F.Y.M.Sc.(Computer Applications)

Semester - II

CSA4204

Networking Concepts

Unit – III

The Physical Layer

Notes

Unit III The Physical Layer

- The basic concepts of analog and digital data and signals
- Line Coding digital to digital conversion: Characteristics, Line coding schemes: Unipolar, NRZ, RZ, Manchester and Differential Manchester
- Transmission modes: Parallel Transmission, Serial Transmission – Asynchronous and Synchronous
- Multiplexing : FDM, TDM and WDM
- Switching: Circuit Switching, Message Switching and Packet Switching

Signals

- Major concern is moving information in the form of electromagnetic signals across the transmission medium
- Signals are categorized into two types:
  - Analog Signals
  - Digital Signals
- Both data and the signals that represent them can take either analog or digital form.

Analog and Digital Data

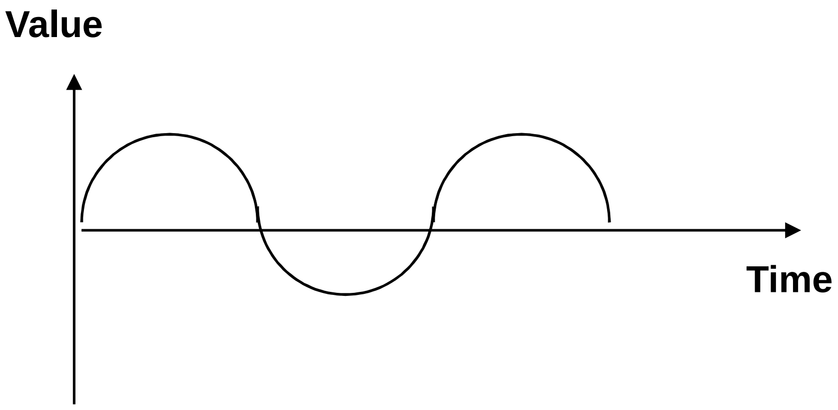
- Data can be analog or digital.
- Term analog data refers to information that is continuous. Digital data refers to information that has discrete states.
- Analog data such as human voice, take on continuous values. This can be captured by a microphone and converted to an analog signal or sampled and converted to a digital signal.
- Digital data take on discrete values. Data stored in computer memory in the form of 0s and 1s can be converted to a digital signal or modulated into an analog signal for transmission across a medium.

Analog and Digital Signals

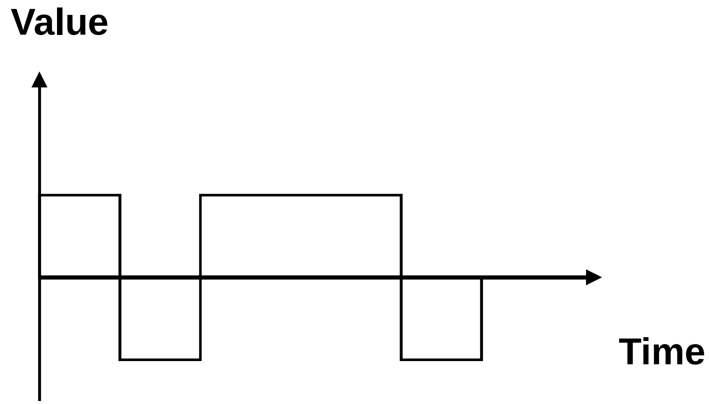
- An analog signals has infinitely many levels of intensity over a period of time. As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path.
- A digital signal, on the other hand, can have only a limited number defined values, often as simple as 0 and 1.
- Simplest way to show signals is by plotting them on a pair of perpendicular axes. The vertical axis represents the value or strength of signal. The horizontal axis represents the time.

Analog and Digital Signals

- The curve representing the analog signal passes through an infinite number of points.
- The vertical lines of the digital signal demonstrate the sudden jump the signal makes from value to value.



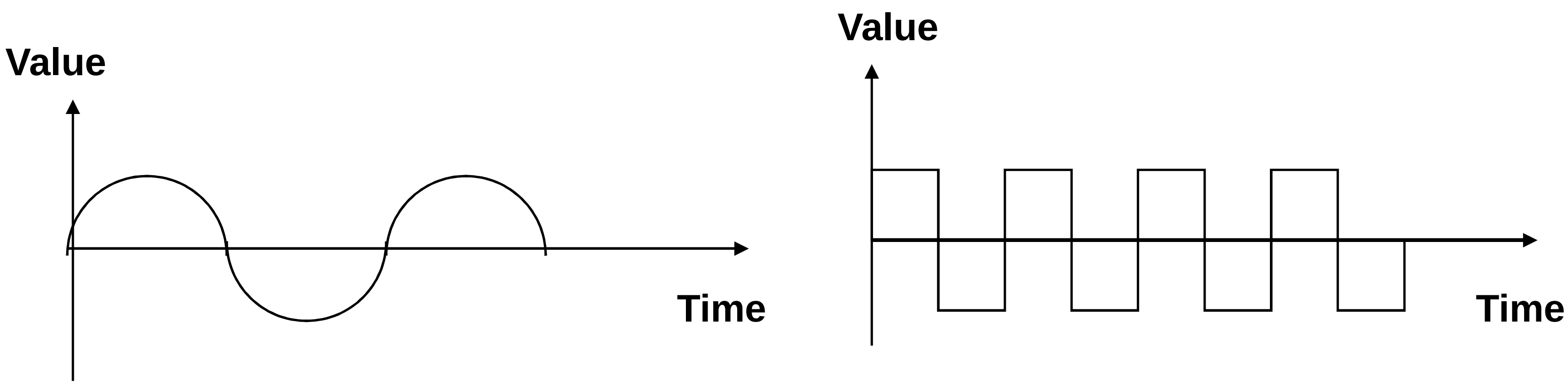
Analog Signal



Digital Signal

Periodic and Non- periodic Signals

- A signal is said to be periodic if it completes a pattern within measurable time frame called period and repeats that pattern over subsequent identical periods.
- The completion of one full pattern is called a cycle.

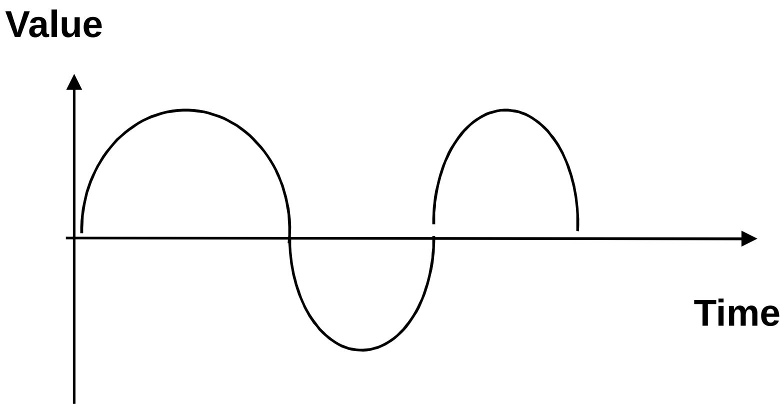


Analog Signal

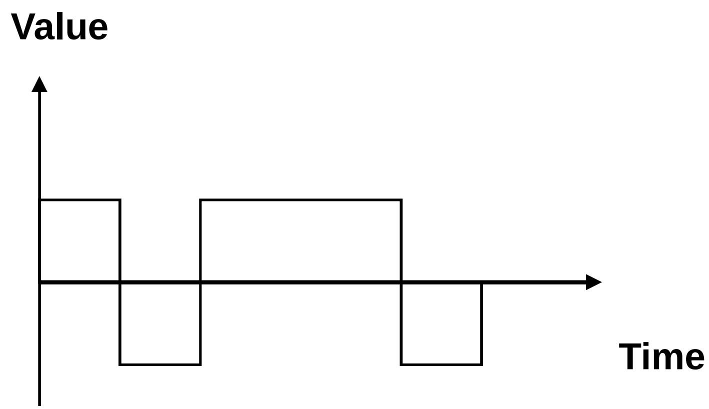
Digital Signal

Periodic and Non- periodic Signals

- A non-periodic signal changes without exhibiting a pattern or cycle that repeats over time.



