TCOM 370

May 8, 1997 Final Exam 1:30 - 3:30

Closed Book 3 Summary Sheets Allowed

Problem 1 (9)

The fastest standard for transmitting data over standard telephone lines allows transmission from an internet service provider to a user's modem at 56 Kbps. Assume that the telephone connection provides a usable bandwidth of 3.5 KHz. What is the minimum signal-to-noise ratio in dB required to support this?

Problem 2 (12)

Consider baseband data transmission at a signaling rate of 4000 pulses per second, where each pulse has one of three allowed amplitude levels.

(a) What is the minimum bandwidth required for no intersymbol interference so that pulse amplitudes can be recovered perfectly in the absence of noise?

(b) What is the number of binary digits that can be encoded onto each individual pulse?

(c) Suppose we consider carrying blocks of K message bits on groups of L pulses at a time. If L=2, how large can K be? What is the number of bits per pulse in this case (L=2)? Is this number close to the best that can be done with three-level pulses?

(d) In practice, what determines the spacing d between the three amplitude levels? Given a certain spacing d, what should the actual amplitudes be to minimize average transmitted signal power? (Power is proportional to the square of amplitude; assume each amplitude level is equally likely)

Problem 3 (12)

Consider a standard telephone-quality PCM scheme for voice digitization at 64 Kbps. An engineer determines that for a certain type of speech the entropy of each quantized sample is 6 bits/sample, and that adjacent samples are statistically dependent.

(a) Is it possible to do a lossless compression after the PCM encoding that results in a bit rate of 50 Kbps for the speech? Explain your answer clearly, and if it is possible, explain what you would need to do to achieve this.

(b) Explain briefly one practical technique to decrease the bit rate to significantly below 64 Kbps without suffering major quality degradation compared to standard PCM speech.

Problem 4 (12)

For synchronous transmission of bits, the Manchester and the B8ZS line codes are useful

(a) State briefly the basic ideas of the clock synchronization schemes used in conjunction with these two codes.

(b) Give one application where the Manchester code is used, and explain why it is appropriate and why the B8ZS code would not be appropriate in this application.

(c) Give one application where the B8ZS code is used, and explain why the Manchester code would not be a reasonable choice in this application.

Problem 5 (15)

(a) 8-bit data words are protected by a single parity check bit.
What is the minimum distance d_{min} for this block code?

(b) Another code for 8-bit data words uses one parity bit (bit 9) for the first 4 bits and a second parity bit (bit 10) for the next 4 bits of the data word.
What is the rate of this code, what is d_{min}, how many errors is it guaranteed to detect?

(c) Suppose that two errors occur in the transmission of a codeword.
What is the probability that the code of part (a) will detect the errors?
What is the probability that the code of part (b) will detect the errors?
(Each transmitted bit is subject to error with a probability of 10^{-4}, independently of other bits)

Problem 6 (20)

A large number of PCs on a factory floor are networked using a variant of slotted ALOHA. A wireless relay station (on the ceiling) broadcasts to all the PCs on one "downlink" channel, whereas there are two separate "uplink" frequency bands (channels) available. Each channel allows a transmission rate of 2 Mbps. The transmission slots are synchronized to have the same slot boundaries on the uplink channel pair, and the slot duration is the same as the fixed-length packet duration. When a PC has a packet to send it randomly selects one of the two uplink channels (each equally likely) and puts its packet in the next slot on the selected channel. If the relay station sees a collision-free packet in only one of a pair of uplink slots, it can relay it on the downlink channel. If it sees collision-free packets on both uplink slots simultaneously, not having any buffer, it picks one of the two packets at random and relays it down; the other packet is discarded. If it sees collisions or empty slots only, it does nothing.

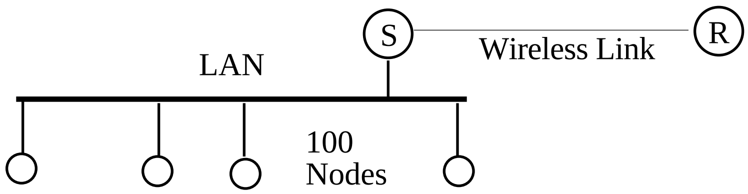
(a) If only one uplink channel is available and all the PCs use that channel, what is the maximum throughput, i.e. the maximum effective transmission rate on the downlink? What fraction of the uplink slots on the channel are empty, and what fraction contain collisions in this situation?

(b) Would your answer to part (a) change if the PCs did not know that one of the uplink receivers at the relay station was dead?

(c) When both uplink channels are available, what is the maximum throughput that can be obtained in this system?

Problem 7 (20)

A 10 Mbps CSMA/CD (IEEE 802.3) LAN has 100 nodes on a cable of length 2250 m on which the propagation speed is 2.25×10^8 m/s. One other node on the LAN is a special node ("S") that functions as one end of a point-to-point wireless link between it and a remote node ("R"). On the wireless link the transmission rate is 10 Mbps in both directions (full-duplex), the propagation speed is 3×10^8 m/s and the probability of frame error is p=0.1 regardless of the length of the link.



The 100 nodes each produce packets of length 1000 bits which are addressed to S on the LAN and destined for the remote node R, and the LAN is heavily loaded.

(a) How many packets per second, on the average, does S get from the nodes on the LAN?

(b) Suppose that R is 15 Km from S and that Idle RQ is used on the wireless link. Assume that ACK/NACK frames are 500 bits long. Determine if the LAN or the wireless link is the bottleneck for packet transmission between the nodes and R.

(c) Suppose Go-Back-N ARQ is used on the wireless link with a transmit window size of K=3 and ACK/NACK frames of negligible length. How far apart can S and R be without making the wirless link the bottleneck for transmission between the LAN nodes and R ?

(d) If R also had frames to send to nodes on the LAN, would your answer to (c) change?

[Given: For Go-Back-N with transmit window size K, frame error probability P_f, and considering *only* propagation delay T_p and I-frame duration T_{ix}, the utilization factor is

$$U_{\text{with error}} = U_{\text{no error}} \frac{1-P_f}{1-P_f + \min\{(1+2a),K\} P_f} \qquad \text{where } a=\frac{T_p}{T_{ix}}$$]