KTH Technology and Health

Written exam January 16th 2014

Wireless networks (EP2950, HI2001)

Help material: pocket calculator and four handwritten A4 pages (two sheets).
Maximum points: 50p. The preliminary limit for passing the course is 25p with grade E to A in steps of approximately 5p.

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1. A radio communication system has transmission power P_t=18mW and the received power at the receiver side is P_r= -134dBW. The distance between teller and receiver is 30km (line-of-sight). The frequency band is centred around 1.9GHz. The transmitting antenna gain is G_t=4dBi. Calculate the receiving antenna gain G_r. (4p)
   Ans: P_r =-134dBW. P_t=18mW is -17.45dBW. L_s=20lg1900MHz+20lg30km+32.44=127.56dB. $P_t+G_t-L_s+G_r=P_r$ which gives $G_r= P_r-P_t+L_s-G_t$=-134-(-17.45)+127.56-4=7dBi.

2. Create eight Walsh codes where each code is eight bits long. Use the starting matrix W_1={0} Show that the codes are orthogonal. (4p)
   Ans: See Fig. 7.17d in Stallings.

3. Orthogonal variable spreading codes are used in W-CDMA networks. Which spreading factors result in 480kbps and 960kbps? (2p)
   Ans: The chip rate is 3.84Mchip/s. SF=4 gives 960kbps and SF=8 gives 480kbps.

4. The number of bits in the spreading code is *k*=4 for two different spread spectrum wireless systems; a frequency hopping system and a direct sequence system. Calculate the processing gain G_p for each of those systems. (2p)
   Ans: Frequency hopping: the processing gain $G_p=2^4$=16. Direct sequence: G_p=4.

5. A seven-bit PN spreading code A={1001011} is transmitted continuously {…100101110010111001011…} in a mobile network. A receiver can use spreading code A or B={0101110} to de-spread the received codes. For definitions of cross correlation and auto correlation see Appendix 1. (4p)
   a) Calculate the cross correlation between code A and code B for τ=0.
   b) Calculate the cross correlation between A and B for τ=1 and τ=2.
   c) Calculate the auto correlation of code A for τ=0 and τ=1.

   Ans: a) The cross correlation $R_{A,B}(0)$= -1/7. b) The cross correlation is $R_{A,B}(1)$=-1/7 and $R_{A,B}(2)$=7/7=1. c) The auto correlation $R_{A,A}(0)$=7/7=1 and $R_{A,A}(1)$=-1/7.

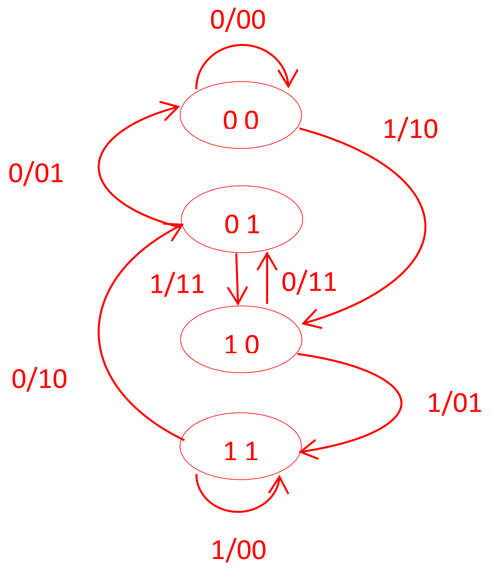
6. Are these sentences true or false? Wrong answer gives one minus point, but in total not below zero point for the entire problem. (4p)
   a) Maximum-length sequences (m-sequences) are orthogonal and have low cross correlation.
   b) Walsh codes are pairwise orthogonal and the cross correlations for τ=0 are zero.
   c) Delay-shifted Walsh codes are orthogonal and their cross correlations are low.

d) Orthogonal codes may be used to distinguish between users in the same cell in mobile networks and pseudo-noise codes may be used to achieve low cross correlation between users in different cells.

Ans: f, s, f, s.

7. Convolutional encoding (n, k, K) = (2, 1, 3) is applied by a mobile system. The starting values in the two memory cells (K-1) are (0, 0). The following sequence of input/output is registered: 1/10, 1/01, 0/10, 0/01. The XOR logic for each of the two output bits is based on *two* of the K elements. (6p)
   a) Determine the XOR logic for each of the output bits.
   b) Determine the complete state diagram.

Ans: a) Output bit 1 υ_{n1}: XOR between the input bit and memory cell 1, $\upsilon_{n1} = u_n + u_{n-1}$. Output bit 2 υ_{n2}: XOR between memory cell 1 and 2, $\upsilon_{n2} = u_{n-1} + u_{n-2}$. b) See below.



8. A cyclic code with four data bits and three bits of frame check sequence for error detection as well as correction uses the generator polynomial $P=x^3+x+1$. The data block is {1010}. (4p)
   a) Determine the codeword.
   b) Assume that the received codeword has a single-bit error in the bit position marked in bold and red text {10**0**0}. Calculate the syndrome word that will be generated on the receiver side. Answer without calculation and motivation is not accepted.

Ans: a) Modulo 2 division between 1011 and 1010000 gives the codeword 1010011. b) The syndrome word is 110 (modulo 2 division between 1011 and 1010011, or modulo 2 division between 1011 and 0010000), which is bit position 5.

