Digital Transmission

A computer network is designed to send information from one point to another. This information needs to be converted to either a digital signal or an analog signal for transmission.

DIGITAL-TO-DIGITAL CONVERSION

We said that data can be either digital or analog. We also said that signals that represent data can also be digital or analog. In this section, **we see how we can represent digital data by using digital signals**. The conversion involves three techniques: **line coding, block coding**, and **scrambling**. Line coding is always needed, block coding and scrambling may or may not be needed.

Line Coding

Line coding is the process of converting digital data to digital signals. We assume that data, in the form of text, numbers, graphical images, audio, or video, are stored in computer memory as sequences of bits. Line coding converts a sequence of bits to a digital signal. At the sender, digital data are encoded into a digital signal; at the receiver, the digital data are recreated by decoding the digital signal.

Characteristics of Line Coding

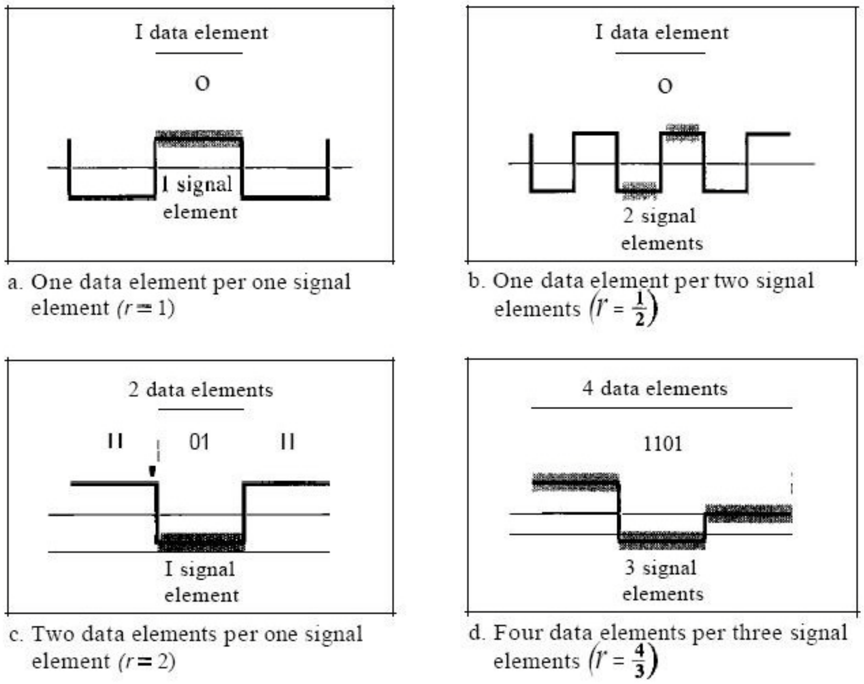
Signal Element Versus Data Element

Let us distinguish between a data element and a signal element. In data communications, our goal is to send data elements. A data element is the smallest entity that can represent a piece of information: this is the bit. In digital data communications**, a signal element carries data elements**. A signal element is the shortest unit (timewise) of a digital signal. In other words, data elements are what we need to send; signal elements are what we can send. Data elements are being carried; signal elements are the carriers.

We define a ratio **r** which is the number of data elements carried by each signal element.

Figure below shows several situations with different values of **r** .

Figure 4.2 *Signal element versus data element*



Data Rate Versus Signal Rate:

The data rate defines the number of data elements (bits) sent in 1s. The unit is bits per second (**bps**). The signal rate is the number of signal elements sent in 1s. The unit is the **baud**. There are several common terminologies used in the literature. The data rate is sometimes called the bit rate; the signal rate is sometimes called the pulse rate, the modulation rate, or the baud rate.

One goal in data communications is to **increase the data rate while decreasing the signal rate.** Increasing the data rate increases the speed of transmission; decreasing the signal rate decreases the bandwidth requirement. In our vehicle-people analogy, we need to carry more people in fewer vehicles to prevent traffic jams. We have a limited bandwidth in our transportation system.

We now need to consider the relationship between data rate and signal rate (bit rate and baud rate). This relationship, of course, depends on the value of r. It also depends on the data pattern. If we have a data pattern of all 1s or all 0s, the signal rate may be different from a data pattern of alternating 0s and 1s. To derive a formula for the relationship, we need to define three cases: the worst,
best, and average. The worst case is when we need the maximum signal rate; the best case is when we need the minimum.
In data communications, we are usually interested in the average case. We can formulate the relationship between data rate and signal rate as

$$S = c * N * (1/r) \quad \text{baud}$$

where N is the data rate (bps); c is the case factor, which varies for each case; S is the number of signal elements; and r is the previously defined factor.

