

Chapter one

Data Communication Basics

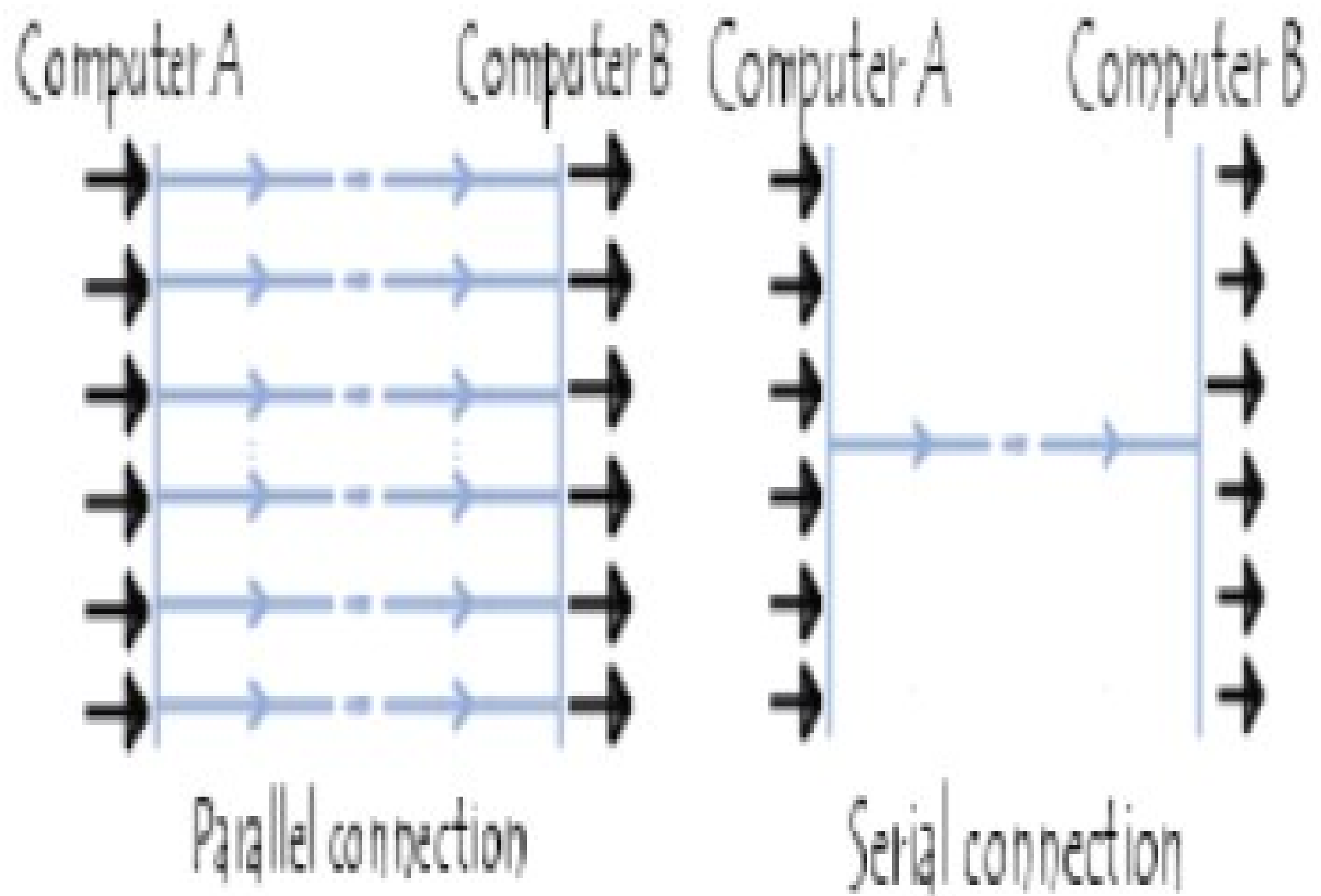
- Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable.
- For data communications to occur, the communicating devices must be part of a communication system made up of a combination of hardware (physical equipment) and software (programs).

