Computer Networks(CS30006)

Spring Semester (2021-2022)

Digital Transmission

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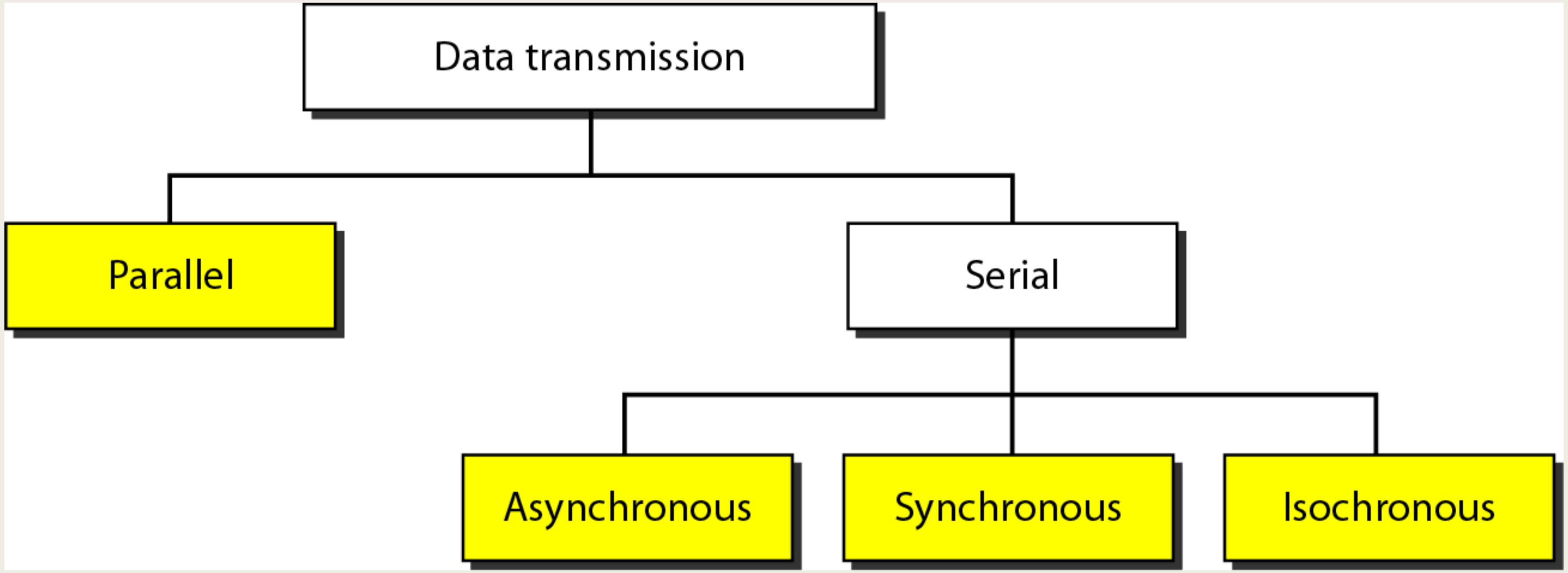
Transmission Modes

The transmission of binary data across a link can be accomplished in either parallel or serial mode. In parallel mode, multiple bits are sent with each clock tick. In serial mode, 1 bit is sent with each clock tick. While there is only one way to send parallel data, there are three subclasses of serial transmission: asynchronous, synchronous, and isochronous.



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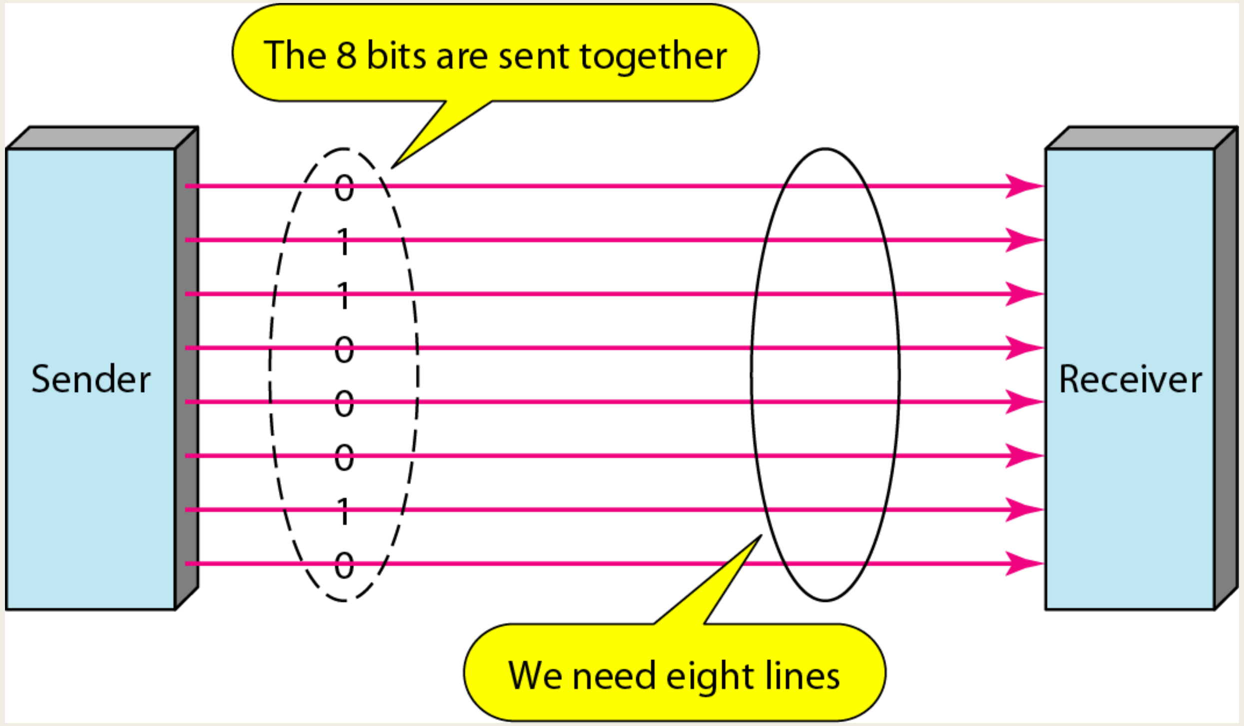
Parallel transmission

Use n wires to send n bits at one time.



