Data Communication Networks
HW 1: Physical Layer

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Problem 1

(a) Circuit Switching (CS) mode:
The transmission starts at t_{setup} seconds and after $\frac{M}{R}$ seconds, all bits are sent. After Kt_{prop} seconds of this time, all bits are received at the receiver.

$$Delay = t_{setup} + \frac{M}{R} + Kt_{prop}$$

Packet Switching (PS) mode:
The number of packets is $\frac{M}{P}$. H header will be added to each packet, and the sum of bits will be $x = \frac{M}{P} \times (H + P)$. In this case, the placement time of the last packet on the channel is in $\frac{x}{R}$ seconds. In order to calculate the time of receiving all packets, we calculate the time of receiving the last packet. The last packet must pass through the intermediate $K - 1$ router, in which case another $(K - 1) \times (\frac{P+H}{R} + t_{queue})$ seconds will be added to the packet's travel time (Here we should consider the queuing delay).

$$Delay = \frac{M \times (H + P)}{PR} + (K - 1) \times (\frac{P + H}{R} + t_{queue}) + Kt_{prop}$$

(b) We must derive the delay of the previous part relative to the size of the packets:

$$\frac{d(Delay_{PS})}{dP} = 0 \rightarrow P = \sqrt{\frac{MH}{K - 1}} = 20bits \rightarrow min(Delay_{PS}) = 8.8ms$$

Problem 2

(a)

$$d_{prop} = \frac{20K \times 1K}{250M} = 0.08s \rightarrow R \times d_{prop} = 2 \times 1K \times 1K \times 0.08 = 160K$$

(b) The bandwidth delay product is the maximum number of bits that can be in the link and 160000 bits $<$ 800000 bits, thus the maximum number of bits in the link at any a given time is 160000 bits.

(c) see (b)

(d) Width of a bit:

$$\frac{m}{R \times d_{prop}} = \frac{m}{R \times \frac{m}{s}} = \frac{s}{R}$$

Problem 3

First, we find the smallest amount of time that the calculated time for the first packet was sent.

$$min(T_B - T_A) = 2.4ms$$

$$avg_{delay} = \frac{(10-2.4)+(2.8-2.4)+(2.4-2.4)+(3-2.4)+(4-2.4)+(5.5-2.4)}{6} = 2.22ms$$

Problem 4

For any x simultaneously supported users/channels, there will be $(x-1)$ required guard channels.

$$2500 = x * 60 + (x-1) * 30 \rightarrow x = 28.11 \rightarrow x = 28$$

Problem 5

We can calculate the capacity of the channel.

$$C = 200 * 1000 * (1 + 10000) = 2.658Mbps$$

According to the slide, the required bit rate for E1, T2, T1 and E2 signals is 1.544, 6.312, 2.048 and 34.368 Mbits per second respectively, only T1 and E1 signals can be sent through this channel.

Problem 6

The inner product of E with all the chip sequences should be zero. So the final answer is not unique.
One possible solution:

$$E = (+1 \quad -1 \quad -1 \quad +1 \quad -1 \quad +1 \quad +1 \quad -1)$$

Hence,

$$A + E + \overline{C} = (+1 \quad -3 \quad -1 \quad +1 \quad -1 \quad -1 \quad +3 \quad +1)$$

Problem 7

$$P_0 = \frac{5}{6}, \quad P_1 = \frac{1}{6}$$

$$P = P_0 \times Power(0) + P_1 \times Power(1)$$

Manchester: For both bits we have changing between 0 level and A level and their power are equal. Hence,

$$Power(0) = Power(1) = \frac{0^2 + A^2}{2} = \frac{A^2}{2}$$

$$P = P_0 \times Power(0) + P_1 \times Power(1) = \frac{A^2}{2}$$

NRZ: for bits 0 and 1 we assign 0 and A signals respectively. Hence,

$$Power(0) = 0, \quad Power(1) = A^2$$

$$P = P_0 \times Power(0) + P_1 \times Power(1) = \frac{A^2}{6}$$

NRZI: for bit 1, the level of the signal will be changed(from 0 to A and from A to 0) and for bit 0 the level of the signal won't change. Hence,

