INSTITUTO SUPERIOR TÉCNICO

Mestrado em

Engenharia Electrotécnica e de Computadores

Redes Móveis e Sem Fios

Exame – 1ª parte

7 de Julho de 2021

Duração 1h30

In order to avoid grading mistakes, please answer each question <u>on a different page</u> and keeping the order as much as possible.

1) In a mobile network using CDMA, there are two mobile stations (A and B) trying to transmit to a common base station. Station A is transmitting the bit sequence "01" with spreading factor 4, using key -1, -1, +1, +1. Station B is transmitting simultaneously a single bit "1" with spreading factor 8. The chip rate is the same for both stations. **The used convention is to represent "0" as +1 and "1" as -1.** The decoding thresholds are +1 and -1, respectively for logical "0" and logical "1".

   a) Which of the following keys should be used by station B: +1, -1, +1, -1, -1, +1, -1, +1 or +1, +1, -1, -1, +1, +1, -1, -1? (1,5 val)

   b) Check if the data from station A is correctly received if station B is using the key -1, +1, +1, -1, -1, +1, +1, -1, the noise is +2, -1, 0, 0, +1, 0, 0, 0 and the signals are received with the same power. (1,5 val)

   c) Provide two advantages of pseudo-noise sequences over perfectly orthogonal codes in the context of DSSS. (2,0 val)

2) Consider a point-to-point UHF radio link operating in a 10 MHz wide channel centered at 1 GHz, with 8-PSK modulation. Each communication endpoint is equipped with a parabolic antenna with physical area $11 m^2$, mounted on a mast 5m high. The terrain is flat between the antennas. The noise power spectral density is -170 dBm/Hz. The transmit power is 500 mW. The receiver sensitivity is -77,85 dBm. The roll-off factor of the employed output filters is 0.

   a) Calculate the FER for 30-byte frames when the received power is equal to the receiver sensitivity. (1,5 val)

   b) Knowing that the effective aperture ($\boldsymbol{A_e}$) of a parabolic antenna is related to its face area ($\boldsymbol{A}$) as $\boldsymbol{A_e = 0.56A}$, calculate the maximum communication range (1,5 val)

   c) Draw the constellation diagram of the 8-PSK modulation. (1,0 val)

   d) What is the bandwidth efficiency attained by the system when using the 8-PSK modulation? (1,0 val)

3) Consider an IEEE 802.11a sensor network with one Access Point and micro cameras operating at 54.0 Mbps. Each camera generates video with an expected image size of 2000 bytes, and a frame rate of 25 images/s . The RTP+UDP+IP headers together have a length of 40 octets and RTS/CTS is not being used. Additional data are as follows: SIFS=10us, DIFS=20us, PHY overhead = 54us, MAC DATA header and trailer = 34 bytes, MAC ACK=14 bytes, avg. Backoff =100us, maximum MPDU payload size (fragmentation threshold) is 1500 bytes. The maximum number of frame retransmissions is 7.

   a) Calculate the total duration of the transaction of one image, including overheads, assuming that there are no frame losses. (2,0 val)

   b) What is the maximum number of micro cameras supported in the network? (1,0 val)

   c) What is the total video throughput of the ensemble of micro cameras calculated in b)? (1,0 val)

   d) Calculate the effective DATA frame loss rate at the MAC layer, considering that the physical frame loss rate is 3% and assuming that ACK frame losses are negligible. (1,0 val)

4) Consider the IPv4 network represented in the picture below, as well as the routing tables of each router and host.

a) What is the path followed by a packet transmitted by H1 towards H2? Justify. (2,0 val)

b) Traffic generated by a host destined to an address outside the subnet where it is attached must be transmitted through a router attached to the host's subnet. Which protocol allows a host to find routers in the subnet where it is located? (1,0 val)

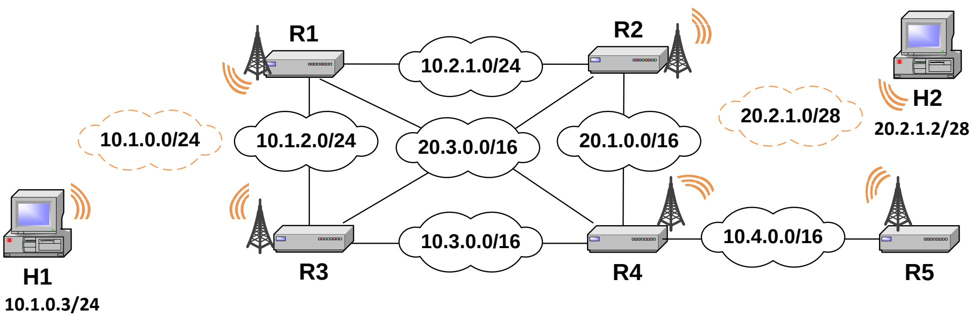
c) Explain the function of the ICMP redirect message. (1,0 val)

d) Explain how an IPv6 station can avoid bypass the DHCP to obtain a link-local IPv6 address. (1,0 val)

Destination	Next Hop
10.1.0.0/24	R3
10.1.2.0/24	direct
10.2.1.0/24	direct
10.3.1.0/24	R3
20.3.0.0/16	direct
30.1.1.0/28	R2
default	R4

Destination	Next Hop
10.1.0.0/24	R1
10.1.2.0/24	R1
10.2.1.0/24	direct
10.3.1.0/24	R4
20.1.0.0/16	direct
20.2.1.0/28	direct
20.2.0.0/16	R4

Destination	Next Hop
10.1.0.0/24	R2
10.1.2.0/24	R2
10.2.1.0/24	R2
10.3.1.0/24	R2
20.1.0.0/16	R2
20.2.1.0/28	direct
10.4.0.0/16	R5