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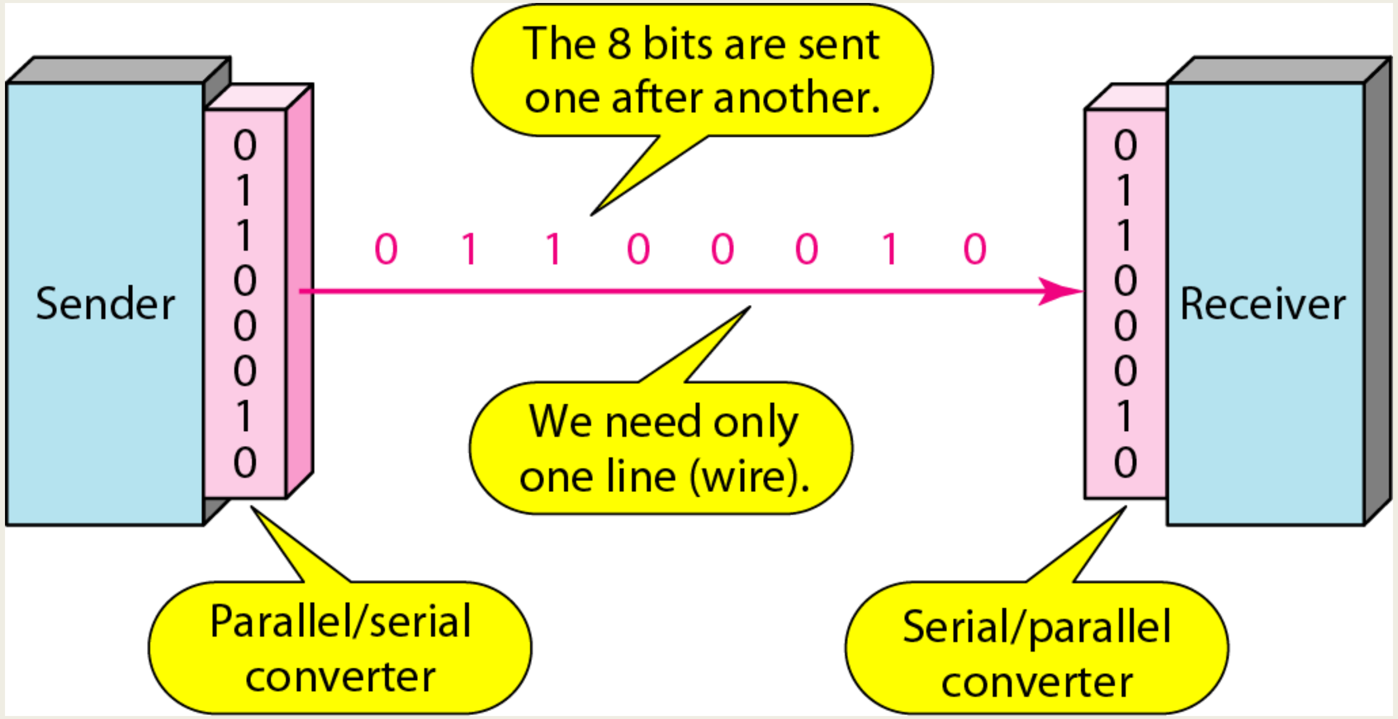
Serial transmission

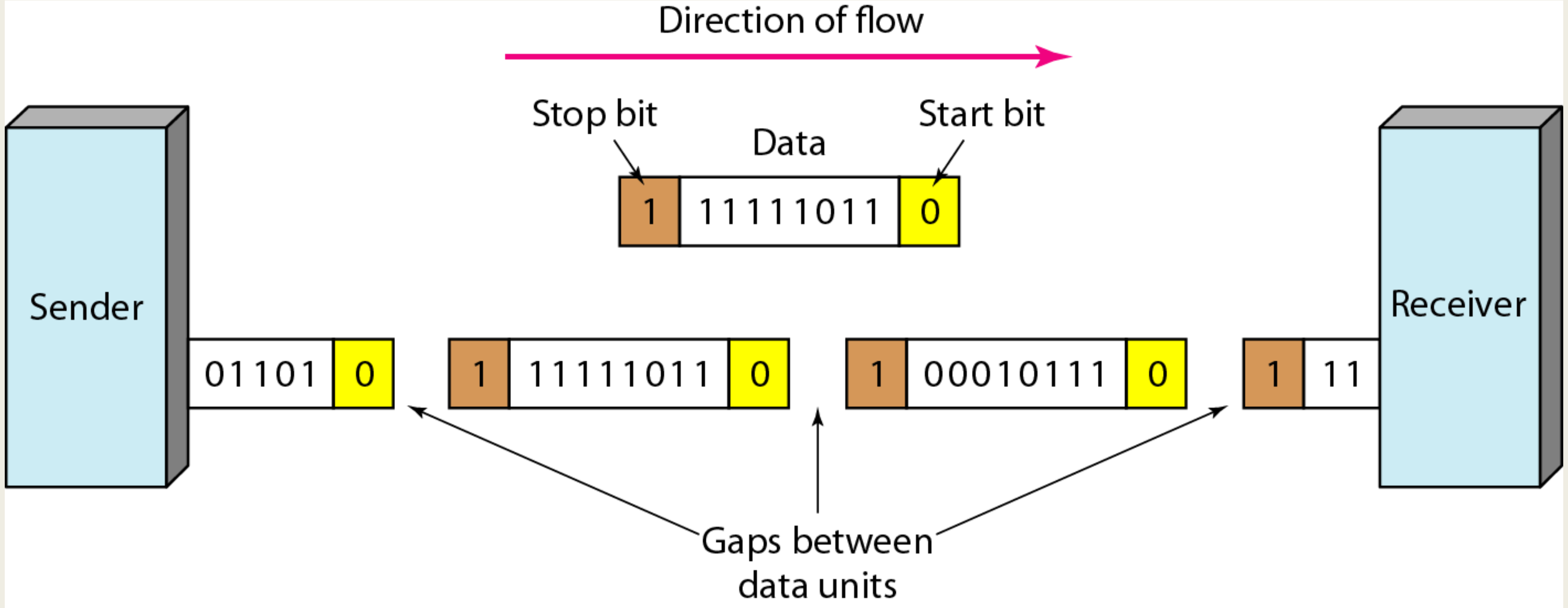
In serial transmission one bit follows another, so we need only one communication channel rather than *n* to transmit data between two communicating devices



Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Asynchronous transmission

In asynchronous transmission, we send 1 start bit (0) at the beginning and 1 or more stop bits (1s) at the end of each byte.
There may be a gap between each byte.