Analog Signal

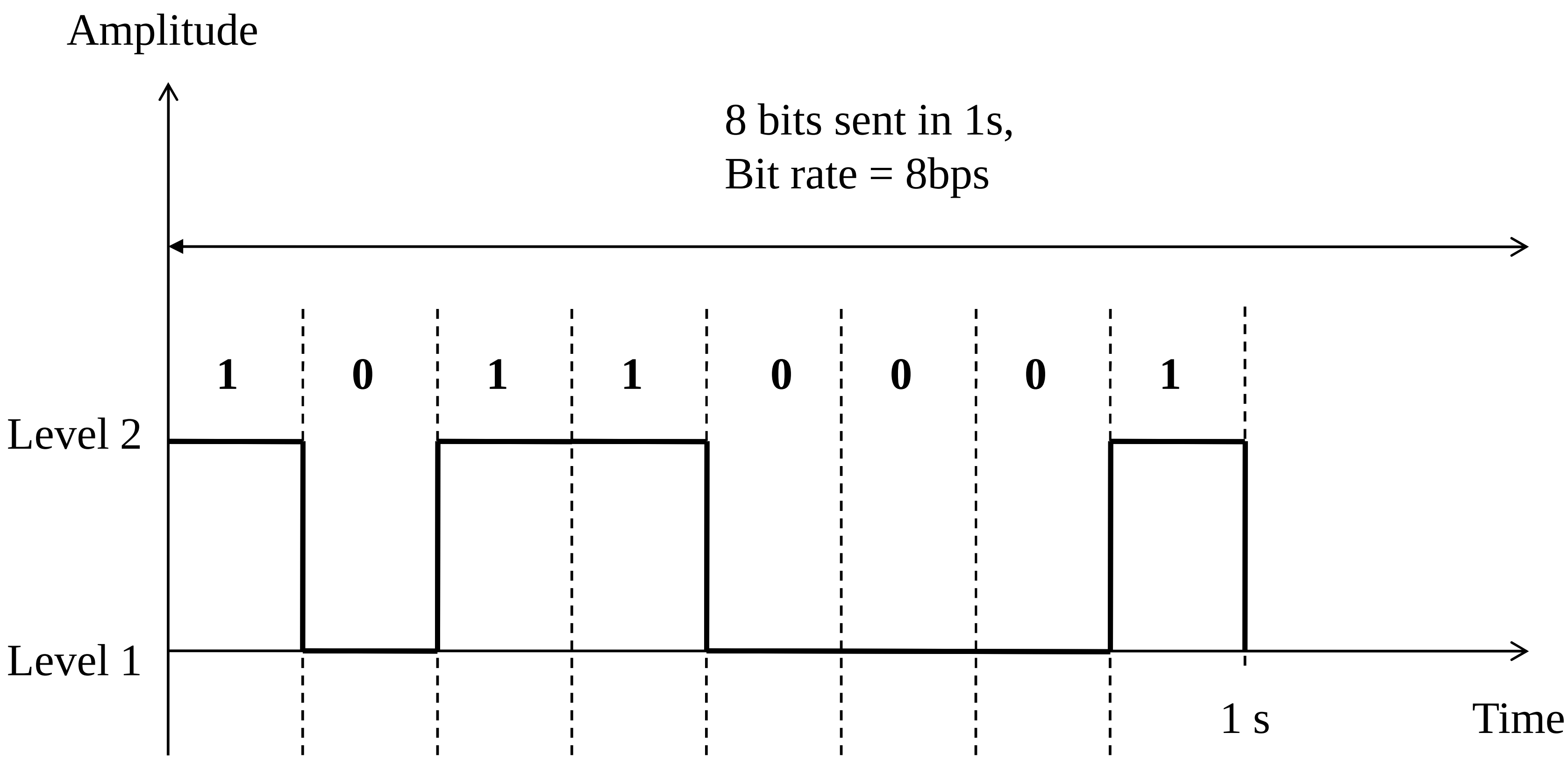


Digital Signal

Digital Signals

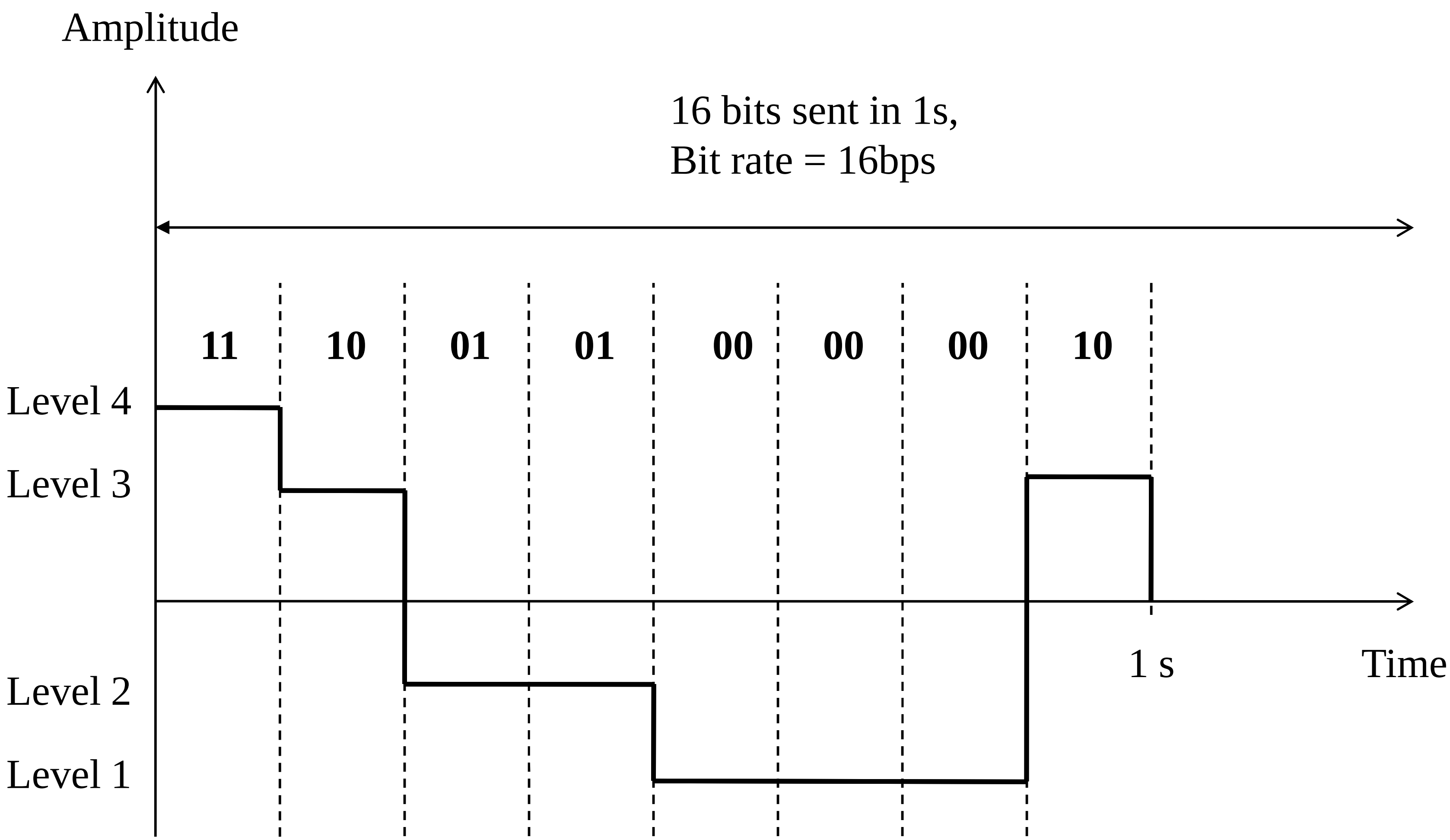
- In addition to analog signal, information can also be represented by a digital signal.
- A 1 can be encoded as a positive voltage and a 0 as zero voltage.
- A digital signal can have more than two levels. We can send more than 1 bit for each level.
- Figure showed next shows two signals, one with two levels and the other with four.
- We send 1 bit per level in part (a) of the figure and 2 bits per level in part (b) of the figure.
- If signal has L levels, each level needs $\log_2 L$ bits.

Digital Signals



a. A digital signal with two levels

Digital Signals



b. A digital signal with four levels

Digital Signals

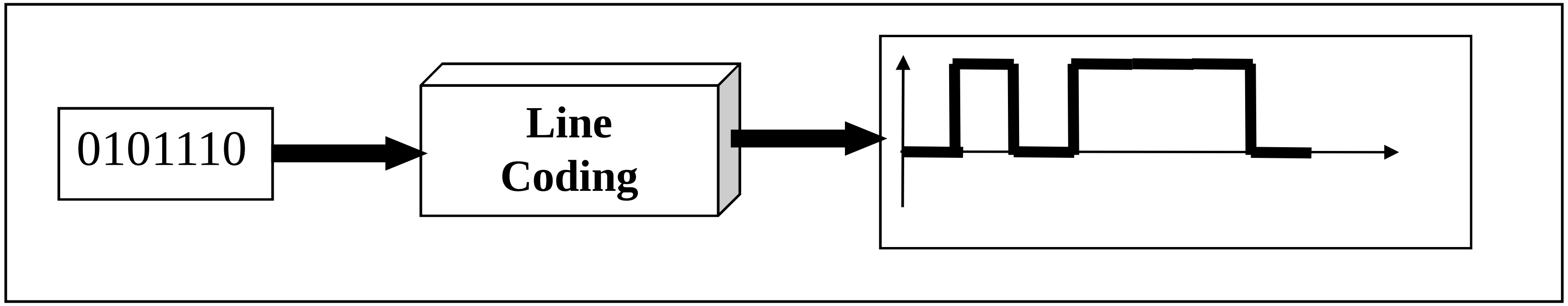
- Bit Rate
  - Most digital signals are nonperiodic, and thus period and frequency are not appropriate characteristics.
  - Term bit rate (instead of frequency) is used to describe digital signals.
  - The bit rate is the number of bits sent in 1s, expressed in bits per second (bps).

Digital Signals

- Bit Length
  - Is the distance one bit occupies on the transmission medium.
  - Bit length = propagation speed x bit duration

Digital-To-Digital Conversion

- Line Coding
  - Is the process of converting digital data, a sequence of bits, to a digital signal.
  - Example: text, data, numbers, graphical images, audio and video that are stored in computer memory are all sequences of bits.
  - Line coding converts a sequence of bits to a digital signal.

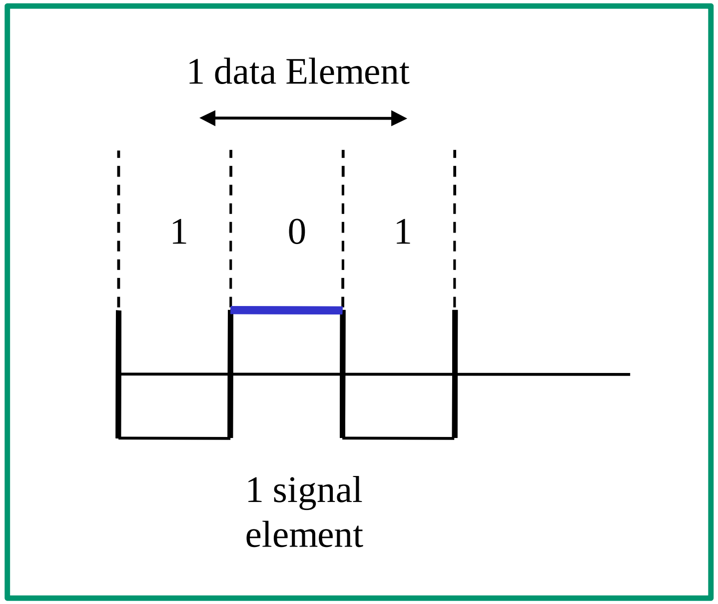


Digital Transmission

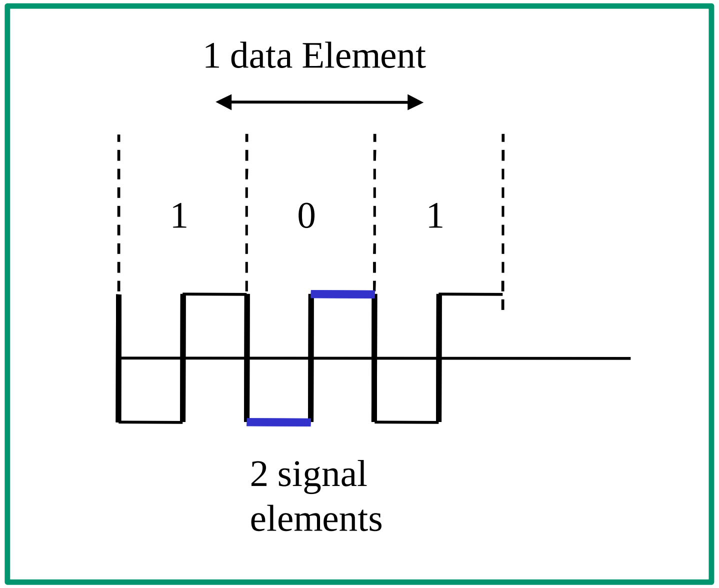
- Line Coding - Characteristics
  - Signal Element versus data Element
    - In data communications, our goal is to send data elements.
    - A data element is the smallest entity that can represent a piece of information: bit. In digital data communications, a signal element carries data elements.
    - A signal element is the shortest unit (timewise) of a signal
    - 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 ratio r which is the number of data elements carried by each signal element.

