KTH Technology and Health

Written exam

May 29th 2013

Wireless networks

(EP2950, HI2001)

Help material: pocket calculator and four handwritten A-4 pages.
Maximum points: 50p. The preliminary limit for passing the course is 24p.

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1. A Bluetooth device transmitting power and its distance to the receiver are unknown. The fading margin is 15dB and the antenna gain is 1dB for the transmitter and also for the receiver. The receiver sensitivity is -80dBm and the link budget is 71dB. Determine the maximum distance (line of sight) between the transmitter and the receiver and the transmitting power in Watt. (5p)
   Ans: The link budget: $L_s[dB]=P_t-(-80)-15+1+1=71dB$. $P_t=4dBm=10^{0.4}=2.5mW$
   Free space loss, $L_s[dB]=-32.4-20\times lgd_{km}-20\times lgf_{MHz}$ used frequency in BT is 2.4GHz=2400MHz.
   $32.44+20\times lgd_{km}+67.6=71$; $20\times lgd_{km}= -29$
   $d=0.0355km\approx 35.5m$. The largest distance is approximately 35m.

2. Seven Walsh codes are used in a CDMA system. See below. (6p)
   a) Channel 2 transmits the data bit sequence 101 at exactly the same time as channel 3 transmits 111. Determine the combined output chip sequence from the two channels.
   b) Show what happens when channel 4 decodes that signal.

   Channel 1: 0101 0101
   Channel 2: 0011 0011
   Channel 3: 0110 0110
   Channel 4: 0000 1111
   Channel 5: 0101 1010
   Channel 6: 0011 1100
   Channel 7: 0110 1001

   Ans: The chip sequence from channel 2 will be:
   a) 0011 0011 1100 1100 0011 0011
   or if you change 0 into -1: -1-1 1 1 -1-1 1 1 1 1-1-1 1 1-1-1 -1-1 1 1 -1-1 1 1.
   The chip sequence from channel 3 will be:
   0110 0110 0110 0110 0110 0110 or -1 1 1-1 -1 1 1-1 -1 1 1-1 -1 1 1-1 -1 1 1-1 -1 1 1-1.
   Add them and you will get the output: -2 0 2 0 -2 0 2 0 0 2 0 -2 0 2 0 -2 -2 0 2 0 -2 0 2 0.
   b) Change 0 to -1 for the code from channel 4 and multiply. (-2 0 2 0 -2 0 2 0 0 2 0 -2 0 2 0 -2 -2 0 2 0 -2 0 2 0) x (-1-1-1-1 1 1 1 1 -1-1-1-1 1 1 1 1 -1-1-1-1 1 1 1 1) = 2 0 -2 0 -2 0 2 0 0 -2 0 2 0 2 0 -2 2 0 -2 0 -2 0 2 0 = 0.

3. Is the Hamming code (14,11) able to correct a single bit error and capable of detecting an additional bit error as well? An answer without motivation is not accepted. (3p)
   Ans: $2^{n-k}-1=2^3-1=7<14$ means that the code is not able to correct bit errors in all positions of the codeword and not detect additional bit errors.

4. The reuse factor in a cellular network is N=3. The total number of frequencies is 27 and the number of channels (timeslots) per frequency is 8. The cell radius R=2km. (6p)
   a) How many frequencies and channels are available in each cell?
   b) What is the minimum distance between the centres of two cells with the same frequencies?
   c) How large is the total service area if the operator can offer in total 864 channels in the service area? Let the cell area $A_c=(3R^2\sqrt{3})/2\approx 10\text{km}^2$.
   Ans: a) 9 frequencies and 72 channels per cell. b) The distance is 3R which is 6km. c) Three cells provide in total 27×8=216 channels. This pattern needs to be repeated 4 times (864/216), which means in total 4×3=12 cells. The total service area is 120km^2.

5. Ethernet uses a CRC-32 polynomial ($x^{32}+\ldots+1$) and a 32-bit trailer in the frame. Why are 32 bits sent in the trailer and not 33 bits? The explanation is not that one of the terms in the polynomial is excluded. (2p)
   Ans: The remainder of the mod2 division is sent in the trailer. The remainder is 32 bits long, one bit less than the polynomial.