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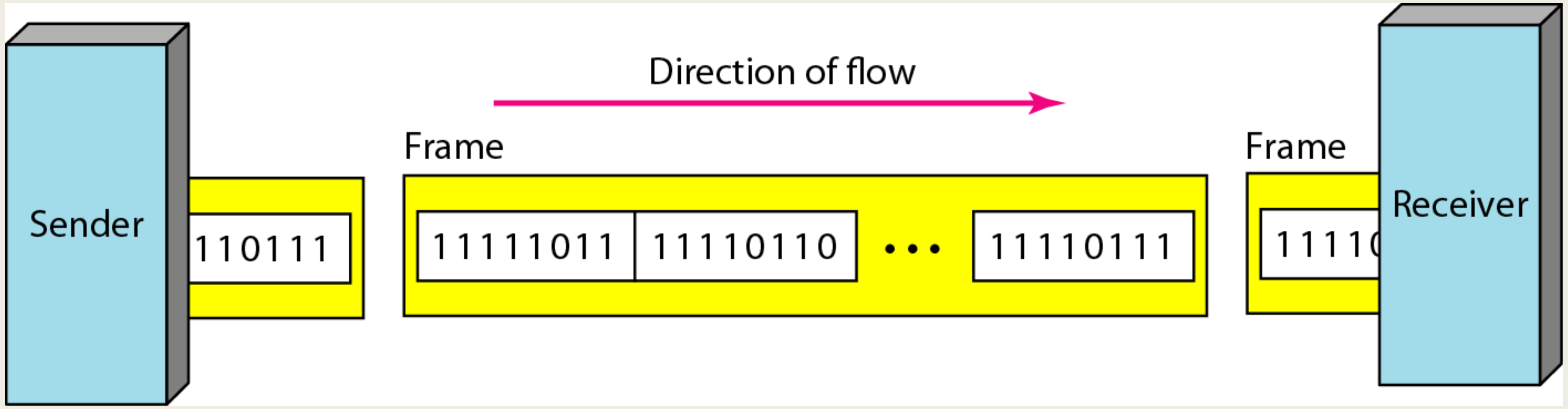
Synchronous transmission

- In synchronous transmission, we send bits one after another without start or stop bits or gaps.
- It is the responsibility of the receiver to group the bits.
- The bits are usually sent as bytes and many bytes are grouped in a frame.
- A frame is identified with a start and an end byte.



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Isochronous

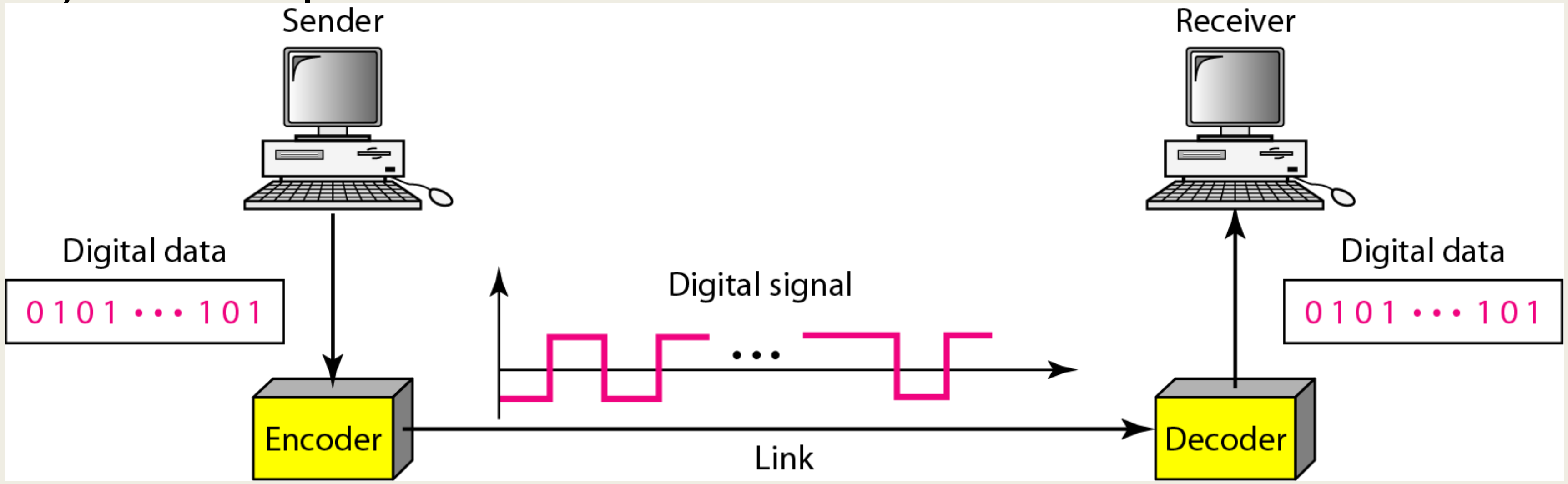
- In isochronous transmission we cannot have uneven gaps between frames.
- Transmission of bits is fixed with equal gaps.

Digital to Digital Conversion

The conversion involves three techniques: line coding, block coding, and scrambling.

Line Coding: Converting a string of 1’s and 0’s (digital data) into a sequence of signals that denote the 1’s and 0’s.

For example: A high voltage level (+V) could represent a “1” and a low voltage level (0 or -V) could represent a “0”.