Digital Transmission

- Line Coding – Characteristics Signal Element versus data Element



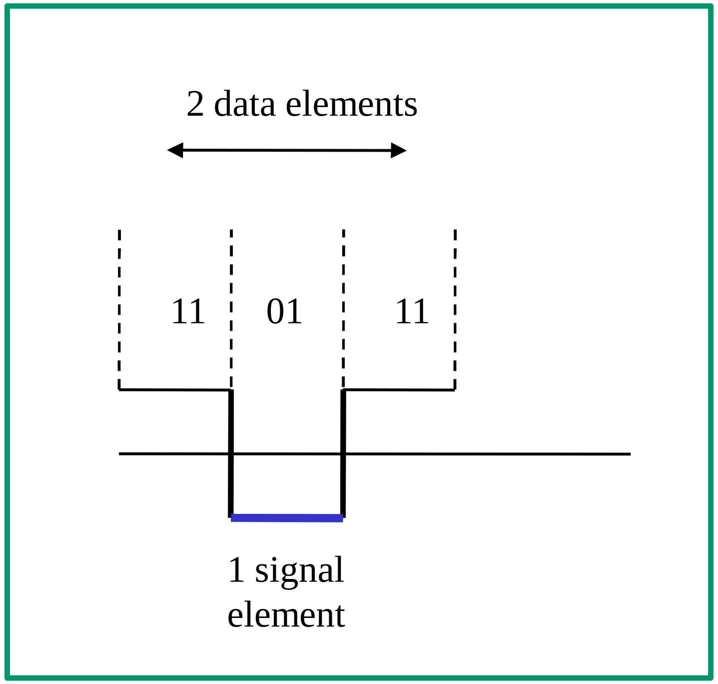
a. One data element per one signal element (r=1)



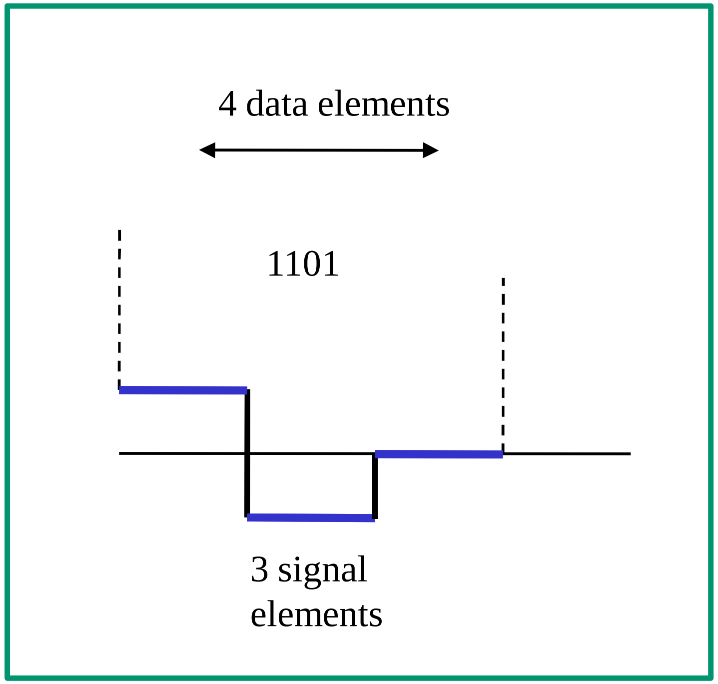
b. One data element per two signal elements (r=1/2)

Digital Transmission

- Line Coding – Characteristics Signal Element versus data Element



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



d. Four data elements per three signal elements (r=4/3)

Digital Transmission

- Line Coding - Characteristics
  - 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.
    - 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.

Digital Transmission

- Line Coding - Characteristics
  - – Bandwidth
    - Most digital signals have a bandwidth with infinite values. In other words, the bandwidth is theoretically infinite, but many of the components have such a small amplitude that they can be ignored. The effective bandwidth is finite.
    - The baud rate, not the bit rate, determines the required bandwidth for a digital signal.

Digital Transmission

- Line Coding - Characteristics
  - Baseline wandering
    - In decoding a digital signal, the receiver calculates a running average of the received signal power – 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 the receiver to decode correctly.
    - Line coding scheme needs to prevent this baseline wandering.

Digital Transmission

- Line Coding - Characteristics
  - 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, presents problems for a system that cannot pass low frequencies or a system that uses electrical coupling.

Digital Transmission

- Line Coding - Characteristics
  - Self-Synchronization
    - To correctly interpret the signals 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 signals.

Digital Transmission

- Line Coding - Characteristics
  - Self-Synchronization
    - A self-synchronizing digital signal includes timing information in the data being transmitted.
    - 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 synchronization, these points can reset the clock.

Digital Transmission

- Line Coding - Characteristics
  - Built –in error detection
    - It is desirable to have a built-in error detecting capability in the generated code to detect some or all the errors that occurred during transmission.
    - Some encoding scheme have this capability to some extent.

Digital Transmission

- Line Coding - Characteristics
  - Immunity to Noise and Interference
    - Another code characteristic is a code that is immune to noise and other interferences.
    - Some encoding scheme have this capability.

Digital Transmission

- Line Coding - Characteristics
  - Complexity
    - A complex scheme is more costly to implement than a simple one.
    - For example, encoding scheme that uses four signal levels is more difficult to interpret than one that uses only two levels.

Digital Transmission

- Line Coding Schemes
  - Unipolar
    - NRZ
  - Polar
    - NRZ
    - RZ
    - Biphase
      - Manchester
      - Differential Manchester

Digital Transmission

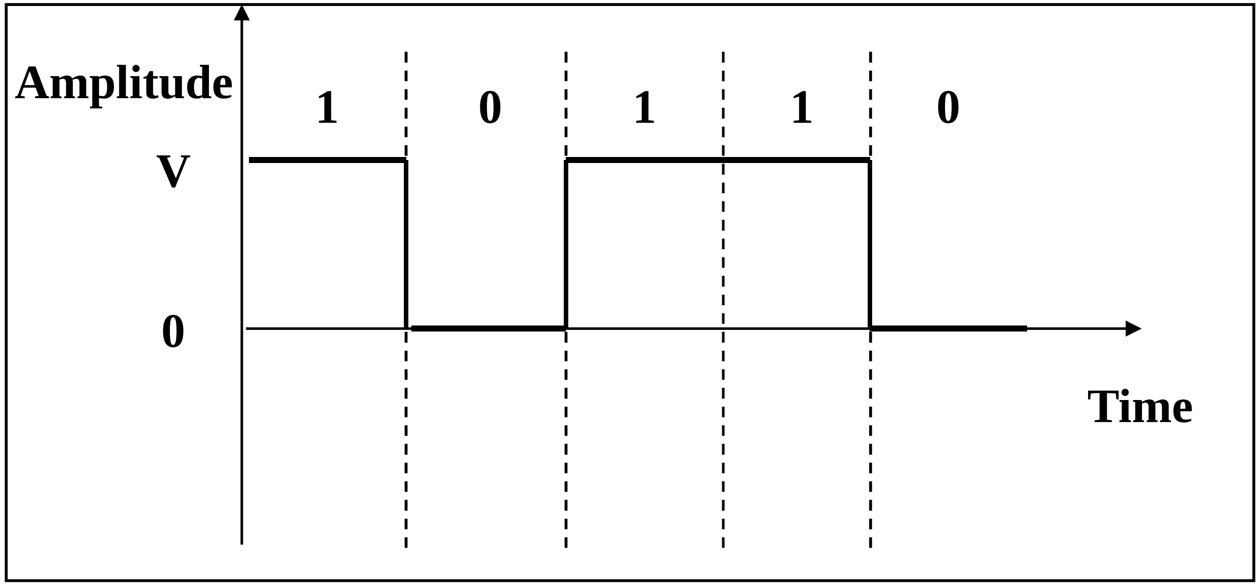
- Line Coding Schemes – Unipolar
  - All the signal levels are on one side of the time axis, either above or below.

Digital Transmission

- 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 showed next gives a unipolar NRZ scheme.

Digital Transmission

- Line Coding Schemes – Unipolar – NRZ scheme



Digital Transmission

- Line Coding Schemes – Polar
  - The voltages are on the both sides of the time axis.
  - The voltage level for 0 can be positive and the voltage level for 1 can be negative.
  - Polar encoding is divided into basic 3 types and 2 subdivided
    - NRZ
      - NRZ-L
      - NRZ-I
    - RZ
    - Biphase
      - Manchester
      - Differential Manchester

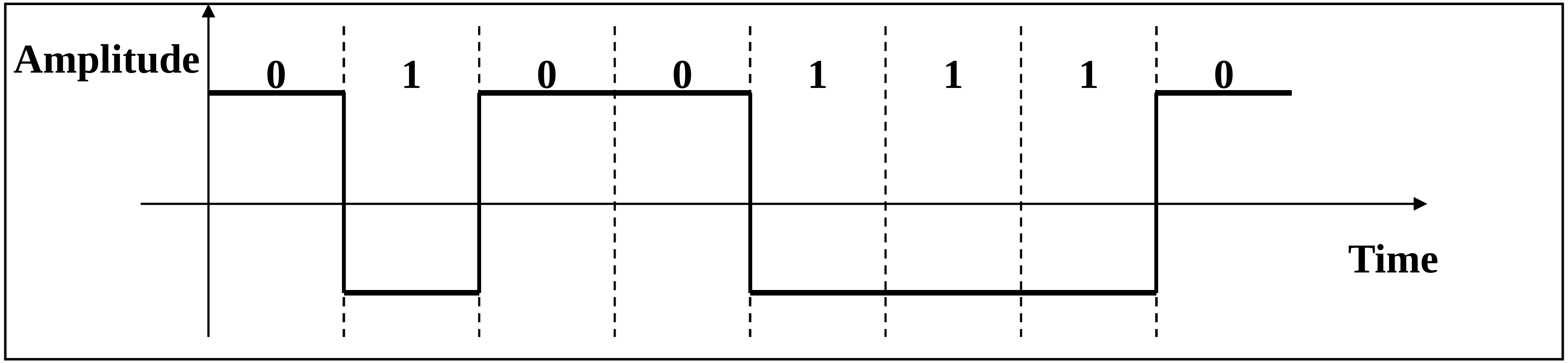
Digital Transmission

- Line Coding Schemes – Polar : NRZ
  - In NRZ, we use two levels of voltage amplitude positive or negative.
  - Two popular methods of NRZ encoding are:
    - NRZ-L (NRZ – Level)
      - The level of the voltage determines the value of the bit.
      - A positive voltage is for 0 and negative voltage is for 1.
    - NRZ-I (NRZ – Invert)
      - The change or lack of change in the level of the voltage determines the value of the bit.
      - If there is no change, the bit is 0; if there is a change, the bit is 1.

