Data Communication Networks

Homework 1: Physical Layer

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Question 1 (25 pts)

In this problem the transmission time of a message over a $\boldsymbol{K}$-hop path in the case of circuit-switching is compared with the case of packet-switching. Suppose the whole message consists $\boldsymbol{L}$ bits. The line rate on each hop is $\boldsymbol{R}$ bps. If we use packet switching, the queuing delay of each hop is $\boldsymbol{\delta}$. The packet size and header size are $\boldsymbol{P}$ and $\boldsymbol{H}$ bits, respectively ($\boldsymbol{L} \gg \boldsymbol{P}+\boldsymbol{H}$).

(a) Assume the circuit setup time is $\boldsymbol{S}$ sec and the propagation delay is $\boldsymbol{D}$ sec per hop. Find the total transmission time of the message in both a circuit-switched network and a packet-switched network. Under what conditions does the packet network have a lower transmission time?

(b) For $\boldsymbol{L}$ = 100 bits, $\boldsymbol{H}$ = 8 bits, $\boldsymbol{R}$ = 56 Kbps, $\boldsymbol{D}$ = 1.5 ms, $\boldsymbol{\delta}$ = 0.4 ms and $\boldsymbol{K}$ = 3 hops in packet-switching mode, calculate the minimum possible transmission time.

Question 2 (20 pts)

One way of generating orthogonal chip sequences of length 2^{k} is employing Walsh matrix of dimension $2^{k}\times2^{k}$. Walsh matrix of dimension $2^{k}\times2^{k}$, $\boldsymbol{W_k}$ can be derived from the Walsh matrix of dimension $2^{k-1}\times2^{k-1}$, $\boldsymbol{W_{k-1}}$ as follows :

$$\mathrm{W_k}=\begin{bmatrix} W_{\text{k-1}} & W_{\text{k-1}} \\ W_{\text{k-1}} & -W_{\text{k-1}} \end{bmatrix}$$

For k = 1, we have $\boldsymbol{W_1}=\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$

(a) By induction show that the columns of $\boldsymbol{W_k}$ for each $\boldsymbol{k}$ construct a set of orthogonal chip sequences.

(b) Using the Walsh method with $\boldsymbol{W_1}=\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$ directly write down 8 valid CDMA chip sequences each of length 8.

(c) Applying the idea of Walsh matrix, can you find another set of 8 CDMA chip sequences of length 8, different from what you found in part (b)?

(d) Now suppose the chip sequences in part b) are utilized by 8 users. If two of the users, U_1 and U_2 use columns 2 and 3 of $\boldsymbol{W_3}$ to transmit bits 0 and 1 respectively, and others send nothing, what is the aggregate resulting sequences on the channel? Also write the detection calculations for extracting the information sent by each user.

Question 3 (15 pts)

We have two computers connected by a long cable for which the ***transmission loss*** is 2 $\frac{dB}{km}$. A packet is to be transmitted from the first computer to the second one. The second computer will return that packet as soon as it is received. The ***RTT*** (Round Trip Time) is 750 μs and there are no processing delays. Assume that we put $\boldsymbol{m}$ identical amplifiers, each with a gain of 10dB, between computers.
The available ***low-pass bandwidth*** is 200 kHz and the ***PSD*** (Power Spectral Density) of white Gaussian noise is $\frac{N_0}{2}$=2×10^{-21} $\frac{W}{Hz}$. Assume the propagation speed on the cable is 2×10^{8}ms.

(a) If we assume that the transmitted power is 100 mW and let the minimum acceptable ***SNR*** at the receiver to be 30 dB, what is the minimum value for $\boldsymbol{m}$?

(b) Using the calculated $\boldsymbol{m}$ what is the ***maximum rate*** of sending information over this cable?

