Computer Networks: The Physical Layer

Concluding Lecture (08/08)

ABET Course Outcomes for CS M117

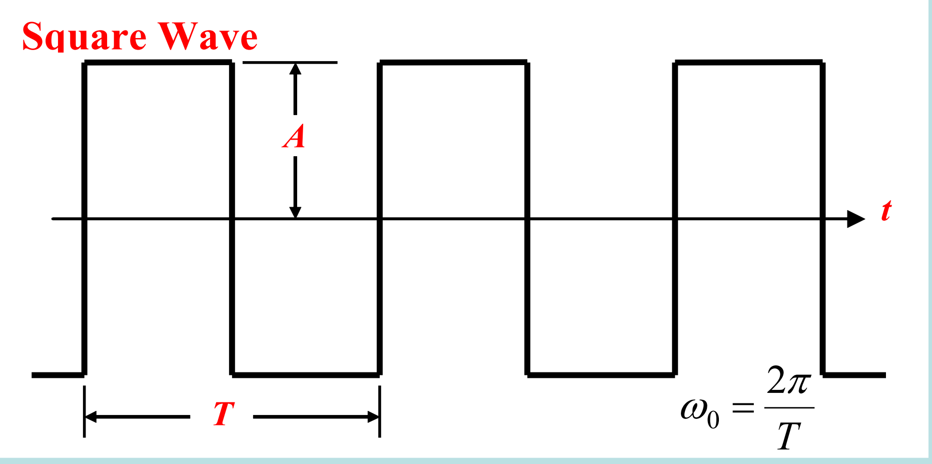
a. Understand the properties of communication channels.

b. Understand signal modulation, multiplexing and multiple access processes.

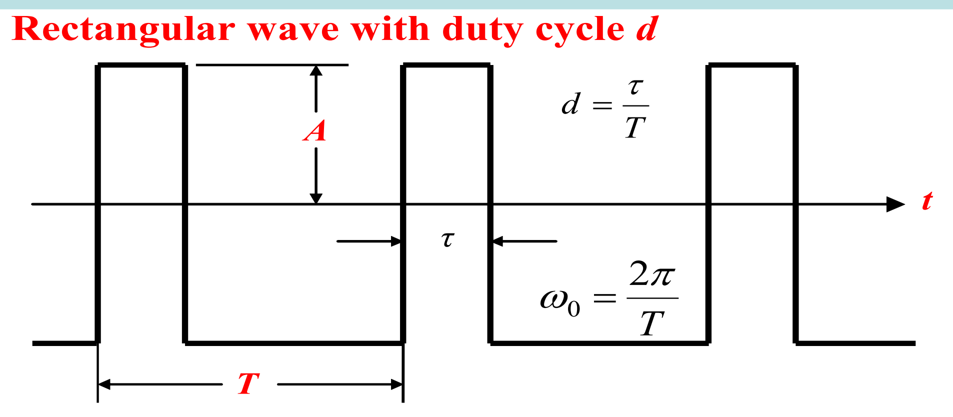
c. Understand MAC Protocols for reliable and noisy channels.

d. Understand Wireless LAN and Bluetooth design and operations.

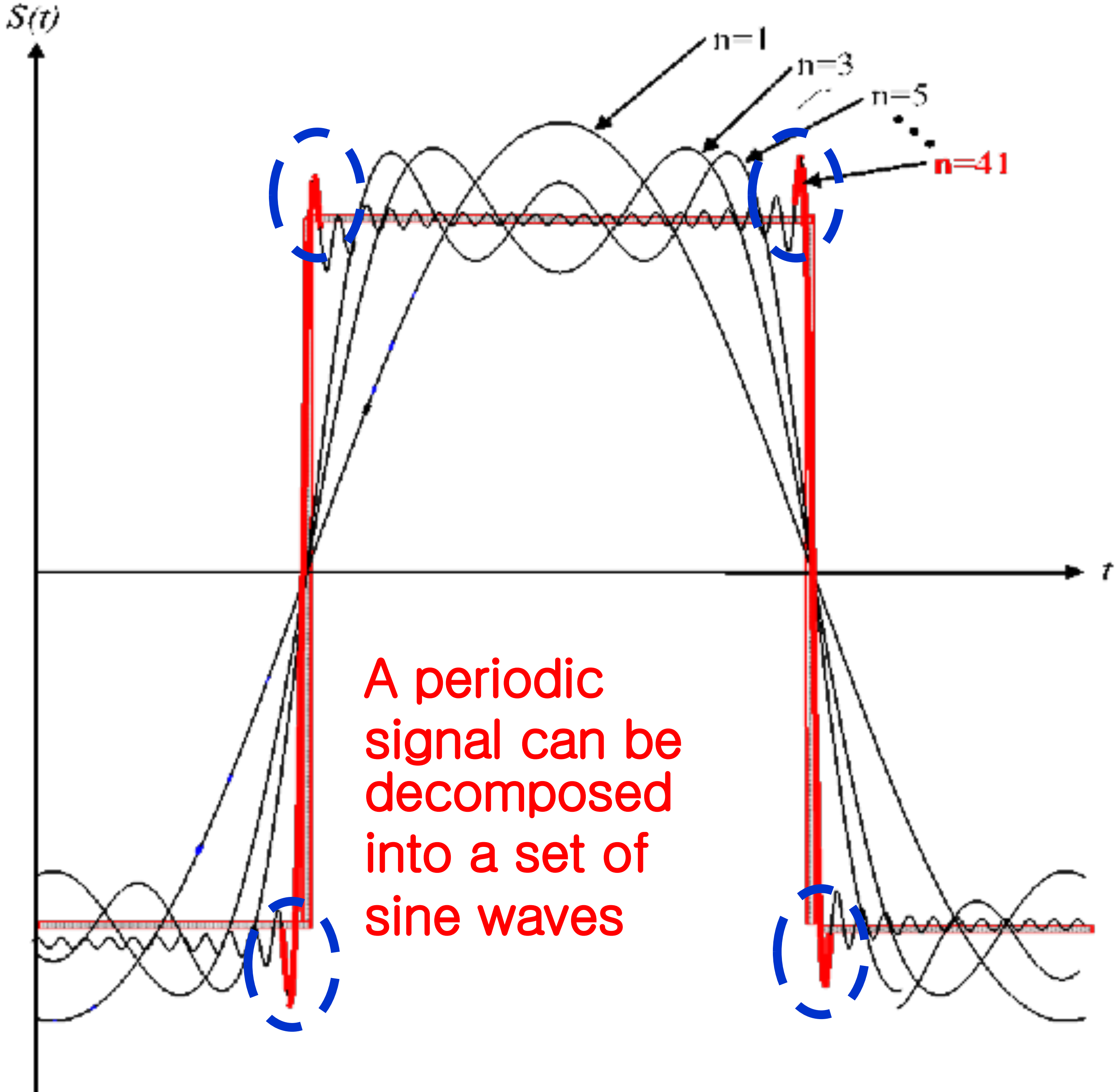
e. **Final comprehensive project requiring the student to re-design and re-think one of the experiments he/she performed.**



$$\frac{4A}{\pi}\left(\cos\omega_0 t - \frac{1}{3}\cos 3\omega_0 t + \frac{1}{5}\cos 5\omega_0 t - \frac{1}{7}\cos 7\omega_0 t + \frac{1}{9}\cos 9\omega_0 t + \ldots + \frac{1}{n}\cos n\omega_0 t\right)$$



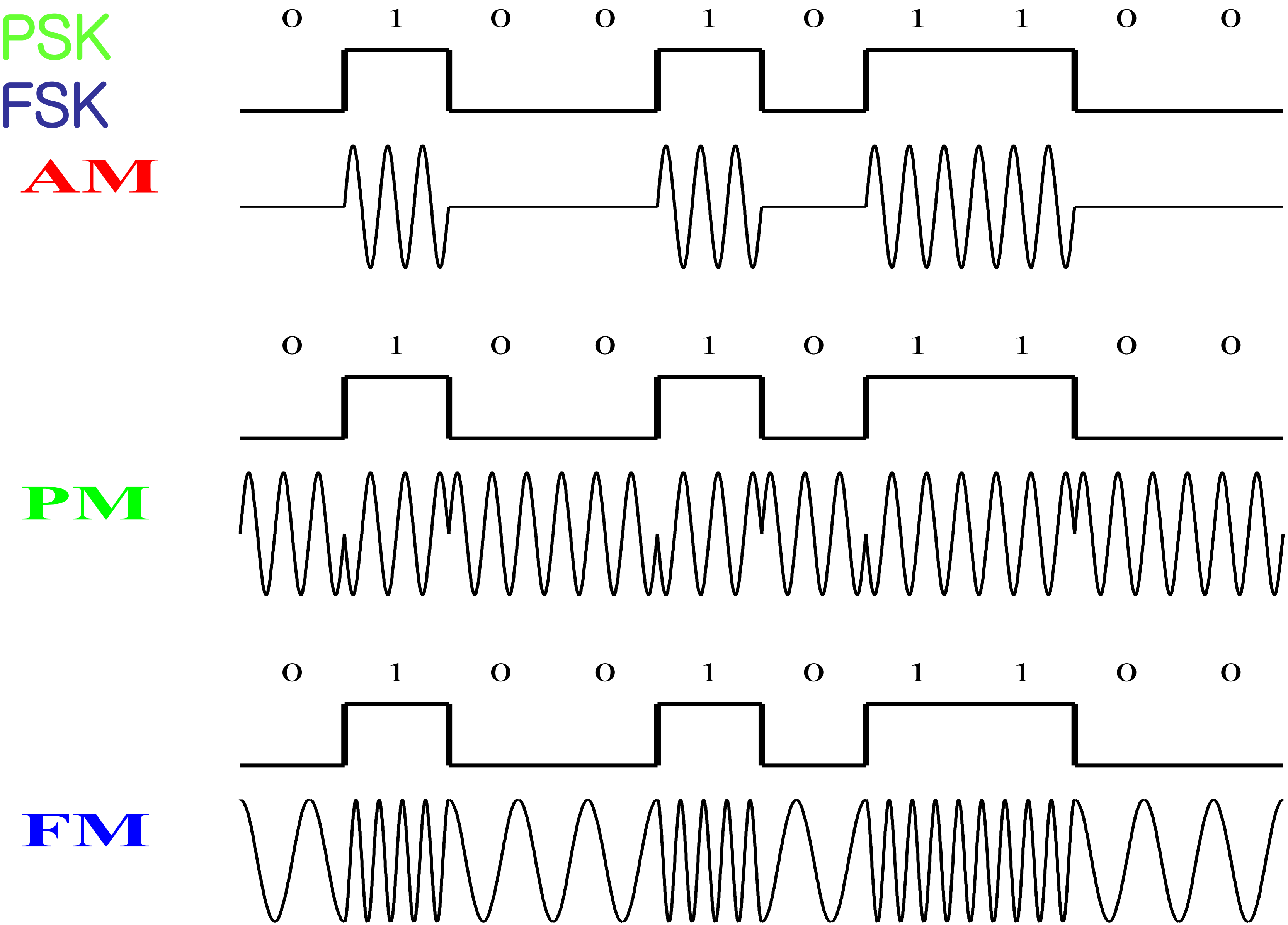
$$A\,(2d-1) + \frac{4A}{\pi}\left((\sin \pi d)\cos\omega_0 t + \frac{\sin 2\pi d}{2}\cos 2\omega_0 t + \frac{\sin 3\pi d}{3}\cos 3\omega_0 t + \ldots + \frac{\sin n\pi d}{n}\cos n\omega_0 t\right)$$



A periodic signal can be decomposed into a set of sine waves

Amplitude, Phase, and Frequency Modulation of a digital baseband signal

ASK,
PSK
FSK

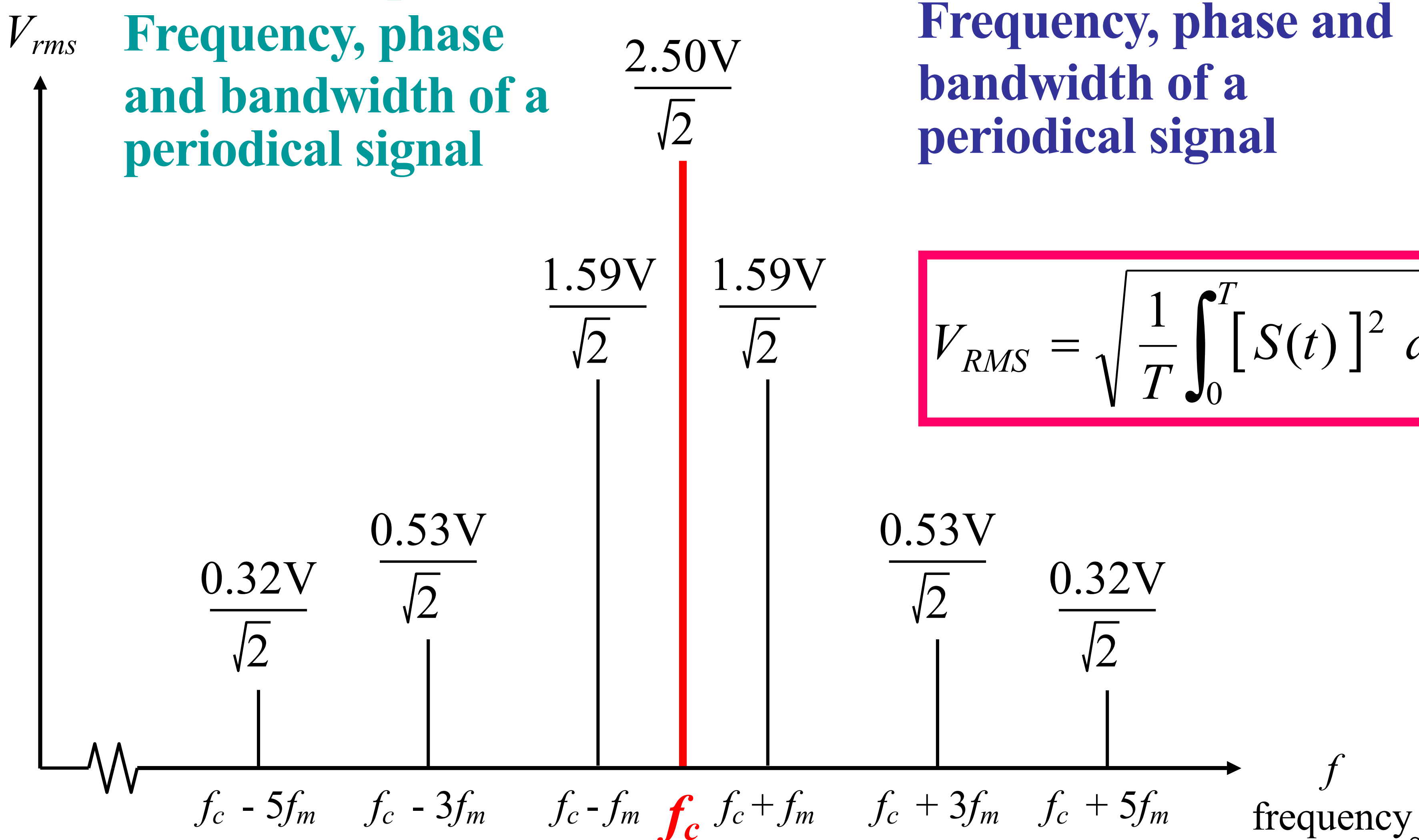


From a time-domain graphs can be determined power, Frequency, phase and bandwidth of a periodical signal