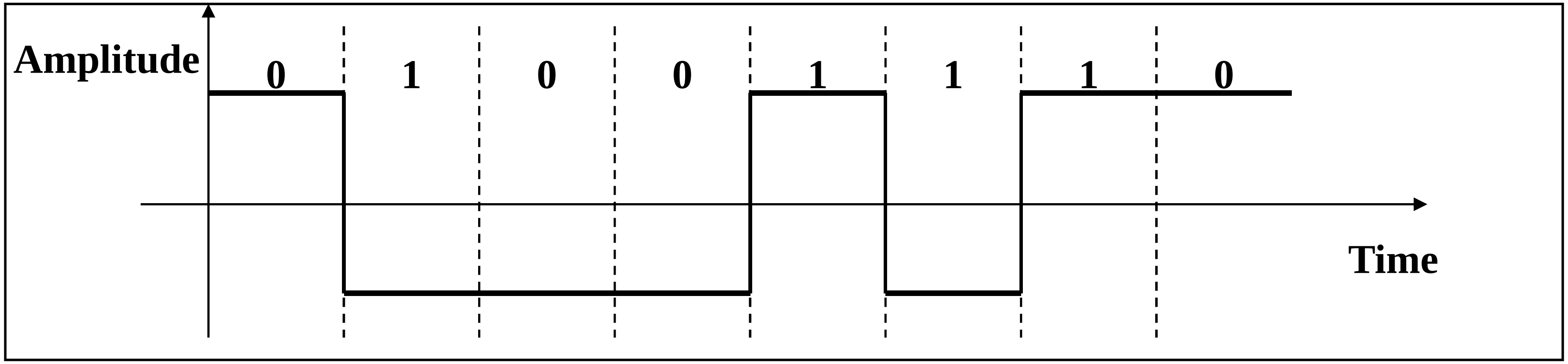
Digital Transmission

- Line Coding Schemes – Polar : NRZ

NRZ – L



NRZ – I

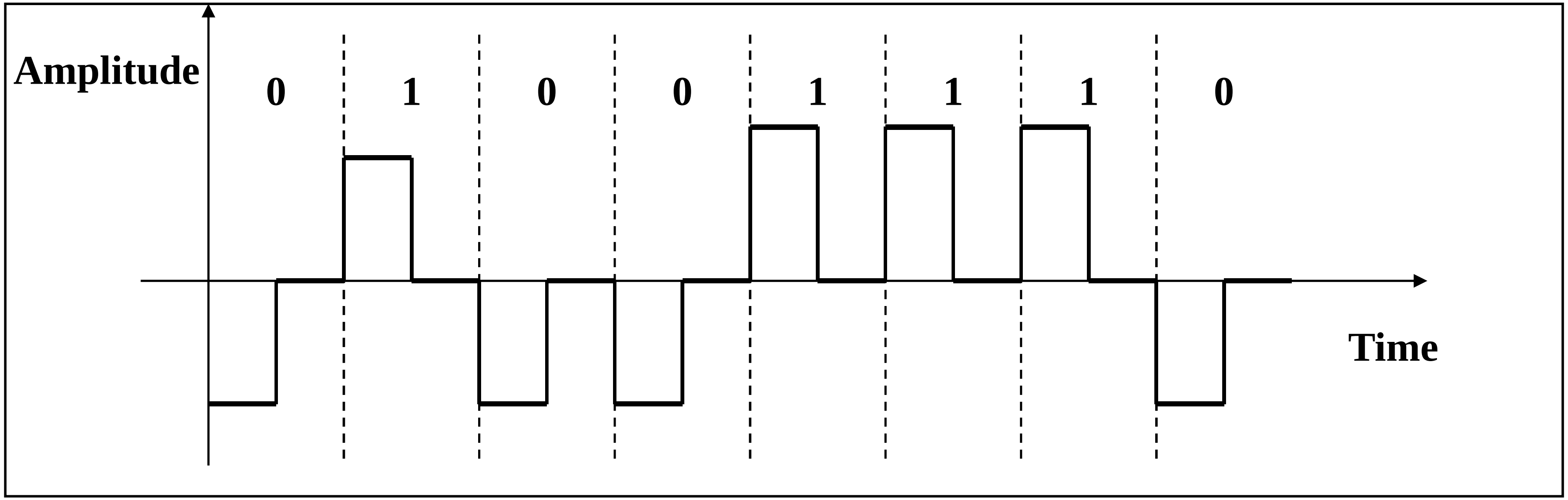


Digital Transmission

- Line Coding Schemes – RZ
  - RZ -Return to Zero uses three levels: Positive, Zero and Negative.
  - The signal changes not between bits but during each bit.
  - Like NRZ-L a positive voltage means 1 and negative voltage means 0. But unlike NRZ-L halfway through each interval, the signal returns to zero.
  - A 1 bit is actually represent by positive to 0 and 0 bit by negative to 0, rather than positive and negative alone.
  - Drawback is it requires more bandwidth due to two signal changes.

Digital Transmission

- Line Coding Schemes – RZ



Digital Transmission

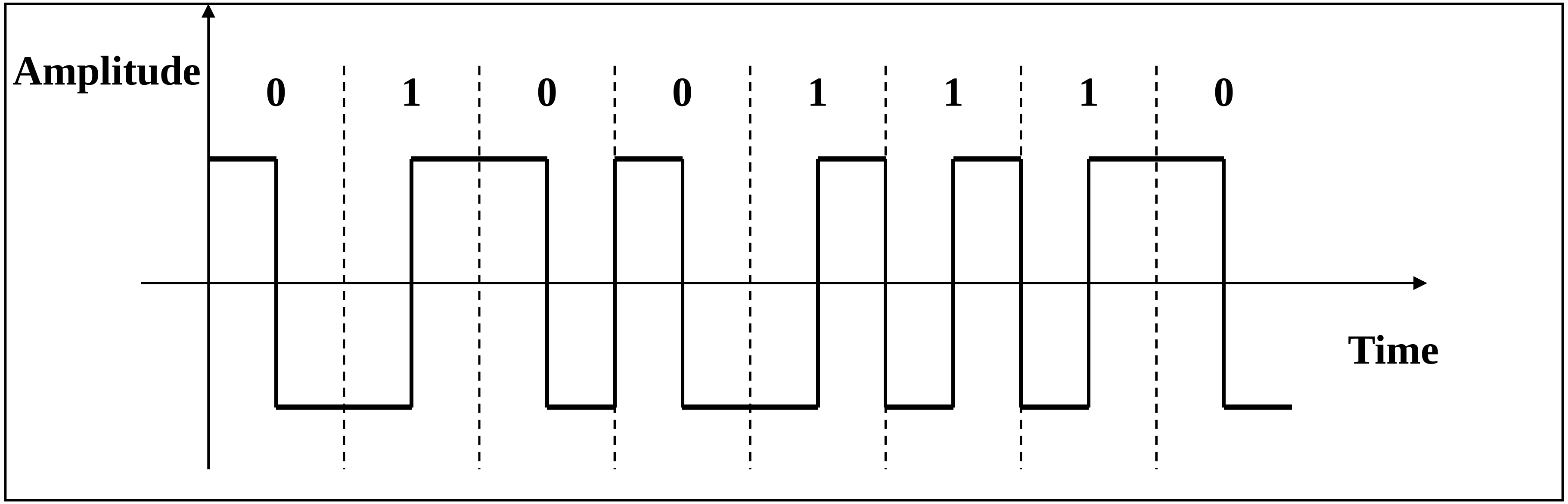
- Line Coding Scheme – Biphase
  - To solve the problem of synchronization
  - The signal changes at the middle of the bit interval but does not return to zero. It continues to opposite pole. Mid transition allow for synchronization
  - Two types
    - Manchester
    - Differential Manchester

Digital Transmission

- Line Coding Scheme – Biphase – Manchester
  - Uses the inversion at the middle of each bit interval for both synchronization and bit representation
  - A negative to positive transition represents binary 1 and positive to negative transition represents 0.
  - By using single transition for dual purpose, Manchester encoding achieves same level of synchronization as RZ but with two levels of amplitude.

Digital Transmission

- Line Coding Scheme – Biphase – Manchester

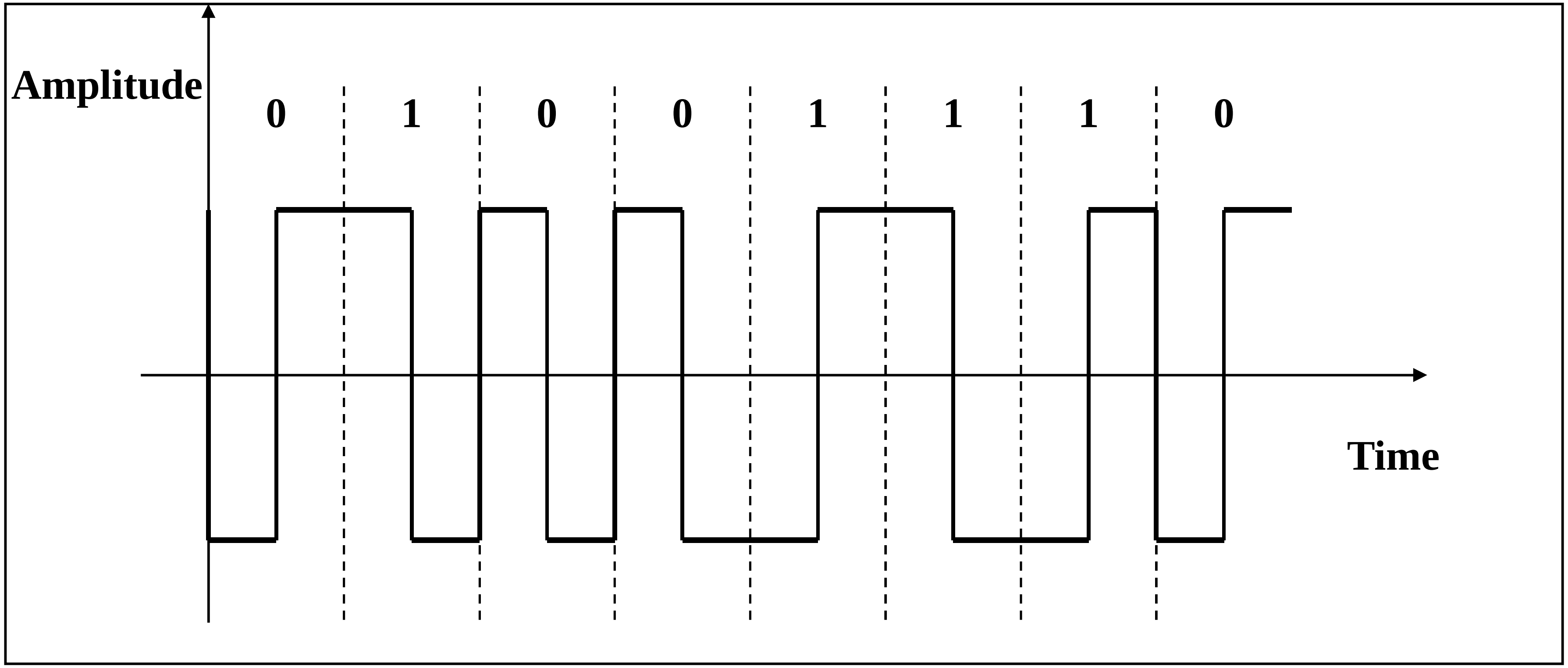


Digital Transmission

- Line Coding Schemes – Biphase - Differential Manchester
  - The inversion at middle of the bit interval is used for synchronization, but presence or absence of an additional transition at beginning of interval is to identify bit.
  - A transition means binary 0 and no transition means binary 1.
  - Two signal changes to represent binary 0 but only one signal change for 1.