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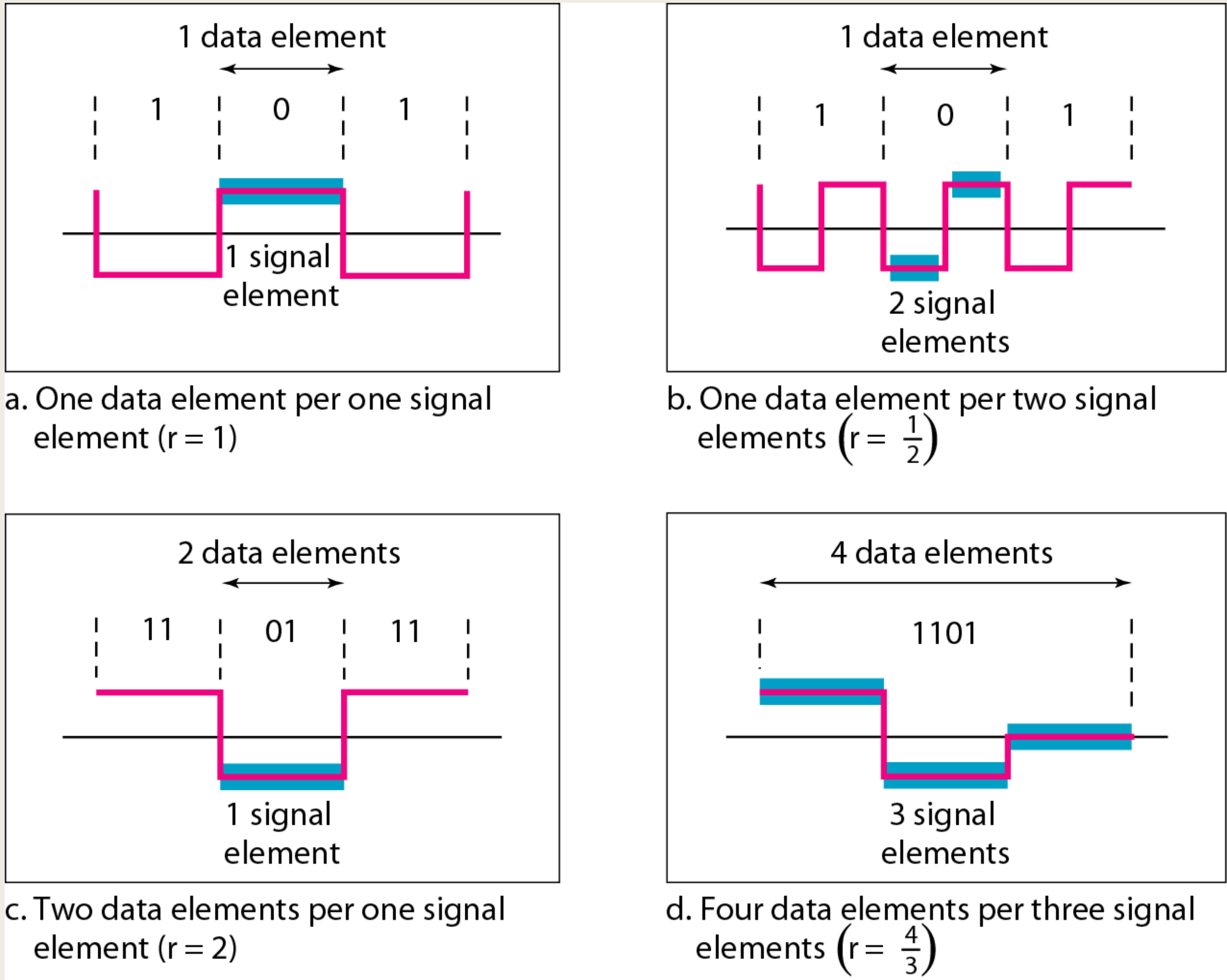
Relationship between data rate and signal rate

- The data rate defines the number of bits sent per sec - bps. It is often referred to the bit rate.
- The signal rate is the number of signal elements sent in a second and is measured in bauds. It is also referred to as the modulation rate.



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Baud rate

The baud or signal rate can be expressed as:

$$S = c \times N \times 1/r \text{ bauds}$$

Where:

N is data rate

c is the case factor (worst, best & avg.)

r is the ratio between data element & signal element

Example

- 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 1?

Solution

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

$$S = c \times N \times (1 / \mathrm{r}) = 1/2 \times 100{,}000 \times (1/1) = 50{,}000 = 50 \text{ kbaud}$$

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 rate is 1 kbps? How many if the data rate is 1 Mbps?

Solution

- At 1 kbps, the receiver receives 1001 bps instead of 1000 bps.

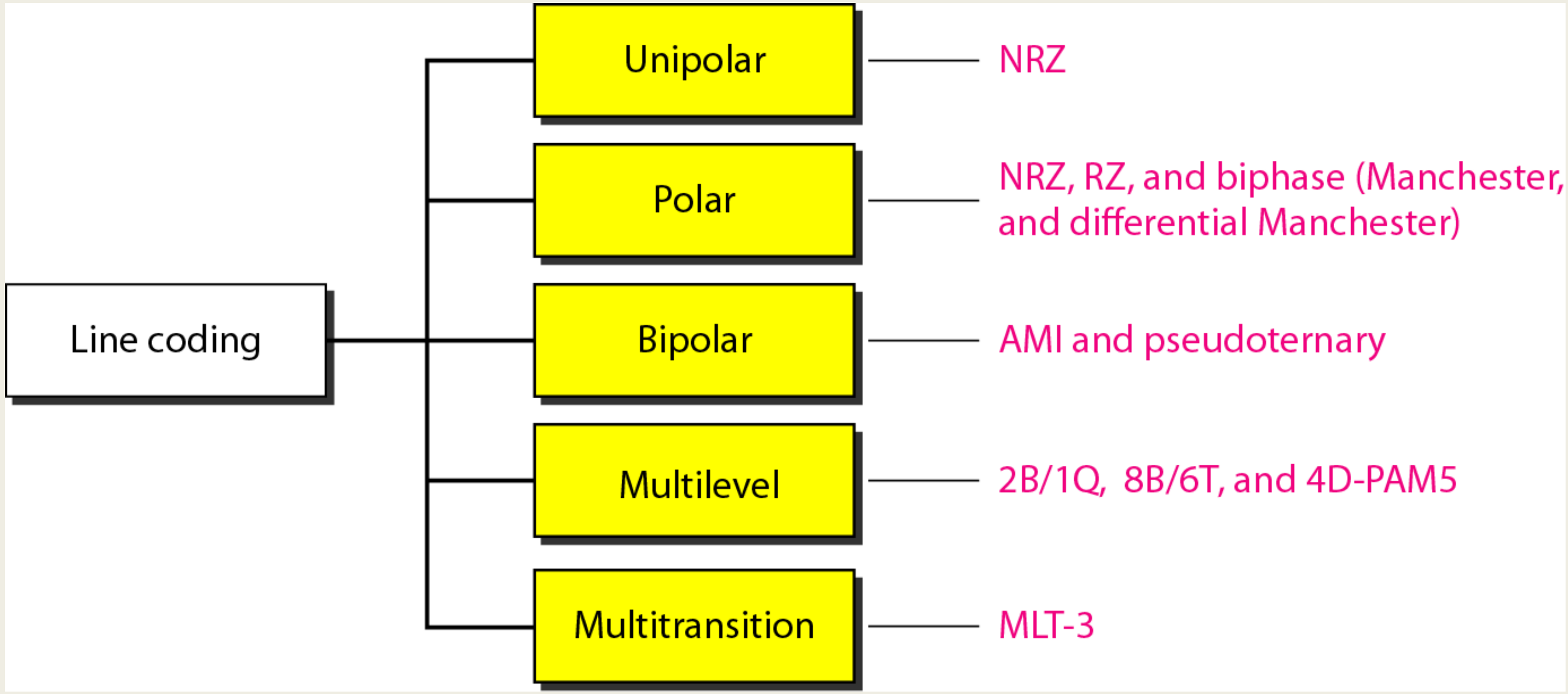
1000 bits sent	$\rightarrow$	1001 bits received	$\rightarrow$	1 extra bps

- At 1 Mbps, the receiver receives 1,001,000 bps instead of 1,000,000 bps

1,000,000 bits sent	$\rightarrow$	1,001,000 bits received	$\rightarrow$	1000 extra bps

Line Encoding

- Considerations for choosing a good signal element referred to as **line encoding.**
- Process of converting digital data to digital signals.