Five components of data communication

- 1Message:** is the information (data) to be communicated. Popular forms of information include text, numbers, pictures, audio, and video.
- 2Sender:** is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on.
- 3Receiver:** is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.
- 4Transmission medium:** is the physical path by which a message travels from sender to receiver. Some examples of transmission media include twisted-pair wire, coaxial cable, fiberoptic cable, and radio waves.
- 5Protocol:** is a set of rules that govern data communications. It represents an agreement between the communicating devices. Without a protocol, two devices may be connected but not communicating, just as a person speaking French cannot be understood by a person who speaks only Japanese.

Serial vs. parallel communications

- In serial communications
 - A single bit will be transferred at a time using the communication channel
 - Bits will be reassembled at the destination
 - Mostly used by computer peripherals like printers,
- In parallel communications
 - Multiple bits (eg. Eight bits) will be transferred at a time
 - Needs multiple (parallel) communication channels



Definitions

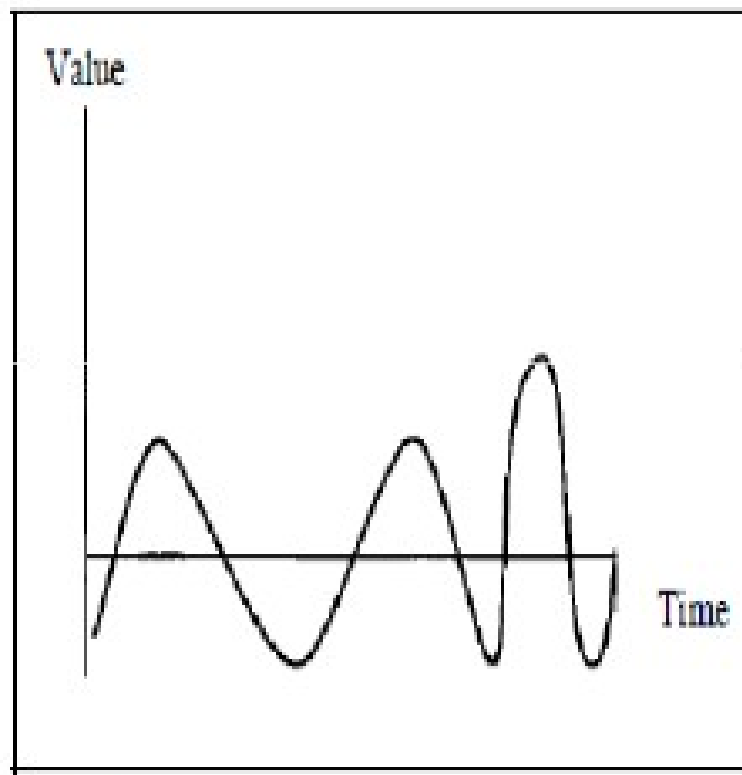
- The word ***data*** refers to information presented in whatever form is agreed upon by the parties creating and using the data.
- ***Signal***: the electrical wave that is used to represent the data. Can be analog or digital signal
- ***Data communications (Transmission)*** are the exchange of data between two devices via some form of transmission medium such as a wire cable using appropriate signal.
- ***Network*** is a system in which a number of independent computers are linked together to share data and peripherals, such as hard disks and printers (more in the next chapters)