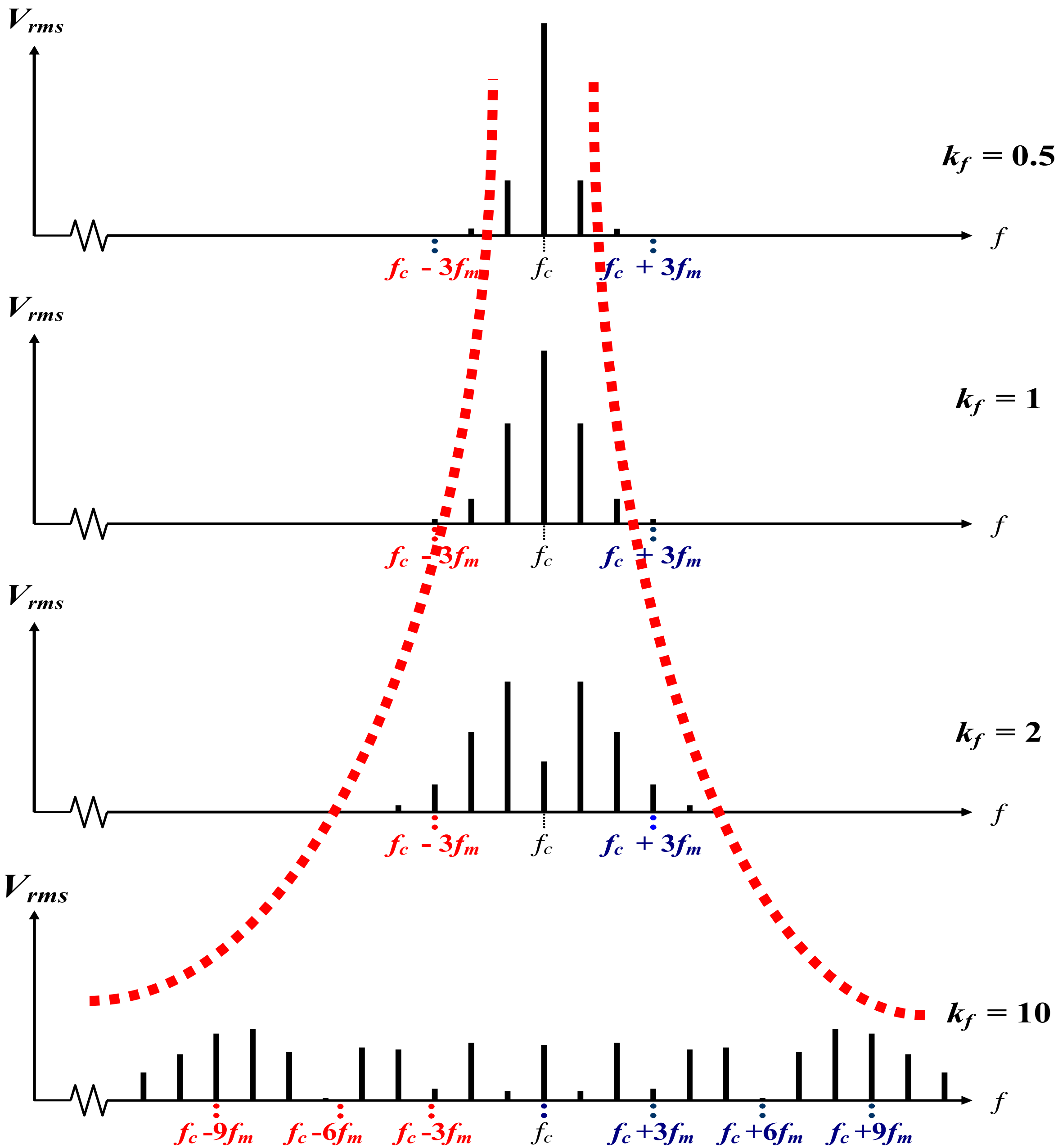
⟺

From a frequency-domain graphs can be determined power Frequency, phase and bandwidth of a periodical signal

$$\boxed{V_{RMS} = \sqrt{\frac{1}{T}\int_0^T \left[S(t) \right]^2 \, dt}}$$

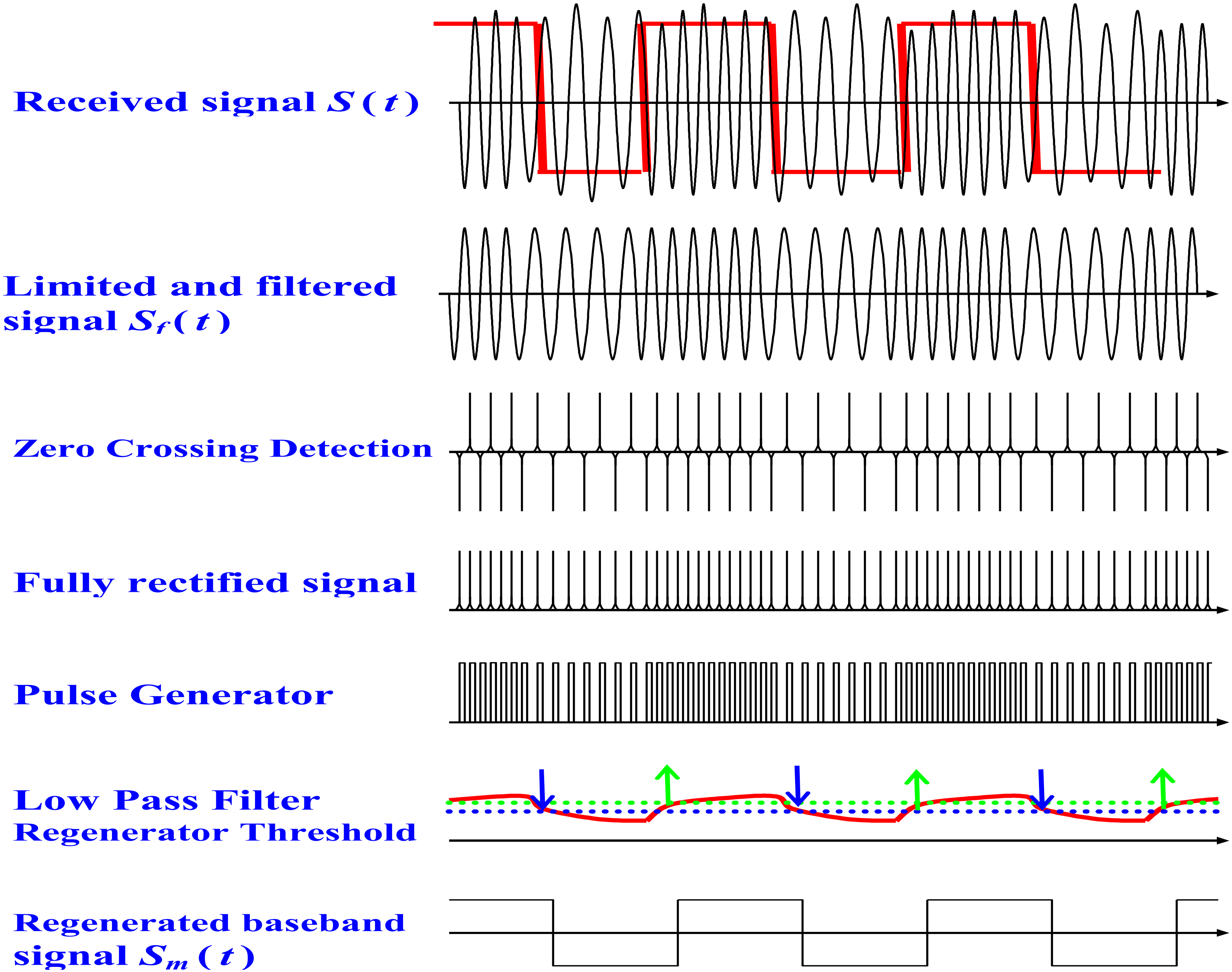


$Ac \cdot \cos(2\pi fc + k_f \cos(2\pi fm))$ at various values of k_f.



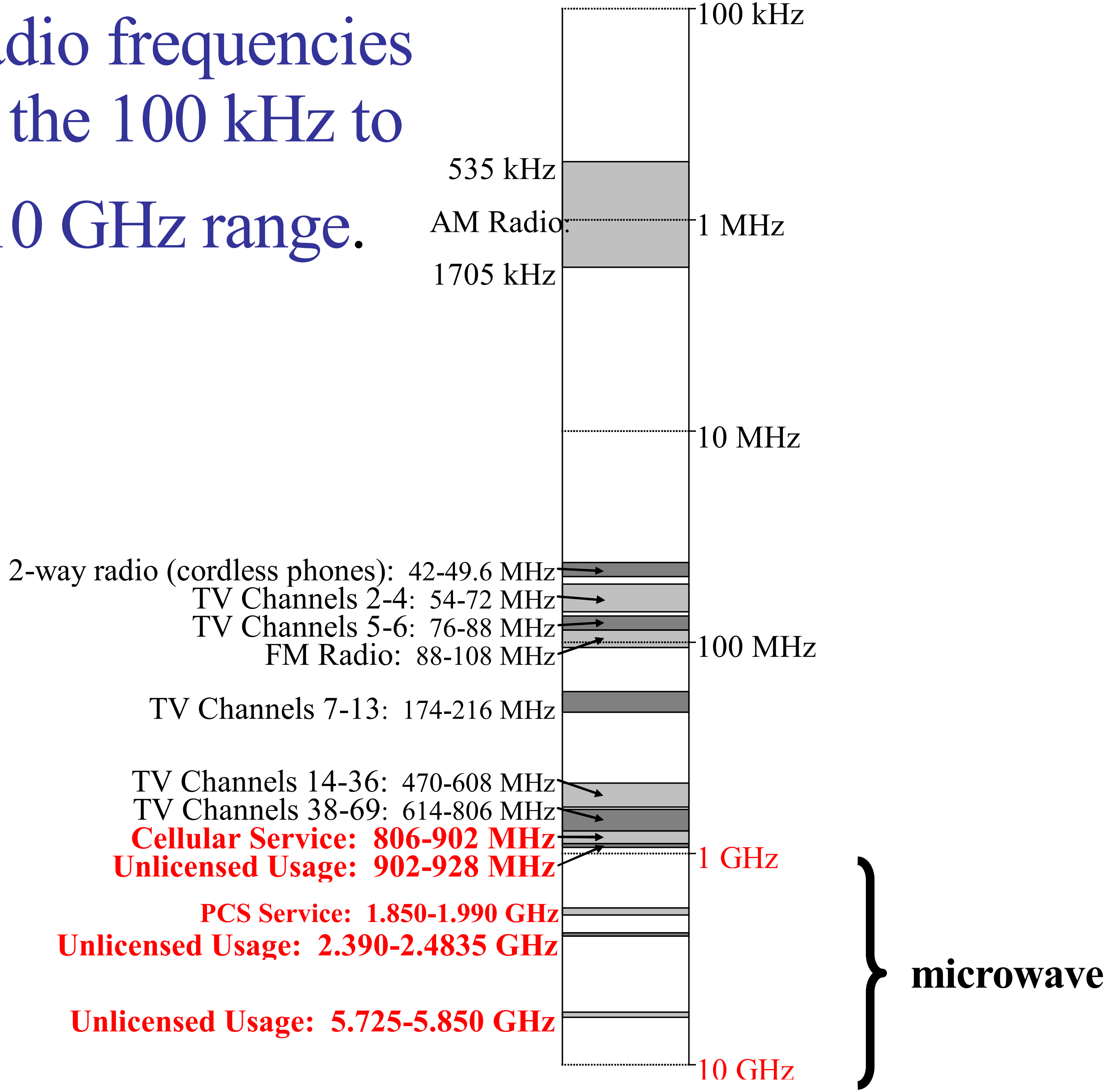
FDM multiplexing technique shifts each data signal to a different carrier frequency

$$\boxed{k_f = \frac{k \cdot A_m}{2\pi \cdot f_m}}$$

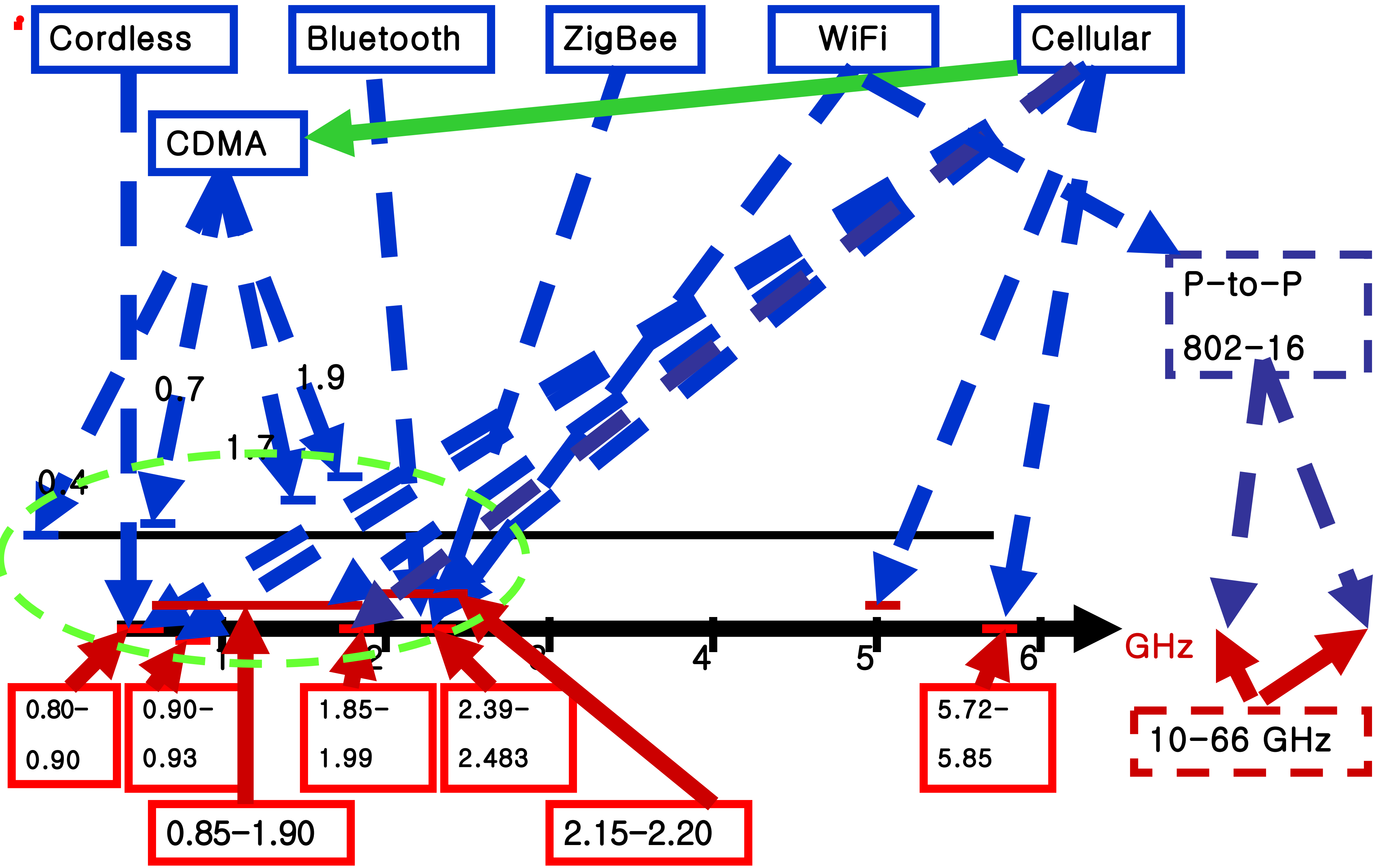


A. Phase-Locked Loop (PLL) B. Zero-Crossing Detection

Radio frequencies in the 100 kHz to 10 GHz range.



