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# Chapter 6
# Network Access

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**Objectives**

After completing this chapter, you will be able to:

- ✓ Explain the role of Physical layer protocols and services in supporting communication across data networks.
  - ✓ Describe the role of signals used to represent bits as a frame as the frame is transported across the local media
- ✓ Describe the purpose of Physical layer signaling and encoding as they are used in networks
- ✓ Identify the basic characteristics of copper, fiber and wireless network media and describe common uses of copper, fiber and wireless network media.
- ✓ Having an Overview of Data Link Layer (DLL) and its protocols.
- ✓ Describe the Media Access Control (MAC) and its classes.

# Chap6 Outlines

- Introduction
- Physical Layer Protocols
- Network Media
- Data Link Layer Protocols
- Media Access Control

**Outlines**

- Introduction
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# Introduction

❖ Data communications refers to the transmission of this digital data between two or more computers.

❖ A computer network or data network is a telecommunications network that allows computers to exchange data.

❖ The physical connection between networked computing devices is established using either cable media or wireless media.

❖ The best-known computer network is the Internet.

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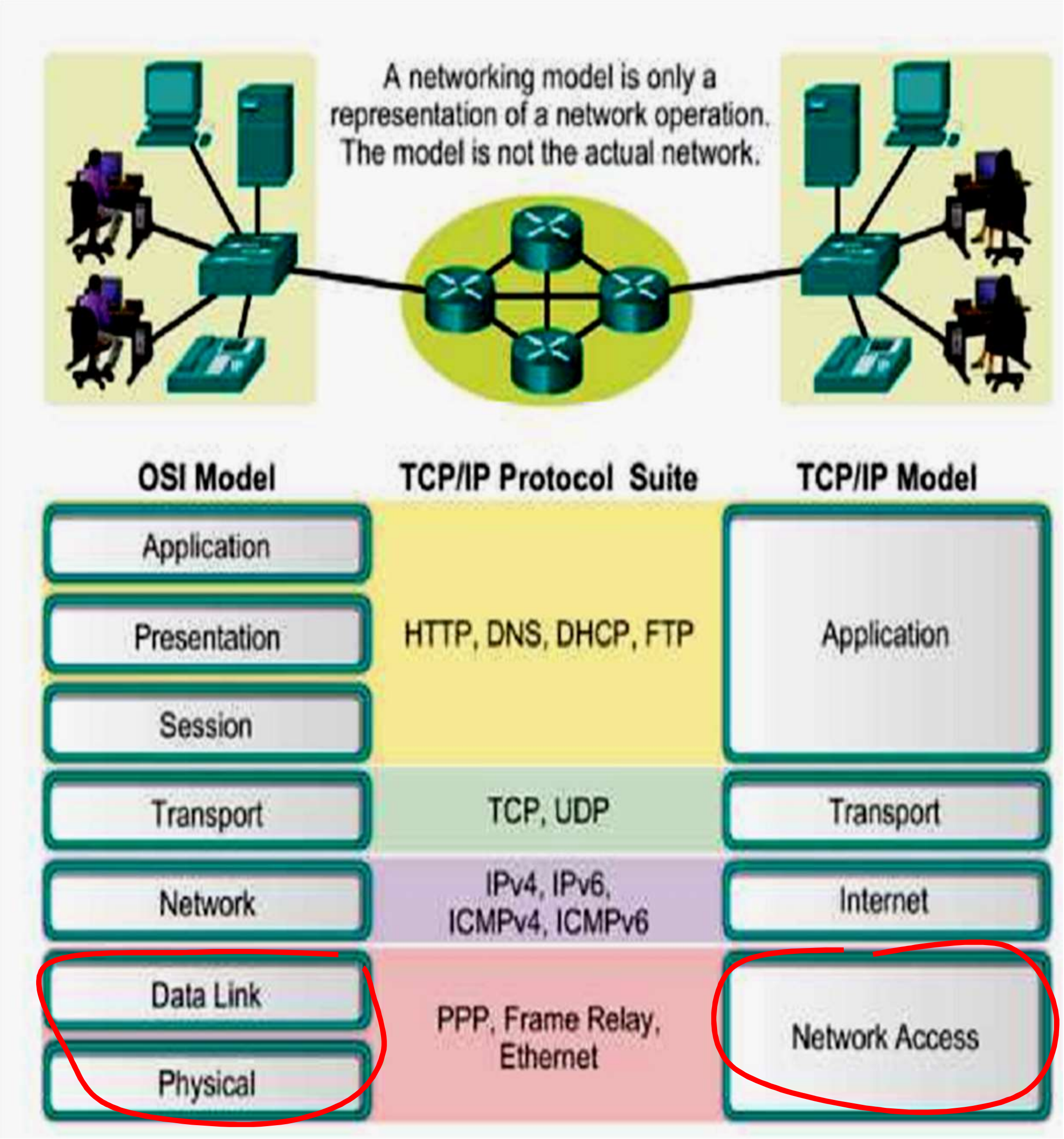

# What is Physical layer?

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- Physical Layer in the OSI model plays the role of interacting with actual hardware and signaling mechanism.
- Physical layer is the only layer of OSI which actually deals with the physical connectivity of two different stations.
- This layer defines the hardware equipments, cabling, wiring, frequencies, pulses used to represent binary signals etc.
- Physical layer provides its services to Data-link layer.
- Data-link layer hands over frames to physical layer and physical layer converts it to electrical pulses which represents binary data and sends over to the wired or wireless media.