Data Representation Techniques

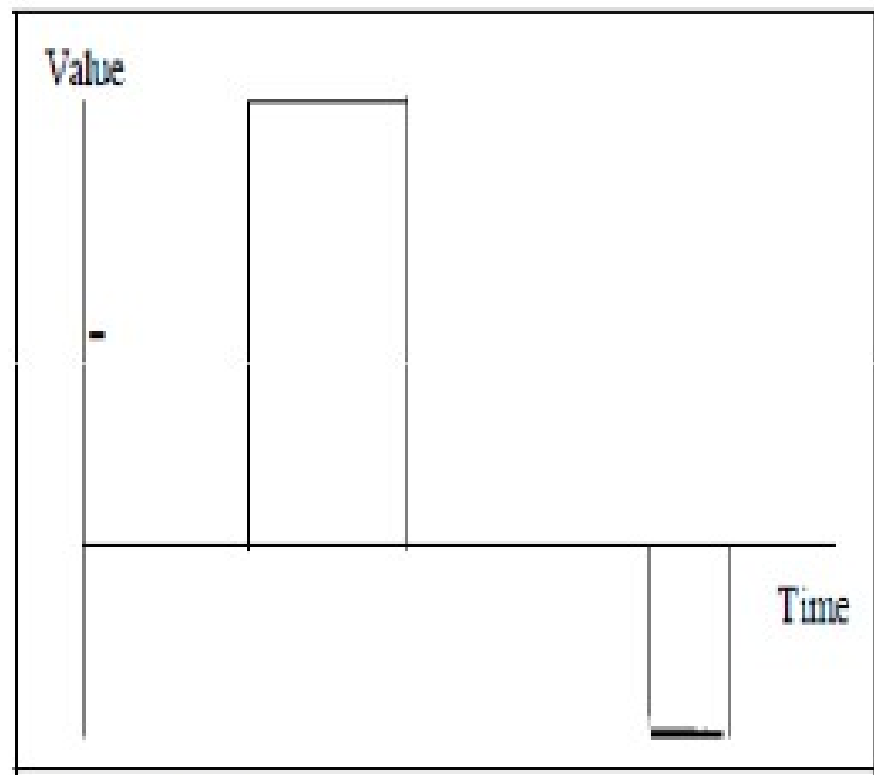
- The type of data to be transmitted can be in the form of text, audio, and video in the form of electrical signal, radio, laser, or other radiated energy source.
- Data can be analog or digital
- The term **analog** data refers to information that is continuous; **digital** data refers to information that has discrete states.
- Example analog clock (with second, minute and hour hands) and digital clock

Analog and digital signals

- An analog signal 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 of defined values. Although each value can be any number, it is often as simple as 1 and 0.



a. Analog signal



b. Digital signal

Signals can be analog or digital. Analog signals can have an infinite number of values in a range; digital signals can have only a limited number of values.

Digital Data Transmission Formats:

Synchronous and asynchronous transmission

- **Asynchronous connection:-** in which each character is sent at irregular intervals in time
 - Starts sending a character using START (bit 1 or bit 0)
 - Ends Sending a character using STOP bit (bit 1 or bit 0)
 - Eg. 1 0100 0001 0
- **Synchronous connection:-** transmitter and receiver are paced by the same clock
 - The receiver continuously receives (even when no bits are transmitted) the information at the same rate the transmitter send it. This is why the transmitter and receiver are paced at the same speed. In addition, supplementary information is inserted to guarantee that there are no errors during transmission

Modes of data transmission

- There are 3 different transmission modes characterized according to the direction of the exchanges:

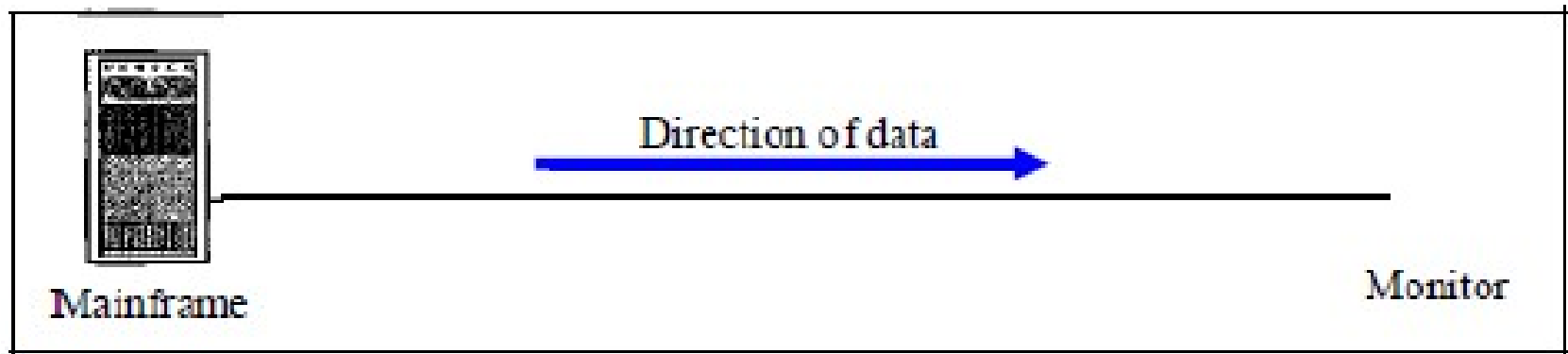
A simplex connection is a connection in which the data flows in only one direction, from the transmitter to the receiver. This type of connection is useful if the data do not need to flow in both directions (for example, from your computer to the printer or from the mouse to your computer...).

A half-duplex connection (sometimes called an *alternating connection* or *semi-duplex*) is a connection in which the data flows in one direction or the other, but not both at the same time. With this type of connection, each end of the connection transmits in turn. This type of connection makes it possible to have bidirectional communications using the full capacity of the line.

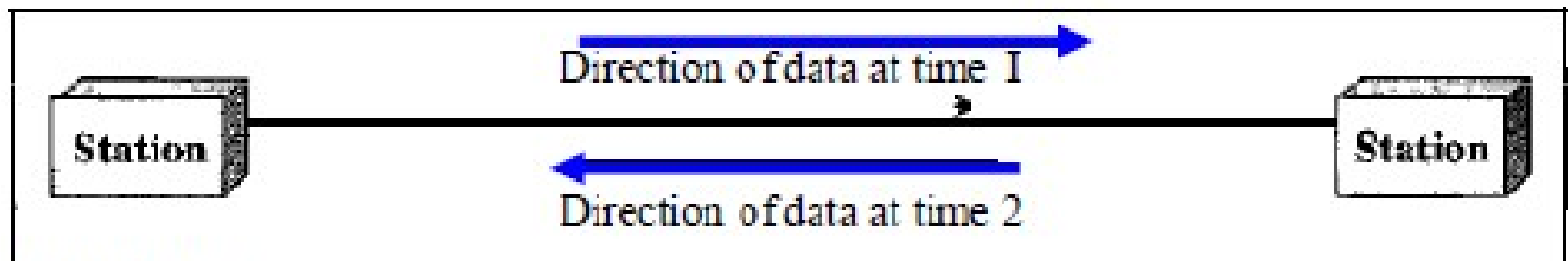
- In a half-duplex transmission, the entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time.
- Walkie-talkies and CB (citizens band) radios are both half-duplex systems.
- The half-duplex mode is used in cases where there is no need for communication in both directions at the same time; the entire capacity of the channel can be utilized for each direction.

Full-Duplex: In full-duplex mode (also called duplex), both stations can transmit and receive simultaneously