Wireless Services



Microwave radio systems:

1. Microwave voice/data transmissions

2. Data-modulate the carrier wave using:
   PM, FM, and SS modulation techniques.

2a. Links (channels) are separated with: FDMA.

- The most important parameter in any SS system is the processing gain *Gp*:

$$\boxed{G_p = \frac{W}{C}}$$

This value measures the ratio of

Transmitted RF bandwidth W

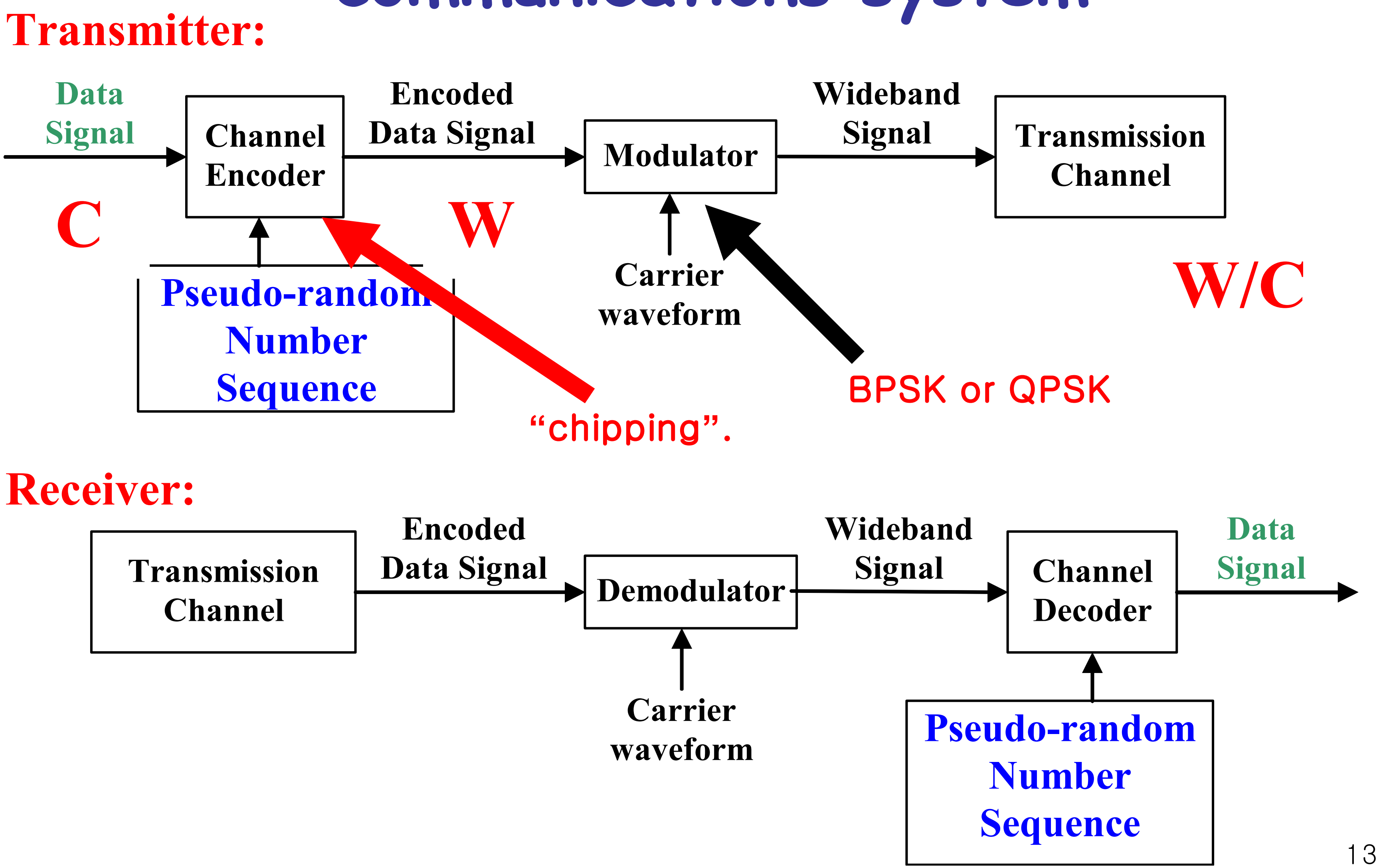
to the narrowband information rate C.

A system with a low signal-to-noise ratio must have a high processing gain Gp in order to recover the original signal.

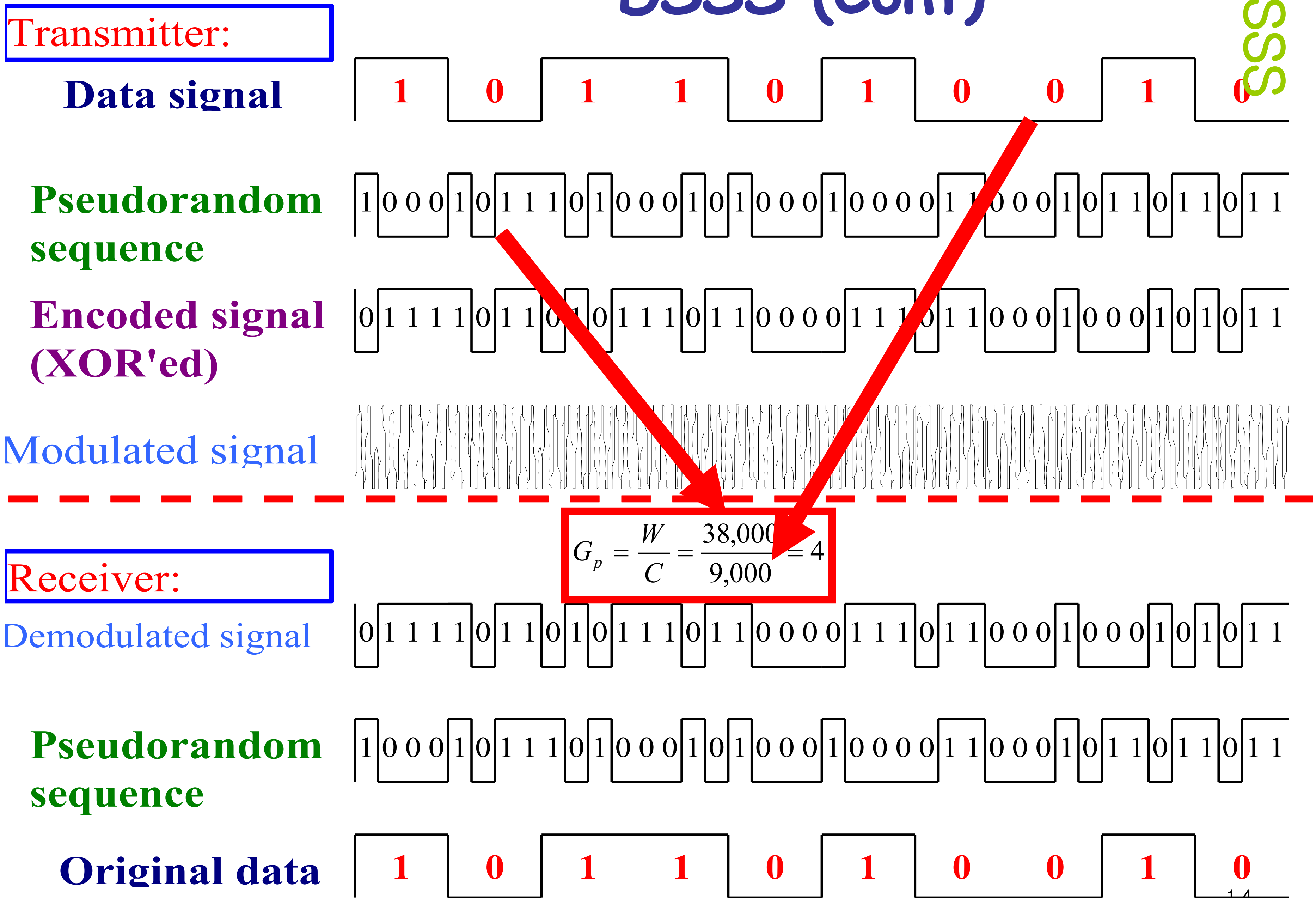
Types of Spread Spectrum Modulation:

- Direct Sequence Spread Spectrum (DSSS)
- Frequency Hopping Spread Spectrum (FHSS)

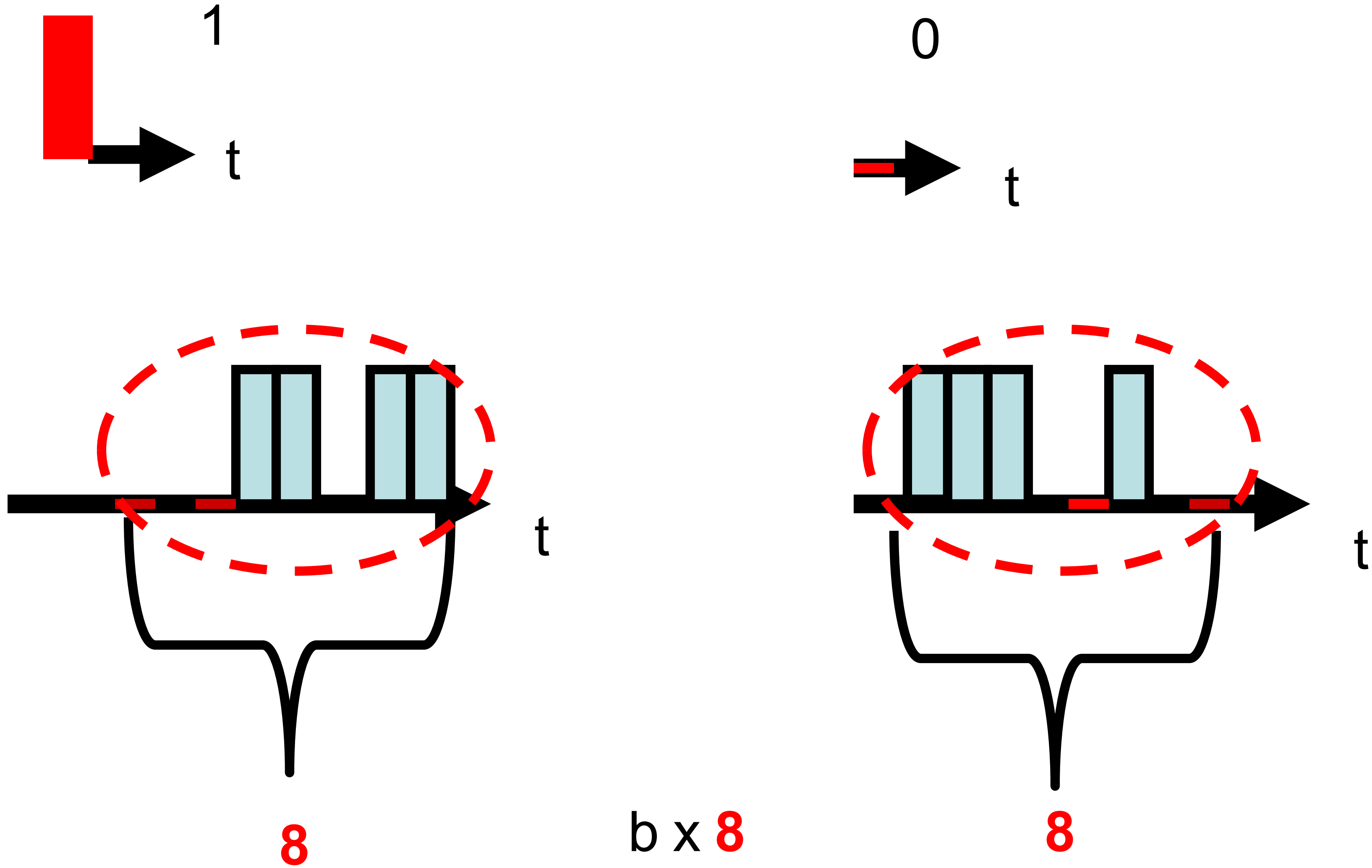
General model of DSSS digital communications system



DSSS (Cont)



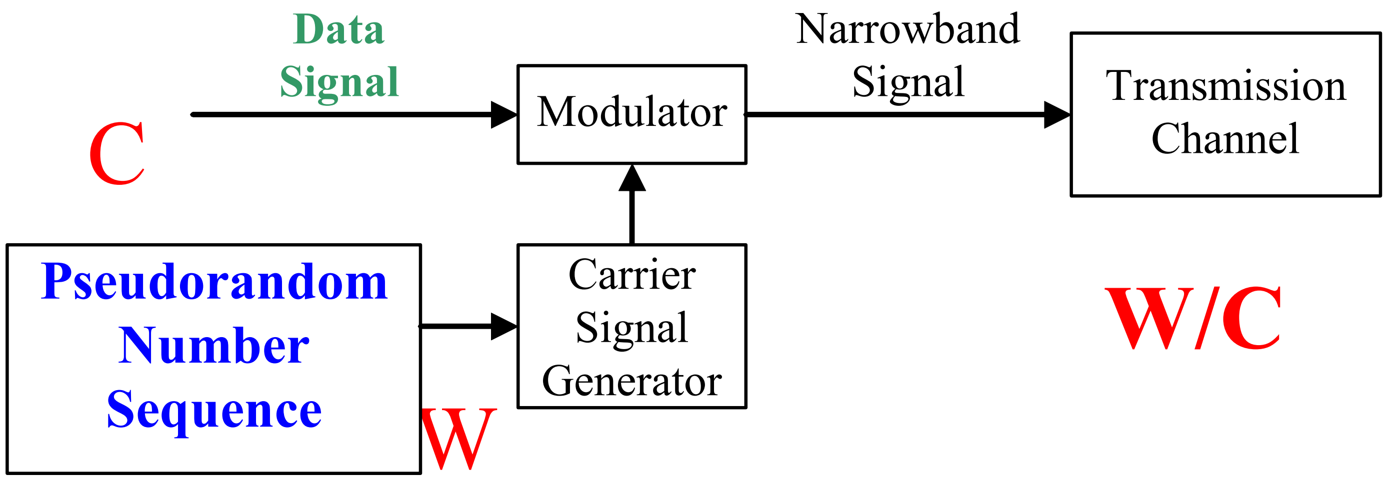
$$G_p = \frac{W}{C} = \frac{38{,}000}{9{,}000} = 4$$