Example 4.1

A signal is carrying data in which one data element is encoded as one signal element (r = 1). If the bit rate is 100 kbps, what is the average value of the baud rate if c is between 0 and l?

Solution

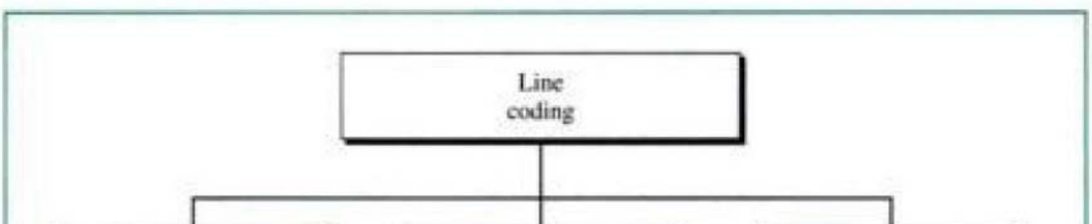
We assume that the average value of c is (1/2). The baud rate is then

$$S = c * N * (1/r) = (1/2) * 100{,}000 * 1 = 50{,}000 = 50 \text{ Kbaud}$$

Line Coding Schemes

We can roughly divide line coding schemes into three broad categories, as shown in Figure below.

Figure 4.5 *Line coding schemes*



Unipolar Scheme

In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below.

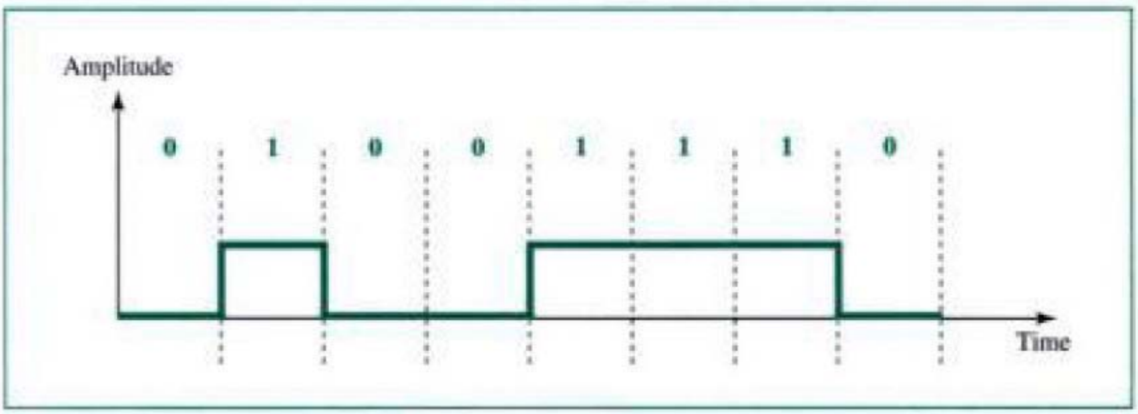
NRZ (Non-Return-to-Zero) Traditionally, a unipolar scheme was designed as a non-return-to-zero (NRZ) scheme in which the positive voltage defines bit 1 and the zero voltage defines bit 0. It is called NRZ because the signal does not return to zero at the middle of the bit. Figure 4.5 show a unipolar NRZ scheme.

Uni Polar

Uni Polar Encoding is very simple and very primitive. Uni Polar is so named because it uses only one polarity. This polarity is assigned to one of the two binary states, usually the 1 . the other state usually the 0 , is represented by zero voltage.

Figure (4.6) show the idea of uni polar encoding.