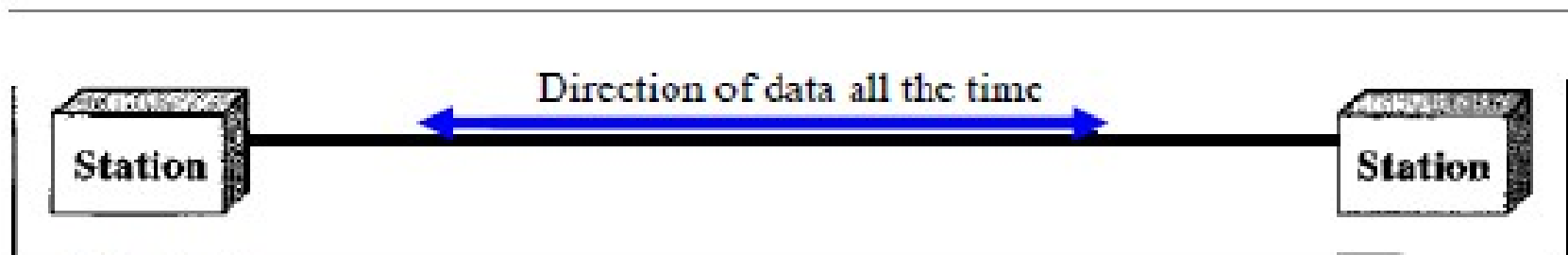
- The full-duplex mode is like a two-way street with traffic flowing in both directions at the same time.
- In full-duplex mode, signals going in one direction share the capacity of the link: with signals going in the other direction.
- This sharing can occur in two ways: Either the link must contain two physically separate transmission paths, one for sending and the other for receiving; or the capacity of the channel is divided between signals travelling in both directions.
- One common example of full-duplex communication is the telephone network. When two people are communicating by a telephone line, both can talk and listen at the same time.
- The full-duplex mode is used when communication in both directions is required all the time.
- The capacity of the channel, however, must be divided between the two directions.



a. Simplex



b. Half-duplex



c. Full-duplex

Signal Encoding techniques

- Digital data:- information that has discrete states
- Analog Data:- information that is continuous
- Digital Signal:- can have only a limited number of defined values.
 - Although each value can be any number, it is often as simple as 1 and 0.
- Analog signal:- 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.

Key data transmission terms.

Term	Units	Definition
Data element	bits	A single binary one or zero.
Data rate	bits per second (bps)	The rate at which data elements are transmitted.
Signal element	Digital: a voltage pulse of constant amplitude.	That part of a signal that occupies the shortest interval of a signaling code.
	Analog: a pulse of constant frequency, phase, and amplitude.	
Signaling rate or modulation rate	Signal elements per second (baud)	The rate at which signal elements are transmitted

Digital Data, Digital Signal

Definition of digital signal encoding formats.

Nonreturn-to-Zero-Level (NRZ-L)

- 0 = high level
- 1 = low level

Nonreturn to Zero Inverted (NRZI)

- 0 = no transition at beginning of interval (one bit time)
- 1 = transition at beginning of interval

Bipolar-AMI

- 0 = no line signal
- 1 = positive or negative level, alternating for successive ones

Pseudoternary

- 0 = positive or negative level, alternating for successive zeros
- 1 = no line signal

Manchester

- 0 = transition from high to low in middle of interval
- 1 = transition from low to high in middle of interval

Differential Manchester

- Always a transition in middle of interval
- 0 = transition at beginning of interval
- 1 = no transition at beginning of interval

B8ZS

- Same as bipolar AMI, except that any string of eight zeros is replaced by a string with two code violations

HDB3

- Same as bipolar AMI, except that any string of four zeros is replaced by a string with one code violation

Assignment

- Describe the following digital signal encoding formats (which format is used by Ethernet?)
 - Non return-to-Zero-Level (NRZ-L)
 - Non return to Zero Inverted (NRZI)
 - Bipolar-AMI
 - Pseudoternary
 - Manchester
 - Differential Manchester