Question 4 (25 pts)

For creating a cellular network to provide call service to subscribers, we divide the area into identical square cells. We have 840 separate frequency bands and each frequency band can transmit one T1 carrier. Using the same frequency bands is prohibited in adjacent cells with a common edge or vertex.
(a) What is the maximum number of analog channels served by one cell?
Now, we want to estimate the quality of signal in our network in part (a). When the signal is propagated in the air, the intensity of the received signal decreases as the distance between transmitter and receiver increases. Let the collected power at receiver, $\boldsymbol{P_r}$ to be equal to $\frac{k\boldsymbol{P_t}}{d^{\nu}}$, where $\boldsymbol{P_t}$ is the transmission power of the source, $\boldsymbol{d}$ is the distance between source and receiver and $\boldsymbol{k}$ and ν are two constant values. Assume a subscriber is being served in some cell. $\boldsymbol{S}$ is defined as the power received by the subscriber, transmitted from the BTS in the center of the subscriber's cell. $\boldsymbol{I}$ is defined as the power received by the subscriber, transmitted by the 8 nearest co-channel[1] cells of the subscriber's cell. $\frac{S}{I}$ is called the signal to interference ratio[2] and is an indicator of the signal quality in the system. Suppose all BTS's transmit at same power $\boldsymbol{P_t}$.
(b) For each of the following cases calculate $\frac{S}{I}$ in dBs. Let the size of the square's edge to be $\boldsymbol{d}$ and $\boldsymbol{v}$=4.

- The subscriber is on a vertex of the square.
- The subscriber is on the middle of one of the square's edges.

(c) Which one of the values from the previous part was larger? Do you have any intuition about this result? Using one of the results from part (b) give an estimate of the worst $\frac{S}{I}$ that a user may experience in this system. Corresponding value when using hexagonal cells is roughly 18dB. Which geometry is better in terms of worst experienced $\frac{S}{I}$, hexagonal cells or square cells?

[1] Co-channel cells of a cell C_0, are the cells which use the same frequency bands with C_0.
[2] For calculating the actual signal to interference ratio, we need to consider the interference effect of all co-channel cells, not just the nearest ones. The $\frac{S}{I}$ discussed in the problem is actually an approximation of the signal to interference ratio.

Question 5 (15 pts)

In a bitstream consider that the probability of having a 0 is four times having a 1.

(a) Compare the power of bitstreams encoded with (i) Manchester encoding, (ii) NRZ (with 0 amplitude for 0), (iii) NRZI (with 0 amplitude for 0) and, (iv) AMI (Alternate Mark Inversion, also called Bipolar encoding.).
(b) For each one of the aforementioned encodings, identify whether it can have problems regarding clock synchronization with:

1. Long strings of consecutive 0s
2. Long strings of consecutive 1s

Bonus Question (10 pts)

Choose "True" or "False" for each of the following statements or questions. Provide sufficient conclusions and calculations.

(a) By making some changes to (***k***)th-layer services, the (***k+1***)th-layer protocols should be reconfigured. But there is no need to change the (***k-1***)th-layer protocols.

(b) By using a voice-band modem, we are connected to an ISP which has a digital connection to PSTN. Is it true that we can download a file with a limited rate of 33.6 kbps because of quantization noise?

(c) During a 600km ***distance*** telecommunication operation, we need a maximum ***RTD*** (Round Trip Delay) of 10ms. The maximum acceptable delay caused by aggregate of processing, switching and queuing can be 8 ms.

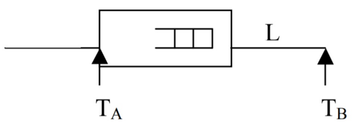
(d) When we are transmitting a 6MB file across a 1Gbps network with a round trip time of 200msec, the ***throughput*** is 193.55Mbps. In the case of ignoring ACKs, the throughput increases to 324.32Mbps.

(e) We can have a maximum of 30GHz of ***bandwidth*** in 0.1 micron of spectrum at a ***wavelength*** of 1micron.

(f) We sent 5 packets of data one after another through the channel below. The box in the figure depicts a routing device and when sending the first packet, the queue in the routing device is completely vacant. The passing times, T_B-T_A of these 5 packets were recorded, but when saving the values, their order was lost. The values are as follows:

$$\{10 \text{ ms}, 2.8 \text{ ms}, 2.4 \text{ ms}, 4 \text{ ms}, 5.5 \text{ ms}\}$$

Is it true that the ***average queuing delay*** is 2.54 ms?



(g) By increasing the number of a bridge tap wiring's terminals, the number of ripples in the magnitude of the channel's frequency response increases.

What SHOULD I prepare?

You must upload a pdf file containing your homework answers ("*YourName_StudentNumber*.pdf") for this assignment.