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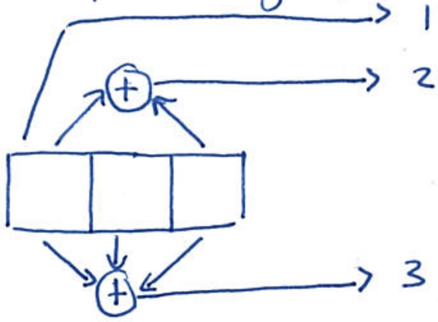
MET 1413 ASSIGNMENT #5 2013/14 SEM 2

Q1 The block diagram of a binary convolutional code is shown in the following figure



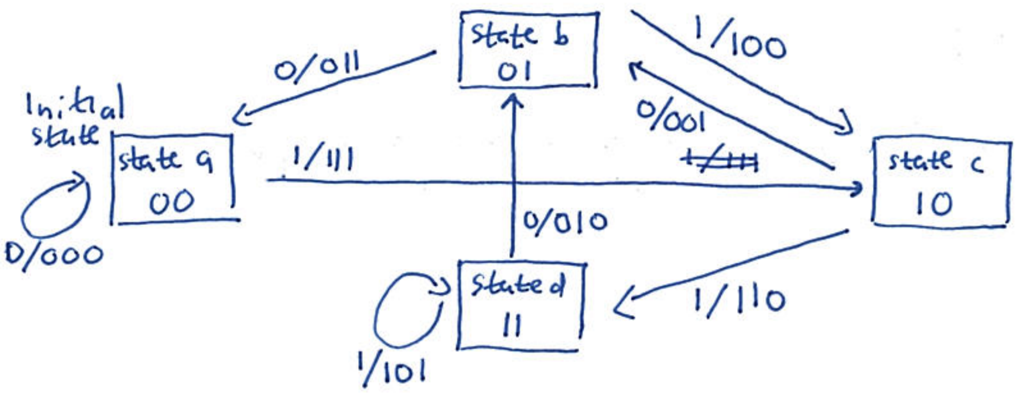
(a) what is the code rate of this convolutional encoder? what is the constraint length?

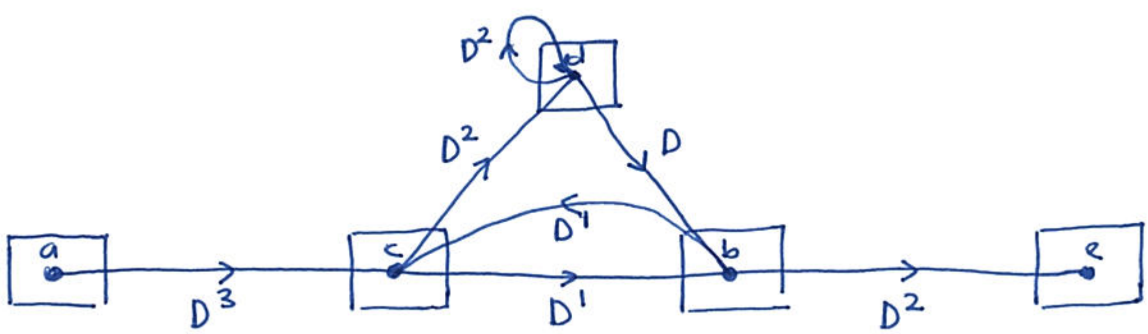
$k = 1$, $n = 3$, $K = 3$

code rate is $k/n = 1/3$

constraint length, K is 3.

(b) Draw the modified state diagram for the code.





(c) Find the transfer function of the code T(D).

$X_c = D^3 X_a + D X_b$

$X_b = D X_c + D X_d$

$X_d = D^2 X_c + D^2 X_d$

$X_e = D^2 X_b$

$T(X) = X_e / X_a =$

(d) What is d_{free}, the minimum free distance of the code?