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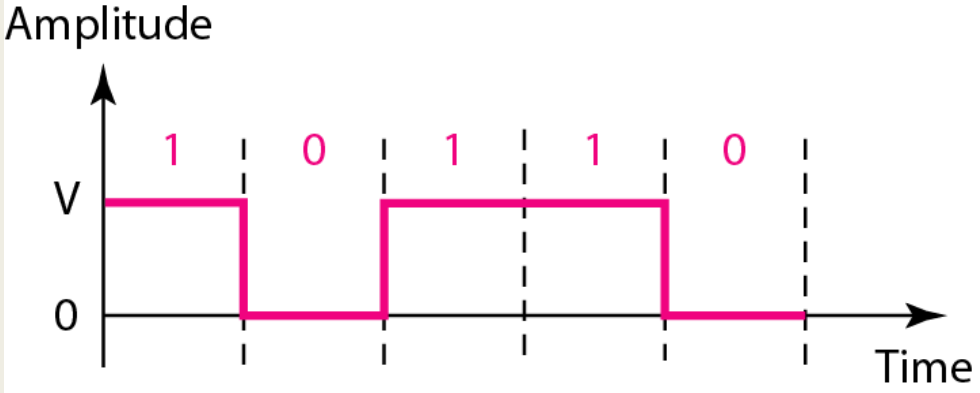
Unipolar

- All signal levels are on one side of the time axis - either above or below
- NRZ - Non Return to Zero scheme is an example of this code. The signal level does not return to zero during a symbol transmission.
- Scheme is prone to baseline wandering and DC components. It has no synchronization or any error detection. It is simple but costly in power consumption.



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

Normalized power

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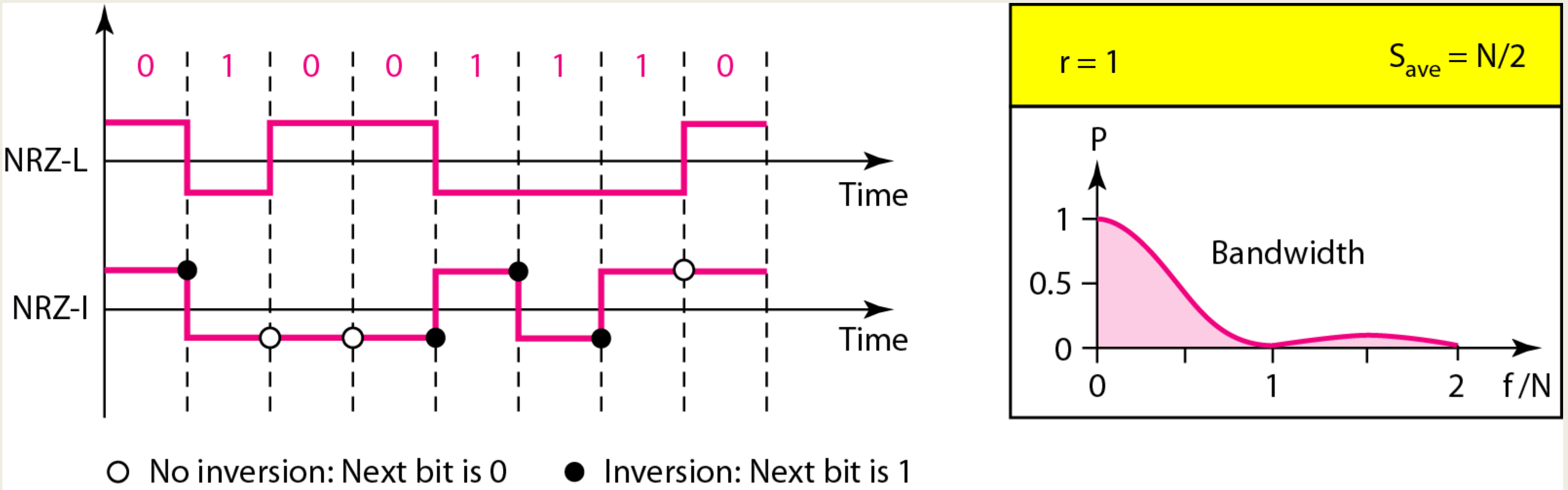
Polar - NRZ

- The voltages are on both sides of the time axis.
- Polar NRZ scheme can be implemented with two voltages. E.g. +V for 0 and -V for 1.
- There are two versions:
  - NZR - Level (NRZ-L) - positive voltage for one symbol and negative for the other
  - NRZ - Inversion (NRZ-I) - the change or lack of change in polarity determines the value of a symbol. E.g. a “1” symbol inverts the polarity a “0” does not.



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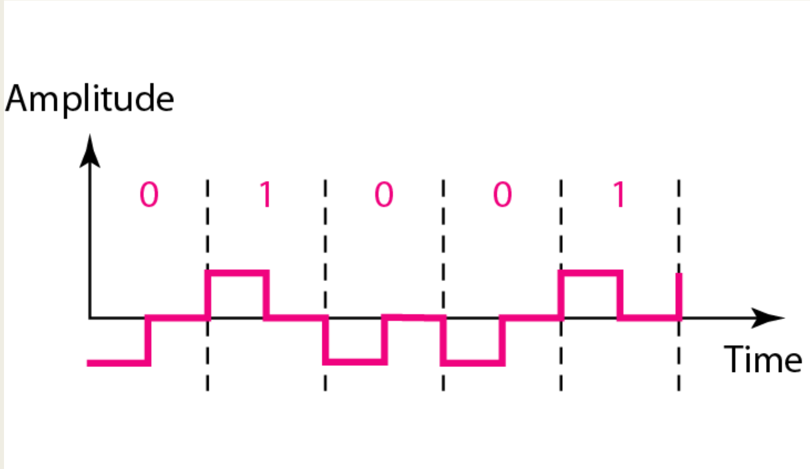
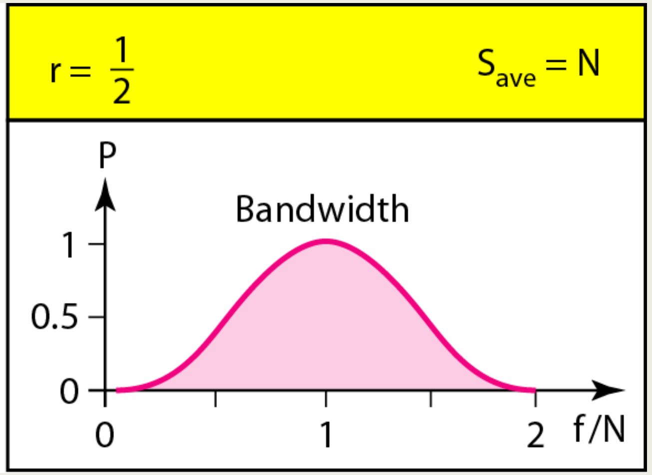
Polar - RZ