$$Power(0) = Power(1) = \frac{0^2 + A^2}{2} = \frac{A^2}{2}$$

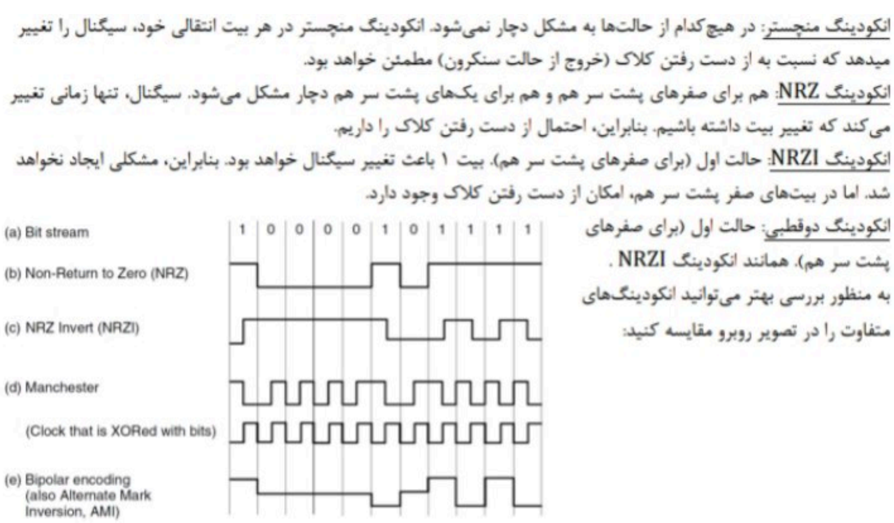
$$P = P_0 \times Power(0) + P_1 \times Power(1) = \frac{A^2}{2}$$

AMI: for bit 1 we have +1 or -1 and for bit 0 we have 0. Hence,

$$Power(0) = 0, \;\; Power(1) = A^2$$

$$P = P_0 \times Power(0) + P_1 \times Power(1) = \frac{A^2}{6}$$

(b)



انکودینگ منچستر: در هیچ‌کدام از حالت‌ها به مشکل دچار نمی‌شود. انکودینگ منچستر در هر بیت انتقالی خود، سیگنال را تغییر میدهد که نسبت به از دست رفتن کلاک (خروج از حالت سنکرون) مطمئن خواهد بود.
انکودینگ NRZ: هم برای صفرهای پشت سر هم و هم برای یک‌های پشت سر هم دچار مشکل می‌شود. سیگنال، تنها زمانی تغییر می‌کند که تغییر بیت داشته باشیم. بنابراین، احتمال از دست رفتن کلاک را داریم.
انکودینگ NRZI: حالت اول (برای صفرهای پشت سر هم). بیت ۱ باعث تغییر سیگنال خواهد بود. بنابراین، مشکلی ایجاد نخواهد شد. اما در بیت‌های صفر پشت سر هم، امکان از دست رفتن کلاک وجود دارد.
انکودینگ دوقطبی: حالت اول (برای صفرهای پشت سر هم). همانند انکودینگ NRZI .
به منظور بررسی بهتر می‌توانید انکودینگ‌های متفاوت را در تصویر روبرو مقایسه کنید:

Problem 8

(a) Assuming the first bit of the frame(which is for recognition) is 1 and the probability of 1 and 0 is 0.5, a transmission has no error if no 1 is transmitted in the second through 193rd bits. Since the bits are generated independently, the probability of having no error is

$$p = (1 - \frac{1}{2})^{192}$$

Since the probability of having error should be less than 0.001, we have,

$$1 - p = 1 - (1 - \frac{1}{2^N})^{192} < 0.001 \rightarrow N \geq 18$$

(b) We should have at least 3 cells with different frequency bands and for each cell $\frac{840}{3} = 280$ frequency bands should be assigned. With each T1 serving 24 users, each cell can serve up to 6,720 users (i.e., 24 $\times$ 280).