# 1. Physical layer

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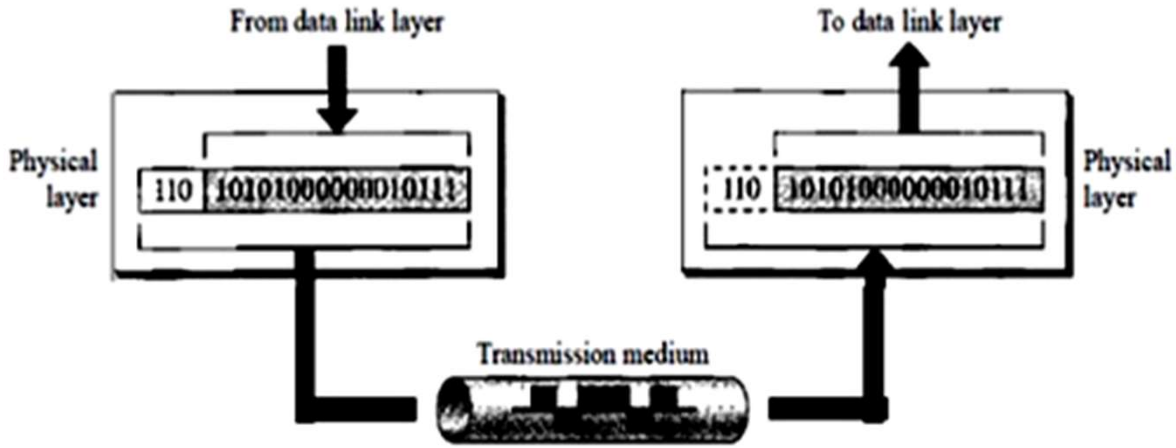
- Physical Layer deals with the mechanical and electrical specifications (Devices)
- Physical characteristics of interfaces and medium.
- To move data in the form of electromagnetic signals across a transmission medium.
- The physical layer data consists of a stream of bits (sequence of 0s or 1s).
- Bits are encoded into signals.



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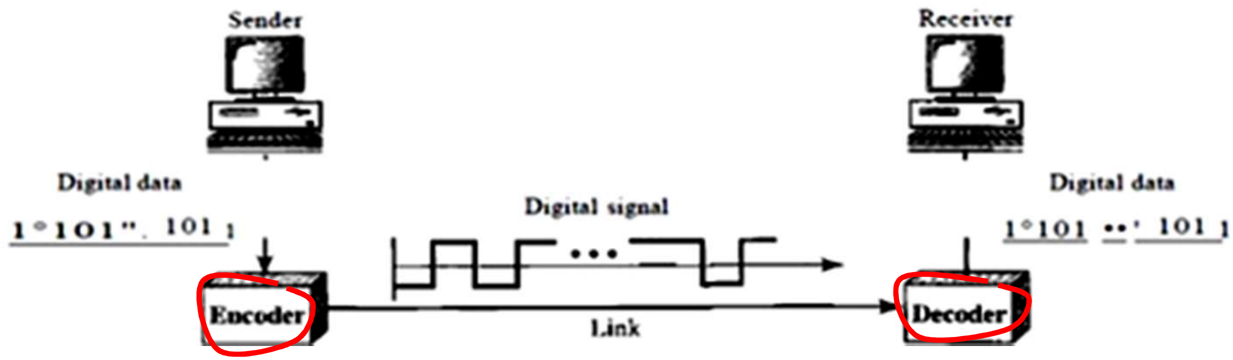
# 1.1. Signal

➢A signal is an electric current or electromagnetic field used to convey data from one place to another.