9. Consider a cellular network with 32 cells. The entire system has a capacity of 336 channels. The cell radius is 1.6km. How many channels will be available per cell and also in the entire system if the reuse factor N=4 is applied? (4p)

Ans: Number of channels per cell=336/4=84. The total number of channels in the system is 84·32=2688.

10. Describe shortly the near-far problem in W-CDMA networks and suggest a possible solution. (4p)

Ans: See Stallings p.299.

11. A mobile network has 20 channels. The total offered traffic is approximately 13.2 erlang measured during a busy period.
    a) Explain and interpret this in terms of busy and idle channels.
    b) Calculate the amount of traffic that the system will block. See Appendix 2. (4p)

    Ans: a) On average around 13 of the channels will be busy. Twenty servers are needed to have a blocking probability of 0.02. b) The amount of traffic that will be blocked is $0.02 \cdot 13.2 = 0.262$ erlang.

12. A station in a local wireless network (IEEE 802.11) has sent a frame but not received an acknowledgement. When trying to retransmit the station finds the channel busy. It waits until the channel is idle, then waits a DCF inter-frame spacing and retransmits after an exponential back-off time. The timeslot is 20µs and the DIFS is 50µs in this WLAN. The minimum contention window (CW) is 16. Make necessary assumptions and calculate the total time from the time the channel became idle until the frame is retransmitted. (4p)

    Ans: Assume that the contention window CW=[0, …, 15] from the beginning. After the missing acknowledge CW=[0, …, 31]. Let the second waiting time be t=20 (randomly chosen between 0 and 31 timeslots). The total time will be: $50 + 20 \cdot 20 = 450$µs=0.45ms.

13. In Bluetooth the size of the timeslot is 625 microseconds. Calculate and explain how many slaves using SCO channels and HV2 packets for voice data that a master can serve simultaneously. Explain each step in the solution. See Appendix 3. (4p)

    Ans: The system access is performed by the master polling the slaves. Every contact between master and slave takes two timeslots, master to slave and slave to master. A HV2 packet of 30 bytes, where 20 bytes (160 bits) are voice samples, is sent in the timeslot from the master to the slave and correspondingly from the slave to the master in the following timeslot. The bit rate for voice is 64kbps. To obtain 64kbps the master needs to transmit in every second timeslot, i.e. only one slave may use HV1 packets. Let N be the number of channels (with two time slots per channel) needed, then $N \cdot 625$µs$\cdot 64$kbps=160bits, which gives N=4, which means that maximum two slaves SCO channels can be served for HV2 packets.

Appendix 1

The cross correlation is defined by $R_{A,B}(\tau) = \frac{1}{N}\sum_{k=1}^{N} A_k B_{k-\tau}$, where A and B are the sequences, N is the sequence length and τ is the lag (phase shift). In auto correlation A=B.

Appendix 2

	Capacity (erlangs) for grade of service of:				
Number of servers (N)	P = 0.02 (1/50)	P = 0.01 (1/100)	P = 0.005 (1/200)	P = 0.002 (1/500)	P = 0.001 (1/1000)
1	0.02	0.01	0.005	0.002	0.001
4	1.09	0.87	0.7	0.53	0.43
5	1.66	1.36	1.13	0.9	0.76
10	5.08	4.46	3.96	3.43	3.09
20	13.19	12.03	11.10	10.07	9.41
24	16.64	15.27	14.21	13.01	12.24
40	31.0	29.0	27.3	25.7	24.5
70	59.13	56.1	53.7	51.0	49.2
100	87.97	84.1	80.9	77.4	75.2

Appendix 3

Table 15.5 Bluetooth Packet Types

Type Code	Physical Link	Name	Number of Slots	Description
0000	Common	NULL	1	Has no payload. Used to return link information to the source regarding the success of the previous transmission (ARQN), or the status of the RX buffer (FLOW). Not acknowledged.
0001	Common	POLL	1	Has no payload. Used by master to poll a slave. Acknowledged.
0010	Common	FHS	1	Special control packet for revealing device address and the clock of the sender. Used in page master response, inquiry response, and frequency hop synchronization. 2/3 FEC encoded.
0011	Common	DM1	1	Supports control messages and can also carry user data. 16-bit CRC. 2/3 FEC encoded.
0101	SCO	HV1	1	Carries 10 information bytes; typically used for 64-kbps voice. 1/3 FEC encoded.
0110	SCO	HV2	1	Carries 20 information bytes; typically used for 64-kbps voice. 2/3 FEC encoded.
0111	SCO	HV3	1	Carries 30 information bytes; typically used for 64-kbps voice. Not FEC encoded.
1000	SCO	DV	1	Combined data (150 bits) and voice (50 bits) packet. Data field 2/3 FEC encoded.
0100	ACL	DH1	1	Carries 28 information bytes plus 16-bit CRC. Not FEC encoded. Typically used for high-speed data.
1001	ACL	AUX1	1	Carries 30 information bytes with no CRC or FEC. Typically used for high-speed data.
1010	ACL	DM3	3	Carries 123 information bytes plus 16-bit CRC. 2/3 FEC encoded.
1011	ACL	DH3	3	Carries 185 information bytes plus 16-bit CRC. Not FEC encoded.
1110	ACL	DM5	5	Carries 226 information bytes plus 16-bit CRC. 2/3 FEC encoded.
1111	ACL	DH5	5	Carries 341 information bytes plus 16-bit CRC. Not FEC encoded.