Data Communication

#1 Digital Transmission

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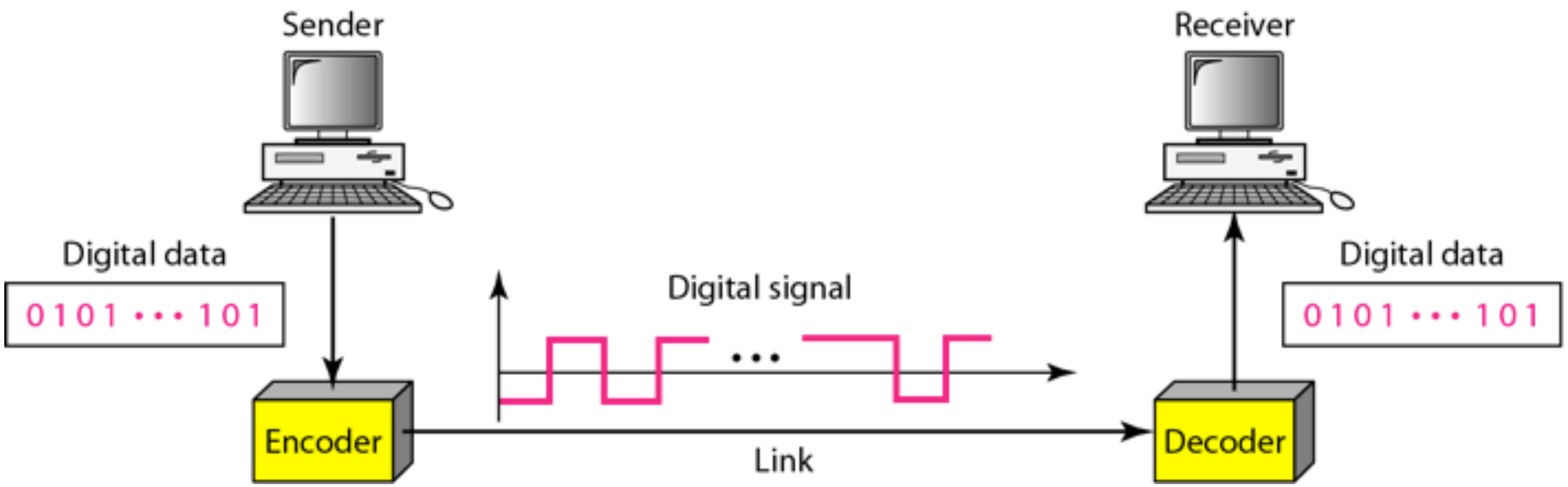
Digital Transmission

- 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,
- 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 into digital signals.
- We assume that data, in the form of text, numbers, graphical images, audio or video, are stored in computer memory as sequence 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 signal data are recreated by decoding the digital signal.



Characteristics

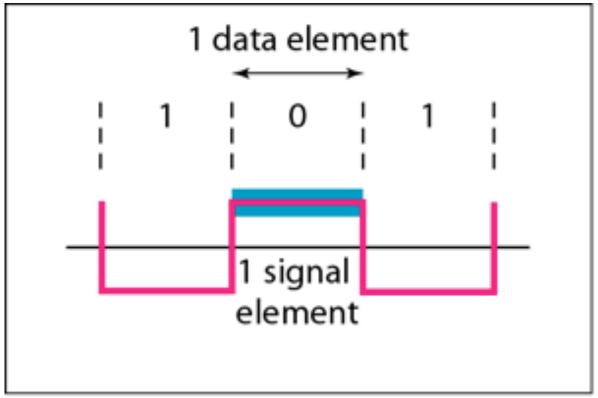
- Signal Element vs Data Element
- Data Rate vs Signal Rate
- Bandwidth
- Baseline Wandering
- DC Components
- Self Synchronization
- Built in Error Detection
- Immunity to Noise and Interference
- Complexity

Data Element vs Signal Element

- In data communications, our goal is to send data elements.
  - A data element is the smallest entity that represent a piece of information; this is the bit.
- In digital communications, a signal element carries data element
  - A signal elements is the shortest unit (timewise) of a digital signal.

