Radio Capacity of FDMA & TDMA-based Systems

- The expression for radio capacity of an FDMA-based system is given by:

$$m = \left\lfloor \frac{W}{W_{ch}\left[\frac{6}{3^{\gamma/2}} SIR_{th}\right]^{2/\gamma}} \right\rfloor$$

where SIR_{th} is the signal-to-interference ratio required for acceptable communication and γ is the path loss exponent

- For a TDMA-based system with N_s users (timeslots) per RF channel:

$$m = \left\lfloor \frac{W}{W_{ch}\left[\frac{6}{3^{\gamma/2}} SIR_{th}\right]^{2/\gamma}} \right\rfloor \times N_s$$

Conclusions:

1. Radio capacity is maximized when both SIR_{th} and W_{ch} are minimized.
2. Transmit power vs. Bandwidth tradeoff: If both the radio capacity m and W are kept constant, there exists an inverse relationship between W_{ch} and SIR_{th}

Spectral Efficiency of FDMA System

For FDMA, the spectral efficiency is given by:

$$\eta_{FDMA} = \frac{N_{tch}}{WKA_{cell}} \quad \text{traffic channels/MHz/km}^2$$

where:

N_{tch}: number of traffic channels in the system

W: total system bandwidth in MHz

K: cluster size

A_{cell}: cell area in km^2

Spectral Efficiency of TDMA System

For TDMA, the spectral efficiency is given by:

$$\eta_{TDMA} = \left(\frac{N_f W_{ch}}{W}\right)\left(\frac{T_f - \tau_p - \tau_{tr}}{T_f}\right)\left(\frac{L_d}{L_s}\right)\varepsilon_{mod}\frac{1}{KA_{cell}} \quad \text{bits/sec/Hz/km}^2$$

where:

N_f: number of frequencies in the given system bandwidth, B_t, assuming allowance for guard bands

