Wireless Data Communication Networks (Lecture 12)

Review for midterm exam

Topics:

* Elements of propagation (Free space and log distance PL model)
* Fundamentals of cellular concepts (reuse, sectoring, cell splitting, duplexing)
* contention based protocols
  - Aloha (unslotted and slotted)
  - CSMA (non-persistent, 1-persistent, p-persistent)
* contention free protocols (FDMA, TDMA/CDMA, CDMA)

Test duration: 1 hour 15 minutes.
Expect 4-5 problems.

1. Consider the situation depicted in figure. The following data are known:

   Propagation: Log distance
   \[ PL(d) = 109 \text{ dB} \quad \text{d}_{0} = 2 \text{ miles} \]

   \[ \alpha = 38.4 \text{ dB/km} \]

   Mobile TX power: 23 dBm
   Base antenna gain: 12 dB
   Cable loss at the base: 2 dB
   Rx sensitivity at base: -102 dBm

   a) Calculate the path loss between the mobile and the base

   \[ PL(d) = PL(d_{0}) + \alpha \log \left( \frac{d}{d_{0}} \right) = 109 + 38.4 \log \left( \frac{2.3}{2} \right) = 122.89 \text{ dB} \]

   b) Determine the transmitted power of the mobile so that it reaches base station receiver above its sensitivity.
\[ P_{Tx} = 10.89 \text{dBm} \]

1. Calculate the maximum distance between the mobile and the base station.

\[ P_{Rx_{max}} = P_{Rx_{min}} = P_{Rx_{sens}} \]

\[ P_{Rx_{max}} = P_L + 10 \log(4l) = P_{Rx_{sens}} \]

\[ P_L = P_{Rx_{max}} - 10 \log(4l) = 23 \text{dBm} + 12 \text{dB} - 2 \text{dB} - (-102 \text{dBm}) = 135 \text{dB} \]

\[ 10 \log(4l) + 10 \log(\frac{d}{d_0}) = P_L \]

\[ 10 \log(384) + 10 \log(\frac{d}{1}) = 135 \implies d = 4.75 \text{ miles} \]

2. Consider the scenario depicted in the figure. The following data are known:

- Propagation: PL(d0) = 113 dB, LA = 41 dB/dB
- EIRP = 50 dBm
- ERP2 = 47 dBm
- Calculate: RSL1, RSL2, RSL12, RSL21, RSS22 (C/E), & (C/E).
\[ R_{SL_{11}} = E_{RP_{1}} - P_{L_{11}} = 50 \text{ dBm} - (113 \text{ dB} + 40 \log (2)) = -75 \text{ dBm} \]
\[ R_{SL_{12}} = E_{RP_{2}} - P_{L_{12}} = 47 \text{ dBm} - (113 \text{ dB} + 40 \log (1.1)) = -94 \text{ dBm} \]
\[ R_{SL_{21}} = E_{RP_{1}} - P_{L_{21}} = 50 \text{ dBm} - (113 \text{ dB} + 40 \log (41)) = -87 \text{ dBm} \]
\[ R_{SL_{22}} = E_{RP_{2}} - P_{L_{22}} = 47 \text{ dBm} - (113 \text{ dB} + 40 \log (11)) = -66 \text{ dBm} \]

\[ (C/I)_1 = R_{SL_{11}} - R_{SL_{12}} = -75 \text{ dBm} - (-94 \text{ dBm}) = 19 \text{ dB} \]
\[ (C/I)_2 = R_{SL_{22}} - R_{SL_{21}} = -66 \text{ dBm} - (-87 \text{ dBm}) = 21 \text{ dB} \]

3) Consider a scenario of an IS-95 communication. Assume that the maximum transmit power is 40 W, and that the operating frequency is 2.4 GHz. Estimate the maximum Doppler spread. If the bandwidth of the channel is 1.5 MHz, express the Doppler spread as a function of the bandwidth.

\[ Ad = \frac{n \text{ dB}}{8} \]
\[ P_{\text{max}} = \frac{500 \times 169}{2400 \times 10^6} = 1.727 \text{ KHz} \]
\[ DS = 2P_{\text{max}} = 3.57 \text{ KHz} \]
\[ DS/BW = \frac{3.57 \text{ KHz}}{1.5 \times 10^6 \text{ Hz}} = 0.0024 \approx 0.3 \% \]

4) Consider a cellular technology capable of working under C/I = 17 dB, 19 dB. The pull loss exponent of the environment is N=4.