Figure 4.6 *Unipolar encoding*

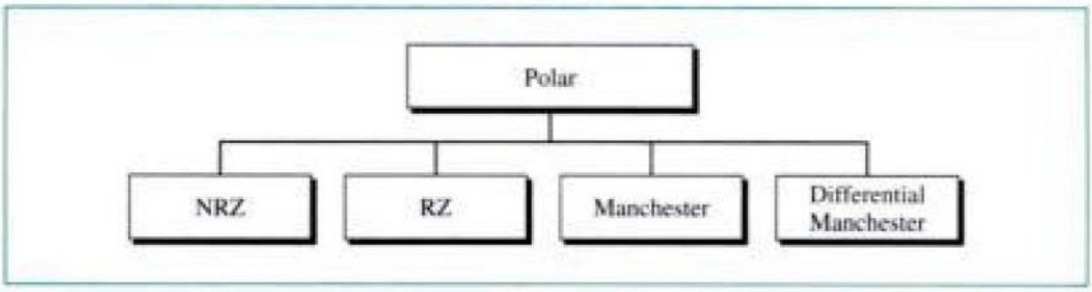


However, unipolar encoding has at least two problems that make it undesirable,a dc component and a lack of synchronization. The average amplitude of a unipolar is encoded as a nonzero.this create a dc component.Lack of synchronization is also an issue in unipolar encoding.if the data contains long sequence of 0's or 1's. there is no change in the signal during this duration that can alert the receiver to potential synchronization problem.

Polar Schemes

In polar schemes, the voltages are on the both sides of the time axis. For example, the voltage level for 0 can be positive and the voltage level for 1 can be negative.
There is 4 most popular variation of polar encoding: nonreturn to zero (NRZ), return to zero (RZ), Manchester, and differential Manchester (see fig 4.7).

Figure 4.7 *Types of polar encoding*



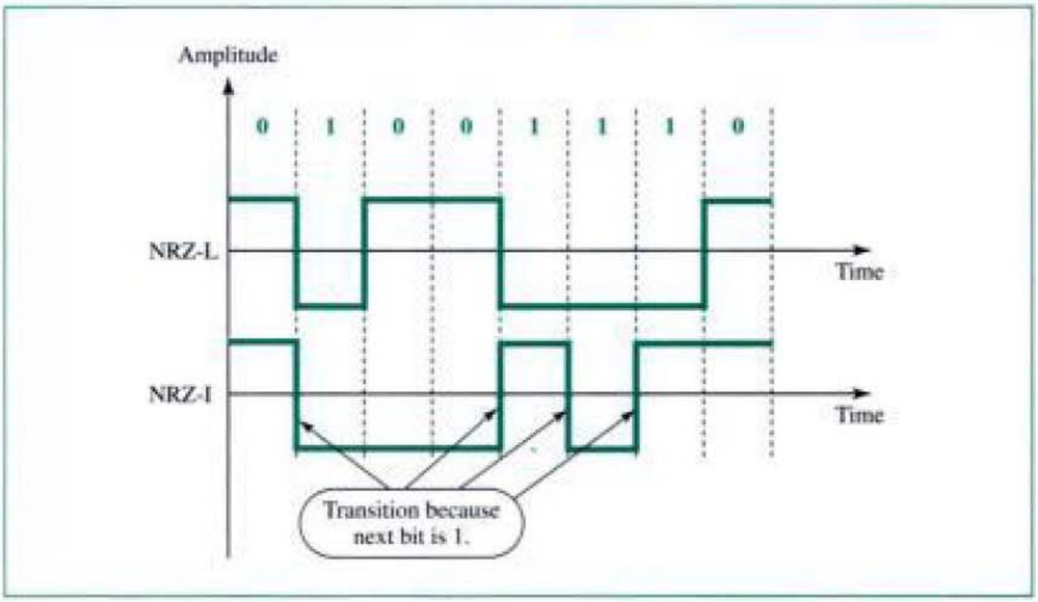
Nonreturn to Zero (NRZ) :

In NRZ encoding , the value of the signal is always either positive or negative. There are two popular forms of NRZ:
In NRZ-L (NRZ-Level) encoding the level of the signal depends on the type of bit that it represent, A positive voltage usually means the bit is a 0 , while a negative voltage means the bit is a 1.

In NRZ-I (NRZ-Invert) an inversion of the voltage level represent a 1 bit. It is the transition between a positive and a negative voltage , not the voltage itself. A 0 bit is represented by no change. If there is no change, the bit is 0; if there is a change, the bit is 1.

Figure below shows the NRZ-L and NRZ-I representation of the same series of bits.