Digital Transmission

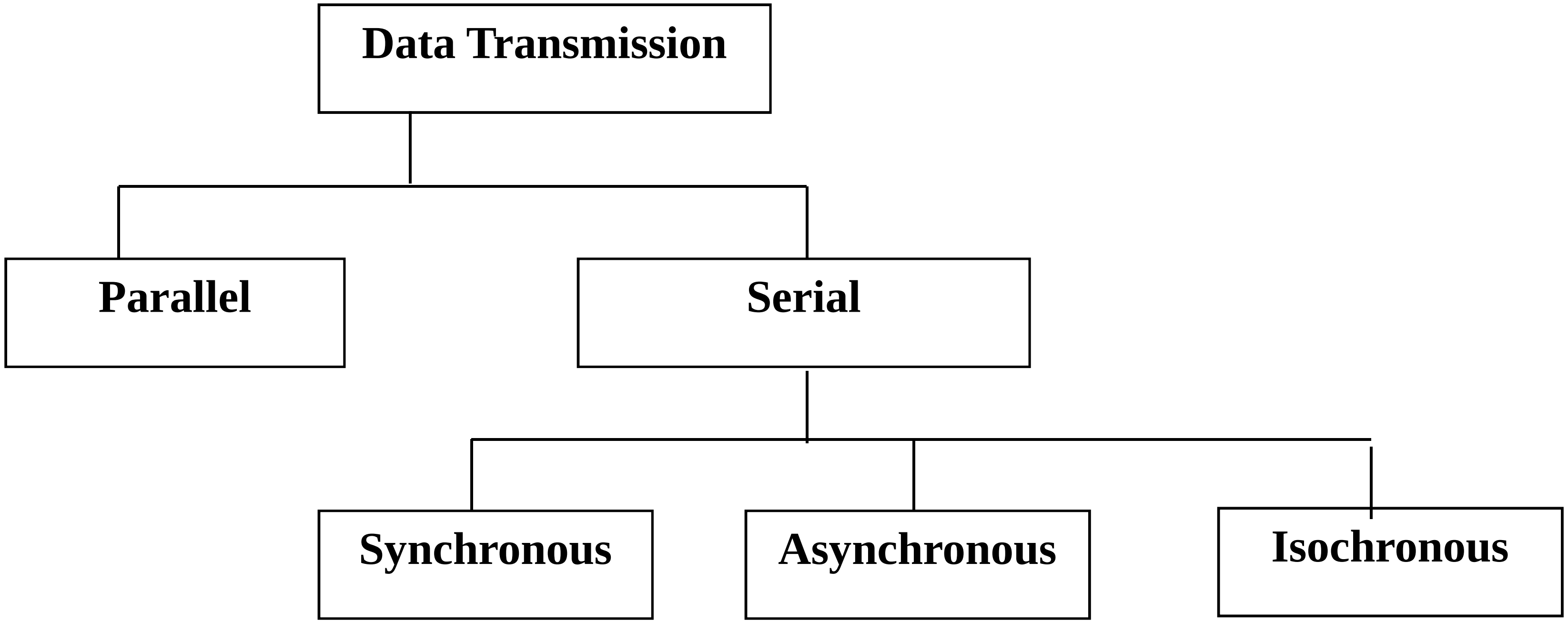
- Line Coding Schemes – Biphase - Differential Manchester



Transmission Mode

- 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.
- There is only one way to send parallel data, there are three subclasses of serial transmission: asynchronous, synchronous and isochronous.

Transmission Mode



Transmission Mode

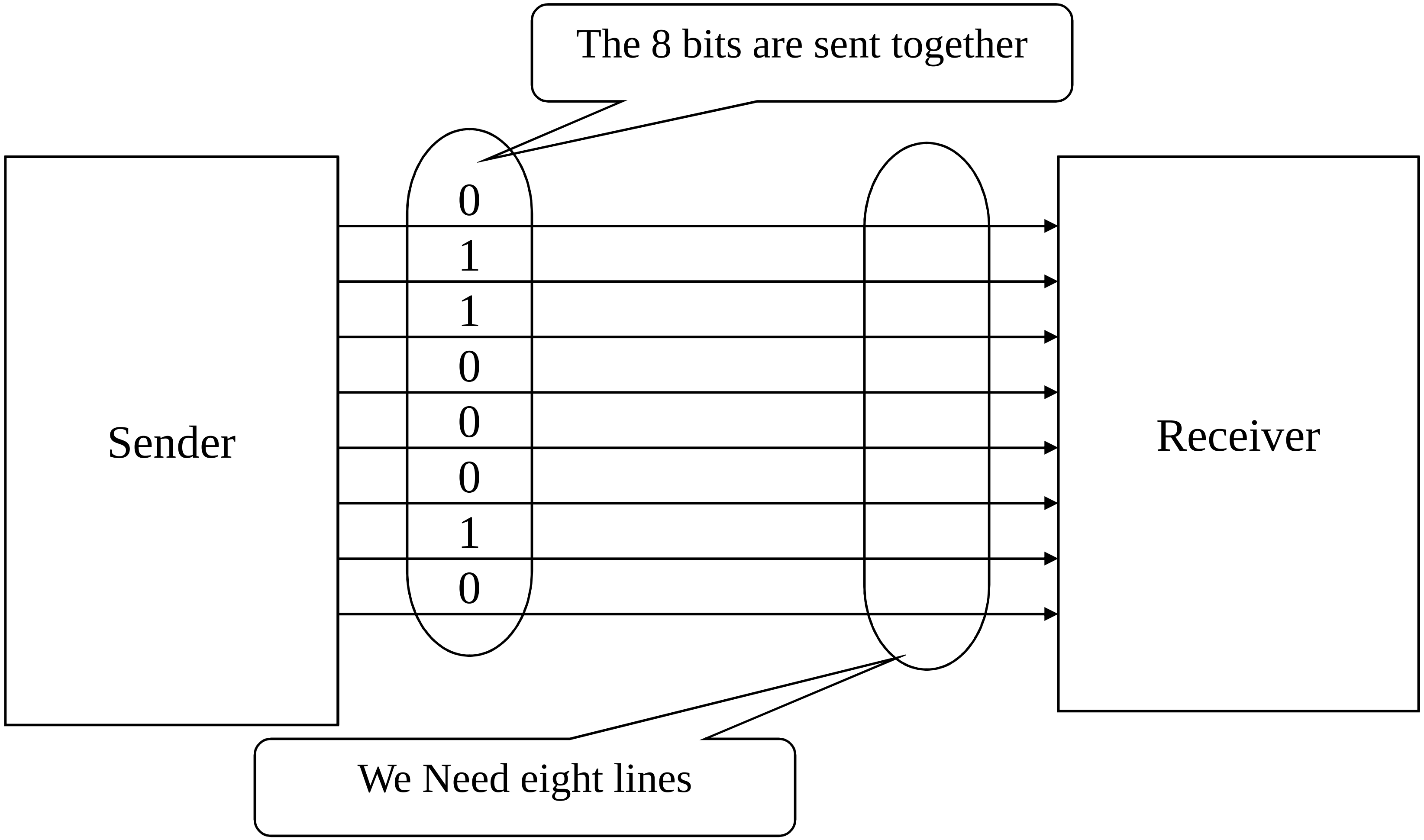
- Parallel Transmission
  - Binary data, consisting of 1s and 0s, may be organized into groups of n bits each.
  - Computers produce and consume data in groups of bits much as we conceive of and use spoken languages in the form of words rather than letters.
  - By grouping, we can send data n bits at a time instead of 1. This is called parallel transmission.

Transmission Mode

- Parallel Transmission
  - The mechanism of parallel transmission is a conceptually simple one: Use n wires to send n bits at one time.
  - Each bit has its own wire, and all n bits of one group can be transmitted with each clock tick from one device to another.
  - Figure showed next has n=8. Typically, the eight wires are bundled in a cable with a connector at each end.

Transmission Mode

- Parallel Transmission



Transmission Mode

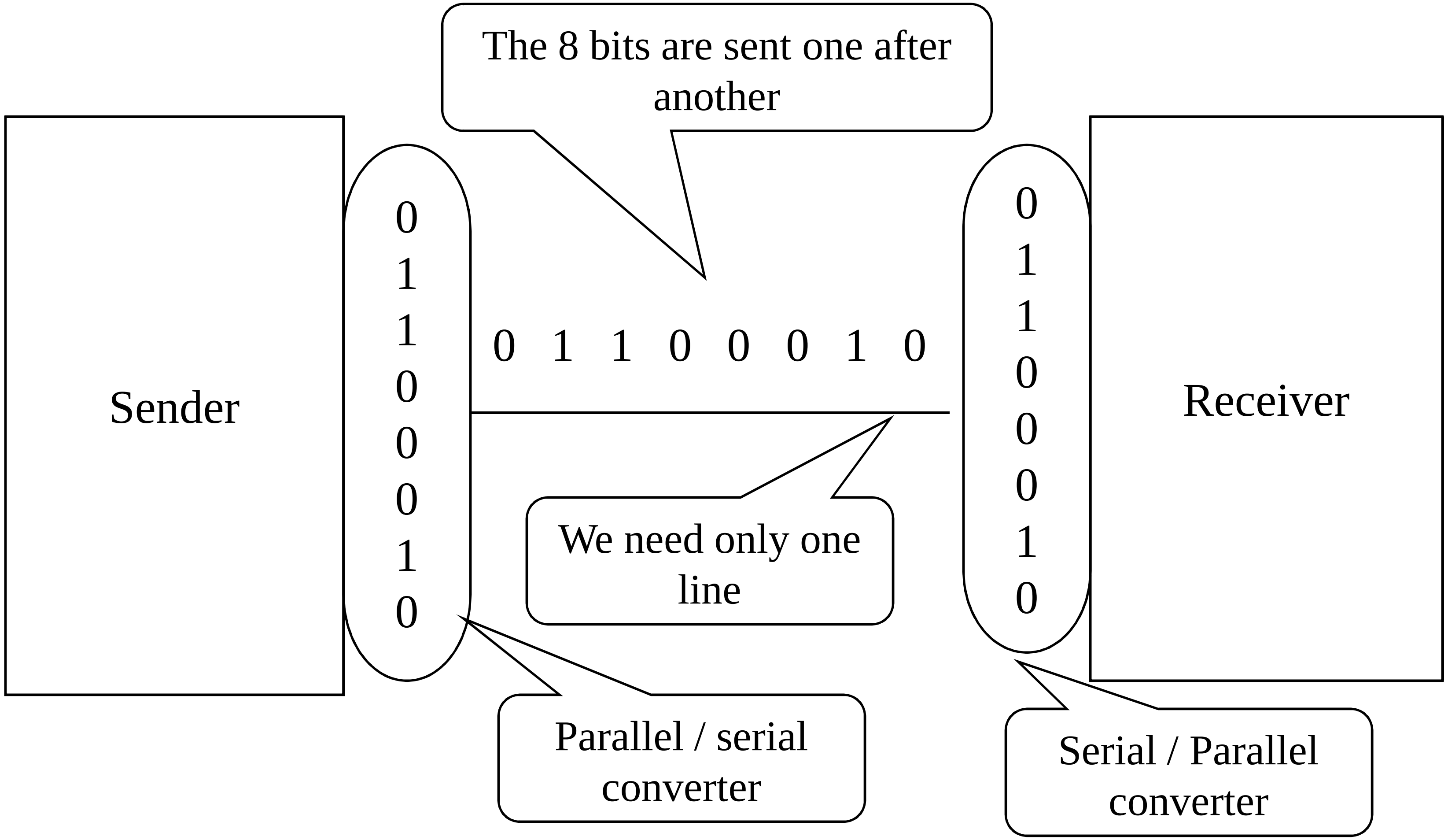
- Parallel Transmission
  - The advantage of parallel transmission is speed. All else being equal, parallel transmission can increase the transfer speed by a factor of n over serial transmission.
  - But there is a significant disadvantage: cost, Parallel transmission requires n communication lines just to transmit the data stream.
  - Since expensive, is usually limited to short distances.

