EE 706: Communication Networks

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Solutions to Assignment 2 February 22, 2011

1. Figure 1 shows an empty block diagram of the communication process involving FEC and CRC codes. Fill in the labels for the blocks from the following list: Noise Source, FEC Decoder, CRC Encoder, Information Destination, CRC Decoder, Modulator, Demodulator, Channel, FEC Encoder, Information Source. In the labelled block diagram, suppose the FEC encoder is interchanged with the CRC encoder and the FEC decoder is interchanged with the CRC decoder. Explain why this system will not function correctly.

   Ans.

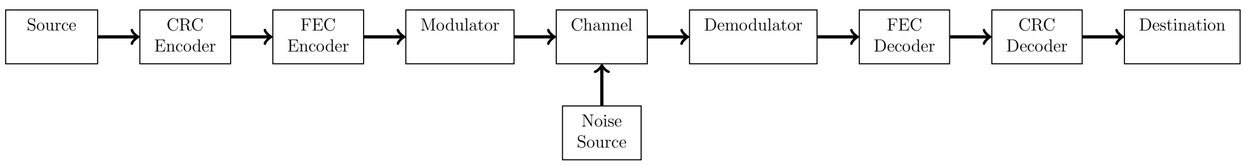

Figure 1: Basic block diagram of the communication process

   If the FEC and CRC operations are interchanged, the CRC decoder will try to detect errors in the demodulated bitstream before the FEC decoder has had a chance to correct the errors. Suppose the channel introduces errors which are detected by the CRC decoder. The FEC decoder may or may not be able to correct these errors. But there is no way for the receiver to know that the FEC decoder was successful if the CRC decoder is located before the FEC decoder.

2. Draw the unipolar NRZ, polar NRZ, polar RZ, NRZI, Manchester and differential Manchester waveforms corresponding to the bit string 1101101. State any assumptions you made with respect to the level of the signal to the left of the first bit's waveform.

   Ans. The signal level before the first bit is assumed to be high. The waveforms are illustrated in Figure 2.

3. A data link layer framing protocol uses bit stuffing to prevent the flag byte 01111110 (01^60) from appearing in the payload.

   (a) What is the bit stuffing rule used at the sender?

   Ans. The bit stuffing rule is to insert a 0 bit after every 5 consecutive 1 bits.

   (b) What is the bit destuffing rule used at the receiver?

   Ans. The bit destuffing rule is to remove zero bits which appear after 5 consecutive 1 bits.

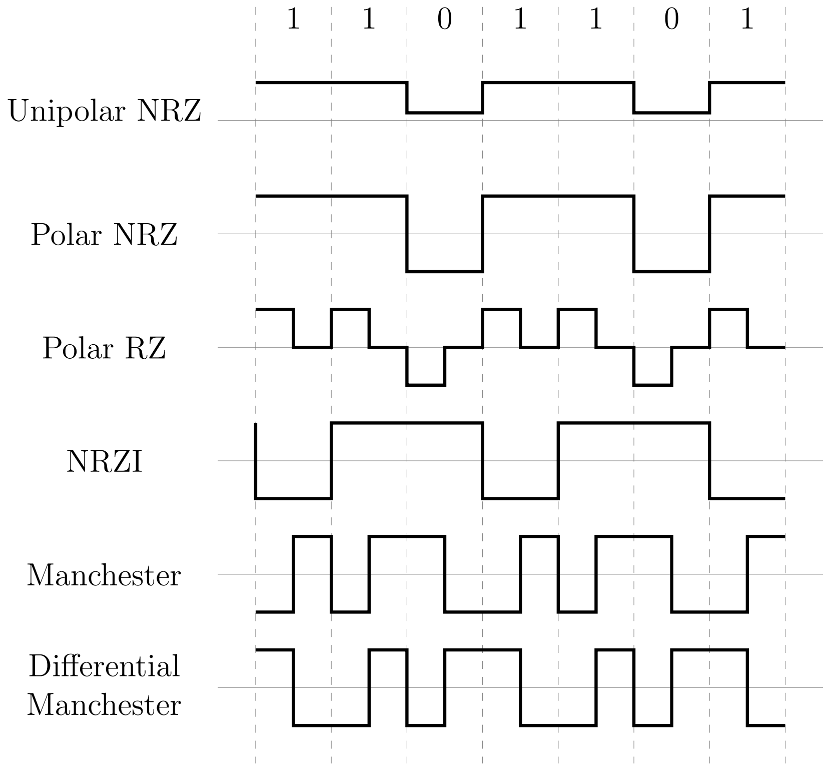

Figure 2: Line coding schemes

(c) Apply the bit stuffing rule to the bit strings 1111111111111111111111111 (1^{25}) and 11111101111111111101111110 ($1^{6}01^{11}01^{5}0$) .

Ans. 111110111110111110111110111110 ($1^{5}01^{5}01^{5}01^{5}01^{5}0$) and 111110101111101111101011 ($1^{5}0101^{5}01^{5}0101^{5}00$)

(d) Apply the bit destuffing rule to the following bit string and show where the actual flags are located. 01111110111011001111100111110110011111010111110

Ans. **01111110**111011001111101111110**01111110**10111110 is the destuffed bit string where the flags are in bold text.

4. Suppose a CRC scheme uses the generator polynomial $g(X) = (X + 1)(X^3 + X + 1)$.

(a) Generate CRC check bits for the information bits strings 1111 and 1010.

Ans. The CRC check bits are 0101 and 0110.

(b) Give an example of a double-bit error which is detected by this CRC scheme.

Ans. Examples are 011, 1001, 10001, 100001 ($X^5 + 1$), 1000001 ($X^6 + 1$).

(c) Give an example of a double-bit error which is **not** detected by this CRC scheme.

Ans. 10000001 ($X^7 + 1$).

(d) Given an example of a burst error of burst length 5 which is detected by this CRC scheme.

Ans. 10011 ($X^4 + X + 1$ which is not divisible by $g(X) = X^4 + X^3 + X^2 + 1$).

(e) Given an example of a burst error of burst length 5 which is **not** detected by this CRC scheme.

Ans. 11101 ($X^4 + X^3 + X^2 + 1$ which is equal to $g(X)$ and is divisible by it).

5. (a) Show that $X^n + X^{n-1} + \cdots + X^2 + X + 1$ is not a primitive polynomial for all positive integers $n > 2$.

   Ans.

   Note that $(X+1)(X^n+X^{n-1}+\cdots+X^2+X+1) = X^{n+1}+1$. So the smallest value of m for which the given polynomial divides X^m+1 is $n+1$. Now $n+1 < 2^n - 1$ for $n > 2$, hence the polynomial is not primitive.

   (b) Does $X + 1$ divide $X^{n^2+n} + X^{n^2+n-1} + X^{n^2+n-2} + \cdots + X + 1$ for all positive integers n?

   Ans.

   The number $n^2+n = n(n+1)$ is the product of two consecutive positive integers which is always even. Thus, the polynomial $X^{n^2+n} + \cdots + 1$ has an odd number of terms. So 1 is not a root of this polynomial. But 1 is a root of $X + 1$ which means $X + 1$ cannot divide the given polynomial.