6. Multiplexing (8p)
   a) Some wireless systems apply time division duplex whereas others use frequency division duplex. Classify GSM and Bluetooth in those terms and motivate your answer.
   b) What is more specifically meant by time division multiplexing in the GSM system?
   c) Explain how 3G systems multiplex several users sharing the same wireless channel.
   d) How is the wireless channel in wireless Ethernet shared among several users?
   Ans: a) GSM applies FDD (different frequencies uplink and downlink). Bluetooth has not reserved specific frequencies for uplink and downlink communication, but uses an odd timeslot from master to slave and an even timeslot from slave to master. b) GSM uses timeslots to multiplex several users of the same frequency channel c) 3G uses code division multiplexing (CDMA) d) IEEE 802.11 uses CSMA/CA

7. Code division multiple access is a multiplexing technique that uses direct sequence spread spectrum. In a CDMA system, the receivers identify the bit sequences sent to it by using orthogonal codes. Bluetooth is based on frequency hopping spread spectrum. Some WLAN systems apply direct sequence spread spectrum as well. (6p)
   a) How can a Bluetooth slave verify that it is the correct receiver of a packet?
   b) How can a Bluetooth master verify that it is the correct receiver of a packet?
   c) How can a station in a wireless local area network (e.g. IEEE 802.11g) verify that it is the correct receiver of a frame?
   Ans: a) and b) The access code CAC, based on the master's BD_ADDR, is unique for a piconet. The master polls a specific slave and expects a response in the next timeslot. The slave's LT_ADDR (formerly AM_ADDR) is used in the header for the frames between the master and the slave. c) The MAC address is used to identify the destination station.

8. A GSM speech encoder output is 32.5 byte every 0.02 second. The transmitted data bits consist of Class A, Class B and Class C data bits plus overhead from CRC and convolutional encoding. Class A consists of 50 data bits, Class B of 132 data bits and Class C of 78 data bits. Class A data bits are protected by 3 CRC bits. Those 53

bits plus the 132 Class B data bits are protected by convolutional encoding (4 tail bits are added). Class C data bits are sent unprotected. The total data rate for the transmitted bits is 22.8kbps. The bits are sent in four frames, where each frame consists of two 57-bit bursts, a training sequence, stealing bits and trail bits. (8p)

a) Determine the convolutional code rate.
b) Determine the bit rate of the CRC overhead and the bit rate of the convolutional overhead including tail bits).
c) What is the purpose of the tail bits?
d) Determine *n*, *k*, *K* in the convolutional code notation (*n*,*k*,*K*) used in this case.

Ans: a) 22.8kbps means 456 bits per 20ms. 456-50-3-132-4-78=189 extra bits for convolutional encoding. Data bits that are protected by convolutional encoding: 50+3+132+4=189 bits, which mean ½ coding rate. b) The overhead data rate for convolutional encoding is (189+4)/20ms=9.65kbps. CRC bit rate is 3/20ms=150b/s. In total: 13+9.65+0.15=22.8kbps. c) 4 tail bits means 4 memory cells are set to zero. d) 1 input bit and 2 output bits. 4 memory cells means 16 states – (n,k,K)=(2,1,16).

9. A WLAN is configured to support distributed coordination functions. A station attempts to send a data frame. It finds the medium busy for a period of 200µs but idle thereafter. After a time period the station transmits the frame and receives an acknowledgement. Draw a timeline and specify the total waiting time and its components from the first transmission attempt by the sending station until the acknowledgement is received. Make proper assumptions if needed. (6p)

Facts:

SIFS=10µs, DIFS=50µs, PIFS=30µs, slot time=20µs, CWmin=15, CWmax=1023. Data frame size: 100 byte. Acknowledgement frame size: 10 byte. Transmission speed: 5Mbps. The previous frame was acknowledged.

Ans:

The station waits a DIFS time period, 50µs, before the first attempt, waits until the busy period is over, waits a DIFS time period, waits during the contention window, waits a DIFS period, and transmits the data frame. The receiver waits a SIFS period and transmits the ack. Frame.

Let the random number drawn from the interval [0,15] be 10. The contention window will then be 10 slot times, i.e. 200µs. Data frame transmission time is 800/5M=160µs. Ack. frame transmission time is 80/5M=16µs. The total waiting time: 50(DIFS)+200(busy period)+50(DIFS)+200(Contention window)+160(frame trans.)+10(SIFS)+16(ack. Trans.)=686µs.