Midterm Offline Homework

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1. Definition
   (a) Baseband signals are for processing of signals(coding, modulation, etc.). Its central frequency is 0. Passband signals are for communication and transmission. Its central frequency > 0.
   (b) LOS link stands for "line-of-sight" link, which is the straight line distance link from transmitter to receiver. NLOS link("Non-line-of-sight") is the link with obstacles in between transmitter and receiver, in which transmission might suffer scattering or reflection.
   (c) The effect that happens when signals reach receiving antenna by two or more paths. The waves might attenuate differently or arrive with different delays, causing signals to arrive with different strength or to get mixed together.
   (d) A collision event happens when multiple stations want to send packet through a same link at the same time. The signals disturb each other, resulting in an unsuccessful transmission. A collision event can still happen even when every device listen before talk. That's because two stations might transmit at the same time. Before they transmit, they both listen to an idle channel. Another reason might be the hidden terminal problem. Two stations might be just not able to sense each other due to distance or obstacles.
   (e) $\dfrac{3 \times 10^8}{5 \times 10^9} = 0.06\ \mathrm{m}$
   (f) CSI represents the characteristics of a wireless communication channel between a transmitter and a receiver. It provides essential information about how the transmitted signal is altered as it propagates through the wireless medium. In the equation, α represents the amplitude of the channel, and ϕ represents the phase difference.

2. Medium Access Control
   (a) $p_1(1-p_2)(1-p_3)+p_2(1-p_1)(1-p_3)+p_3(1-p_1)(1-p_2)$
   (b) $p_1(1-p_2)(1-p_3)$
   (c) $(1-p_1)(1-p_2)(1-p_3)$
   (d) $E_1 = \dfrac{1}{p_1(1-p_2)(1-p_3)} + \dfrac{1}{p_2(1-p_1)(1-p_3)} + \dfrac{1}{p_3(1-p_1)(1-p_2)}$

   $E_2 = \dfrac{1}{p_1(1-p_2)} + \dfrac{1}{p_1(1-p_3)} + \dfrac{1}{p_2(1-p_1)} + \dfrac{1}{p_2(1-p_3)} + \dfrac{1}{p_3(1-p_1)} + \dfrac{1}{p_3(1-p_2)}$

   $E_3 = \dfrac{1}{p_1} + \dfrac{1}{p_2} + \dfrac{1}{p_3}$

   Expected time slots $= 1 + \dfrac{1}{3}E_1 + \dfrac{1}{6}E_2 + \dfrac{1}{3}E_3$

3. Path loss and capacity

(a) $\lambda = \dfrac{3 \times 10^8}{5 \times 10^9} = 0.06$

$\dfrac{P_r}{P_t} = 1 \times (\dfrac{0.06}{4\pi \times 50})^2 = 9.12 \times 10^{-9}$

(b) $P_{r,dbm} = 20 + 0 + 0 + 20\log_{10}\dfrac{c}{4\pi \times 50 \times 5e9} = 20 + 20(7.3781 - 9.6989 - 1.6989)$

$P_{r,dbm} = 20(1 - 4.0197) = -60.394$

$\text{SNR}_{db} = -60.394 - (-90) = 29.606$

(c) $\text{SNR} = 10^{\frac{\text{SNR}_{db}}{10}} = 10^{2.9606}$

Capacity $= 20 \times 10^6 \times \log_2(1 + 10^{2.9606})$

(d) Wifi 5GHz has larger wavelength than 2.4GHz mode. According to the Friis free-space path loss model, the pass loss $(\frac{P_r}{P_t})$ increases when the signal wavelength increases.

4. Modulation and throughput

(a)

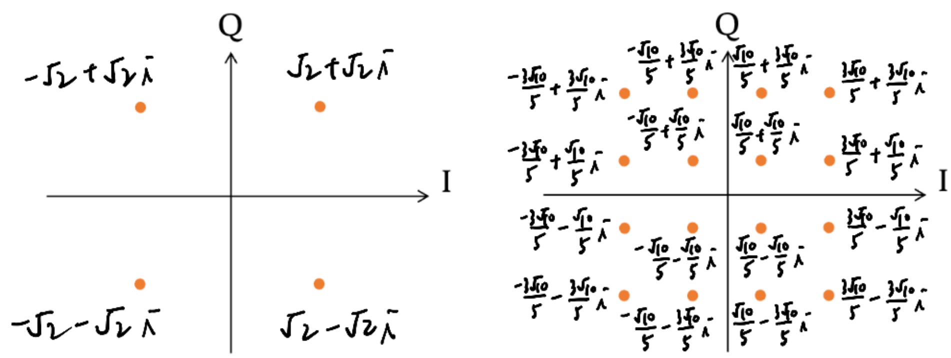
- QPSK:

$a^2 + a^2 = 4$, $a = \sqrt{2}$

- BPSK:

$\dfrac{2a^2 + 10a^2 + 10a^2 + 18a^2}{4} = 10a^2 = 4$

$a^2 = \dfrac{2}{5}$, $a = \dfrac{\sqrt{10}}{5}$



QPSK 16QAM

(b) The distance between the constellation points are closer. Therefore, the possibility of a signal being mapped to a wrong point is higher.