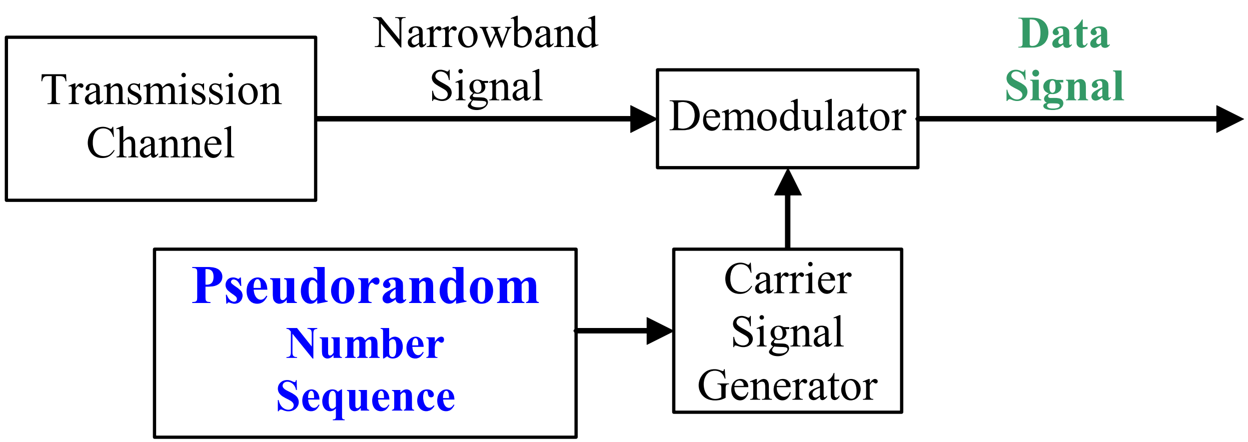
M=8, 16, 32, 64, …

General model of FHSS digital communications system

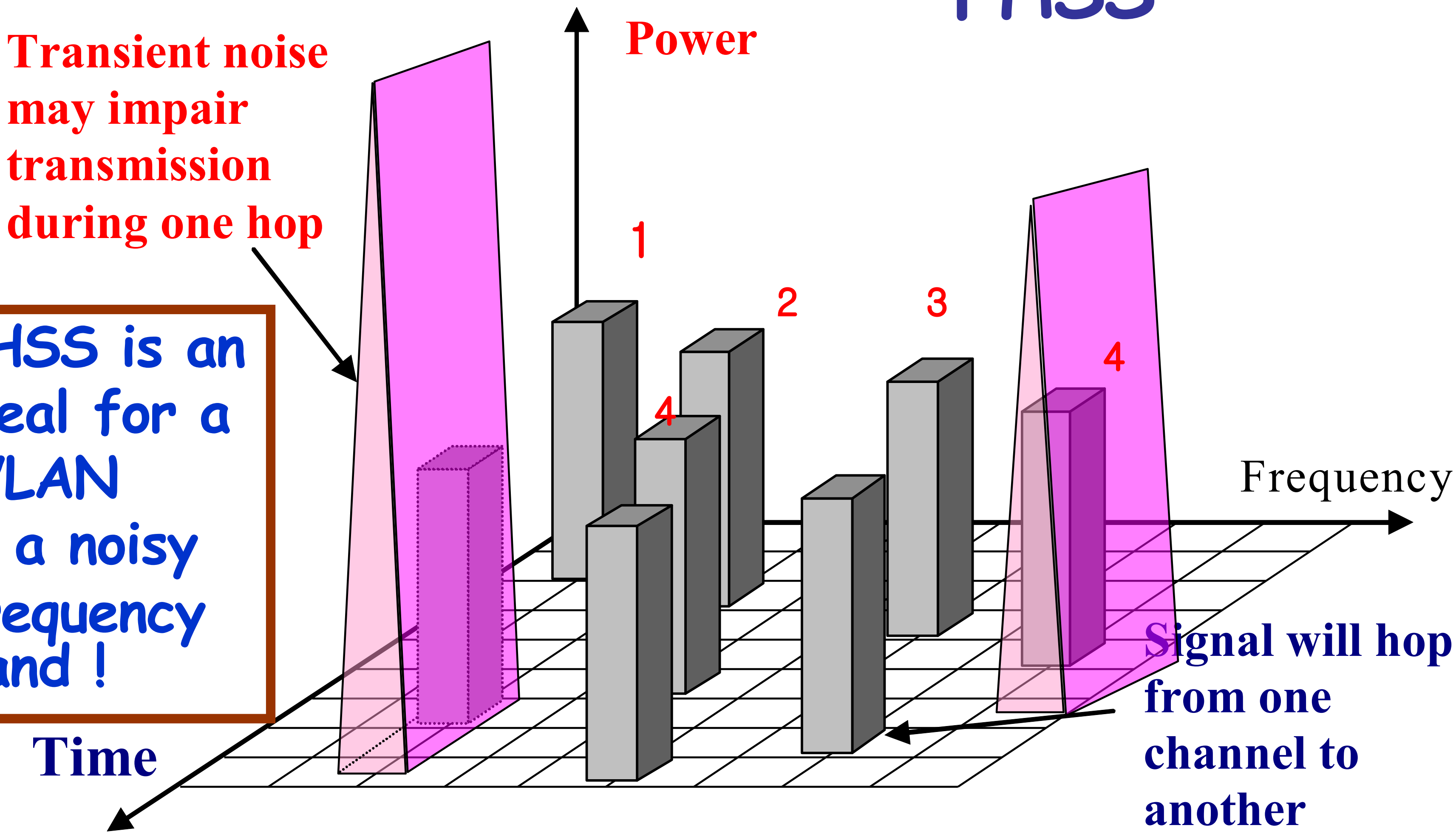
Transmitter:



Receiver:



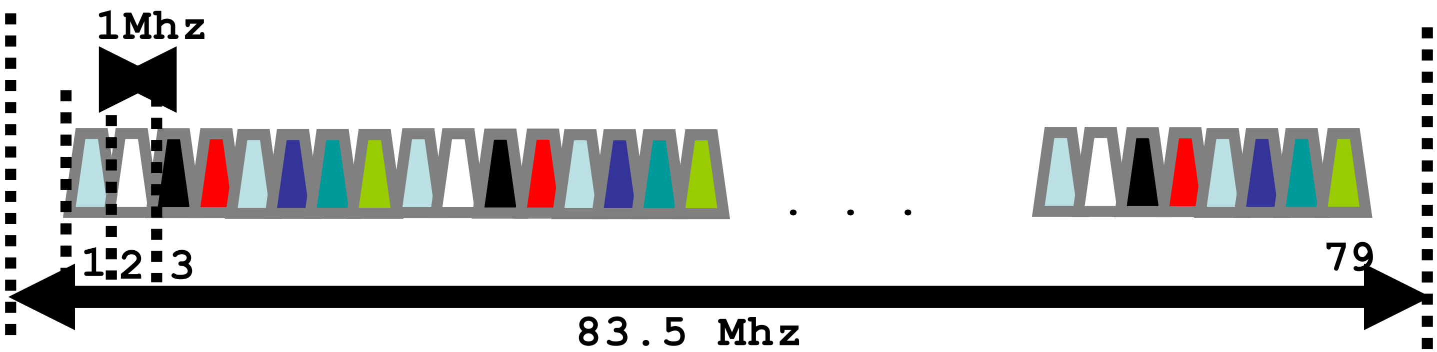
FHSS



FHSS is an ideal for a WLAN in a noisy frequency band !

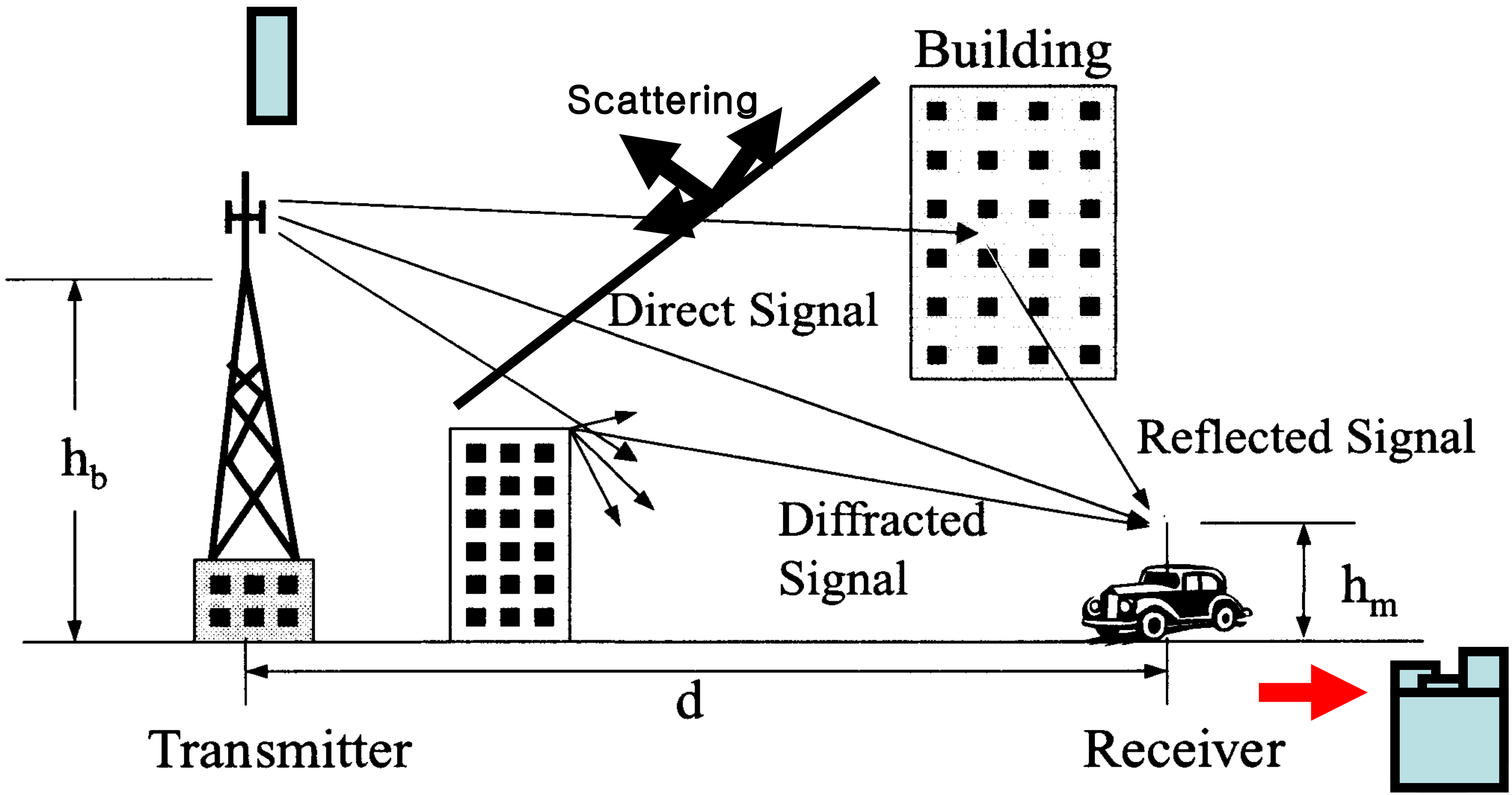
During any one hop, the signal is vulnerable to noise in that frequency band, but it will soon move to another frequency with less noise. This new band will be sufficiently removed from the previous noisy band

Example: Bluetooth Frequency Hopping



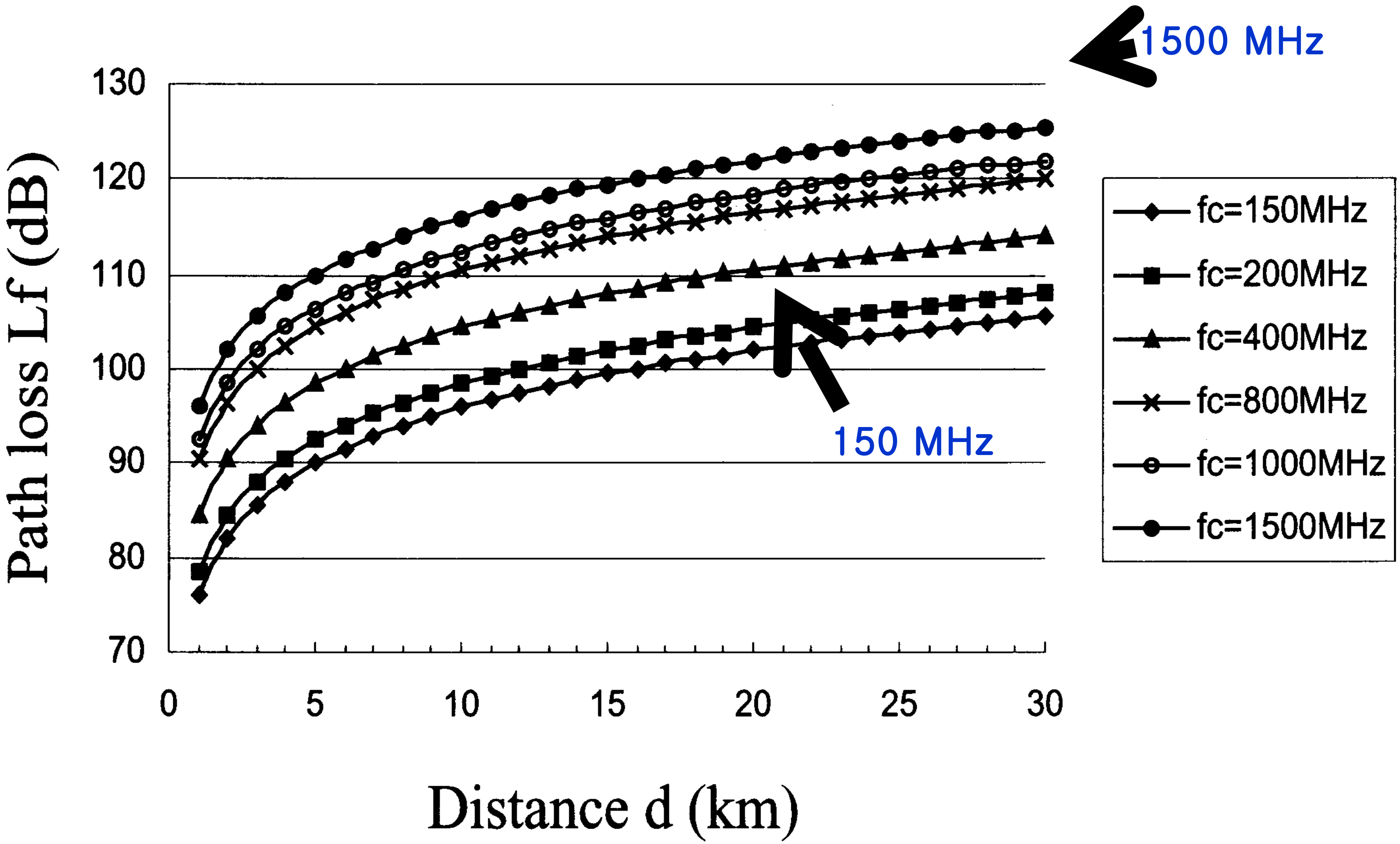
- frequency hopping spread spectrum
  - 2.402 GHz + k MHz, k=0, …, 79
  - 1,600 hops per second(1:1600=625 µs)
- GFSK modulation
  - 1 Mb/s symbol rate
- transmit power
  - 0 dBm (up to 20 dBm with power control)