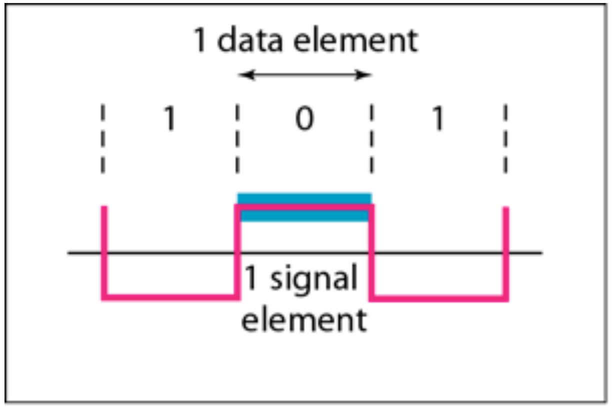
- **In other words, data elements are what we need to send; signal element are what we can send.**
- **Data elements are being carried; signal element are the carriers.**

- We define ratio (r) which is the number of data element carried by each signal element.

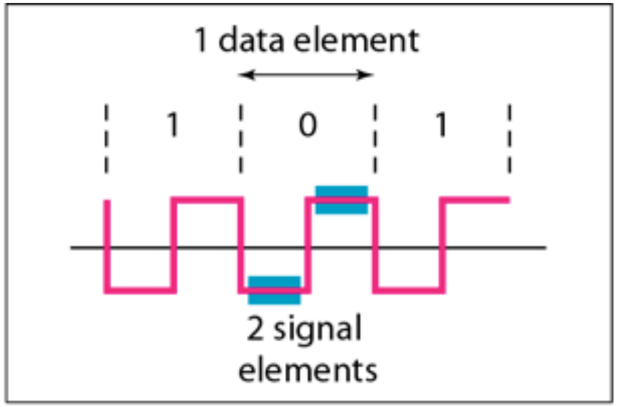


a. One data element per one signal element (r = 1)

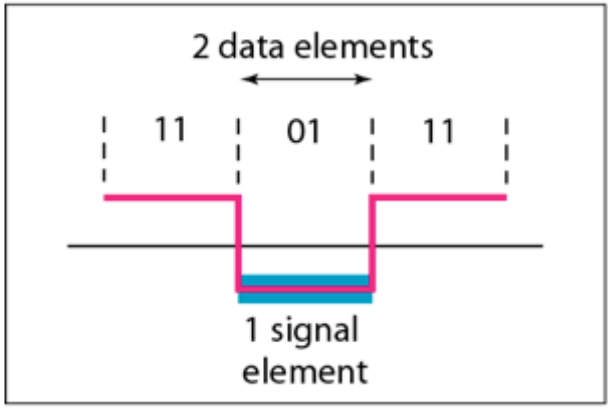
Signal Element vs Data Element



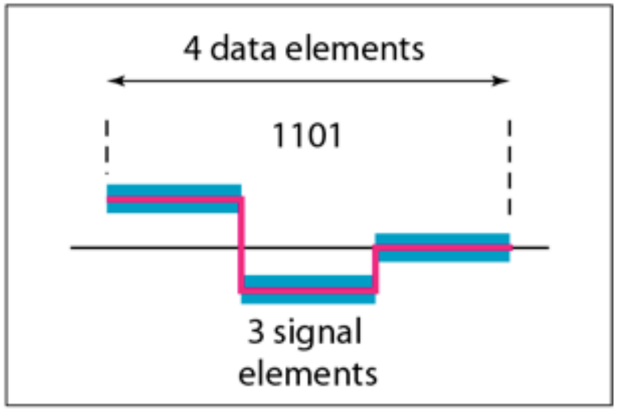
a. One data element per one signal element (r = 1)



b. One data element per two signal elements $\left(r = \frac{1}{2}\right)$



c. Two data elements per one signal element (r = 2)



d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

Data Rate vs Bit Rate

- Data rate defines the number of data elements (bit) sent in 1s. The unit is bits per second (bps)
- The signal rate is the number of signal elements sent in 1 s. The unit is baud.
- The data rate is sometimes called the bit rate; the signal rate is sometimes call 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 increase the speed of transmission; decreasing the signal rate decrease the bandwidth requirement.
- Relationship between data rate and signal rate as:

$$S = C \, x \, N \, x \, \frac{1}{r}$$

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

Example

- A signal is carrying data in which one data element is encoded as one signal element. If the bit rate is 100 kbps, what is the average value of the baud rate if c is between 0 and 1?
- Solution:
- We assume that the average value of C is 1/2. The baud rate is then:

Bandwidth

- The bandwidth is theoretically infinite, but the effective bandwidth is finite.
- We can say that the baud rate, not the bit rate, determines the required bandwidth for a digital signal.
- The bandwidth reflects the range of frequencies we need.
- there is a relationship between baud rate (signal rate) and the bandwidth.
- The minimum bandwidth can be given as:

$$B_{min} = c \times N \times 1/r$$

Baseline Wandering

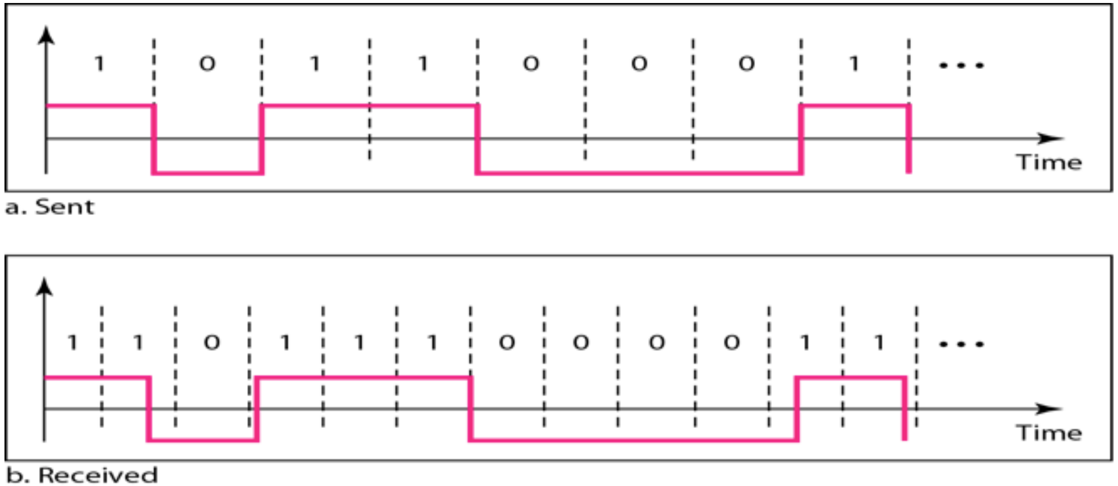
- In decoding a digital signal , the receiver calculates a running average of the received signal power. This average is called the **Baseline.**
- The incoming signal power is evaluated against this baseline to determine the value of the data element.
- A long string of 0s or 1s can cause a drift in the baseline (baseline wandering) and make it difficult for a receiver to decode correctly.
- A good line coding scheme needs to prevent baseline wandering

DC Components

- When the voltage level in a digital signal is constant for a while, the spectrum creates very low frequencies. These frequencies around zero, called DC (direct-current) components, present problems for a system that cannot pass low frequencies or a system that uses electrical coupling (via a transformers)
- For example, a telephone line cannot pass frequencies below 200Hz. Also a long distance link may use one or more transformers to isolate different parts of the line electrically.
- For these system, we need a scheme with no DC Components

Self Synchronization

- To correctly interpret the signal received from the sender, the receiver's bit intervals must correspond exactly to the sender's bit intervals.
- if the receiver clock is faster or slower, the bit intervals are not matched and the receiver might misinterpret the signal.



effect of lack synchronisation:

The sender send 10110001, while the receiver receives 110111000011

- A self synchronising digital signal includes timing information in the data being transmitted. This can be achieved if there are transitions in the signal that alert the receiver to the beginning, middle, or end of the pulse. If the receiver's clock is out of synchronisation, these points can reset the clock.

Example

- In a digital transmission, the receiver clock is 0.1 percent faster than the sender clock. How many extra bits per second does the receiver receive if the data is 1 kbps? how many if the data rate is 1 Mbps?
- Solution
    - At 1 kbps, the receiver receive 1001 bps instead of 1000bps

1000 bits sent	1001 bits received	1 extra bps

    - At 1Mbps, the receiver receive 1.001.000 bps instead of 1.000.000 bps

1,000,000 bits sent	1,001,000 bits received	1000 extra bps

Built in Error Detection

- It is desirable to have a built in error detecting capability in the generated code to detect some of or all errors that occurred during transmission.
- Some encoding schemes that we will discuss have this capability to some extent

Immunity to Noise and Interference

- Another desirable code characteristics is a code that is immune to noise and other interferences. Some encoding schemes that we will discuss have this capability

Built in Error Detection

- A complex scheme is more costly to implement than a simple one.