- The Return to Zero (RZ) scheme uses three voltage values. +, 0, -.
- Each symbol has a transition in the middle. Either from high to zero or from low to zero.
- This scheme has more signal transitions (two per symbol) and therefore requires a wider bandwidth.
- No DC components or baseline wandering.
- Self synchronization - transition indicates symbol value.
- More complex as it uses three voltage level. It has no error detection capability.





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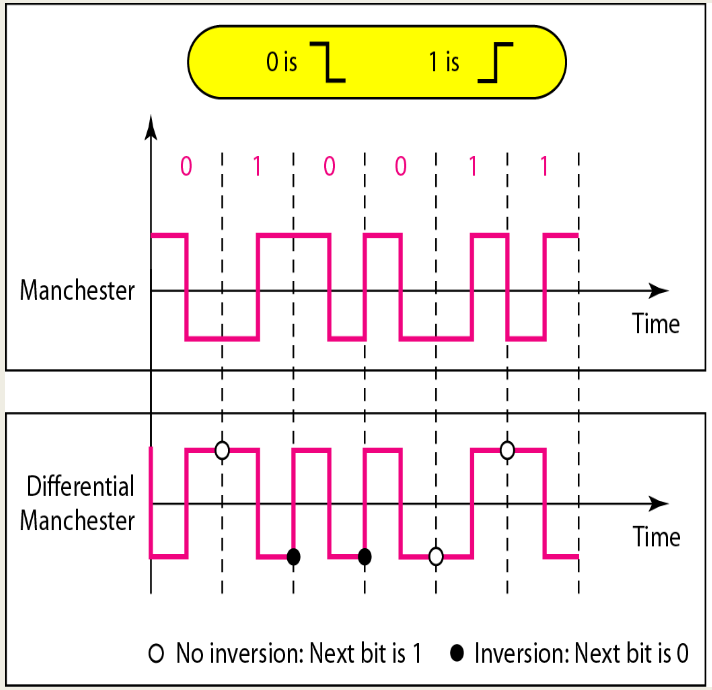
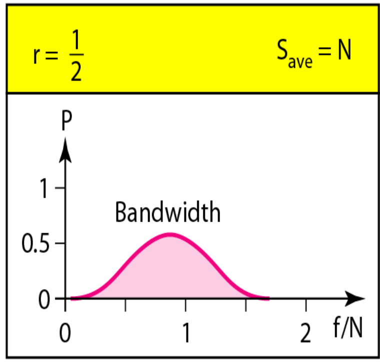
Polar - Biphase: Manchester and Differential Manchester

- Manchester coding consists of combining the NRZ-L and RZ schemes.
  - Every symbol has a level transition in the middle: from high to low or low to high. Uses only two voltage levels.

- Differential Manchester coding consists of combining the NRZ-I and RZ schemes.
  - Every symbol has a level transition in the middle. But the level at the beginning of the symbol is determined by the symbol value. One symbol causes a level change the other does not.





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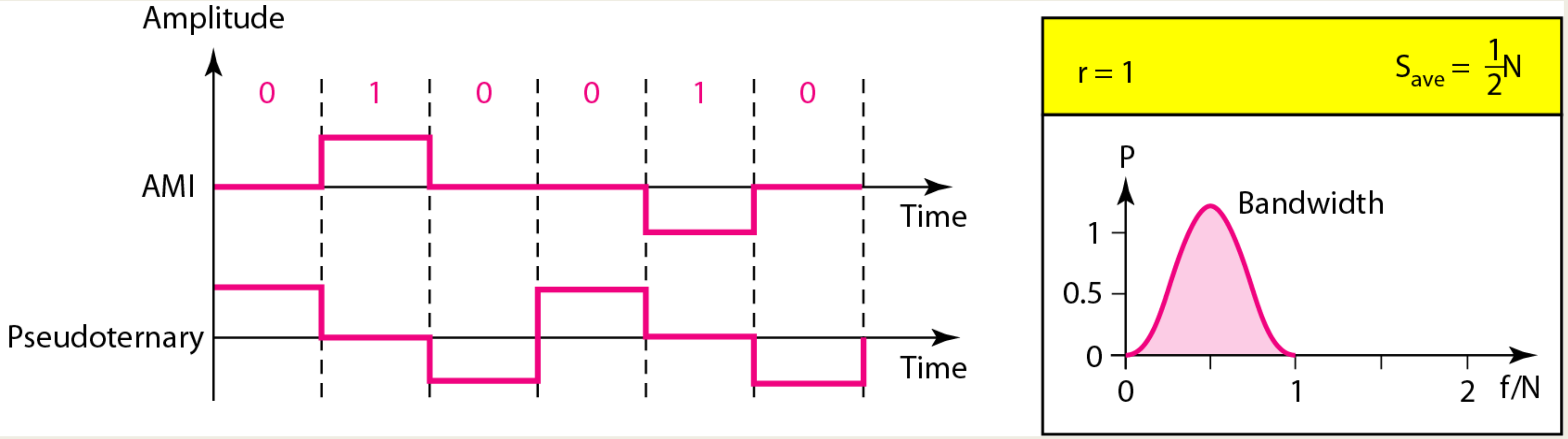
Bipolar - AMI and Pseudo-ternary

- Code uses 3 voltage levels: - +, 0, -, to represent the symbols (note not transitions to zero as in RZ).
- Voltage level for one symbol is at "0" and the other alternates between + & -.
- Bipolar Alternate Mark Inversion (AMI) - the "0" symbol is represented by zero voltage and the "1" symbol alternates between +V and -V.
- Pseudo-ternary is the reverse of AMI.