Reflection and diffraction of radio signals (1:1600=625 μs)

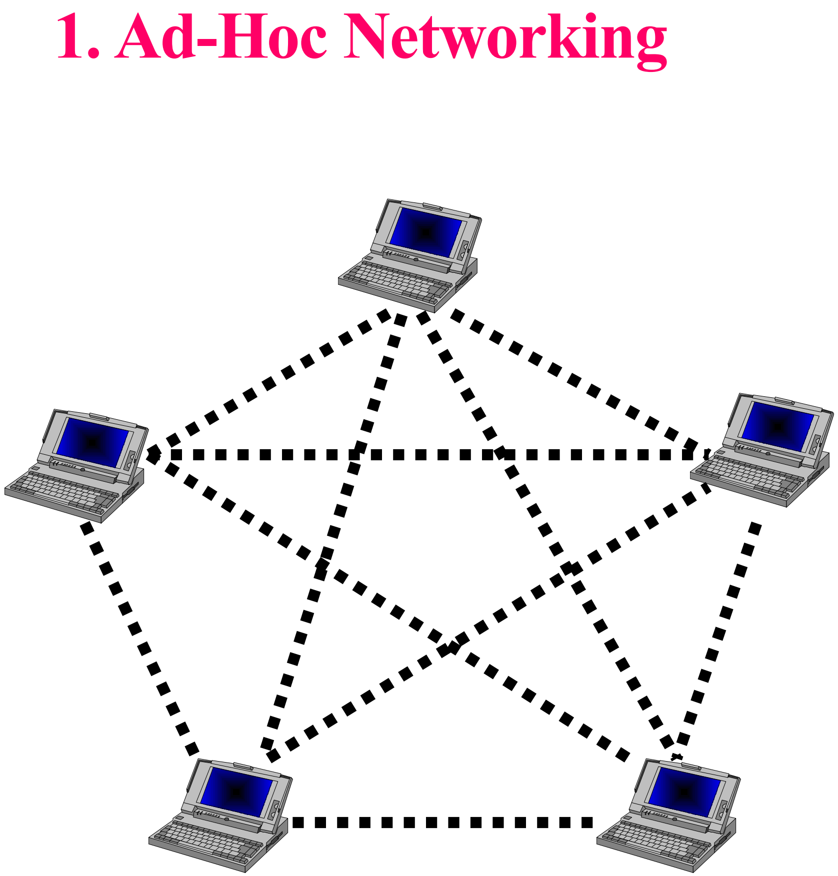


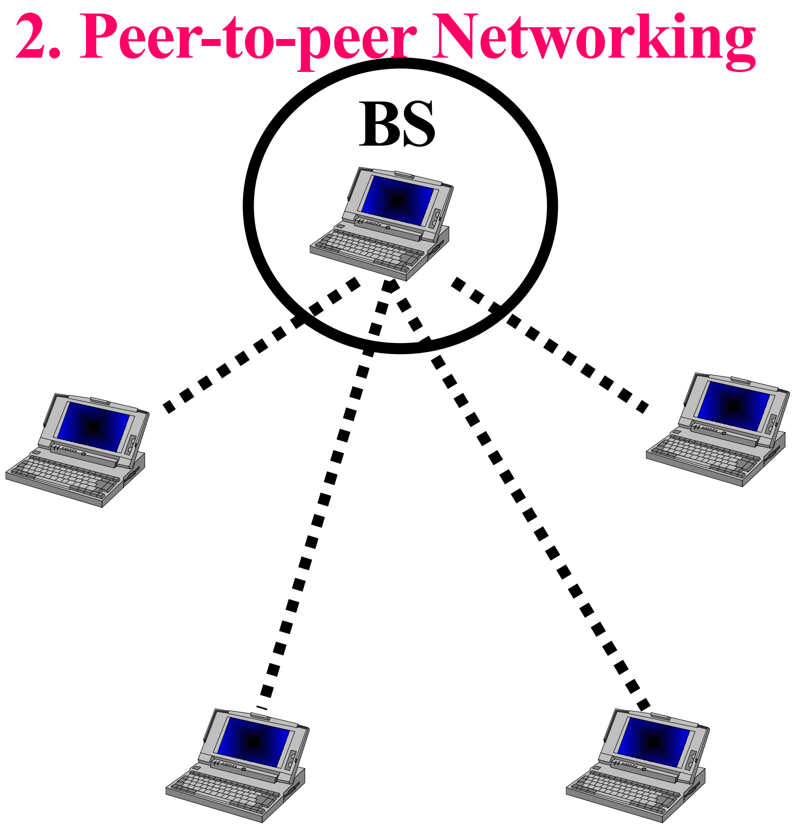
Free-space path loss (Cont)

$$L_f = 32.45 + 20\log_{10} f_c(MHz) + 20\log_{10} d(km)$$



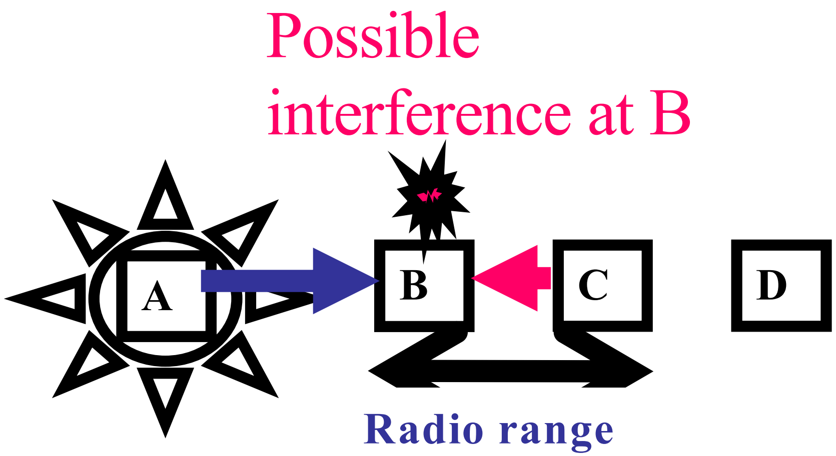
802.11 (WiFi) Wireless LAN Configurations



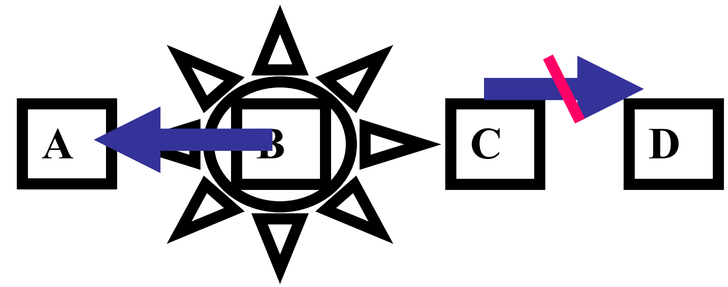


To send an IP packet over the WLAN,
Make 802.11 compatible with Ethernet above the DLL.

Motivation for a specialized MAC



a



b

Hidden station problem

Exposed station problem

Two Major Problems

Medium Access with CSMA/CA

When many users are located in the same area, and use the same wireless LAN at the same time, two different MAC methods are defined for signal multiplexing:

1. **Distributed Coordination Function (DCF) (no control)**
2. **Point Coordination Function (PCF) (BS controls cell)**

The basic access mechanism, called the **DCF**, Each unit senses the medium before it starts to transmit. If the medium **is free** for several microseconds, the unit can transmit for a **limited time**. If the medium **is busy**, the unit will **back-off** for a random time before it senses again.

It does not sense the channel while transmitting,

Medium Access with CSMA/CA (Cont)

The basic access mechanism:

- DCF = CSMA/CA algorithm: 2 methods.

1). Physical channel sensing. 2). Virtual channel sensing

1. Physical channel sensing (PCS):

Like Ethernet

- **It does not sense the channel while transmitting,**

a) CSMA/CD needs full-duplex channel

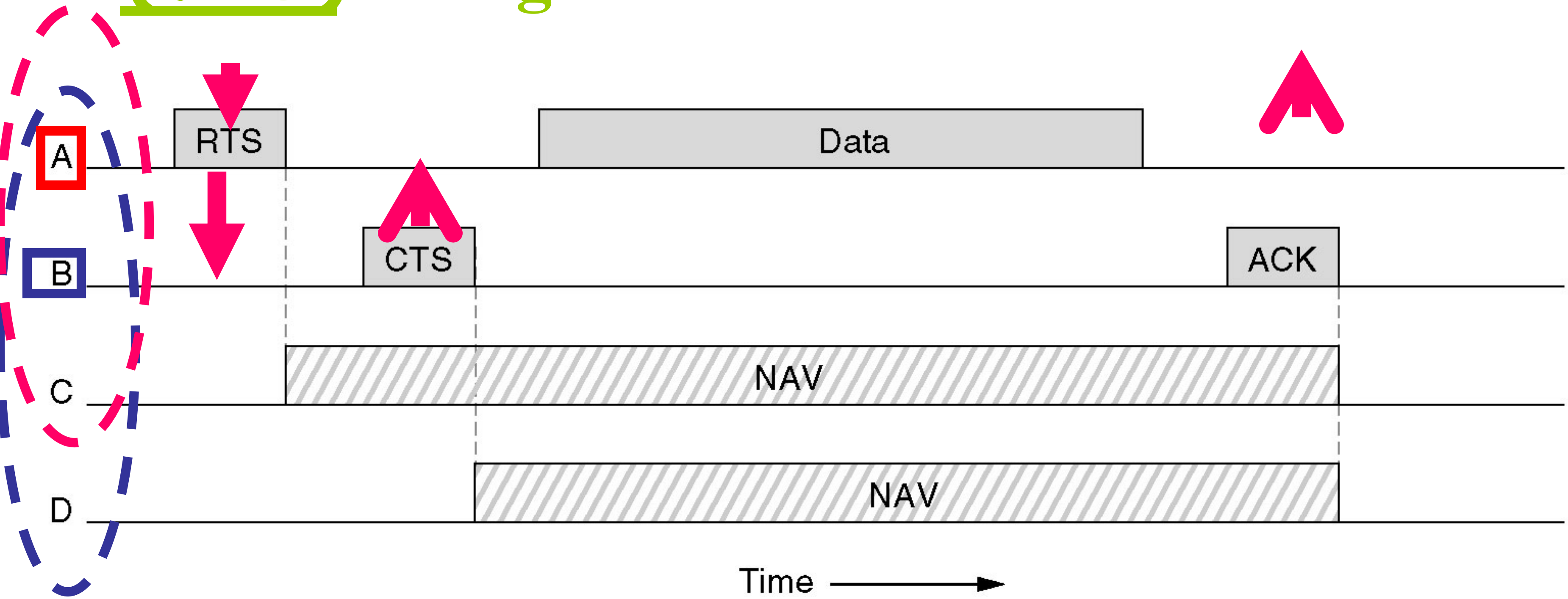
b) 802.11 all stations cannot hear each other

802.11 =802.3 + Positive Acknowledge Scheme

2. MACAW-Virtual Carrier Sense (VCS)

The 802.11 MAC Protocol (MACAW)

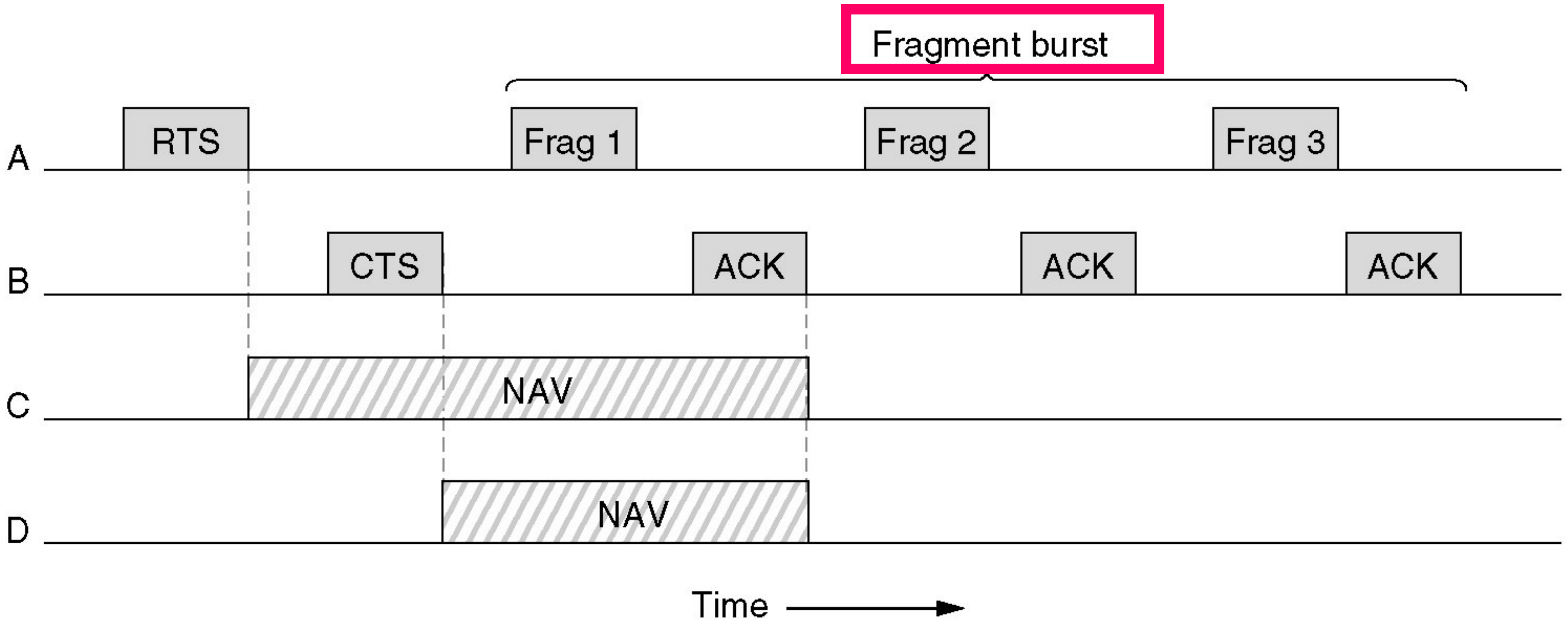
2. MACAW-Virtual Carrier Sense (VCS) using CSMA/CA.