1) Determine the reuse cluster size.
2) Draw the reuse cluster size.
3) If the cell has a radius of R = 3 miles, what is the distance between the cells using the same frequencies.

\[ C/I = \frac{1}{6} (\sqrt[3]{3N})^4 \]
\[ 17 \text{ dB} \to 50 \]
\[ 50 = \frac{1}{6} (\sqrt[3]{3N})^4 \Rightarrow N = 571 \Rightarrow N = 7 \]
Consider a system with a single access point on N sensors. Each sensor is generating 300 megawatts of messages/minute and it takes 30 ms to deliver a message to the access point. Assuming that the system is operating in pure ALOHA, how many sensor units can be accommodated? What is the expected number of transmission for number of sensors k? A fraction 1/2 of the maximum value. Repeat for slotted ALOHA.

\[ D_{on} = D_n \cdot T = 60 \text{ ms} \times 300 \times 10^{-2} \text{ sec} = 0.015 \text{ sec} \]

\[ S_{on} = 0.184, \quad N_{max} = \frac{S_{on}}{D_{on}} = \frac{0.184}{0.015} = 12.266 \rightarrow 12 \]

\[ N = 6 \text{ units} \]

\[ D_n = N \cdot D_{on} = 6 \cdot 0.015 = 0.09 \]

\[ \bar{N}_{tx} = \frac{1.2145+1.2159}{2} = 1.2152 \]

For slotted ALOHA:

\[ S_{on} = 0.268 \]

\[ N_{max} = \frac{S_{on}}{D_{on}} = \frac{0.268}{0.015} = 18.53 \rightarrow 24 \]

\[ N = 12, \quad D_n = N \cdot D_{on} = 12 \cdot 0.015 = 0.18 \]

\[ \bar{N}_{tx} = \frac{(1.2145+1.2159)}{2} = 1.2152 \]
Consider a system using non-persistent CSMA access protocol. The duration of the packet is 7 and $a = 0.01$. The number of users is 400. The average backoff time is set to $B = 10$ ms and the acknowledgment time is $T_a = 2$ ms. Determine the average length of the packet if the average number of packets generated per mobile is 5 packets/sec? The average number of retransmissions is 0.7.

$$\bar{N_T} = 1 + 0.07 = 1.7$$

$$P_s = 1/\bar{N_T} = 0.5882$$

$$P_s = \exp(-a \cdot \frac{2n}{P_s}) = \frac{\exp(-0.01 \cdot \frac{2n}{0.5882})}{(1 + 2a) \cdot \frac{2n}{P_s} + \exp(-a \cdot \frac{2n}{P_s})} = 0.5882$$

Solving for $2n$ (one way we humble as well)

$$2n = 0.4010 \Rightarrow 2n = 2n \cdot T_N \Rightarrow T = \frac{2n}{2n} = \frac{0.4010}{5 \times 100} = 8 \times 10^{-4} \text{sec.}$$
Consider a deployment of cellular system in the D block of the US PCS spectrum. The technology selected for the deployment has the following properties:

\[ (C/I)_{eq} = 17 \text{ dB} \]

FDMA/TDMA access with \( BW = 30 \text{ KHz} \) and 3 users/channel in TDMA mode. Assuming that one TS at each cell is reserved for control and that the system uses 3-sectored cells, determine:

1) Total number of channels available (2x30KHz quad band)
2) The size of the reuse cluster \( (n=4) \)
3) The number of channels per sector
4) The number of active slots per sector
5) Maximum number of users that can be served by sector

\[ N_{ch} = \frac{511K}{2 \times 0.08 \times 1000} = 164.67 \rightarrow 164 \text{ channels} \]

\[ C/I = \frac{1}{6} \left( \sqrt[3]{N} \right)^n = 1 \]

\[ C/I = 7 \text{ dB} \rightarrow 50 \Rightarrow \sqrt[3]{N} = \frac{50}{1} \Rightarrow N = 5.77 \]