$d_{free} = 6$ *

$a \xrightarrow{D^3} c \xrightarrow{D} b \xrightarrow{D^2} e$

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SKLAR P9.15

You are required to provide a real-time communication system to support 9600 bits/s with a required bit-error probability of at most 10^{-5} within an available bandwidth of 2700 Hz. The predetection P_r/N_0 is 54.8 dB-Hz. Choose one of two modulation schemes - either MPSK with Gray coding or noncoherent orthogonal MFSK, such that the available bandwidth is not exceeded and power is conserved. If error-correction coding is needed, choose the simplest (shortest) code in Table 9.3 that provides the needed error performance, but does not exceed the available bandwidth. Verify that your design choices result in meeting the requirements.

Using Table 9.1, use 16-PSK which requires Nyquist minimum bandwidth of 2400 Hz (less than available bandwidth of 2700Hz) and an $E_b/N_0 = 17.5$ dB @ $P_B = 10^{-5}$.

$$\frac{E_b}{N_0}\,[\text{dB}] = \frac{P_r}{N_0}\,[\text{dB-Hz}] - R\,[\text{dB-bits/s}]$$

$$= 54.8 \text{ dB-Hz} - (10 \log_{10} 9600) \text{ dB-Hz}$$

$$= 54.8 - 39.8 = 15 \text{ dB} = 31.6$$

For $P_B \leq 10^{-5}$, need error-correction coding.

Coding gain, G [dB] $= 17.5 - 15 = 2.5$ dB

Using Table 9.3, choose BCH(127,113)

$$\frac{E_s}{N_0} = (\log_2 M)\frac{E_c}{N_0} = (\log_2 M)\left(\frac{k}{n}\right)\frac{E_b}{N_0} = (\log_2 16)\left(\frac{113}{127}\right)(31.6)$$

$$= 112.47$$

which is close to $2700\text{H}/2400\text{ Hz} \times 100\% = 112.5$

$$P_E(M) \approx 2Q\left[\sqrt{\frac{2E_s}{N_0}}\,\sin\left(\frac{\pi}{M}\right)\right]$$

$M = 16$, $$P_E \approx 2Q\left[\sqrt{2(112.47)}\,\sin\left(\frac{\pi}{16}\right)\right]$$

$$= 2Q[(15)(0.1951)]$$

$$= 2Q[2.9264]$$

$$= 0.00169$$

$$P_c \approx \frac{P_E}{\log_2 M}$$, for $P_E \ll 1$, assuming Gray coding

$$\approx \frac{0.00169}{4} = 0.00042$$

$$P_B \approx \frac{1}{n}\sum_{j=t+1}^{n} j\binom{n}{j} p_c^{j}(1-p_c)^{n-j}$$

$$= \frac{1}{127}\sum_{j=t+1=3}^{127} j\binom{127}{j}(0.00042)^{j}(1-0.00042)^{127-j}$$

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SKLAR P12.9

There are 11 equal-power terminals in a CDMA communication system, transmitting signals toward a central node. Each terminal transmits information at 1 kbit/s on a 100 kchips/s direct-sequence spreading signal using BPSK modulation.

(a) If receiver noise is negligible with respect to the interference from other users, what is the ratio of bit energy to interference power spectral density (E_b/I_0) received by a receiving terminal?

Processing gain, $G_p = \frac{R_{ch}}{R} = \frac{100 \text{ kchips/s}}{1 \text{ kbit/s}} = 100$

Using equation,

$\left(\frac{E_b}{I_0}\right)_r = \frac{G_p}{M-1}$, given $M = 11$ $\Rightarrow \left(\frac{E_b}{I_0}\right)_r = \frac{100}{11-1} = \frac{100}{10}$

$= 10$

$= 10 \text{ dB}$ //

(b) What is the effect on E_b/I_0 if all users double their output power?

If all users double their output power,

$E_b' = 2E_b$ and $I_0' = 2I_0$

New $\frac{E_b}{I_0} = \frac{E_b'}{I_0'} = \frac{2E_b}{2I_0} = \frac{E_b}{I_0}$ 4. ~~remain~~

$\therefore \frac{E_b}{I_0}$ is independent of the output power.

