2.3 40 channels accommodate 800-1000 customers in a given area.

* Trunking system concept is used (i.e., blocking probability concept)

$$\text{The average calling time/user} \propto \frac{1}{\text{The Number of customers}}$$

3. Solutions to alleviate the mobile system capacity (1947 Bell Lab)

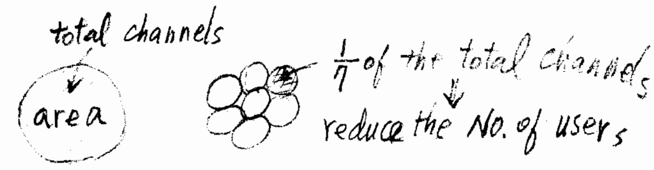
3.1. Move the mobile system to a high Freq. band $\xrightarrow{\text{means}}$ allowing more system bandwidth.



3.2 Introduce a cellular geographic structure

cellular concept ⟹ Freq. reuse (channel reuse)

Example: (1) 7 cell reuse

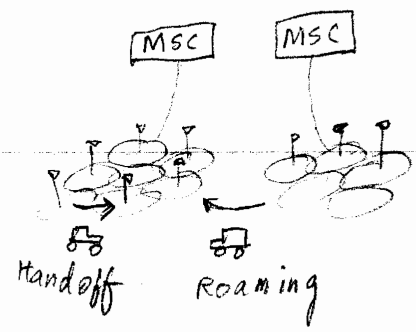


(2) If cell small enough, than

Total users in area ≫ Non cell reuse case (ex. in P.6)

3.2.1 cell concept need to consider

(1) Roaming



(2) Handoff. (e.g., Hard Handoff, soft H.O., softer H.O)

Hard Handoff: FD/TDMA; soft H.O., softer H.O: CDMA

Hard H.O. studies:

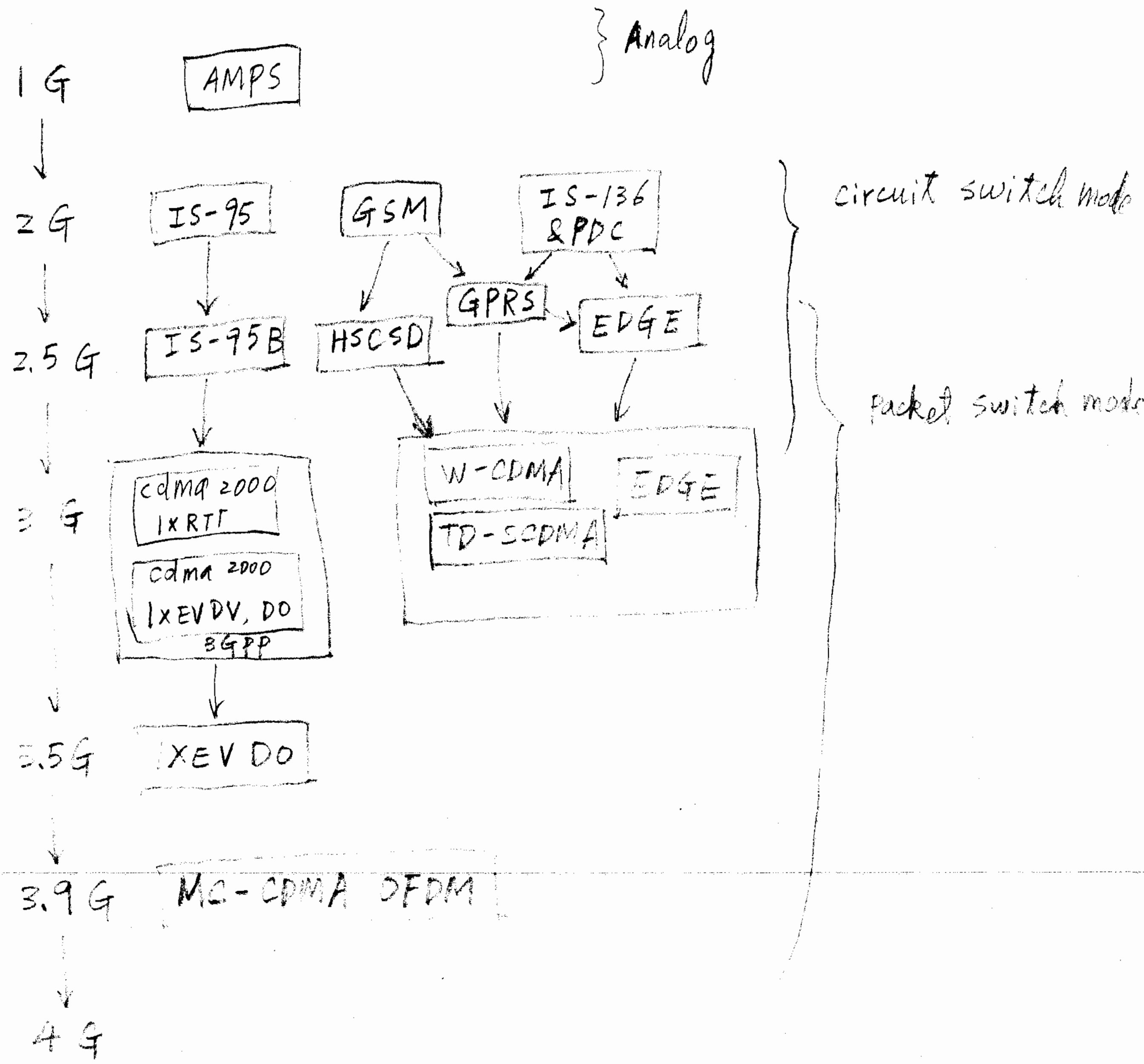
(i) channel assignment

H.O. dropping probability vs. New Call blocking Prob.

(ii) H.O. optimization

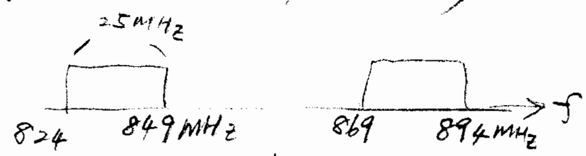
H.O. prob. vs. Dropped call prob.

III. Cellular system evolution



(1) North American cellular systems

① AMPS (Advanced Mobile Phone service) 1983, 1G



1). Analog sys.

2). FDMA

3). FDD

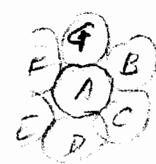
4). 30KHz/Radio channel ← (flat fading or Rayleigh fading channel)

5). FM modulation

6). Voice signal

Ex: The total of 12.5 MHz allocated, Freq. reuse factor is 7

$12.5\,MHz \div 7\ cell \div 30\,KHz/\text{user call} \approx 60$ simultaneous user calls/cell ※



② IS-54 (American Digital Cellular system) 1991, 2G

renamed IS-136 (D-AMPS) backward compatibility to AMPS.

1). Digital sys.

2). FD/TDMA

3). FDD

4). 30KHz/Radio channel

5). 3 voice channels/Radio channel (∵ use more advanced speech coding)

6). π/4 DQPSK (Differential quadrature phase shift Keying)

7). Hard capacity

(① Design envisioned non-coherent demodulation.
② using differential phase detectors
③ simple receiver design)

③ IS-95 (Qualcomm) 1993, 2G

It is spread-spectrum system in non-military applications modern communications & information theory disciplines.

1). Digital sys.

2). FD/CDMA

3). FDD

4). 1.25 MHz/radio channel (i.e., Freq. selective fading channel)

5). ≈ 20 users/1.25 MHz

6). soft capacity $\xrightarrow{\text{imply}}$ (users ↑ ⇒ interference ↑ ⇒ call quality ↓)

CDMA systems <u>NEED</u>

1°. power control (overcome Near-Far problem)
power control rate = 800 kbps = 1.25 ms

2°. Variable rate transmission (reduce sys. interference)

3°. Rake receiver (reduce the Freq-selective multipath fading effects in time domain.
The current Rake receiver only can co-phase 3 multipath fingers.
The rest multipath fingers are discard.
However, if MC-CDMA system is used
The receiver can take care all the multipath fingers in the Freq. domain)

4°. soft handoff

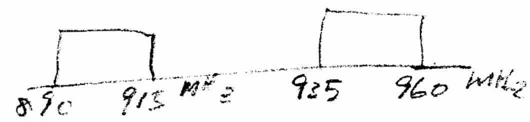
④ cdma 2000 (3GPP2) 3G

⋮

(2). PAN-European Cellular Systems

① GSM (Global system for mobile communication), 2G . 1992

1). Digital system

① 

2). FD/TDMA

② DCS 1800

3). 200 KHz /Radio channel (Freq - selective fading channel
use ① Freq. hopping
② Equalizer

4). 8 users/Radio channel

5). GMSK (Gaussian Filtered Minimum shift keying)

* which permits the use of low-cost nonlinear amplifier in handsets, reduce the cost.

6). Hard hand off (Different Freq handoff).

② WCDMA , 3G

:

※ May 2003 GSM 72% total digital mobile users throughout the world.