The paper reuse cluster size is \( N = 7 \)

\[ N_{ch/sector} = \frac{164}{7 \times 3} = 7.8095 \text{ (some sectors have 7 channels, some have 8 channels)} \]

\[ N_{ts/sector} = 7.8095 	imes 3 = 23.4 \text{ time slots/sector} \]

1 time slot reserved for control

\[ N_{ts/sector for control} = 22.4 \text{ (some sectors will have 22 TS and some will have 23 TS)} \]
9. Consider a CDMA system with the following parameters:

- $R_c = 1.2288 \times 10^6$ chips/sec
- $\alpha = 0.5$
- $B = 1.3 \text{ MHz}$
- $E_{\text{B/F}} = 5 \text{ dB}$

2 vocoders are considered:

Vocoder 1: $R_b = 14.4 \text{ kbps}$, $E_b/N_0 = 6 \text{ dB}$

Vocoder 2: $R_b = 9.6 \text{ kbps}$, $E_b/N_0 = 7 \text{ dB}$

Which solution provides higher small cell capacity?

$$N_{pp} = 1 + \frac{R_c/R_b}{\alpha E_b/N_0}$$

1) $N_{pp1} = 1 + \frac{1.2288 \times 10^6 / 14.4 \times 10^2}{0.5 \times 10^{0.1 \times 0.8}} = 48.87$

2) $N_{pp2} = 1 + \frac{1.2288 \times 10^6 / 9.6 \times 10^2}{0.5 \times 10^{0.1 \times 0.7}} = 52.07$

The second vocoder provides a higher capacity.

10. Consider a CDMA system with the following parameters:

- $R_c = 3.84 \times 10^6$ chips/sec
- $R_b = 8 \text{ kbps}$
- $E_b/N_0 = 5 \text{ dB}$, $\alpha = 0.5$
- $B = 8 \text{ MHz}$
- $E_{\text{B/F}} = 5 \text{ dB}$
- $\lambda = 12 \text{ users}$
- $P_t x_{\text{ideal}} = 2.5 \text{ dB}$
- $D_L(d_0) = 12.3 \text{ dB}$, $d_0 = 1 \text{ mile}$
- $M = 3.84 \text{ dB/km}$
- $P_x \text{ antenna gain} = 12 \text{ dB}$
- $\text{Cable loss} = 2 \text{ dB}$
1) Received power of each user
2) Noise nsc
3) Maximum cell radius of the cell

$$\frac{E_b}{N_t} = \frac{P \cdot \frac{R_c}{R_b} \cdot \frac{1}{\alpha_i}}{(N-1)P + KTFB}, \quad E_b/N_t = 5 \text{ dB} \rightarrow 3.16$$
$$P = 5 \text{ dB} \rightarrow 3.16$$

After substituting values:

$$8.16 = \frac{P \cdot 3.84 \cdot 10^6 \cdot \frac{1}{8 \cdot 10^6}}{(12-1)P + 4 \cdot 10^{-12} \text{ mW} \cdot 3.16 \cdot 5 \cdot 10^6} \quad \Rightarrow P =$$
$$P = 2.16 \cdot 10^{-13} \text{ mW} \rightarrow -126.7 \text{ dBm}$$

$$N_{pp} = 1 + \frac{P_c/R_b}{d \cdot E_b/m} = 1 + \frac{3.84 \cdot 10^6 / 8 \cdot 10^{-3}}{0.5 \times 3.16} = 304.79$$

$$\beta = \frac{N}{N_{pp}} = 0.0394$$

$$N_{dB} = -10 \log (1 - \beta) = -10 \log (1 - 0.0394) = 0.1746 \text{ dB}$$

$$P_{TX} = P_L + AG - CL = \text{Rx Power}$$
$$25 \text{ dBm} + P_L + 12.2 = -126.7 \text{ dBm}$$
$$P_L = 161.7 \text{ dB}$$

$$P_L = P_L(d_0) + 10 \log (d/d_0)$$

$$161.7 = 123 + 38.4 \log (d/0.2) \quad \Rightarrow d = 10.2 \text{ miles}$$