Transmission Mode

- 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.
  - The advantage of serial over parallel transmission is that with only one communication channel, serial transmission reduces the cost of transmission over parallel by roughly a factor of n.
  - Since communication within devices is parallel, conversion devices are required at the interface between the sender and the line (parallel-to-serial) and between the line and the receiver (serial-to-parallel).
  - Serial transmission occurs in one of three ways: asynchronous, synchronous and Isochronous.

Transmission Mode

- Serial Transmission



Transmission Mode

- Serial Transmission - Asynchronous
  - Named so because the timing of a signal is unimportant. Instead information is received and translated by agreed-upon patterns.
  - As long as patterns are followed, the receiving device can retrieve the information without regard to the rhythm in which it is sent.
  - Patterns are based on grouping the bit stream into bytes. Each group, usually 8-bits, is sent along the link as unit.
  - The sending system handles each group independently, relaying it to the link whenever ready, without regard to a timer.

Transmission Mode

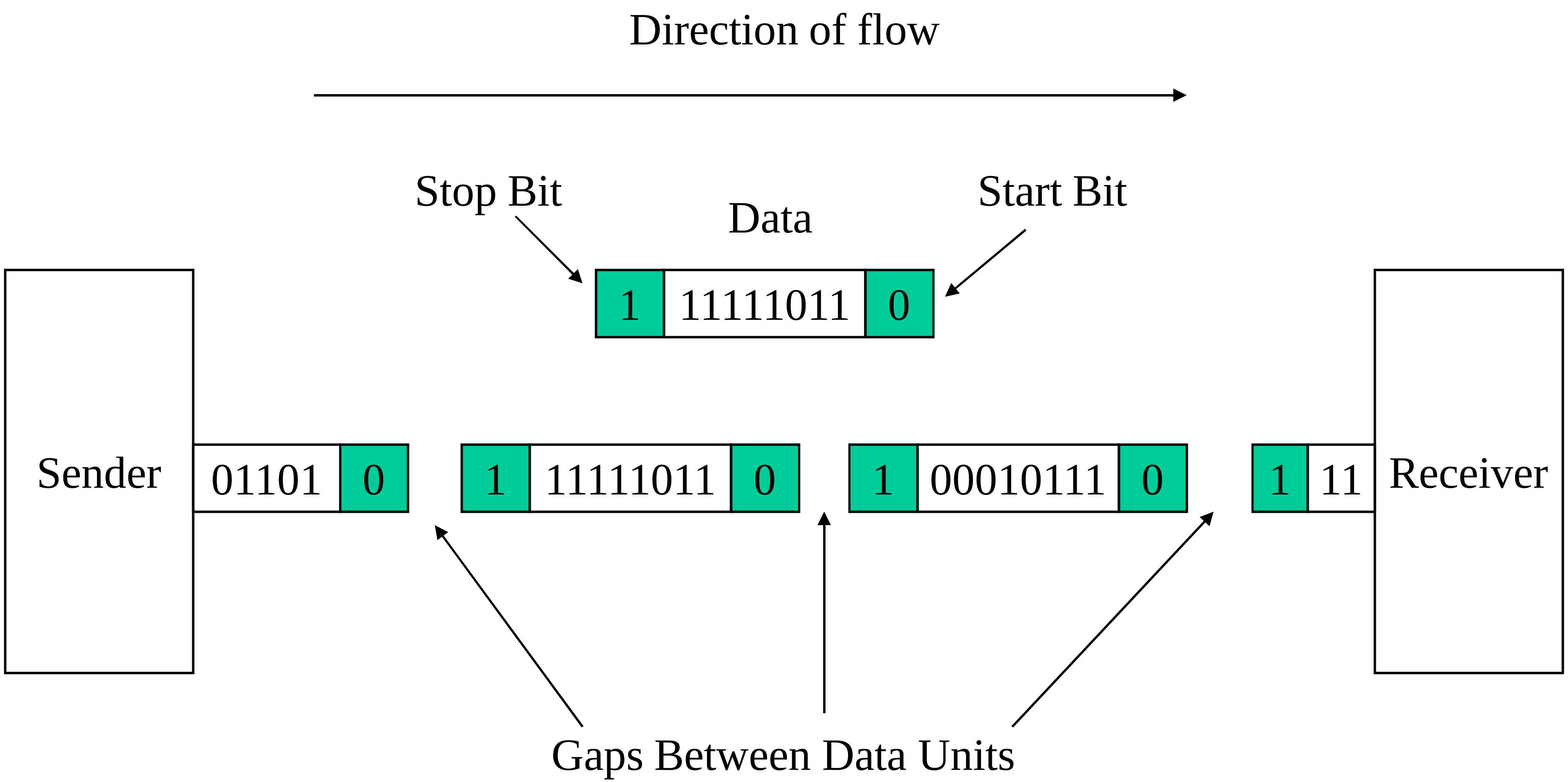
- Serial Transmission - Asynchronous
  - Without synchronization, receiver can’t use timing to predict when the next group will arrive.
  - To alert the receiver to the arrival of a new group, an extra bit is added to the beginning of each byte. This bit usually a 0, is called the start bit.
  - To let the receiver know that the byte is finished, 1 or more additional bits are appended to the end of the byte. These bits, usually 1s are called stop bits.
  - By this method, each byte is increase in size to at least 10 bits, of which 8 are information and 2 or more are signals to the receiver.
  - The transmission of each byte may then be followed by a gap of varying duration, represented by an idle channel or by a stream of additional stop bits.

Transmission Mode

- Serial Transmission - Asynchronous
  - The start and stop bits and the gap alert the receiver to the beginning and end of each byte and allow it to synchronize with the data stream.
  - Mechanism is called asynchronous because, at the byte level, sender and receiver do not have to be synchronized. But within each byte, the receiver must still be synchronized with the incoming bit stream.
  - The receiving device resynchronizes at the onset of each new byte. When receiver detects a start bit, it sets a timer and begins counting bits as they come in.
  - After n bits, the receiver looks for a stop bit, as detects stop bit, it waits until it detects the next start bit.

Transmission Mode

- Serial Transmission - Asynchronous



Transmission Mode

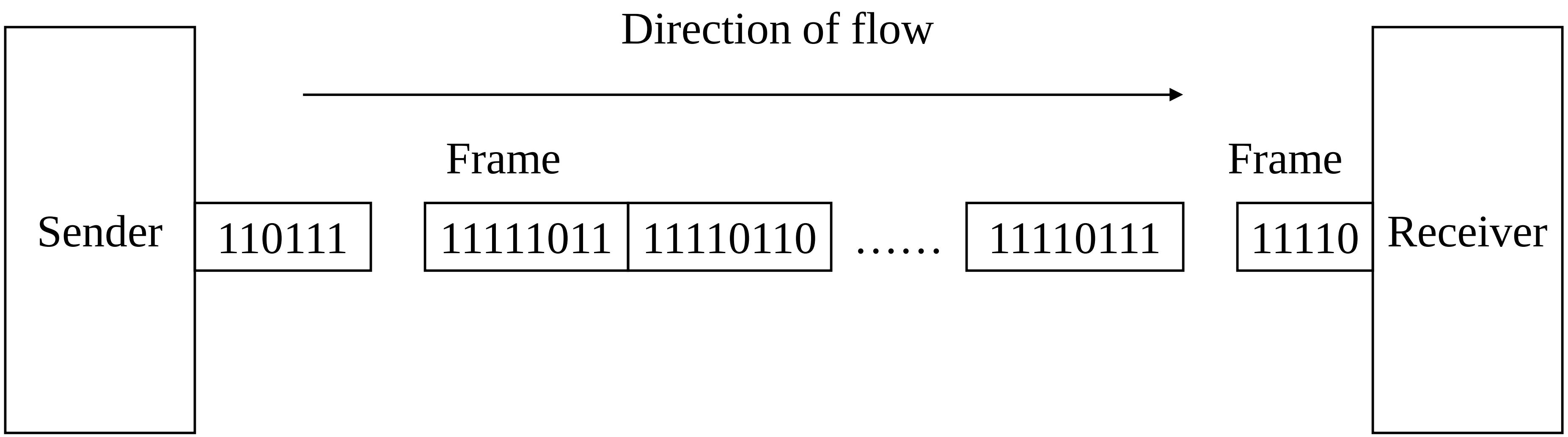
- Serial Transmission - Asynchronous
  - The addition of start and stop bits and the insertion of gaps into the bit stream make asynchronous transmission slower than forms of transmission that can operate without the addition of control information. It is cheap and effective, two advantages that make it attractive choice for situations such as low-speed communication.
  - Example: connection of keyboard to a computer is a natural application for asynchronous transmission. A user types only one character, types extremely slowly in data processing terms and leaves unpredictable gaps of time between each character.

Transmission Mode

- Serial Transmission - Synchronous
  - The bit stream is combined into longer “frames” which may contain multiple bytes. Each byte, is introduced onto the transmission link without a gap between it and the next one.
  - It is left to the receiver to separate the bit stream into bytes for decoding purposes.
  - Data are transmitted as an unbroken string of 1s and 0s, and the receiver separates that string into the bytes, or characters, it needs to reconstruct the information.