W: total system bandwidth in Hz

W_{ch}: RF channel bandwidth in Hz

T_f: length of TDMA frame in seconds

τ_p: length of TDMA frame preamble in seconds

τ_{tr}: length of TDMA frame trailer in seconds

L_d: length of information bits in a TDMA slot

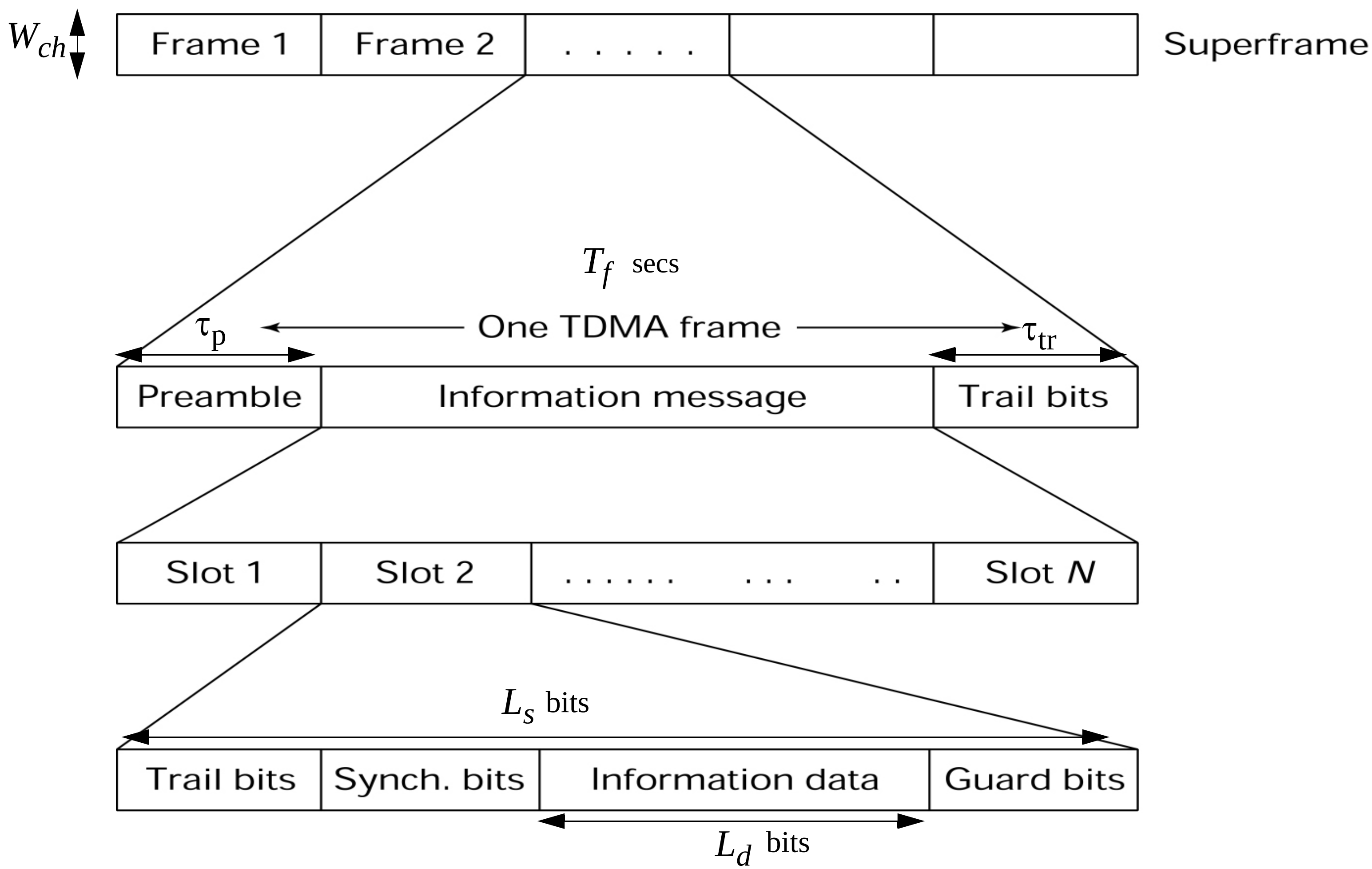
L_s: length of information and overhead bits in a TDMA slot

ε_{mod}: bandwidth efficiency in bits/sec/Hz of modulation technique

K: cluster size

A_{cell}: cell area in km^2

TDMA Frame and Slot Efficiency



Radio Capacity of CDMA

Case 1: One Cell (i.e., isolated cell) e.g., in rural areas

$$m = \left\lfloor 1 + \frac{W/R_b}{(E_b/I_o)_{th}} - \left(\frac{P_{noise}}{S}\right) \right\rfloor \text{ users/cell}$$

Case 2: Multiple Cells e.g., in urban areas

$$m = \left\lfloor 1 + \eta_f \left[\frac{W/R_b}{(E_b/I_o)_{th}} - \left(\frac{P_{noise}}{S}\right) \right] \right\rfloor \quad \text{users/cell}$$

where:

R_b: data rate

P_{noise}: thermal noise power

S: constant received power at the base station

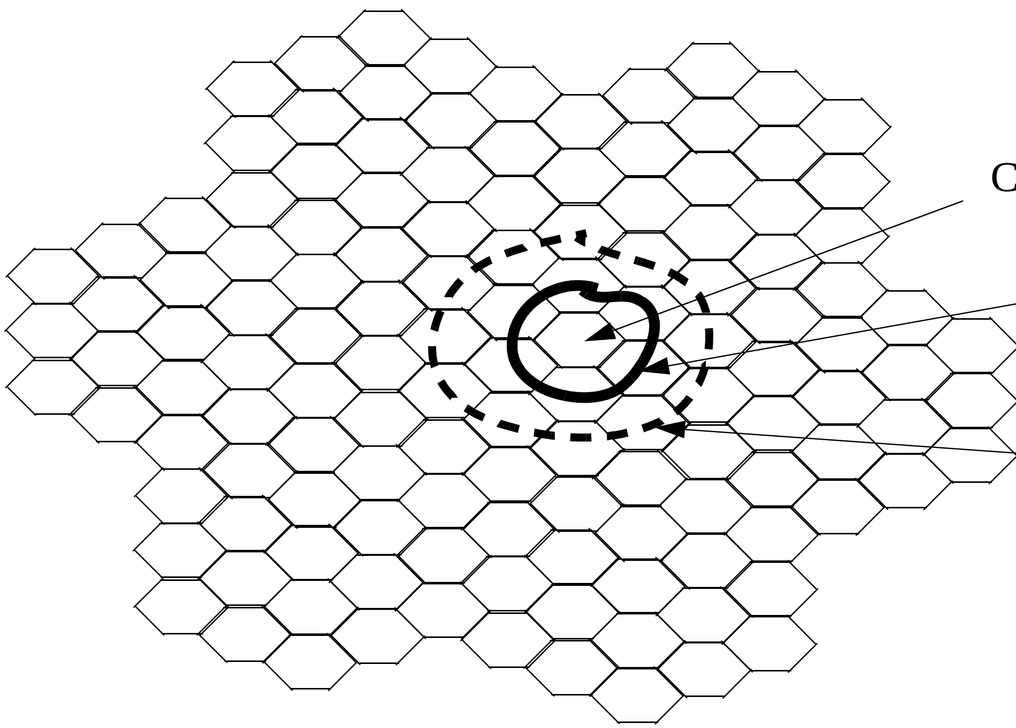
W/R_b: processing gain

$(E_b/I_o)_{th}$: required E_b/I_o for acceptable communication (e.g., required E_b/I_o for a given BER)

η_f: frequency reuse efficiency

Note: CDMA capacity can be enhanced by sectorization and voice activity detection.

Radio Capacity for CDMA: Intra- and Inter-cell Interference



Spectral Efficiency for CDMA System

For CDMA, spectral efficiency is given by:

$$\eta_{CDMA} = m_{CDMA}\left(\frac{R_b}{W}\right) \quad \text{bits/sec/Hz}$$

where

m_{CDMA} is calculated by the formulas on Page 15, for a given $(E_b/I_o)_{th}$

$\frac{W}{R_b}$ is the processing gain

Class Example on FDMA System

Problem Statement:

An FDMA-based cellular system has a one-way bandwidth of 12.5 MHz, rf channel spacing is 30 kHz, and the guard band at each boundary of the spectrum is 10 kHz. Other system specifications include: cell area = 6 km^2, cluster size K = 7 and 21 channels are used for control signaling.

Calculate:

a) the system spectral efficiency in units of channels/MHz/km^2

b) the system spectral efficiency in Erlang/MHz/km^2, assuming a 2% blocking

Class Example on TDMA System

Problem Statement:

Consider the North American digital cellular system that uses a one-way bandwidth of 25 MHz for the forward or reverse link. The system bandwidth is divided into rf channels of 30 kHz, each supporting transmission at a rate of 16.2 kbps. Two guard bands each with W_g = 20 kHz are used. The frame duration is 40 msecs, consisting of 6 timeslots. A single rf channel supports 3 full-rate speech channels, each channel using 2 slots in a frame. Each slot consists of 324 bits, among which 260 bits are actual data and the remaining 64 bits are overhead for access control. The speech codec is 7.95 kbps. If the cluster size is 7, find the spectral efficiency in bits/sec/Hz/cell. Assume that: $\tau_p = \tau_{tr} = 2$ msecs.

Class Example on CDMA System

Problem Statement:

If $W = 1.25$ MHz, $R_b = 9600$ bps and $(E_b/I_o)_{th} = 10$ dB:

a) Assuming thermal noise is negligible, determine the radio capacity for CDMA under:

i) single-cell scenario

ii) multiple-cell scenario with a frequency reuse efficiency of 90%

b) Calculate the spectral efficiency for cases i) and ii) above

c) Compare the results in a) with those calculated for an FDMA system with $W = 1.25$ MHz and $W_{ch} = 30$ kHz under:

i) single-cell scenario

ii) multiple cell scenario with cluster size $K = 7$