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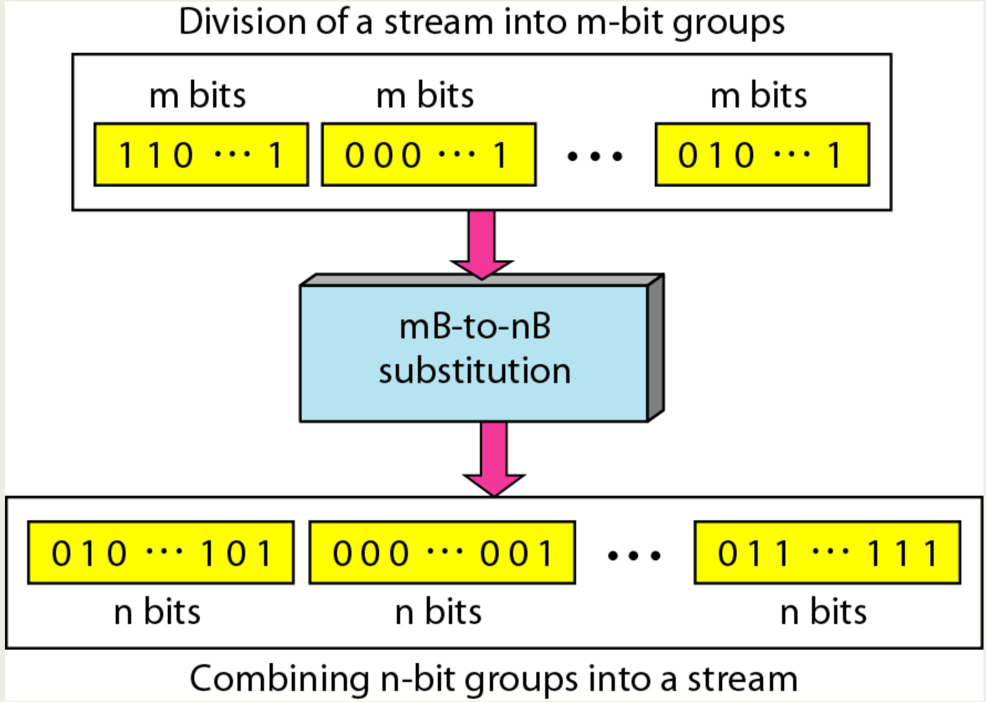
Block Coding

- For a code to be capable of error detection, we need to add redundancy, i.e., extra bits to the data bits.
- Synchronization also requires redundancy - transitions are important in the signal flow and must occur frequently.
- Block coding is done in three steps: division, substitution and combination.
- It is distinguished from multilevel coding by use of the slash - xB/yB.
- The resulting bit stream prevents certain bit combinations that when used with line encoding would result in DC components or poor sync. quality.



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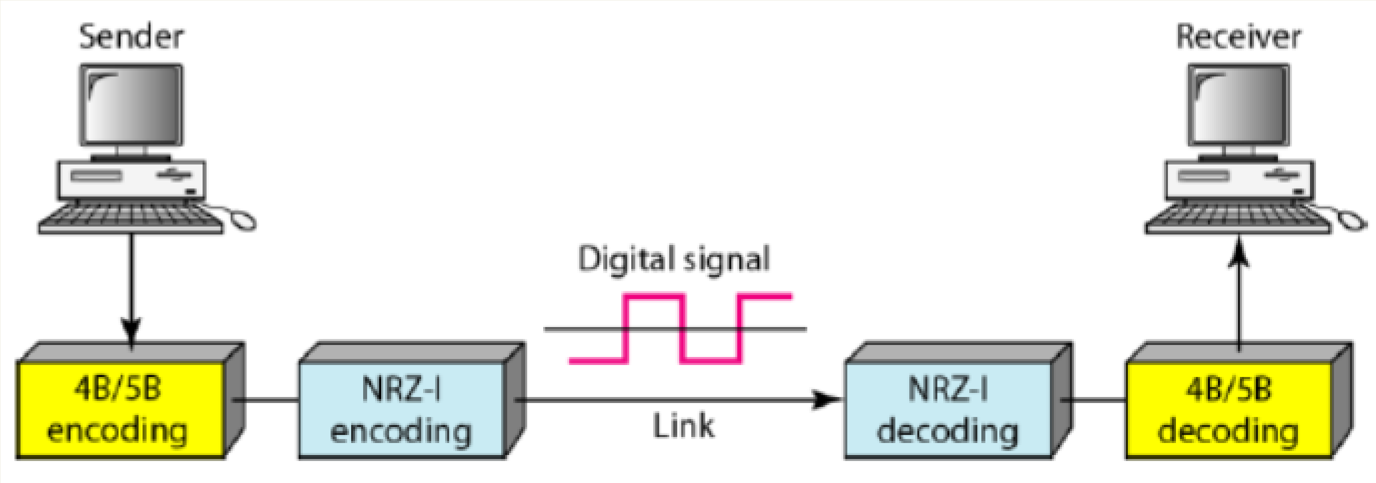
4B/5B

In 4B/5B encoding:

- Initially, input bit sequence is divided into 4 bit groups.
- The 4 bit group is now substituted with 5 bit group as per table.
- Finally, n-bit groups are combined to form output stream.

- Designed to work along with NRZ-I line coding.
- NRZ-I offers better signal rate which is (1/2) of biphase but it suffers from synchronization issue.
- This issue is solved by incorporating 4B/5B before NRZ-I encoder



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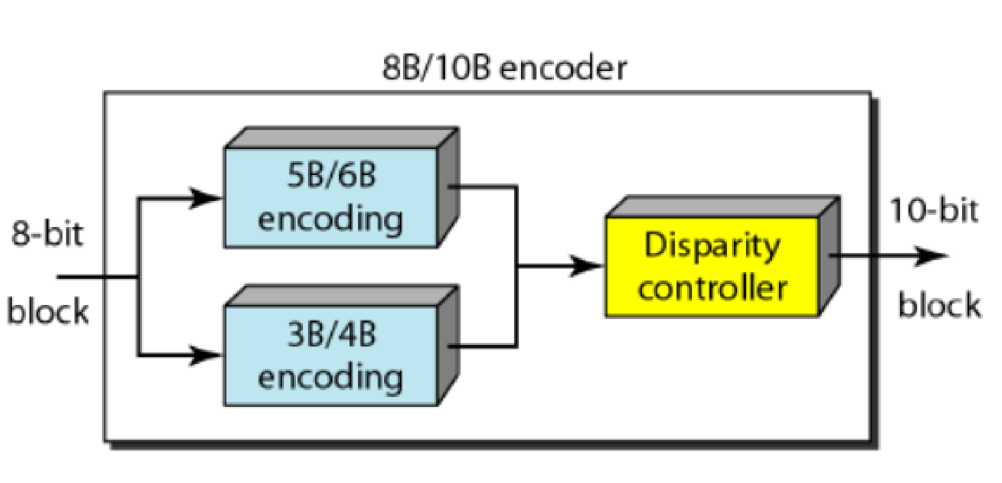
8B/10B

- Uses redundancy to ensure synchronization and to improve performance of this line coding.
- It offers better error detection capability.
- The 8B/10B indicates that this block coding takes 8 bit blocks as input and produces 10 bit blocks as output.
- The MSBs of 8 bit block are fed into 5B/6B encoder whereas 3 LSBs are fed into 3B/4B encoder modules.
- The coding has 2^{10} - 2^{8} redundant groups.
- The 8B/10B block coding is a combination of 5B/6B and 3B/4B encoding.