DIGITAL DATA, ANALOG SIGNALS

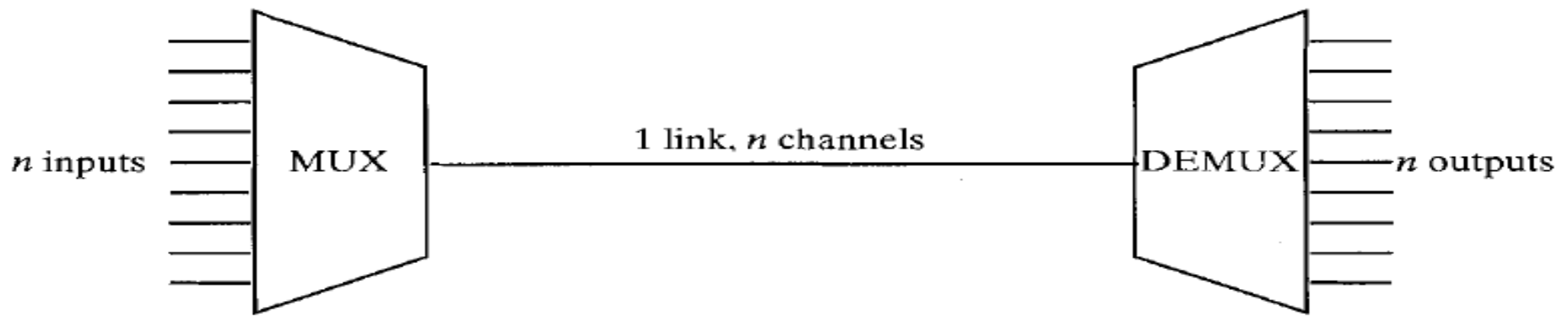
- The most familiar use of this transformation is for transmitting digital data through the public telephone network.
- The telephone network was designed to receive, switch, and transmit analog signals in the voice-voice frequency range of about 300 to 3400 Hz.
- digital devices are attached to the network via a modem (modulator-demodulator), which converts digital data to analog signals, and vice versa.

Digital into Analog Encoding Techniques

- Modulation involves operation on one or more of the three characteristics of a carrier signal: amplitude, frequency, and phase.
- Accordingly, there are three basic encoding or modulation techniques for transforming digital data into analog signals
 - Amplitude-shift keying (ASK)
 - Frequency-shift keying (FSK)
 - Phase-shift keying (PSK)
- Read about these techniques

Multiplexing

- In data communication, there might be a need to share a single media for multiple communication (media sharing)
- Sharing of a single media (fiber, coaxial, microwave,..) is known as multiplexing



- In the above figure, there are n inputs to a multiplexer. The multiplexer is connected by a single data link to a demultiplexer.
- The link is able to carry n separate channels of data. The multiplexer combines (multiplexes) data from the n input lines and transmits over a higher capacity data link.
- The demultiplexer accepts the multiplexed data stream, separates (demultiplexes) the data according to channel, and delivers them to the appropriate output lines.

Types of Multiplexing

- 1. Frequency-division multiplexing (FDM)**
- 2. Time-division multiplexing (TDM)**
- 3. Statistical multiplexing**

Frequency-division multiplexing

- FDM is a signal transmission technology in which multiple signals can simultaneously be transmitted over the same line or channel. Frequency-division multiplexing (FDM) can be used in both wired and wireless networking for transmitting large amounts of data at high speeds. FDM is the simplest and oldest form of multiplexing in wireless networking technology.
- Frequency division multiplexing involves simultaneously transmitting multiple signals on different frequencies. These different frequencies, called channels, share non-overlapping portions of the total frequency band being used. Signals from different data sources are fed into a multiplexer that modulates each signal and transmits them at different frequencies. These signals are then transmitted over the wire or through wireless communication and are separated at the destination into individual data signals using a demultiplexer.

Time-division multiplexing (TDM)

- A multiplexing method for transmitting multiple data streams in a single communication path.
- In TDM, the data from different input channels is divided into fixed-length segments and then combined in round-robin fashion into a single output data stream, which can then be transmitted over a single channel transmission system and demultiplexed at the destination location. The segments can be created by the multiplexer itself or can be inherent in the input channel signals, such as fixed-length frames.