(c) If the users wish to expand their service to 101 equal-power users, what must be done to the spreading codes to maintain the original E_b/I_o ratio?

$$\left(\frac{E_b}{I_o}\right)_r = \frac{G_p}{M-1} = 10 \text{ dB}$$

$m = 101$, but keep $\left(\frac{E_b}{I_o}\right)_r$ at 10 dB

$$G_p = 10(101-1) = 1000 \text{ dB}$$

$$G_p = \frac{R_{ch}}{R}$$

To maintain ~~Eb~~ original $\frac{E_b}{I_o}$, increase the spread bandwidth.

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SKLAR P12.23

A direct-sequence spread-spectrum system using BPSK modulation for both the data and the code is required to support a data rate of 9600 bits/s. ~~Is~~ The received predetection power-received versus N_0 (P_r/N_0) is 48-dB Hz and the SS-processing gain is 1000. A BCH ($\overset{n}{63}$, $\overset{k}{51}$) error-correcting code is used. Verify that these system specifications can provide a bit-error probability of 10^{-4}. Hint: Use equation (6.46) in chapter 6, for computing decoded bit-error probability.

$$\frac{E_b}{N_0}[\text{dB}] = \frac{P_r}{N_0}[\text{dB-Hz}] - R\,[\text{dB-bits/s}]$$

$$= 48 \text{ dB-Hz} - (10\log_{10} 9600) \text{ dB-bits/s}$$

$$= 48 - 39.8 = 8.2 \text{ dB} = 6.6$$

$$\frac{P_r}{N_0} = \frac{E_b}{N_0}R = \frac{E_c}{N_0}R_c = \frac{E_{ch}}{N_0}R_{ch}, \quad G_p = \frac{R_{ch}}{R}, \quad R_c = \left(\frac{n}{k}\right)R$$

$$\Rightarrow \frac{E_{ch}}{N_0} = \frac{P_r}{N_0}\left(\frac{1}{R_{ch}}\right) = \frac{P_r}{N_0}\left(\frac{1}{G_pR}\right) = \frac{E_b}{N_0}\left(\frac{1}{G_p}\right)$$

$$\frac{E_c}{N_0}R_c = \frac{E_{ch}}{N_0}R_{ch} \Rightarrow \frac{E_c}{N_0} = \frac{E_{ch}}{N_0}\left(\frac{R_{ch}}{R_c}\right)$$

$$= \frac{E_b}{N_0}\left(\frac{1}{G_p}\right)(G_pR)\left(\frac{k}{n}\right)\left(\frac{1}{R}\right)$$

$$\frac{E_c}{N_0} = \frac{E_b}{N_0}\left(\frac{k}{n}\right) = 6.6 \times \left(\frac{51}{63}\right) = 5.34$$

$$P_c = P_E = Q\left(\sqrt{\frac{2E_c}{N_0}}\right) = Q(3.27) = 0.5377 \times 10^{-3}$$

Equation 6.46,

$$P_B \approx \frac{1}{n} \sum_{j=t+1}^{n} j \binom{n}{j} p^j (1-p)^{n-j}$$

$$= \frac{1}{63} \sum_{j=}$$

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SKLAR P12.26

A direct-sequence spread-spectrum system with a processing gain of 20 dB uses QPSK modulation for transmitting data. A rate ½ error-correcting code is used, and the required bit-error probability is 10^{-5}. Assuming perfect synchronization, what is the minimum value of E_{ch}/I_0 (E_c/I_0) needed to support these requirements?

$$G_p = \frac{E_b/I_0}{E_{ch}/I_0} \Rightarrow \frac{E_{ch}}{I_0} = \frac{E_b/I_0}{G_p}$$

$$= \frac{E_b}{I_0}[dB] - G_p[dB]$$

$$= 9.6 - 20 = -10.4 \text{ dB}$$

$$\frac{P_r}{I_0} = \frac{E_b}{I_0}R = \frac{E_c}{I_0}R_c = \frac{E_{ch}}{I_0}R_{ch}, \quad R_c = \left(\frac{n}{k}\right)R$$

$$\frac{E_c}{I_0} = \frac{E_b}{I_0}\left(\frac{R}{R_c}\right) = \frac{E_b}{I_0}\left(\frac{k}{n}\right)$$

$$\frac{E_c}{I_0}[dB] = 9.6 \text{ dB} - 3 \text{ dB} = 6.6 \text{ dB}$$