NAV-Network Allocation Vector -keeps other stations quiet

The 802.11 MAC Protocol: fragments (MACAW)

2. DCF-The use of virtual channel sensing using CSMA/CA.



stop-and-wait protocol

The 802.11 Protocol Stack

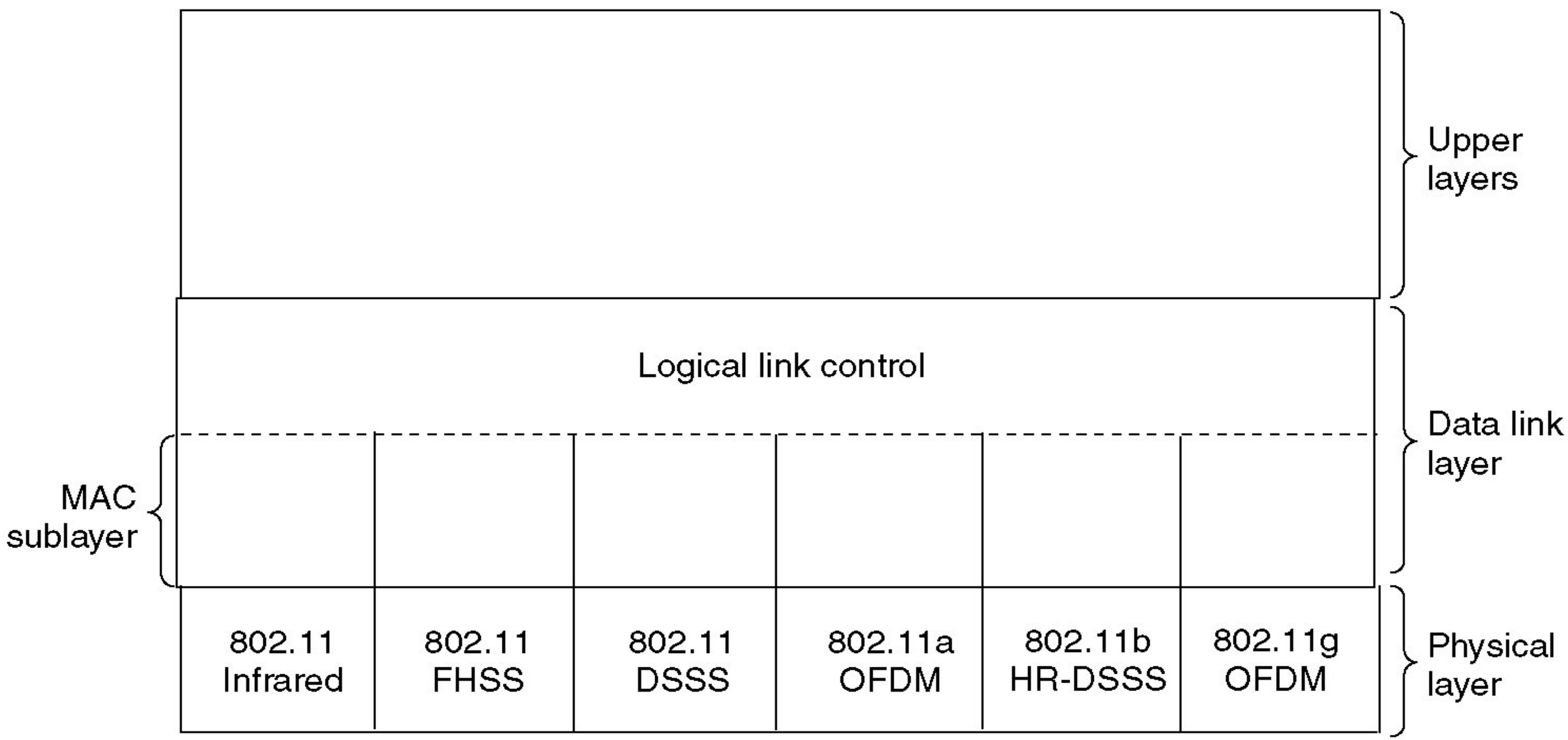
DLL

LLC

MAC

LLC sublayer, hides the differences between the different 802 variants and make them undistinguishable for the network .

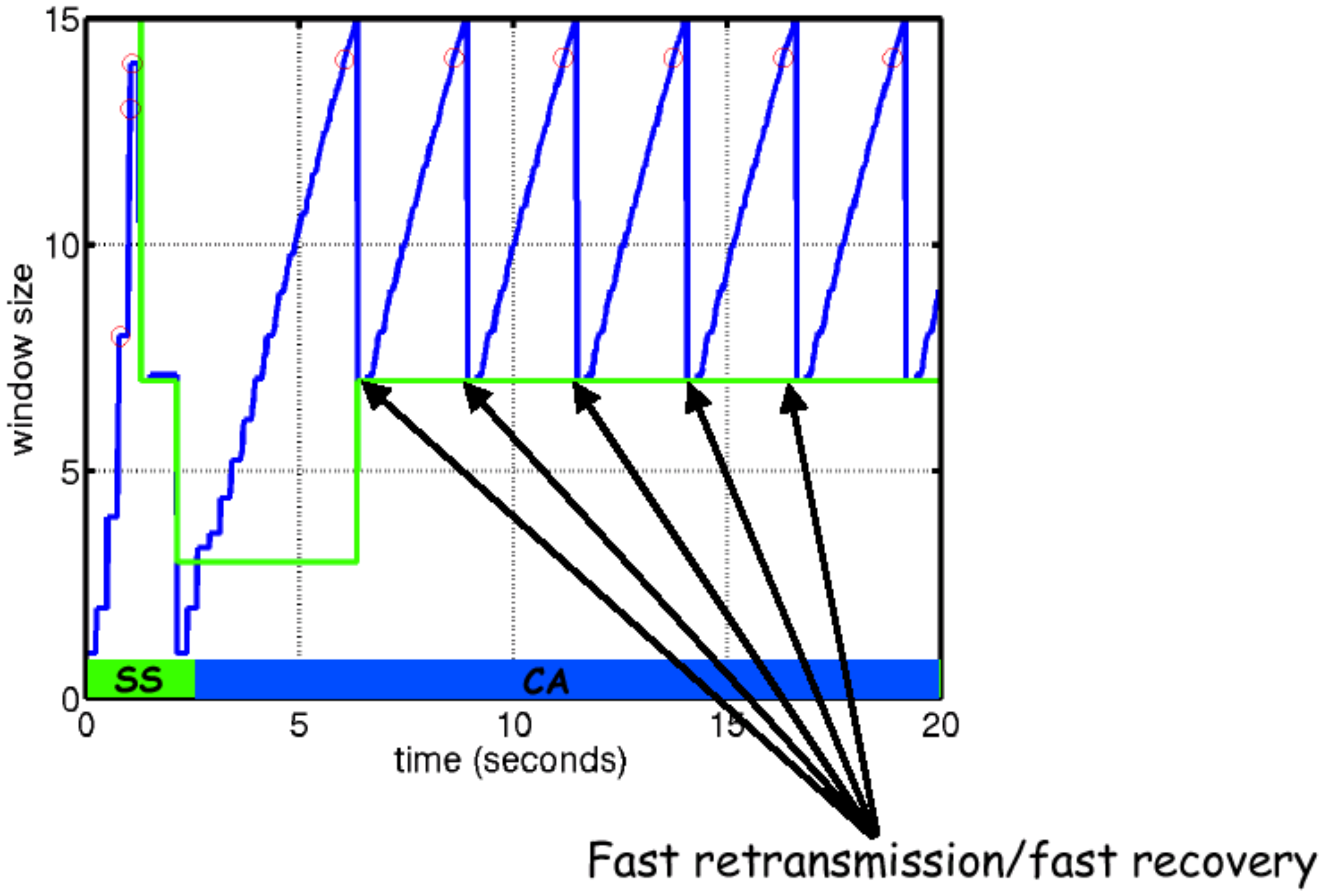
The MAC sublayer determines how the channel is allocated, who gets to transmit next.



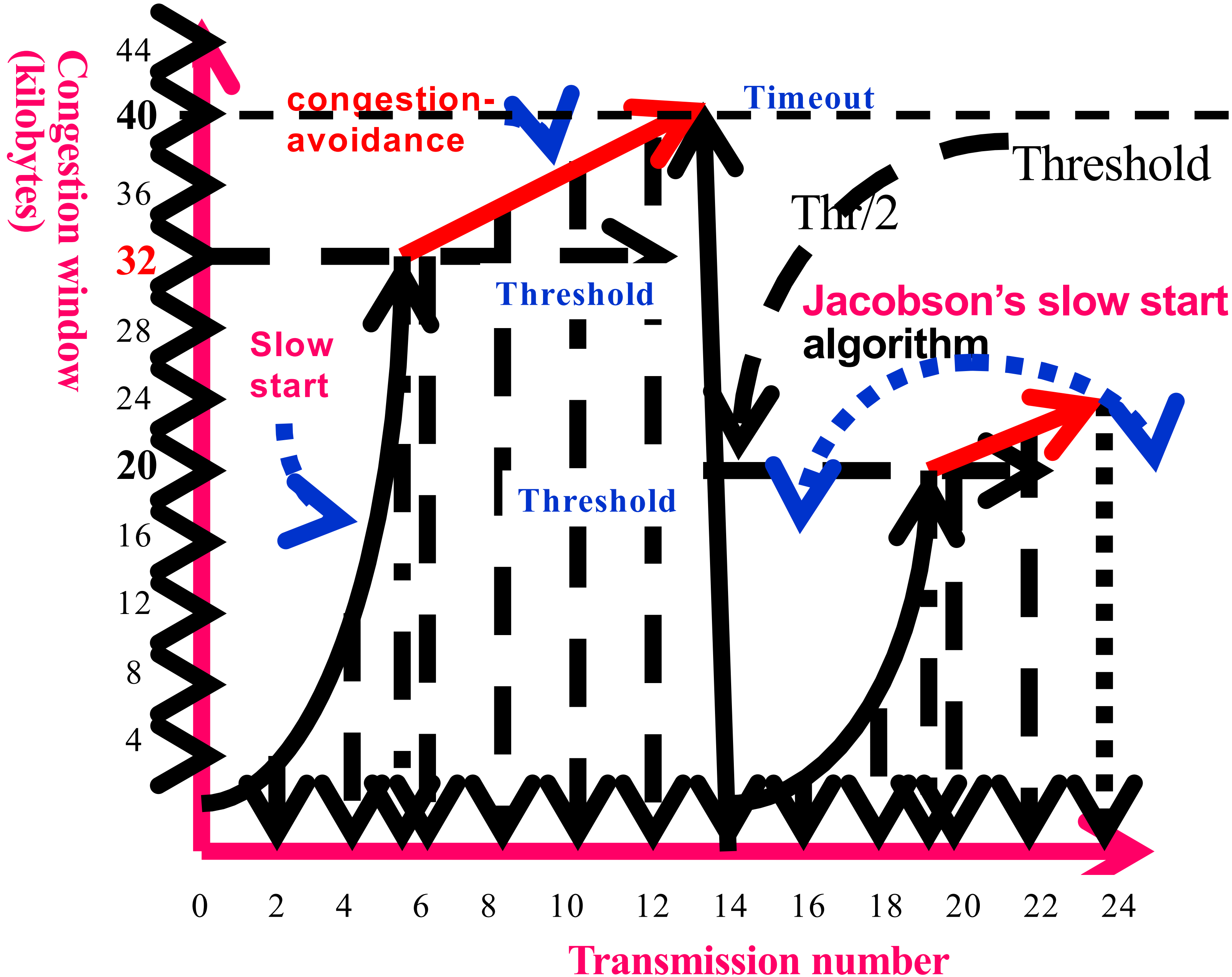
Congestion control (Cont)

- Traditional **TCP** **congestion control** **(TCP Reno)** has four key phases:
- **Slow Start (SS),**
- **Congestion Avoidance (CA),**
- **Fast Retransmit (FT),** and
- **Fast Recovery (FR).**
- In addition to have a **varying** **Contention Window (CWIN),** TCP also employs a value called the **"Slow Start Threshold"** **(SSTresh)** to decide between **SS** and **CA** phases.
- A TCP sender initially begins in the **SS** phase, which begins with **CWIN** set to **1**. On each successful ACK, we increment by the same CWIN **size.** Thus, this results in the **exponential growth** of the CWIN because in each RTT, **CWIN = 2 * CWIN**. When the CWIN finally exceeds SSTresh, TCP enters the **CA** phase

Congestion control (Cont)



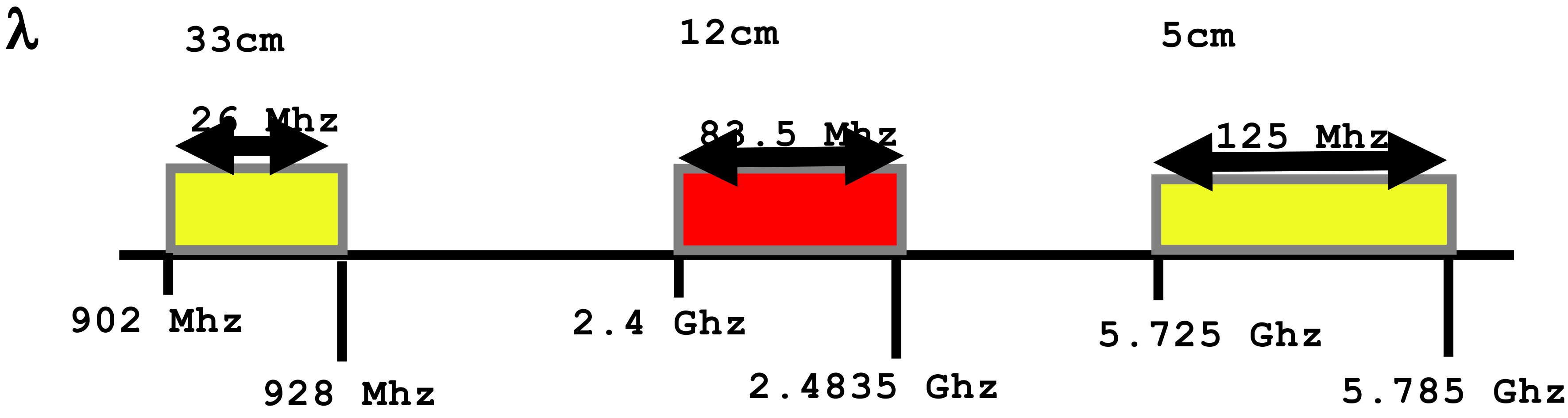
TCP Slow Start for reliable comm.