Transmission Mode

- Serial Transmission - Synchronous



Transmission Mode

- Serial Transmission - Synchronous
  - In figure we have divisions between bytes. In reality, those divisions do not exist, the sender puts its data onto the line as one long string.
  - If the sender wishes to send data in separate bursts, the gaps between bursts must be filled with a special sequence of 0s and 1s that means idle.
  - The receiver counts the bits as they arrive and groups them in 8-bit units.

Transmission Mode

- Serial Transmission - Synchronous
  - Without gaps and start/stop bits, there is no built-in mechanism to help the receiving device adjust its bit synchronization midstream.
  - Timing becomes important since, the accuracy of the received information is completely dependent on the ability of the receiving device to keep an accurate count of the bits as they come in.

Transmission Mode

- Serial Transmission - Synchronous
  - The advantage is speed. With no extra bits or gaps to introduce at the sending end and remove at the receiving end and by extension, with fewer bits to move across the link, synchronous transmission is faster than asynchronous transmission.
  - It is more useful for high-speed applications such as the transmission of data from one computer to another.
  - Byte synchronization is accomplished in the data link layer.

Transmission Mode

- Serial Transmission – Isochronous
  - In real-time audio and video, in which uneven delays between frames are not acceptable, synchronous transmission fails.
  - For example, TV images are broadcast at the rate of 30 images per second; they must be viewed at the same rate. If each image is sent by using one or more frames, there should be no delays between frames. For this type of application, synchronization between characters is not enough; the entire stream of bits must be synchronized.
  - The Isochronous transmission guarantees that the data arrive at a fixed rate.

Multiplexing - FDM

- An analog technique that can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted.
- Signals generated by each sending device modulate different carrier frequencies.
- These modulated signals are then combined into a single composite signal that can be transported by the link.

Multiplexing - FDM

- Carrier frequencies are separated by sufficient bandwidth to accommodate the modulated signal.
- These bandwidth ranges are the channels through which the various signals travel.
- Channels can be separated by strips of unused bandwidth – guard bands – to prevent signals from overlapping.
- Carrier frequencies must not interfere with the original data frequencies.

Multiplexing - WDM

- Designed to use the high-data-rate capability of fiber-optic cable.
- The optical fiber data rate is higher than the data rate of metallic transmission cable.
- Using a fiber-optic cable for one single line wastes the available bandwidth.
- Multiplexing allows us to combine several lines into one.

Multiplexing - WDM

- WDM is conceptually the same as FDM, except that the multiplexing and demultiplexing involve optical signals transmitted through fiber-optic channels.
- Idea is same – we are combining different signals of different frequencies.
- The difference is that the frequency are very high.

Multiplexing - TDM

- TDM is a digital process that allows several connections to share the high bandwidth of a link.
- Instead of sharing a portion of the bandwidth as in FDM, time is shared.
- Each connection occupies a portion of time in the link.
- TDM is, in principle, a digital multiplexing technique.
- Digital data from different sources are combine into one timeshared link.

Multiplexing - TDM

- However, this does not mean that the sources cannot produce analog data; analog data can be sampled, changed to digital data, and then multiplexed by using TDM.

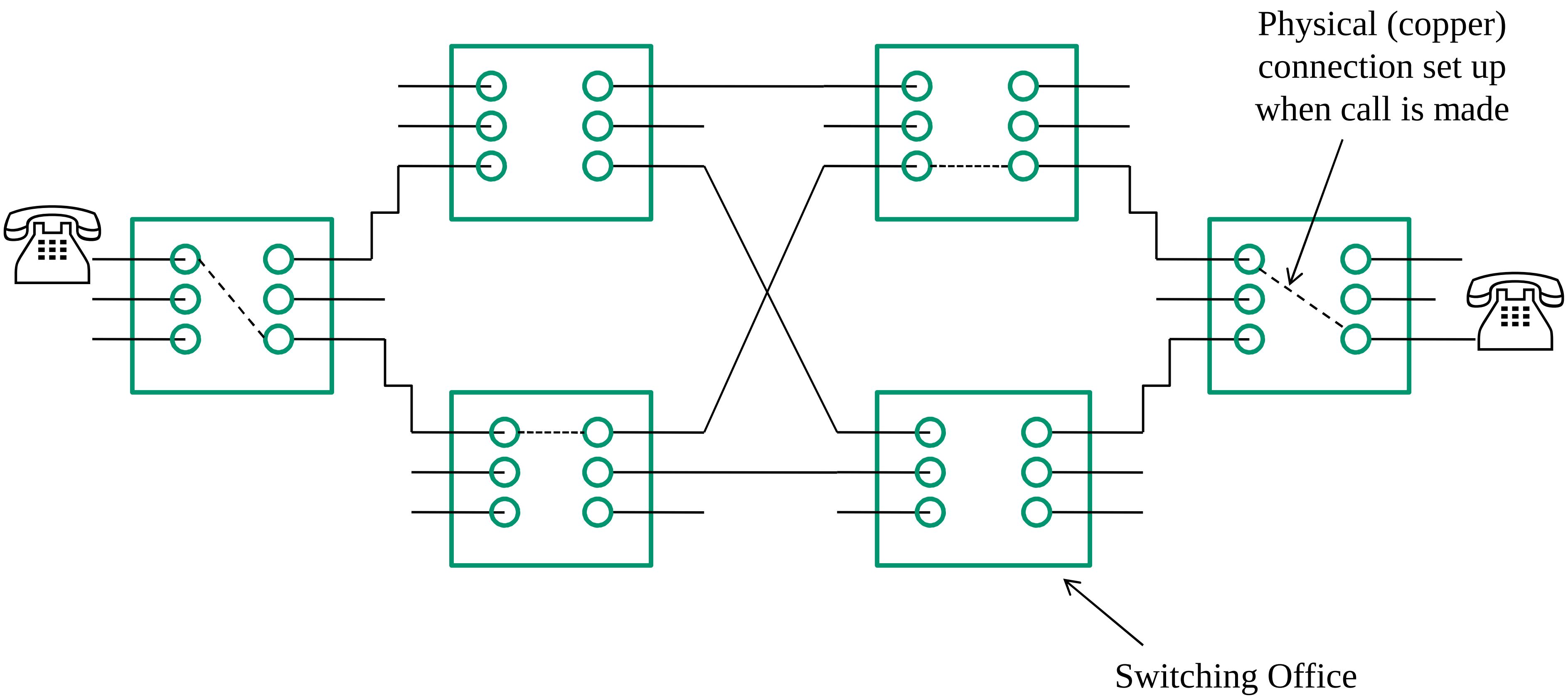
Switching

- The phone system is divided into two parts
  - Outside plant (local loops and trunks, since they are outside office)
  - Inside plant (the switches)
- Different switching techniques are used:
  - Circuit switching
  - Message switching
  - Packet switching

Circuit Switching

- When you or your computer places telephone call, the switching equipment within telephone system seeks out physical “copper” path all the way from your telephone to receiver’s telephone.
- This technique is called as “Circuit switching” as:

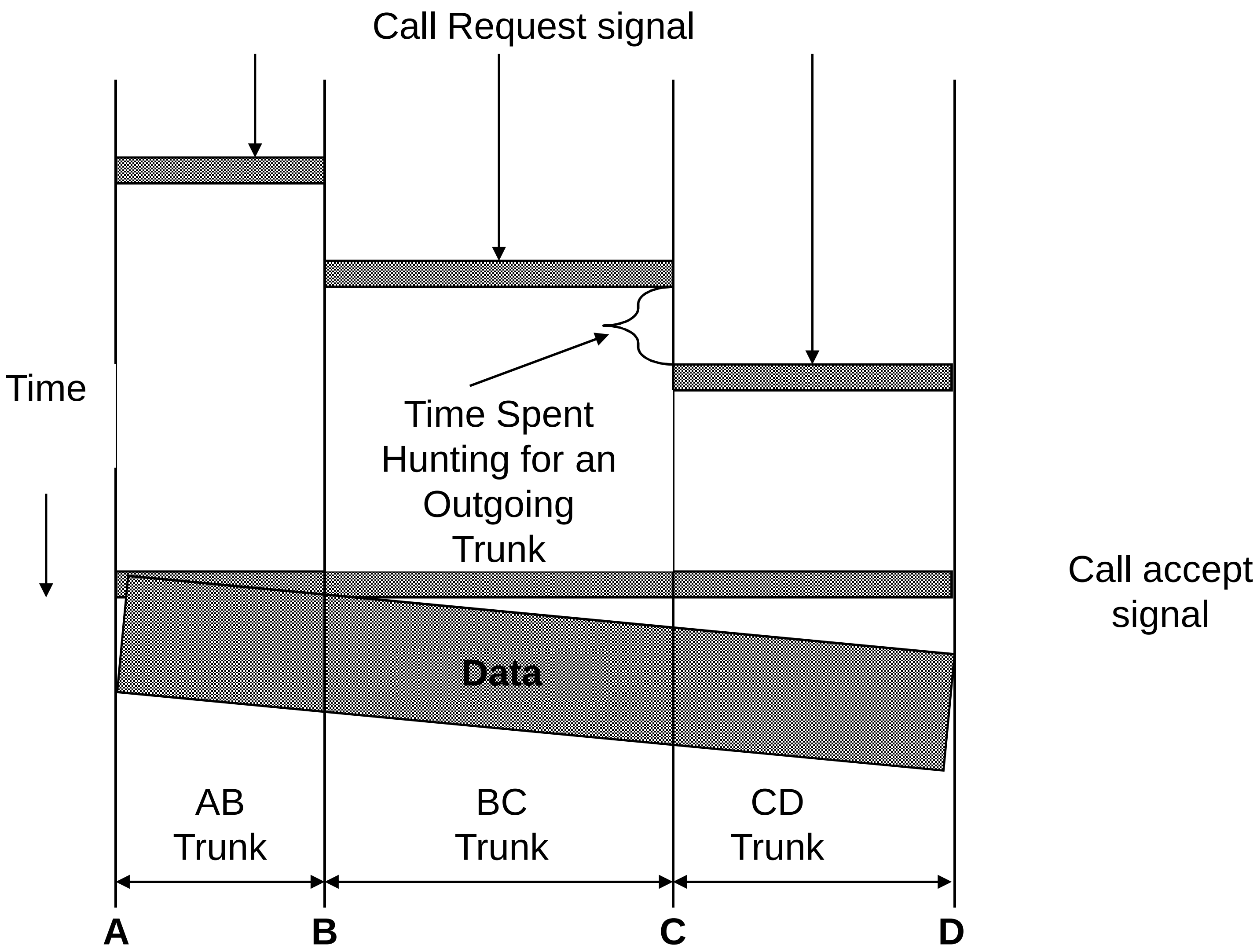
Circuit Switching



Circuit Switching

- Each of six rectangles represents a carrier switching office (end office, toll office)
- Each office has three incoming lines and three outgoing lines.
- When call passes through switching office physical connection is established between the line on which call came in and one of output line shown by dotted line