- For example, if input streams A, B, and C are divided into segments as shown here:
 - A: A1, A2, A3,...
 - B: B1, B2, B3,...
 - C: C1, C2, C3,...
 - the output stream will look like this:
 - MUX(ABC) A1, B1, C1, A2, B2, C2, A3, B3, C3,...
- One weakness in TDM is that if an input channel does not have anything important to carry for a time, empty segments are inserted into the output stream anyway. For example, if channel A is not transmitting data, one-third of the output channel is not being used. You can overcome this weakness by using a more sophisticated multiplexing technique called statistical multiplexing

Statistical multiplexing

- It is a multiplexing technique that allows information from a number of channels to be combined for transmission over a single channel.
- Statistical multiplexing dynamically allocates bandwidth to each channel on an as-needed basis. This is in contrast to time-division multiplexing (TDM) techniques, in which quiet devices use up a portion of the multiplexed data stream, filling it with empty packets. Statistical multiplexing allocates bandwidth only to channels that are currently transmitting. It packages the data from the active channels into packets and dynamically feeds them into the output channel, usually on a FIFO (first in, first out) basis, but it's also able to allocate extra bandwidth to specific input channels.
- Statistical multiplexing is sometimes referred to as statistical time-division multiplexing (STDM)

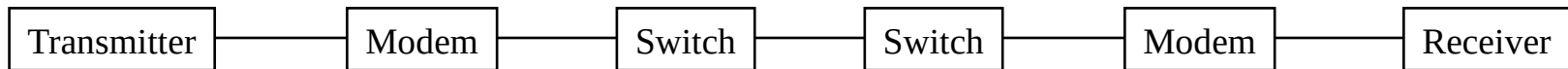
Data Transmission

Error Detection and Correction

- Errors in transmitted data can occur for a variety of reasons.
- Some errors are due to equipment failure.
- Some errors are due dispersion in optical fibers (i.e. light pulses spread out).
- Some errors are due to attenuation (loss of signal power over a line).
- Most errors are due to thermal noise that occurs naturally on the line.

Dealing with Equipment Failure

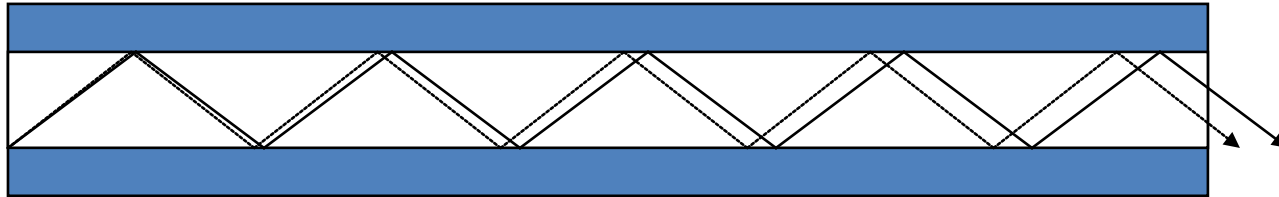
- The more pieces of equipment that your signal needs to pass through, the more likely it is that you'll have a failure.



- Fewer intermediate devices or more reliable devices will reduce the probability of failure.
- Redundant devices can also reduce the probability of failure by taking over from other devices when they fail.

Dispersion

- Dispersion mainly occurs in optical fibers.



- A light pulse is made of billions of photons. Each photon follows a slightly different path as it bounces along the optical fiber.
- A crisp light pulse will eventually spread out and overlap with other pulses.

Attenuation

- Attenuation is the reduction in the power of a signal as it is transmitted.
- Attenuation is a problem because the signal eventually loses so much power that it becomes difficult to distinguish it from the thermal noise in the background

Dealing With Errors

- We need to build systems that are resilient to errors in data.
- There is no way to guarantee that all bits will be sent uncorrupted.
- One way to cope with this is to detect errors and request that corrupted data should be retransmitted.
- Detecting errors cannot be guaranteed either. We can at least make it extremely unlikely that errors will go undetected.