Destination	Next Hop
10.1.0.0/24	direct
10.1.2.0/24	R3
10.2.1.0/24	R3
10.3.1.0/24	R3
20.2.1.0/24	R3
20.2.1.0/28	R1
default	R3

Destination	Next Hop
10.1.0.0/24	direct
10.1.2.0/24	direct
10.2.1.0/24	R4
10.3.1.0/24	direct
10.4.0.0/16	R4
20.2.0.0/22	R1
20.2.0.0/23	R4

Destination	Next Hop
10.1.0.0/24	R3
10.1.2.0/24	R3
10.2.1.0/24	R2
10.3.1.0/24	direct
20.1.0.0/16	direct
20.2.1.0/28	direct
default	R5

Destination	Next Hop
10.1.0.0/24	R4
10.1.2.0/24	R4
10.2.1.0/24	R2
10.3.0.0/16	R4
10.4.0.0/16	direct
20.2.1.0/28	direct

Propagation Models	
Antenna Apperture and Gain	$A_{eff} = \eta \cdot A_{phy} = \frac{\lambda^2}{4\pi} G$
Log-distance Model	$P_r\,[dBm] = P_t\,[dBm] - PL_0 + G_t\,[dBi] + G_r\,[dBi] - 10 \cdot \alpha \cdot \log_{10}(d/d_0)$
Friis Free Space Model	$P_r = P_t \cdot \frac{G_t \cdot G_r \cdot \lambda^2}{(4 \cdot \pi \cdot d)^2}$
Two-Ray Model	$P_r = P_t \cdot \frac{G_t \cdot G_r \cdot (h_t \cdot h_r)^2}{d^4}$ $d_c = \frac{4 \cdot \pi \cdot h_t \cdot h_r}{\lambda}$
Fresnel Zone Radius	$r(F_n) = \sqrt{\frac{n \cdot \lambda \cdot d_1 \cdot d_2}{d_1 + d_2}}$

Maximum Channel Capacity	
Shannon-Heartley Theorem	$C = B \cdot \log_2\left(1 + \frac{S}{N}\right)$
Nyquist Rate (applicable in baseband)	$C = 2 \cdot B \cdot \log_2(M)$

Modulation Performance (B)	
ASK	$B = (1 + r) \cdot R_b$
M-PSK	$B = \left(\frac{1 + r}{\log_2(M)}\right) \cdot R_b$
M-FSK	$B = \left(\frac{(1 + r) \cdot M}{\log_2(M)}\right) \cdot R_b$

Modulation Performance (BER)

BASK	$BER_{ASK} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$
BFSK	$BER_{BFSK} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$
DBPSK	$BER_{DBPSK} = 0.5 \cdot e^{-\frac{E_b}{N_0}}$
BPSK	$BER_{BPSK} = Q\left(\sqrt{\frac{2 \cdot E_b}{N_0}}\right)$
QPSK	$BER_{QPSK} = Q\left(\sqrt{\frac{2 \cdot E_b}{N_0}}\right)$

M-PSK	$BER_{MPSK} = 2Q\left(\sqrt{\frac{2 \cdot E_b}{N_0}} \cdot sin\left(\frac{\pi}{M}\right)\right)$
Q function	$Q(k) = P(X > \mu + k\sigma) = \frac{1}{\sqrt{2\pi}}\int_k^{+\infty} e^{-\lambda^2/2} d\lambda$

Probabilities
$\sum_{i=1}^{+\infty} i \cdot (1-p)^{i-1} \cdot p = \frac{1}{p}$
$\sum_{i=0}^{+\infty} i \cdot (1-p)^{i} \cdot p = \frac{p-1}{p}$

TABLE OF THE Q FUNCTION

0	5.000000e–01	2.4	8.197534e–03	4.8	7.933274e–07
0.1	4.601722e–01	2.5	6.209665e–03	4.9	4.791830e–07
0.2	4.207403e–01	2.6	4.661189e–03	5.0	2.866516e–07
0.3	3.820886e–01	2.7	3.466973e–03	5.1	1.698268e–07
0.4	3.445783e–01	2.8	2.555131e–03	5.2	9.964437e–06
0.5	3.085375e–01	2.9	1.865812e–03	5.3	5.790128e–08
0.6	2.742531e–01	3.0	1.349898e–03	5.4	3.332043e–08
0.7	2.419637e–01	3.1	9.676035e–04	5.5	1.898956e–08
0.8	2.118554e–01	3.2	6.871378e–04	5.6	1.071760e–08
0.9	1.840601e–01	3.3	4.834242e–04	5.7	5.990378e–09
1.0	1.586553e–01	3.4	3.369291e–04	5.8	3.315742e–09
1.1	1.356661e–01	3.5	2.326291e–04	5.9	1.817507e–09
1.2	1.150697e–01	3.6	1.591086e–04	6.0	9.865876e–10
1.3	9.680049e–02	3.7	1.077997e–04	6.1	5.303426e–10
1.4	8.075666e–02	3.8	7.234806e–05	6.2	2.823161e–10
1.5	6.680720e–02	3.9	4.809633e–05	6.3	1.488226e–10
1.6	5.479929e–02	4.0	3.167124e–05	6.4	7.768843e–11
1.7	4.456546e–02	4.1	2.065752e–05	6.5	4.016001e–11
1.8	3.593032e–02	4.2	1.334576e–05	6.6	2.055790e–11
1.9	2.871656e–02	4.3	8.539898e–06	6.7	1.042099e–11
2.0	2.275013e–02	4.4	5.412542e–06	6.8	5.230951e–12
2.1	1.786442e–02	4.5	3.397673e–06	6.9	2.600125e–12
2.2	1.390345e–02	4.6	2.112456e–06	7.0	1.279813e–12
2.3	1.072411e–02	4.7	1.300809e–06		