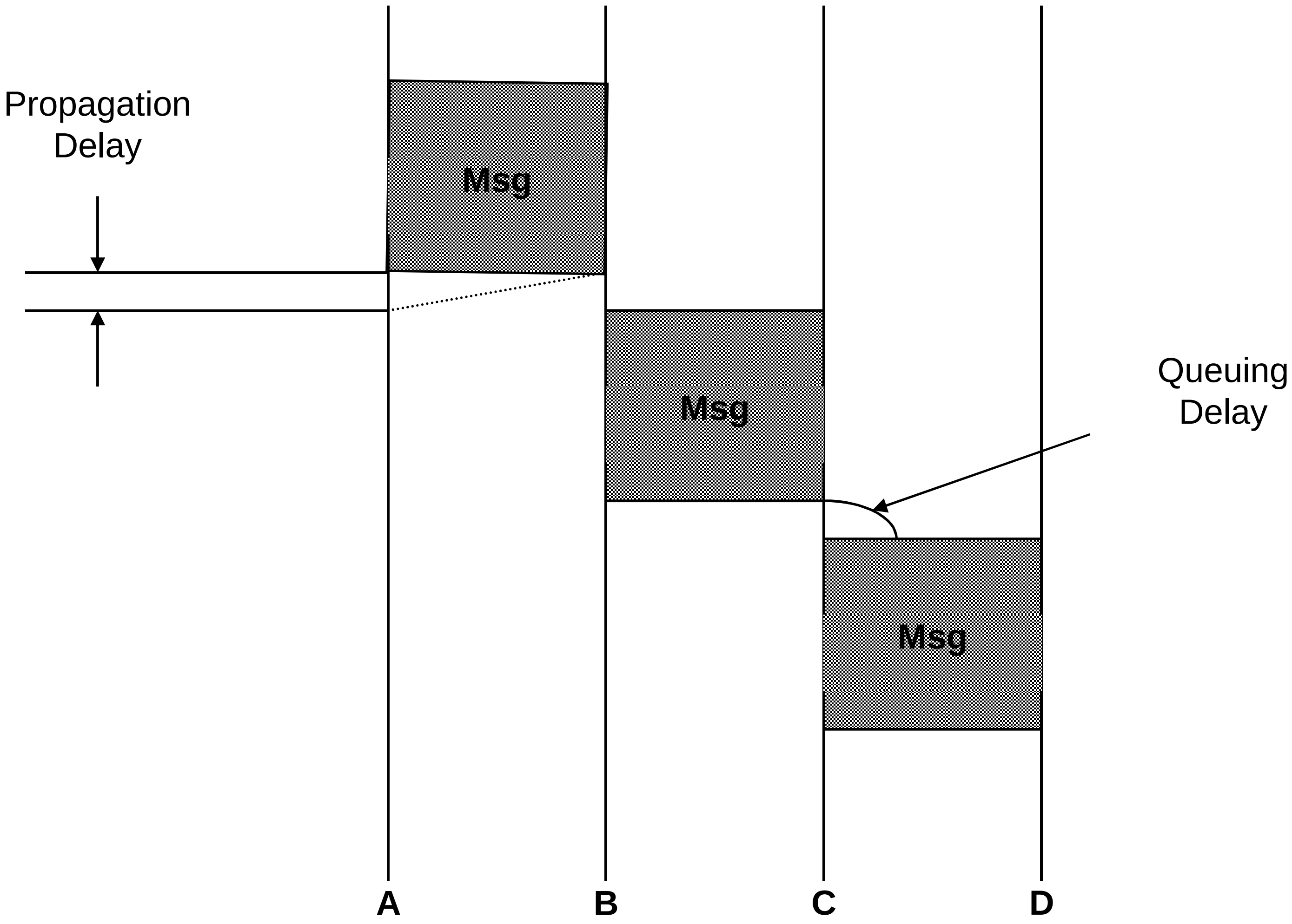
Circuit Switching



Message Switching

- Here no physical path is established in advance between sender and receiver
- When sender has block of data to be sent, it is stored in first switching office and then forwarded later, one hop at time.
- Each block is received, inspected for errors and then retransmitted. Technique is known as "Store and Forward" network.
- No limit on block size, routers must have disks to buffer long blocks.

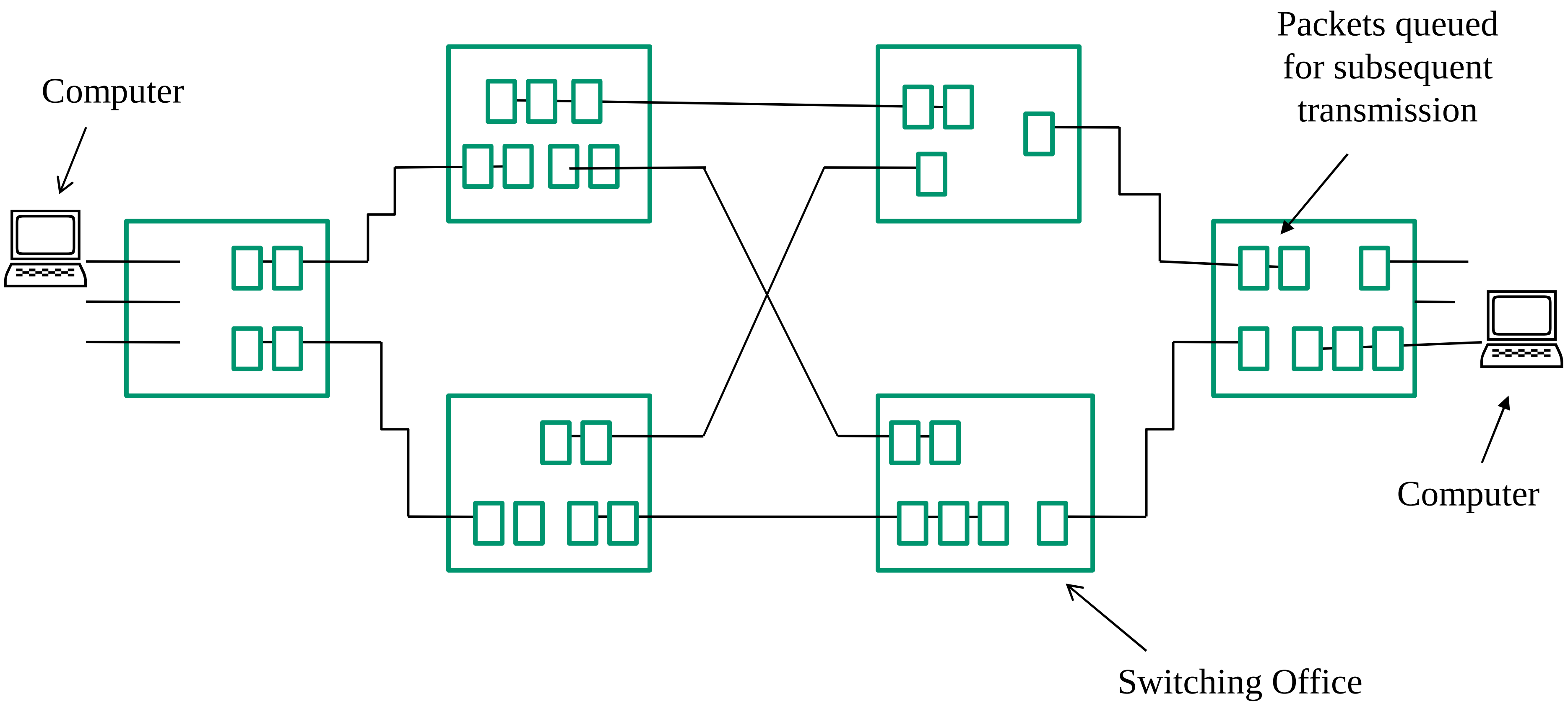
Message Switching



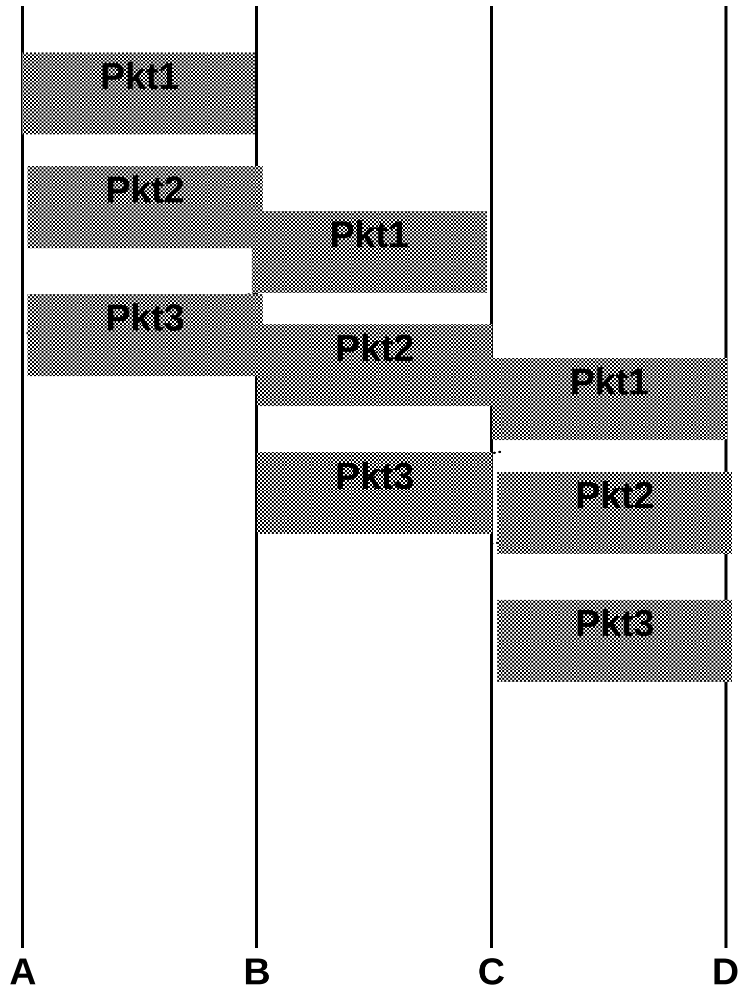
Packet Switching

- Place a tight upper limit on block size, allowing packets to be buffered in router main memory instead on disk.
- Packet switching networks are more suited to handling interactive traffic.
- The first packet of multipacket message can be forwarded before the second one has fully arrived reducing delay and improving throughput
- Thus computer networks are packet switched or circuit switch but never message switching.

Packet Switching



Packet Switching



Comparison of Circuit and Packet Switching

Item	Circuit switched	Packet switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
Time of possible congestion	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

References

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