Some characteristics of 802.11 WLAN

Characteristic	802.11A	802.11B	802.11B
Topology	Physical star and a logical bus	Physical star and a logical bus	Physical star and a logical bus
MAC	CSMA/CA; Error control Stop-and-wait (S-a-W)	CSMA/CA; S-a-W	CSMA/CA; S-a-W.
Data Transmission in the Physical Layer	D/A – A/D conversion, Combinations of BPSK, QPSK,	D/A – A/D conversion, Combinations of PSK and QPSK modulation	D/A – A/D conversion. For 1 to 11 Mbps uses same modulations as 11 For 6 to 54 Mbps it uses the same modulations as 802.11a.
Rate; Mbps	6; 9; 12; 18; 24; 36; 48; 54.	1; 2; and 5.5	5.5-11
AP range, m	15 to 50	about 100 to 150	50–150
Frequency range and BW	5-GHz. The total BW is 300 MHz,	2.400 GHz - 2.4835 G Hz = 83.5 MHz;	2.4 GHz. Compatible with 802.11b
Separate radio frequency channels	**4–12 channels**; 12 channels with 20 MHz BW is broken into 52 separate 312.5 KHz sub-channels, plus guard bands. 48 of thes e sub-channels for data; the four are for co ntrol. Data is sent across all 48 sub-chann els in parallel using a *OFDM*.	**3 channels centered on: 2.412; 2.437; 2.462 GHz. with a 3-MHz guard-band**	3–6 channels depending upon configuration

Unlicensed Radio Spectrum

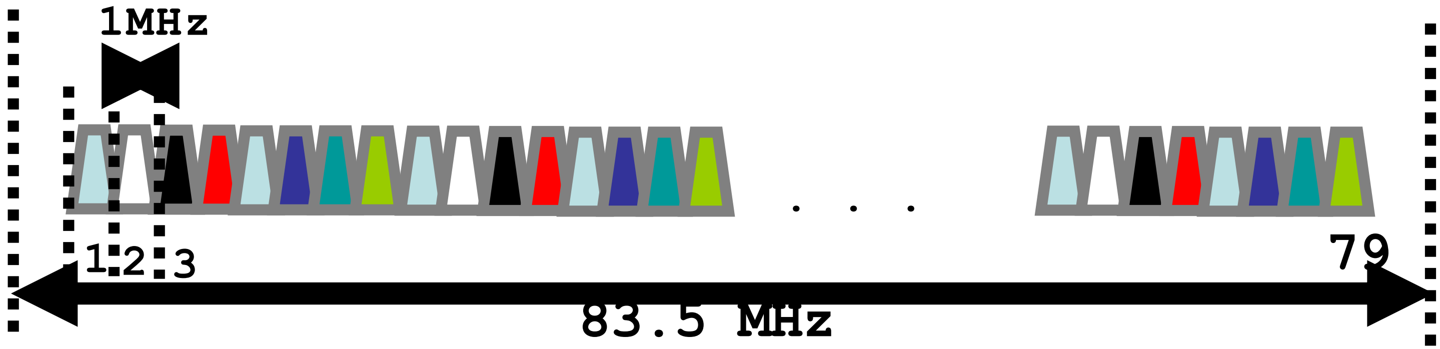


cordless phones,
baby monitors,
Wireless LANs

802.11 Cell.
802.15 Bluetooth,
Microwave oven

802.11a
HyperLan

Bluetooth radio link



- frequency hopping spread spectrum
  - **2.402 GHz + k x1MHz, k=0, …, 78=79**
  - **1,600 hops per second (1:1600=625 μs)**

FHSS/TDD channel applied in Bluetooth.

Multiple Ad hoc links will make use of different hopping channels with different hopping sequences and have **misaligned slot timing**

Voice and Data Links

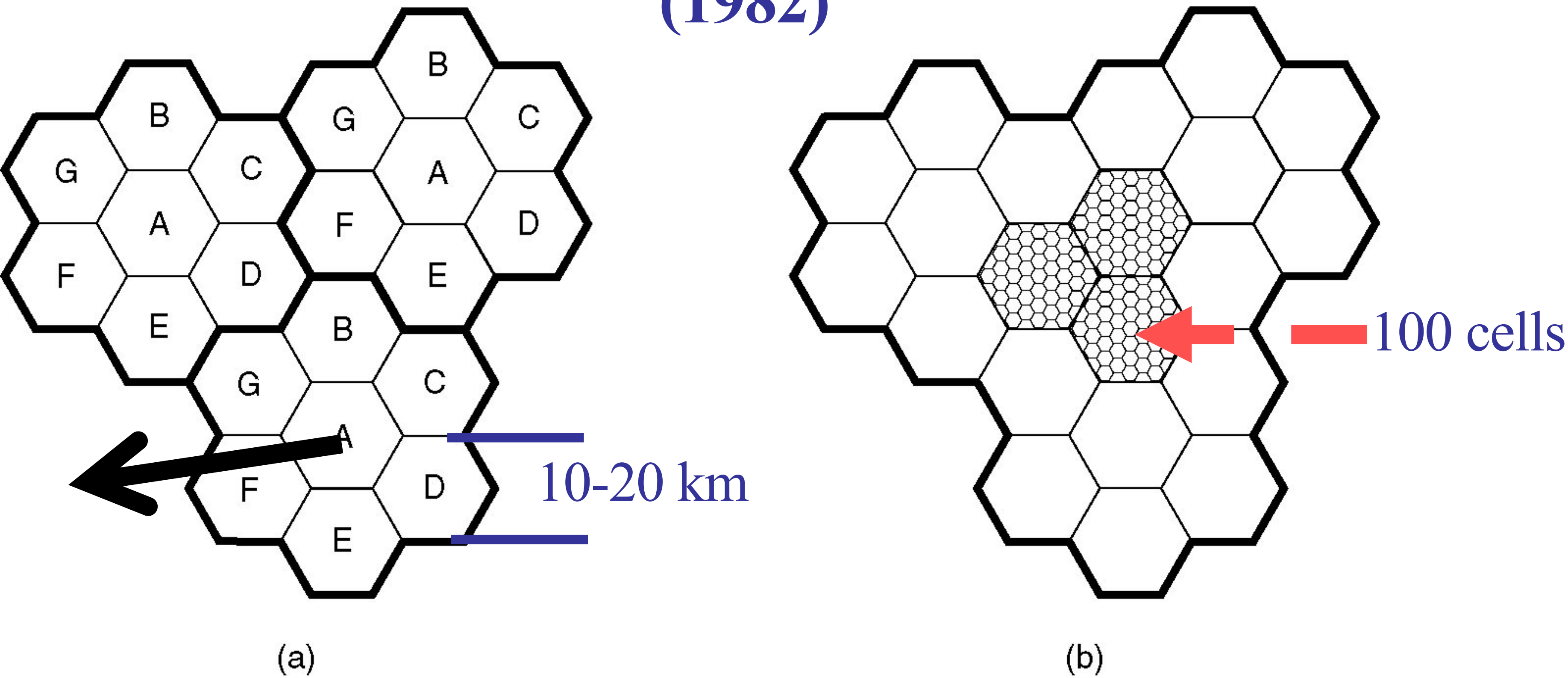
- Bluetooth allows both **time sensitive** communication: **voice or audio**, and **time insensitive** packet: **data communication**.
- So, two different types of **links** are defined:
- **Synchronous Connection Oriented (SCO)** links for **voice communication**
- **Asynchronous Connectionless (ACL)** links for **data communication**.
- ACL data packets are: a 72-bit access code, a **54-bit packet header** and a **16-bit CRC** code, in **addition to the payload data**.
- Different types of **packets** allow different amounts of data to be sent : The largest packet data payload is a **DH5 (Data High)** packet, with **5 slots**. A DH5 packet carry **339 bytes, or 2712 bits** of data. So, 2858 bits are sent for 2712 bits of information, and the minimum length reply is one slot.
- Thus, the maximum baseband data rate in one direction is **723.2 kb/s.**
- With 5-slot packet sent in one direction, the 1-slot packet sent in the other direction, so this would be an **asymmetric link.**

ZigBee General Characteristics

Specification	802.15.4
Data rate	200 Kbps
Distance about	70 meters
MAC, Non-beacon	CSMA/CA, but no RTS/CRS
MAC Beacon-enabled	slotted CSMA/CA, with super-frames
Bands and Channels	868-1; 915 MHz-10 BPSK; 2.4 GHz-16 O-QPSK
Three devices	Network Coordinator-1; FFD- 254; RFD-1000
Packet size	128 bytes
Payload size	104 bytes
IEEE addresses	64 bit; short addresses 16 bit; 65,000 nodes
transmit Set up	15ms to 252sec, 16 width between beacons
Encoding	DSSS- 11 chips/ symbol
Network join time	30ms typically
Sleeping / to active	15ms typically
Active channel access	15ms typically

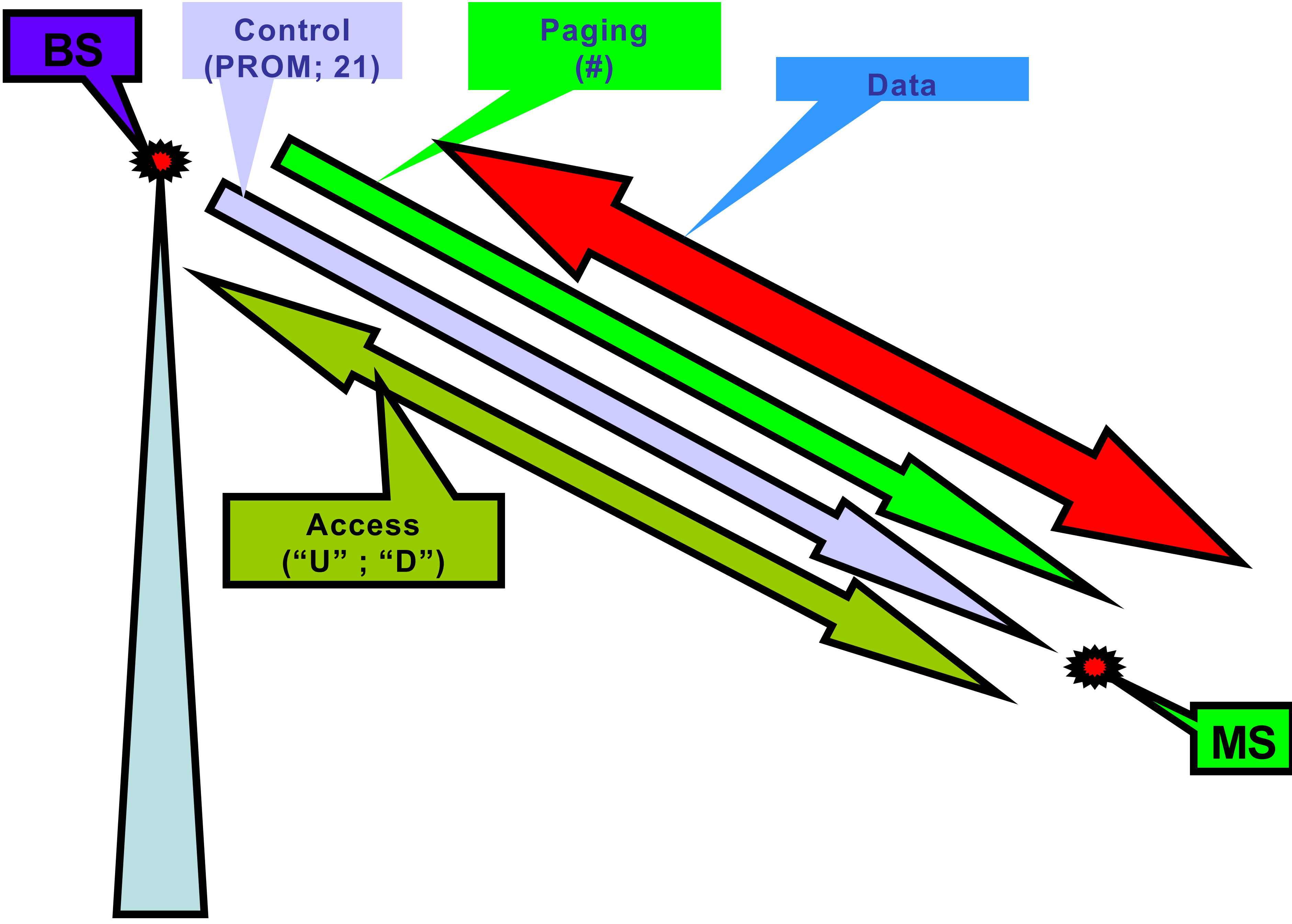
Advanced Mobile Phone System (AMPS)

(1982)



- Frequencies are not reused in in a group of 7 adjacent cells
- To add more users, smaller cells can be used.
- In each cell, 57 channels (duplex: uplink and downlink)
- about 800 channels total (across the entire AMPS system

AMPS is an analog system using FDMA.