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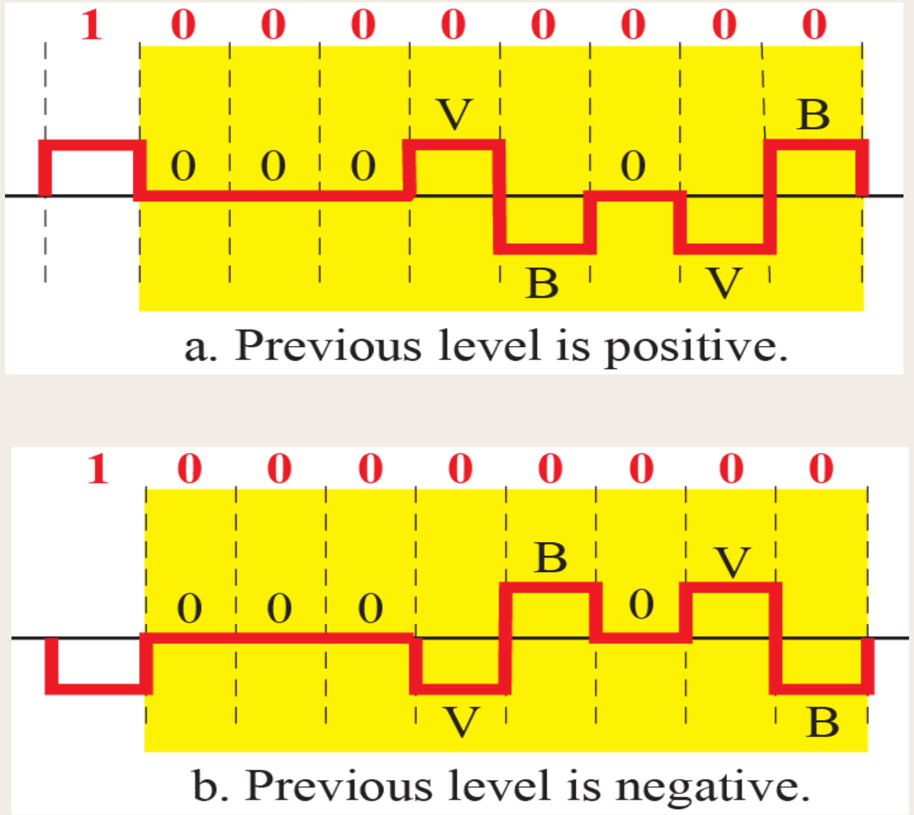
Scrambling

- Line and block coding are modified to include scrambling.
- Scrambling, as opposed to block coding, is done at the same time as encoding.
- In Scrambling, no extra bits are introduced unlike Block Coding.
- The objective is to replace long sequences of 0's and 1's with pe-defined bit sequences to improve synchronization.
- The system needs to insert the required pulses based on the defined scrambling rules.
- Thus, scrambling does not change bit rate and maintains DC balance by balancing positive and negative voltage levels
- Two common scrambling techniques are B8ZS and HDB3.

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Scrambling - B8ZS

- Bipolar with 8-zero substitution (B8ZS), commonly used in North America
- Replaces a sequence of 8-zeros by the bit pattern 000VB0VB
- V denotes the violation bit, which is a nonzero voltage that breaks an AMI rule of encoding
  - *Same polarity as previous non-zero bit*
- B denotes the bipolar bit, which is a nonzero level voltage in accordance with the AMI rule
  - *Opposite polarity as previous non-zero bit*

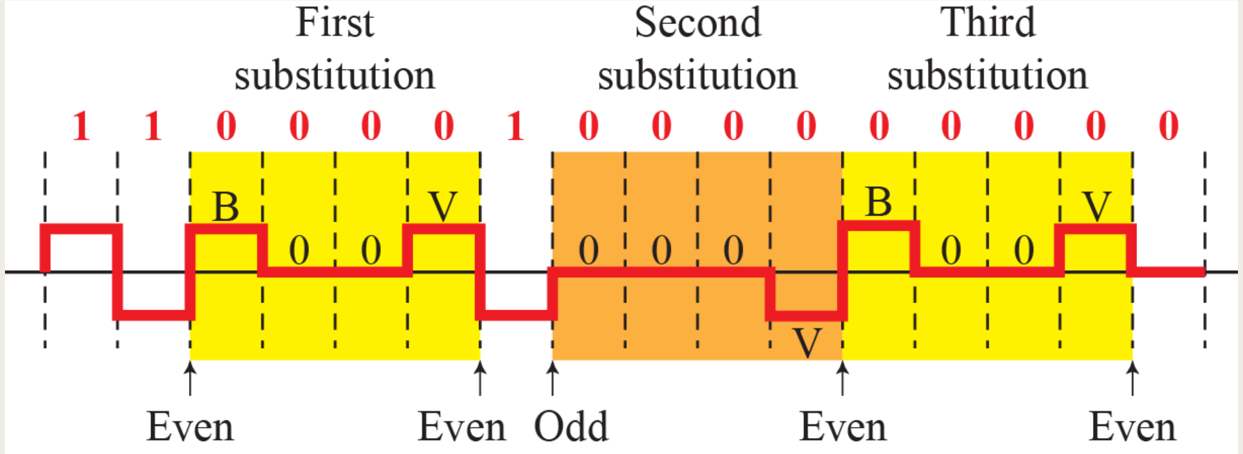


Two cases of B8ZS scrambling technique

Source: B. A. Forouzan, “ Data Communications and Networking ,” *McGraw-Hill Forouzan Networking Series*,5E.

Scrambling - HDB3

- High Density Bipolar 3-zero, commonly used outside North America
- Four consecutive zero-level voltages are replaced with a sequence of
  - *000V - if number of nonzero pulses after last substitution is odd*
  - *B00V - if number of nonzero pulses after last substitution is even*



An Example of HDB3 Scrambling

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Analog to Digital Conversion

A digital signal is superior to an analog signal because it is more robust to noise and can easily be recovered, corrected and amplified.

For this reason, the tendency today is to change an analog signal to digital data.

Thank You!!!