Figure 4.8 *NRZ-L and NRZ-I encoding*



Return to Zero (RZ) :

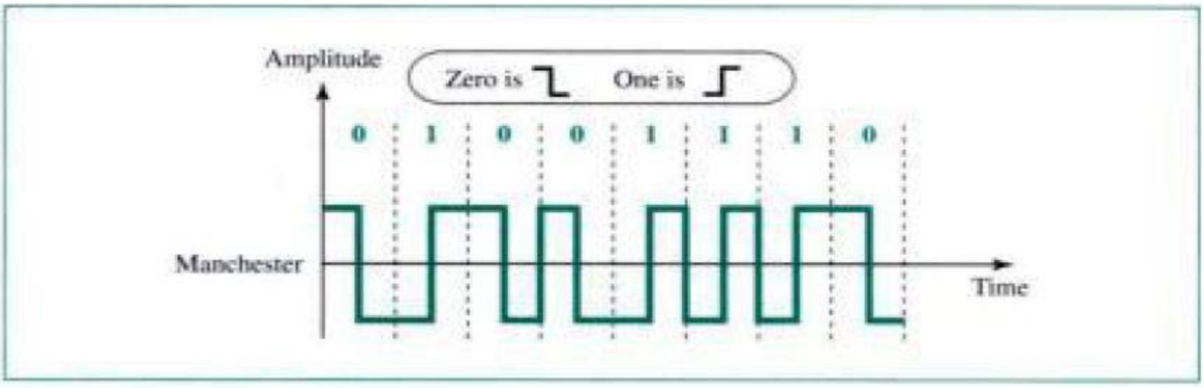
RZ encoding uses three values, positive, negative and zero. In RZ the signal changes not between the bits but during each bit. A positive voltage means 1 and negative voltage means 0.halfway through each bit interval the signals returns to zero. A 1 bit is represented by positive-to-zero and a 0 bit represented by negative-to-zero. Fig (4.9)illustrate the concept.

The main disadvantage of RZ encoding is that it requires two signals changes to encoded one bit and therefore occupies more bandwidth.

Figure 4.9 *RZ encoding*

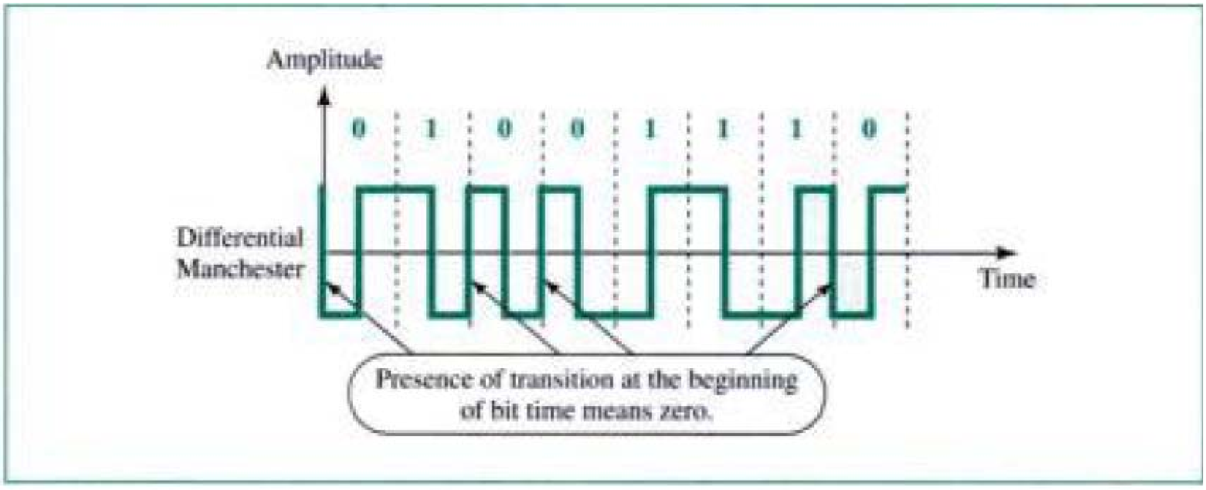
Manchester :

Manchester encoding uses an inversion at the middle of each bit interval for both synchronization and bit representation. A negative to positive transition represent binary 1, and a positive to negative transition represent binary 0. Figure (4.10) shows Manchester encoding .



Differential Manchester:

In differential Manchester encoding the inversion at the middle of bit interval is used for synchronization, but the presence or absence of an additional transition at the beginning of the interval is used to identify the bit, a transition means binary 0 and no transition means binary 1. Differential Manchester encoding requires two signal changes to represent binary 0 but only one to represent binary 1. figure (4.11) show Differential Manchester encoding.



Bipolar:

Bipolar encoding like RZ uses three voltage levels, positive , negative, and zero. The zero level in Bipolar encoding is used to represent binary 0 . the 1's are represented by alternating positive and negative voltages. If the first 1 bit is represented by the positive amplitude, the second will be represented by negative amplitude, the third by the positive amplitude and so on, and so on.