BS
Control
(PROM; 21)
Paging
(#)
Data
Access
(“U” ; “D”)
MS

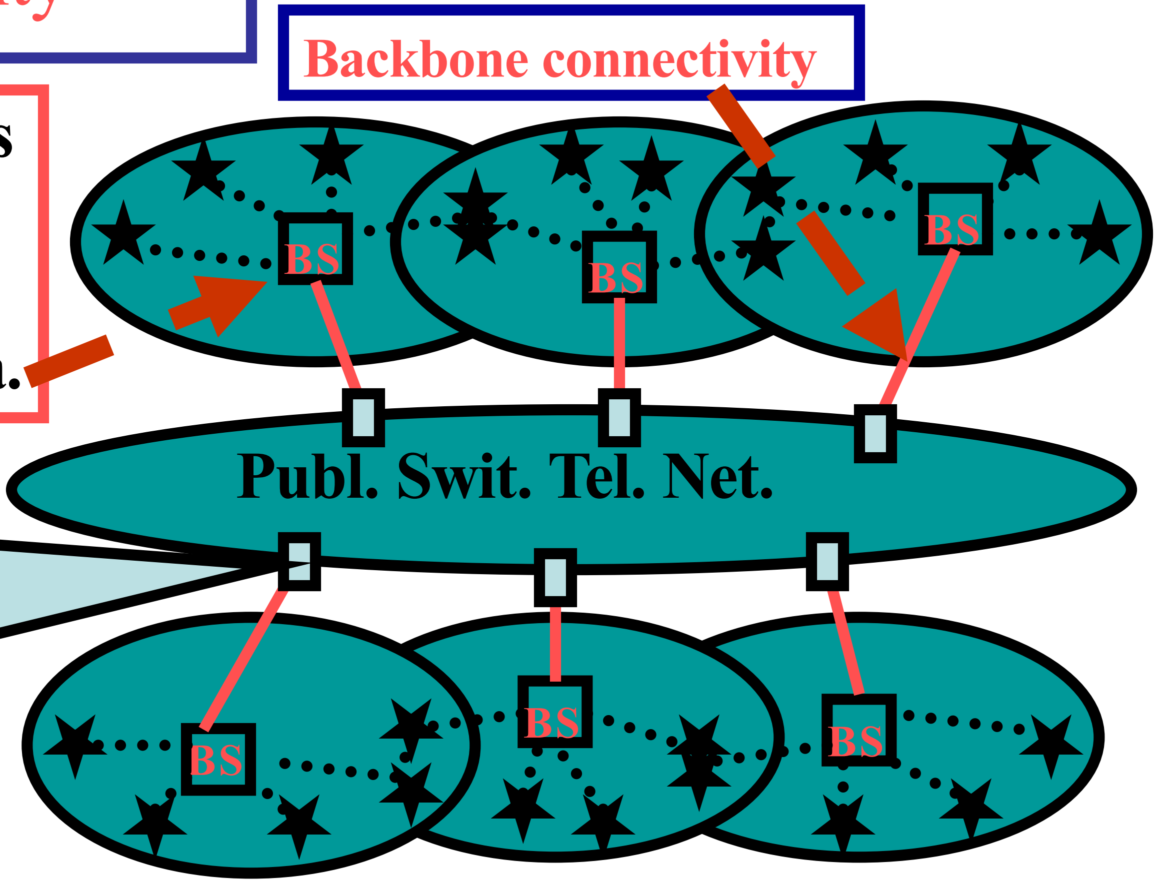
Cellular Concepts

- Geographical separation
- Capacity (frequency) reuse
- Backbone connectivity

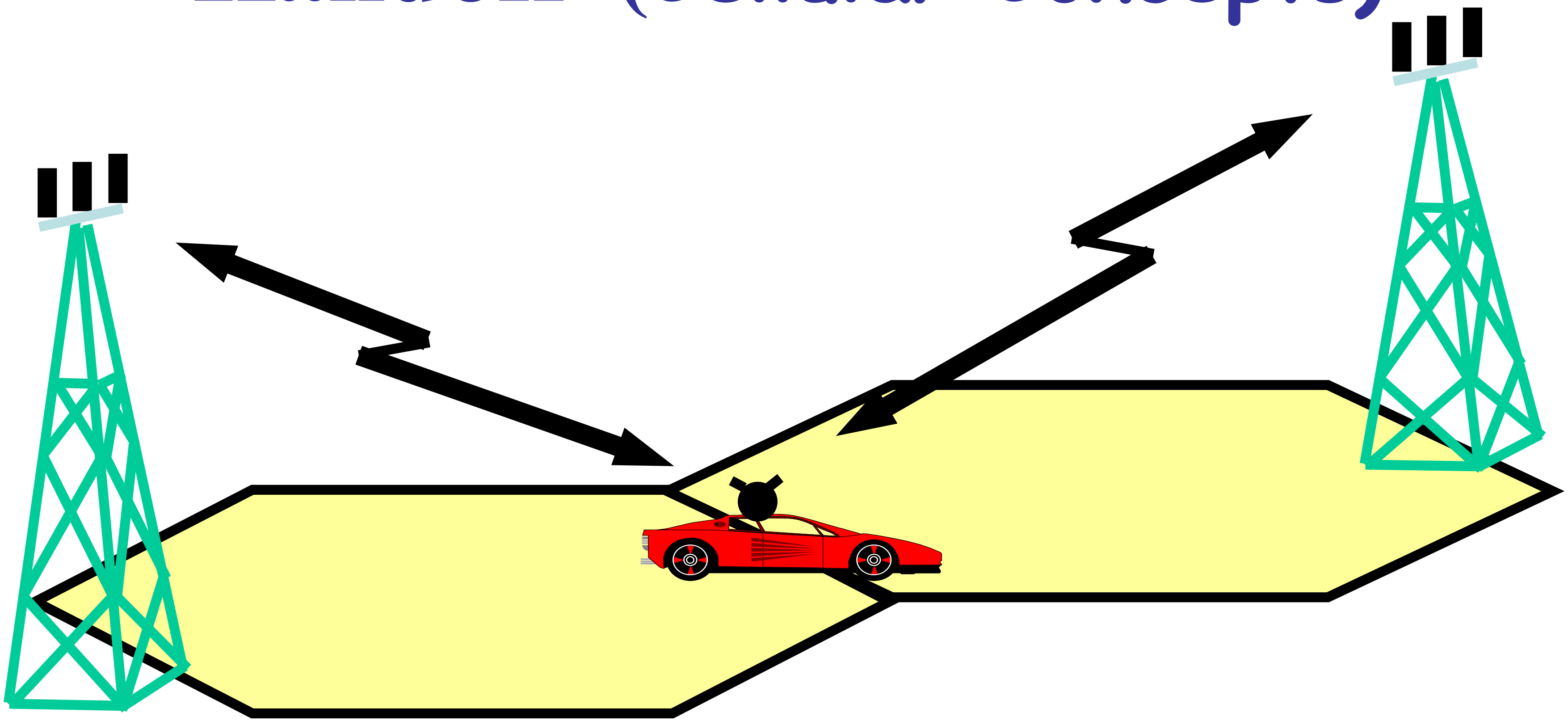
Hand-held telephone 0.6 watts; Car transmitters are 3 watts, Maximum. by the FCC.

The base station consists of a computers and transmitter/receiver connected to an antenna.

MTSO (Mobile Telephone Switching office)- MSC (Mobile Switching Center).



Handoff (Cellular Concepts)



- **Soft Handoff**: simultaneous radio link between MS and different BSs
- **Hard handoff:** The old BS drops the MS before the new one acquires it.

AMPS: physical layer

AMPS uses FDD to separate the channels.

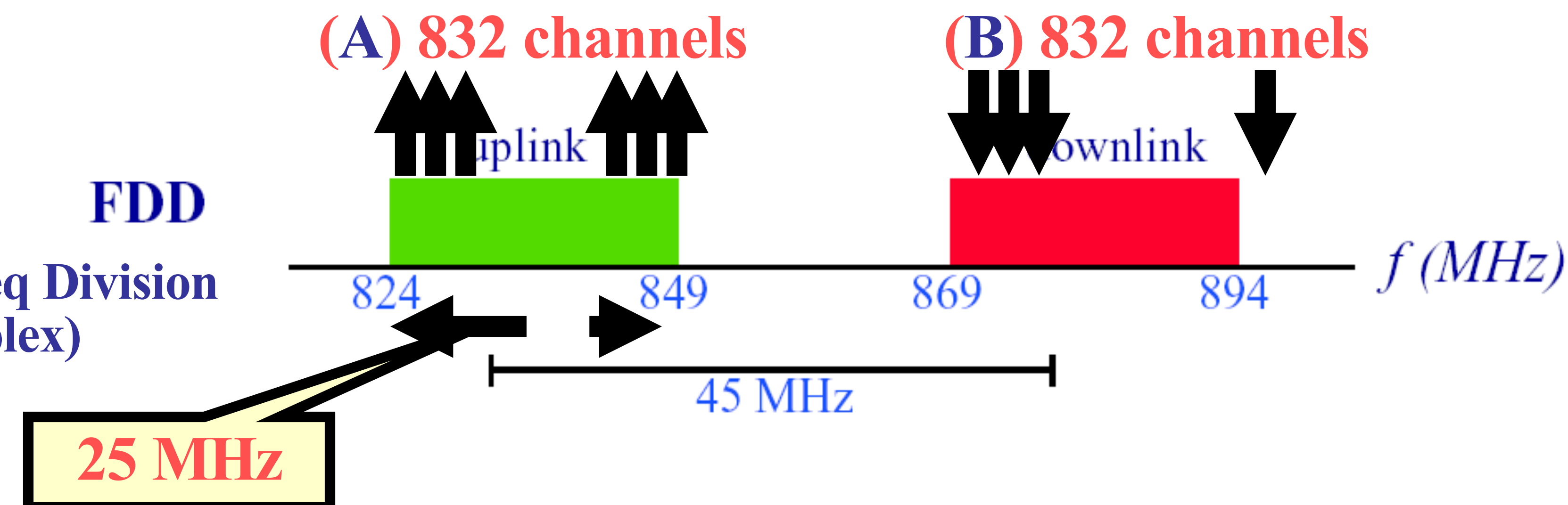
Radio bands

– 832 duplex (paired) channels

Each simplex channels is 30 KHz wide. 832 x 30 =24960 KHz

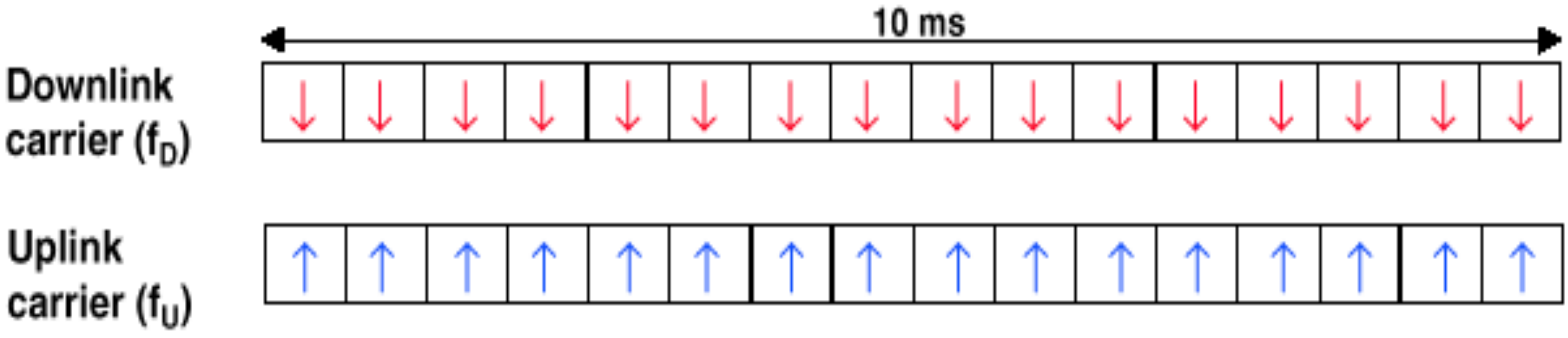
FDD

(Freq Division Duplex)

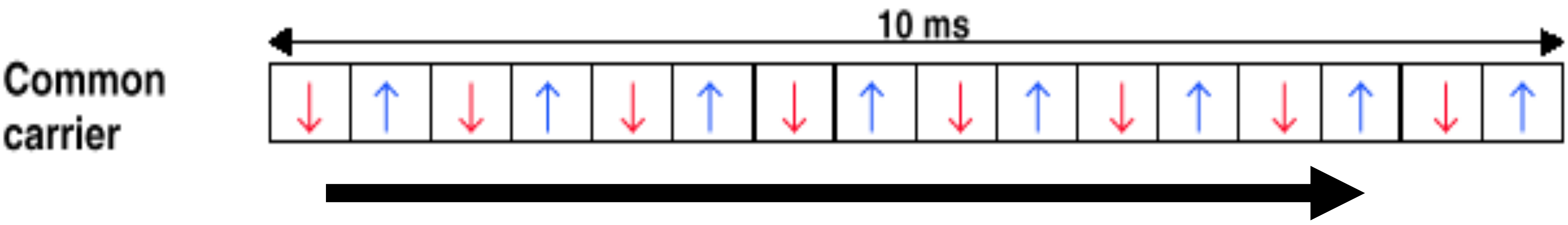


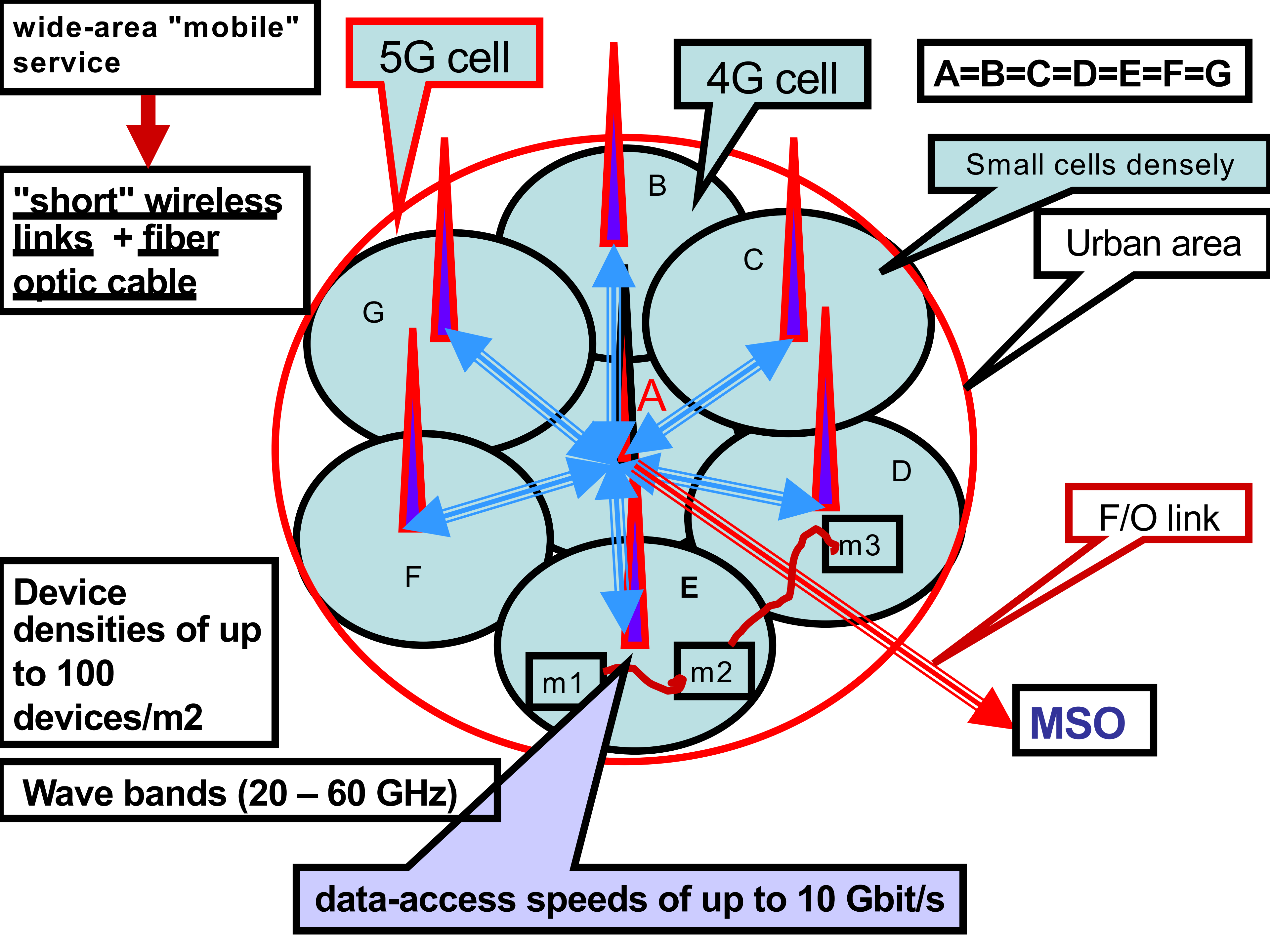
FDD & TDD duplexing

FDD (Frequency Division Duplex)



TDD (Time Division Duplex)





wide-area "mobile" service
"short" wireless links + fiber optic cable
5G cell
4G cell
A=B=C=D=E=F=G
Small cells densely
Urban area
B
C
G
A
D
F
E
m1
m2
m3
F/O link
MSO
Device densities of up to 100 devices/m2
Wave bands (20 – 60 GHz)
data-access speeds of up to 10 Gbit/s

The following course outcome for CS M117

a. Understand the properties of communication channe

b. Understand signal modulation, multiplexing and multiple access processes.

c. Understand MAC Protocols for reliable and noisy channels.

d. Understand Wireless LAN and PAN design and operations.

e. Understand structures of Computer Communication systems.

f. Final comprehensive project requiring the student to re-design and re-think one of the experiments he/she performed.

THANK YOU!

Grading
A numerical scores conversion to the letter grades

A+	A	A−	B+	B	B−
[100−96]	(96−93]	(93−90]	(90−86]	(86−83]	(83−80]

$\boxed{+0.5}$