(c) SER is the proportion of error signals in a sequence of signals. BER is is proportion of error bits in a decoded bitstream. SER is typically a modulation scheme larger than BER, since a signal can be decoded to multiple bits. Given a error signal, usually not all bits are wrong.

(d) BPSK: $\frac{1}{4} = 0.25$ Mbps

QPSK: $\frac{2}{4} = 0.5$ Mbps

16-QAM: $\frac{4}{4} = 1$ Mbps

(e)

- PDR

BPSK: $(1-0.1)^4 = 0.9^4$

QPSK: $(1-0.01)^4 = 0.99^4$

16-QAM: $(1-0.001)^4 = 0.999^4$

- average tput

BPSK: $0.25 \times 0.9^4 \fallingdotseq 0.164$ Mbps

QPSK: $0.5 \times 0.99^4 \fallingdotseq 0.480$ Mbps

16-QAM: $1 \times 0.999^4 \fallingdotseq 0.996$ Mbps

5. Rate adaption

(a) Synchronous ACK is a control frame sent immediately after SIFS with minimum overhead. It can inform the transmitter if the packet is received successfully. Asynchronous ACK is sent as a independent data frame, containing more information about the channel. It costs additional overhead.

(b) Transmitter-based rate adaption decide the transmission rate by transmitter. Receiver-based rate adaption decide the transmission rate by receiver.

(c) pros: more accurate
cons: higher overhead

(d) pros: lower overhead
cons: less accurate

(e)

r':

$$T_{tx} = 20 + \frac{2000}{10} = 220\ \mu s$$

$$tput = \frac{2000}{220} \fallingdotseq 9.09\ \text{Mbps}$$

r'':

$T_{tx} = 20 + 2 \cdot \frac{2000}{40} = 120$ ms

$tput = \frac{2000}{120} \doteqdot 16.67$ Mbps

(2) Estimated tput of r:

T_1:

$T_{tx} = 20 \times 5 + 6 \times \frac{2000}{20}$

$= 100 + 600 = 700$

$tput = \frac{10000}{700} \doteqdot 14.29$

T_2:

$T_{tx} = 20 \times 11 + 13 \times \frac{2000}{20}$

$= 220 + 1300$

$= 1520$

$tput = \frac{22000}{1520} \approx 14.47$

At T_1 selects $r = 20$ Mbps

since 14.29 Mbps > 9.09 Mbps

At T_2 selects $r'' = 40$ Mbps

since 16.67 Mbps > 14.47 Mbps

6. Packet detection and equalization
   (a) To detect what is the starting time of a packet.
   (b) Set the preamble as two replicative patterns, and calculate the correlation of data in two windows. When the correlation reaches a peak, meaning that the two patterns completely occupies the two windows, then it's the start of a packet.
   (c) Using the preamble to estimate the CSI.
   (d) $\frac{1}{3}(2.7 + 0.3i + 2 - 0.4i + 2.5 + 0.1i) = 2.4 + 0i$

   estimated channel = -2.4
   (e) $\frac{2.5 + 0.6i}{-2.4} = -1.04 - 0.25i$

$$\frac{-1.5-0.12i}{-2.4}=0.625+0.05i$$

$$\frac{2+0.8i}{-2.4}=-0.83-0.33i$$

(f)

demodulated signal :

$2.5+0.6i \rightarrow$ "0"

$-1.5-0.12i \rightarrow$ "1"

$2+0.8i \rightarrow$ "0"

decoding error :

$$\sqrt{(0.04)^2+(0.25)^2} \approx 0.25$$

$$\sqrt{(0.375)^2+(0.05)^2} \approx 0.38$$

$$\sqrt{(0.17)^2+(0.33)^2} \approx 0.37$$

average SNR

$$\frac{1}{\frac{1}{3}(0.25^2+0.38^2+0.37^2)}=\frac{1}{\frac{1}{3}(0.3438)} \doteqdot 8.726$$

(g) Channel coherence time is the time interval that the channel stays coherent and constant.

(h) Mobile, because the channel state is changing much more quickly in mobile scenario.