Errors in Data

- Data is sent in the form of binary numbers.
- The binary numbers consist bites - which are either 0 or 1.
- There are four possible ways that noise can affect a bit:
 - If a bit is 0, the noise can affect it so it stays 0 – no error
 - If a bit is 0, the noise can change it to 1
 - If a bit is 1, the noise can affect it so it stays 1 - no error
 - if a bit is 1, the noise can change it to 0

Pure Noise

- If the noise is overwhelming then (with some surprise perhaps) we will still receive half the bits correctly.
- The problem is that there is no way of telling which bits are correct and which bits are not.
- The data is no better than if we generated the bits randomly.

Detecting Errors

- Usually, noise levels are fairly low and most of the bits are received correctly by the receiver.
- The question is, how can the receiver know when an error has occurred?
- Because errors occur randomly, there is no way of knowing with complete certainty if the data is correct.
- The best we can do is detect most errors.

Detecting Errors

- We could try sending the data twice and comparing the two transmissions to see where the errors are.
- This is inefficient, particularly if all we want to know is if there is an error in a particular block of data.
- Even when we detect an error, the next question is: what to do about it?

Parity Checking (Vertical Redundancy Check (VRC))

- One of the most common ways of checking to see if an error is to count the bits in a character to see if there is an even or odd number.
- Before transmission, an extra bit (parity bit) is appended to the character to force the number of bits to be even (or odd).
- If the received character does not have an even (or odd) number of bits then an error must have occurred.

Parity

- Both the sender and receiver must know which form of parity to use.
- A character such as 0110001 would be transmitted as:

Odd Parity: 01100010 (There are an odd number of 1s)

Even Parity: 01100011 (There are an even number of 1s)

- Parity checking will detect a single error in a character but not double errors.

Hamming Distance

- The Hamming distance between two bit patterns is the number of dissimilar bits.
- It measures the minimum number of *substitutions* required to change one string into the other, or the number of *errors* that transformed one string into the other.
- For example, the Hamming distance between 01000001 ('A') and 01000011 ('C') is 1 because there is only one dissimilar bit.
- One error in the wrong place can turn an 'A' into a 'C'.

Hamming Distance

- The Hamming distance between 01000001 ('A') and 01000010 ('B') is 2 because there are two dissimilar bits.
- It would take two errors in the wrong place to turn an 'A' into a 'B'.
- Adding a parity bit ensures that there is at least a Hamming distance of 2 between any two *code words*.

Checksum

- Another simple way of checking if there has been an error in a block of data is to find a *checksum*.
- Imagine we send the data 121, 17, 29 and 47. Adding these numbers up, we get 214.
- We actually send 121,17,29,47 and 214.
- The receiver can total up the first numbers and compare it to the last one.
- A difference means an error has occurred.

Checksum

- Typically pairs of bytes are joined to make 16 bit numbers. It is these 16 bit numbers that are totaled to make the checksum.
- If the checksum becomes larger than 65535 (the largest possible 16 bit number) then the carried bits are discarded.
- Checksums are common but not particularly good at catching errors. Later errors can easily hide earlier ones.

Cyclic Redundancy Code (CRC)

- A far more effective way of detecting errors in a block of data is to use a *Cyclic Redundancy Code*.
- In CRC, a number is mathematically calculated for a packet by its source computer, and then recalculated by the destination computer.
- If the original and recalculated versions at the destination computer differ, the packet is corrupt and needs to be resent or ignored.

- The mathematical procedure for performing a CRC is specified by the International Telecommunication Union (ITU) and involves applying a 16-bit polynomial to the data being transmitted by the packet for packets of 4 KB of data or less, or a 32-bit polynomial for packets larger than 4 KB.
- The results of this calculation are appended to the packet as a trailer. The receiving station applies the same polynomial to the data and compares the results to the trailer appended to the packet. Implementations of Ethernet use 32-bit polynomials to calculate their CRC.