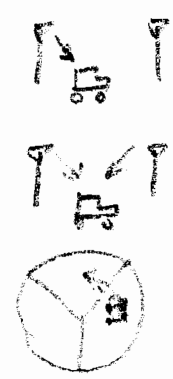
Hand-off (Hand over) Concept.

the process in which a mobile unit is transferred from one channel to another (intra cell Hand off) or from one base station to another (inter cell Hand off)

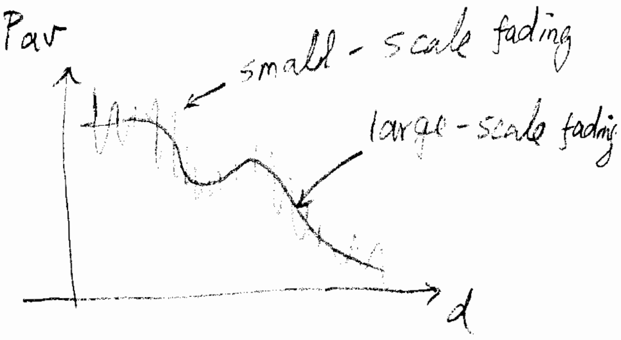
1°. Hard Hand off (MSC controlled Hand off)

2°. Soft Hand off (MSC ")

3° Softer Hand off (BSC ")



IV overview of book



Chap. 2 propagation effects

1. $Pav \propto \frac{1}{(distance)^n}$

2. large-scale fading (Log-normal fading)

   signal power changes in many wavelength

3. small-scale fading due to mobile receiver moves.

   Rayleigh / Rician distribution
   ↑ NLOS ↑ LOS situation

3.1 Fading rate vs. mobile velocity

3.2 slow or Fast fading due to mobile moves

3.3. Flat or Freq-selective fading due to multipath

3.4. Multipath fading mitigation

   1. Equalization tech.
   2. Diversity procedures
   3. RAKE Receiver tech.

chap. 3

1. cellular concept
2. channel reuse
   ⟹ reuse distance vs. SIR (Based on average signal power, ignore fading effects)
3. Trunking systems.
   statistical form for blocking prob. in Telephone system.
   (Erlang distribution concept).

chap. 4

1. Dynamic channel allocation (DCA) reduces the call blocking prob.
2. power control (PC) reduces co-channel interference
3. using analytical approach to compare DCA/Fixed CA

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chap. 5

1. Digital modulation techniques used in digital mobile communication systems.
   - PSK
   - FSK
   - QAM
   - DPSK
   - GMSK
   - OFDM

Chap. 6

1. Multiple access Technique

FDMA
TDMA } system capacity based on BER prob.
CDMA }

Chap. 7

Channel coding for error detection & correction

1. block coding → cyclic codes
2. convolutional coding
3. Viterbi decoding
4. turbo coding
5. LDPC coding *

Chap. 8

2G cellular systems (GSM, IS-136, IS-95)

1. Radio interface
2. signaling through core Network
3. Mobile management (H.O. , location, paging)
4. Voice signal processing & coding (i.e., source coding)

Chap. 9.

performance analysis :-

1. The process of admission & handoff control in wireless Network
2. Examples.

Chap. 10

2.5G/3G systems

1. packet switch data → QoS

(CDMA 2000, 1xEV DV & WCDMA, EDGE, GPRS)

2. 1xEV DO (2.5G tutorial slides)

Chap. 11

Access & scheduling of data packets.

1. QoS
2. full use of the system resources.

Chap. 12

Non-cellular systems

1. WLAN (802.11)

(carrier sense multiple access / collision avoidance)

2. WPAN (BlueTooth)

* How to increase the system capacity.

Shannon's law:-

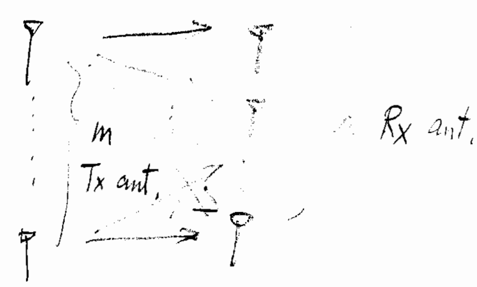
under certain assumptions, the maximum information measured in bits that can be transmitted per second per Hz of radio spectrum is

$$C = B \log_2 \left(1 + \frac{S}{N}\right) \text{ bps}$$

(C = capacity; B = BW in Hz; S = power of the Tx; N = power of thermal noise)

(1) MIMO (multiple-input multiple-output antennas)

$$\begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix} = \begin{bmatrix} h_{11} & h_{21} & \cdots & h_{m1} \\ \vdots & & \ddots & \vdots \\ h_{1n} & & \cdots & h_{mn} \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \\ \vdots \\ S_m \end{bmatrix}$$



In principle, this technique is possible to achieve an infinite increase in capacity by using an infinite array of antennas.

However, this technique will NOT be possible due to the following assumptions:

(1) Each path from an antenna to another antenna there is no multipath.

(2) Extract channel parameters accurately in a mobile env. for a large No. of high data rate streams to be transmitted simultaneously.

SO, the single parameter left is the number of cells.

Microcell mounted on every lamppost (covering 100 m) & picocells located in every room.

But, small cells bring many other problems.

(1). BS needs small & inexpensive
(2). BS to core network needs to be simple
(3). Complexity of managing numerous BSs in area.
(4). Handover & other mobility features become more critical in small cells as less time MS is spent in each cell.