1 Part 1: IEEE 802.11 MAC (10 points)

An Ad Hoc network using IEEE802.11 has 4 nodes:N1,N2,N3,N4. Assume that SIFS is 1 unit of time, PIFS 2 units of time, DIFS 3 units of time, and slot time is 2 (these value are not the real values but are taken to simplify the packets scheduling).

Assume that at the beginning the channel is idle (no transmission), and that at instant 1,N2has a packet to be sent toN4. At instant 2, bothN1andN3have a packet to be sent toN4. Assume that the random number generator (for back-off) will give the following values forN1: 2, 5, ... and forN2: 4, 3, and forN3: 1, 4, ... Assume that we dont use RTS/CTS nor fragmentation, and that all data packets have the same length: 6 units of time and that the Ack packet has length 3 units of time. Furthermore the channel Bit Error Rate is assumed to be 0. Show the execution of the DCF mode of IEEE802.11.

Instant	event
1	N2 sense the medium is free and wait for DIFS time
2	N1 and N3 sense the medium is free and wait for DIFS time
4	N2 starts transmit the packet; N1 and N3 sense the medium is busy, they get the back-off time, which is 4 for N1(2*2) and 2 for N3(2*1).
10	N2 finishes packet transmission to N4, N4 waits for SIFS time and then send the ACK
11	N4 sends the ACK
14	N2 receives N4s ACK, N1 and N3 sense the free channel then start to wait for DIFS time
17	N1 and N3 start to wait for back-off time
19	N3s back-off time finishes first, so N3 starts transmit packet to N4. N1 stop counting back-off time and have 2 residual backoff time
25	N3 finishes packet transmission, N4 waits for SIFS time and then send the ACK
26	N4 sends the ACK
29	N3 receives ACK, N1 starts its residual backoff time
31	N1 starts transmit packet to N4
37	N1 finishes transmission
38	N4 sends the ACK
41	N1 receives the ACK

2 Part 2: Text book Problems

2.1 Problem 6.1

For radio transmission in free space signal power is reduced in proportion to the square of distance from the source whereas in wire transmission attenuation is a fixed number of Db per kilometre. The following table is used to show the Db reduction relative to some reference for free space radio and uniform wire. Fill the missing numbers to complete the table.

Radio:

$L_d = 10log(P_t/P_r) = 20log(4\pi d/\lambda) = 20log(4\pi/\lambda) + 20log(d)$

When d = 1, $20log(4\pi/\lambda) = 6$

When d = 2, $L_d = 6 + 20log(2) = 12.021$

When d = 4, $L_d = 6 + 20log(4) = 18.041$

When d = 8, $L_d = 6 + 20log(8) = 24.062$

When d = 16, $L_d = 6 + 20log(16) = 30.082$

Wired:

Since it's fixed number of dB per km, it is 3 dB per km(linear) in this example.

Distance(km)	Radio(dB)	Wire(dB)
1	-6	-3
2	-12	-6
4	-18	-12
8	-24	-24
16	-30	-48

2.2 Problem 6.6

Suppose a transmitter produces 50Watts of Power.

a. Express transmit power in dBm and dBW.

b. If a transmitters power is applied to Unity gain Antenna with 900MHz carrier frequency, what is the free space power in dBm at a free space distance of 100m?

c. Repeat (b) for 10Km

d. Repeat (c) for antenna gain 2

a)

$N(dBW) = 10log(P2/1W) = 10log(50)dBW = 16.98dBW$

$N(dBm) = 10log(P2/1mW) = 10log(50 * 10^3) = 16.98 + 30 = 46.98dBm$

b)

$P_r = (c^2)/(4fd)^2$

$P_r = (3 * 10^8)^2/(4 * (900MHz * 10^6) * 100m)^2$

$P_r = 3.52 * 10^{-6}W$

$P_r = 10log(3.52 * 10^{-6}W/1mW) + 30 = -54.53 + 30 = -24.53dBm$

c)

$P_r = 3.52 * 10^{-10}W$

$P_r = 10log(3.52 * 10^{-10}W/1mW) + 30 = -94.53 + 30 = -64.53dBm$

d)

$P_r = 2 * 3.52 * 10^{-10}W = 7.04 * 10^{-10}$

$P_r = 10log(7.04 * 10^{-10}W/1mW) + 30 = -61.52dBm$

2.3 Problem 6.7

Instead of assuming free space environment in 6.6 assume an urban area cellular radio scenario. Path loss exponent n=3.1 and a transmitter power of 50W.
a. What is the range of path loss exponent for this environment?
b. If a transmitters power is applied to Unity gain Antenna with 900MHz carrier frequency, what is the free space power in dBm at a free space distance of 100m?
c. Repeat (b) for a distance of 10km.
d. Repeat (c) but assume a receiver antenna gain of 2.
a) 2.7 to 3.5
b)
$P_r = (c^2)/(4\pi f)^2 * d^{3.1}$
$P_r = (3 * 10^8)^2/(4\pi * (900MHz * 10^6))^2 * 100^(3.1)$
$P_r = 4.44 * 10^{-10}W$
$P_r = 10log(4.44 * 10^{-10}W/1mW) + 30 = -63.53dBm$
$c)$
$P_r = (3 * 10^8)^2/(4\pi * (900MHz * 10^6))^2 * 10000^{3.1}$
$P_r = 2.8 * 10^{-16}W$
$P_r = 10log(2.8 * 10^{-16}W/1mW) + 30 = -125.53dBm$
$d)$
$P_r = 2 * 2.8 * 10^{-16}W = 5.6 * 10^{-10}$
$P_r = 10log(5.6 * 10^{-10}W/1mW) + 30 = -183.03dBm$

2.4 Problem 6.12

Determine the height of the Antenna for TV stations that must be able to reach customers 80Kms away. Use Okumura-Hatta Model for rural environment with fc=75Mhz and Hr=1.5m. Transmitter power 150Kw and received power must be greater than 10^{-13} W
$L_{ru} = 10log(150 * 10^3/10^{-13})$
$L_{ru} = 181.76dbBW$
$L_{ru} = L_u 4.78[log(76 * 10^6)]^2 - 18.33log(76 * 10^6)40.94$
$L_u = L_{ru} + 4.78[log(76 * 10^6)]^2 - 18.33log(76 * 10^6) + 40.94$
$L_u = 663.49$
$= 69.55 + 26.16log(f)13.82logh_b A(h_m) + (44.96.55log(h_b))logdA(h_m)$
$= (1.1logf0.7)h_m(1.56logf - 0.8)$
$= 0.46663.49$
$= 69.55 + 26.16log(76 * 10^6)13.82logh_b A(h_m) + (44.96.55log(h_b))logd$
$= 69.55 + 26.16log(76 * 10^6)13.82logh_b 0.46 + (44.96.55log(h_b))log(80 * 10^3)$
$log(h_b) = -3.66$
$h_b = 0.0002m$

2.5 Problem 6.15

Suppose a car is moving through the suburban environment that has a wireless channel with a coherence time of 10ms and the coherence bandwidth of 600Khz. The bitrate of system used is 50kbps. Characterize the channel.a. Is the channel slow or fast fading?b. Is the channel flat or frequency selective fading? a)
$T_b = 1/(50000) = 0.00002s = 0.02ms$
$T_c = 10ms > T_b$, Slow Fading
b)
$B_c >> B_s$, Flat Fading

3 Part 3

The goal of this exercise is to compute the BER using some simple assumptions. Consider a binary digital communication at bitrate 50bps. The receiver is mobile and is moving toward the transmitter at speed 10m/s and the communication is over 1500MHZ frequency band. What is the value of the frequency of Doppler shift? Consider fadings (due to Doppler shift) of the received signal strength R below0.1RMS. What is the average fade duration? Assume that a bit is lost whenever the received signal strength R of any portion of the bit is below0.1RMS. What would the BER of this communication?
1. $f_m = v/\lambda = v/(c/f) = vf/c = (10 * 1500 * 10^6)/(3 * 10^8)$
$= 50Hz$
2.$\rho = R/R_{rms} = 0.1R_{rms}/R_{rms} = 0.1$
Use Average fade duration:
$e^{(\rho^2-1)}/\rho f_d \sqrt(2\pi) = 0.01/12.53 = 0.0008s$
3.$N_T = \sqrt{2}\pi * f_m \rho e^{(-\rho^2)} = 12.4$
$BitErrorRate = 12/50 = 0.24$