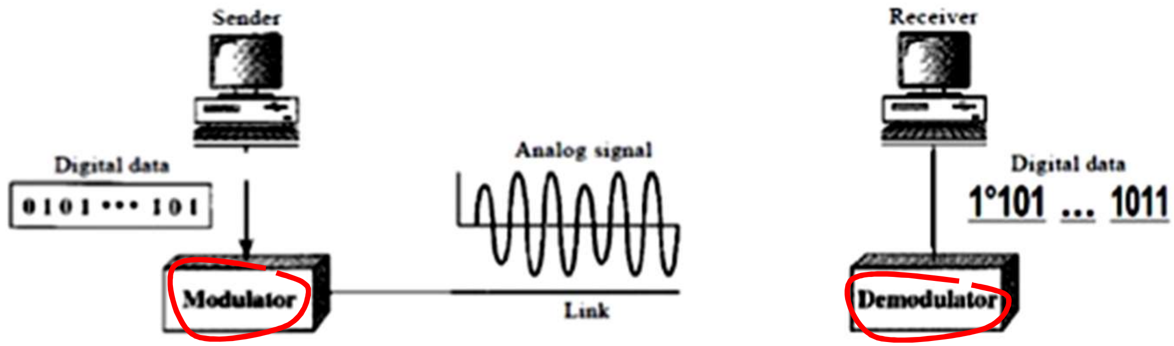
➢A transmitter encodes a message into a signal, which is carried to a receiver by the communications channel.

➢Signals can be interpreted as either Analog or Digital.

➢Digital signals are non-continuous, discrete.




➢Analog signals are continuous, non-discrete.



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# 1.2. Physical layer elements

The delivery of frames across the local media requires the following physical layer elements:

✓The physical media and associated connectors

✓A representation of bits on the media

✓Encoding of data and control information

✓Transmitter and receiver circuit on the network devices

✓At this stage of the communication process, the user data has been segmented by the Transport layer, placed into packets by Network layer, and further encapsulated as a frames by the Data link layer.

✓The purpose of the Physical layer is to create the electrical, optical, or microwave signal that represents the bits in each frame.

✓These signals are then sent on the media one at a time.

✓It is also the job of the physical layer to retrieve these individual signals from the media and restore them to their bit representations.

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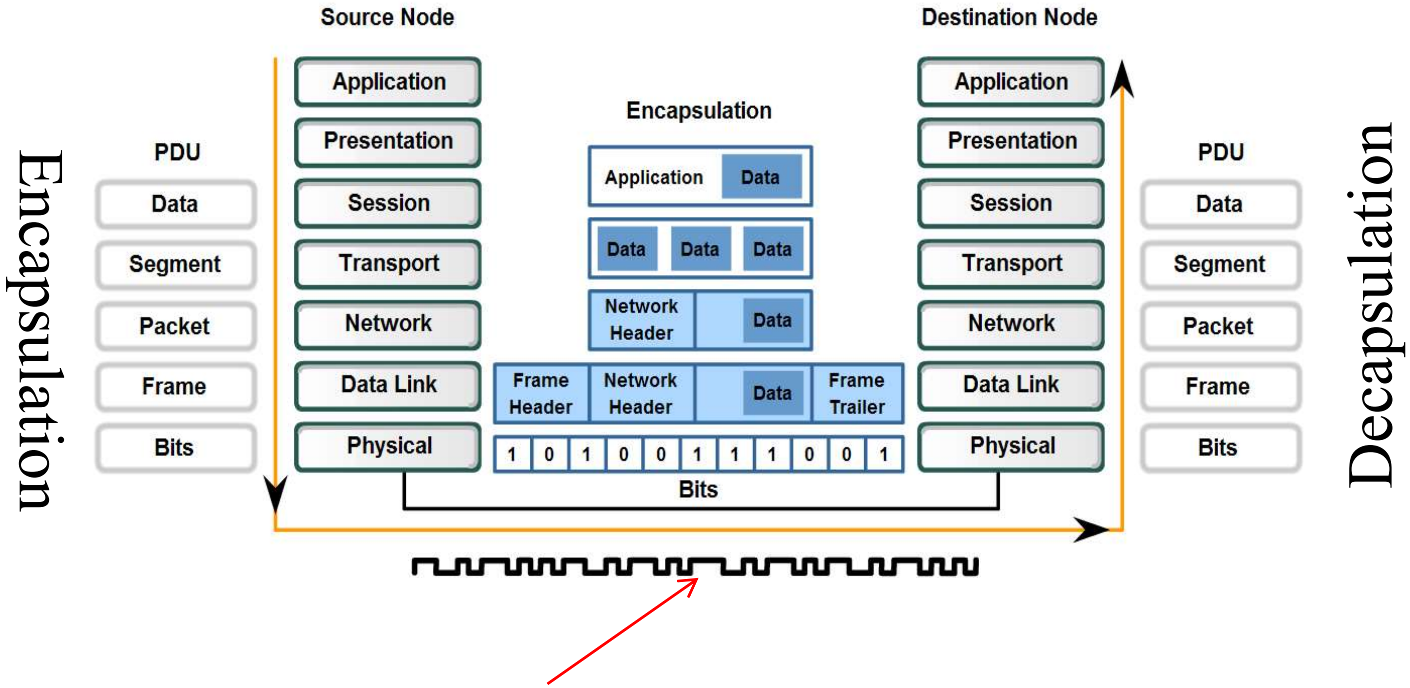
## Transforming Human Network Communications to Bits




In diagrams, signals on the physical media are depicted by this symbol.

# 1.3. Physical layer Standards

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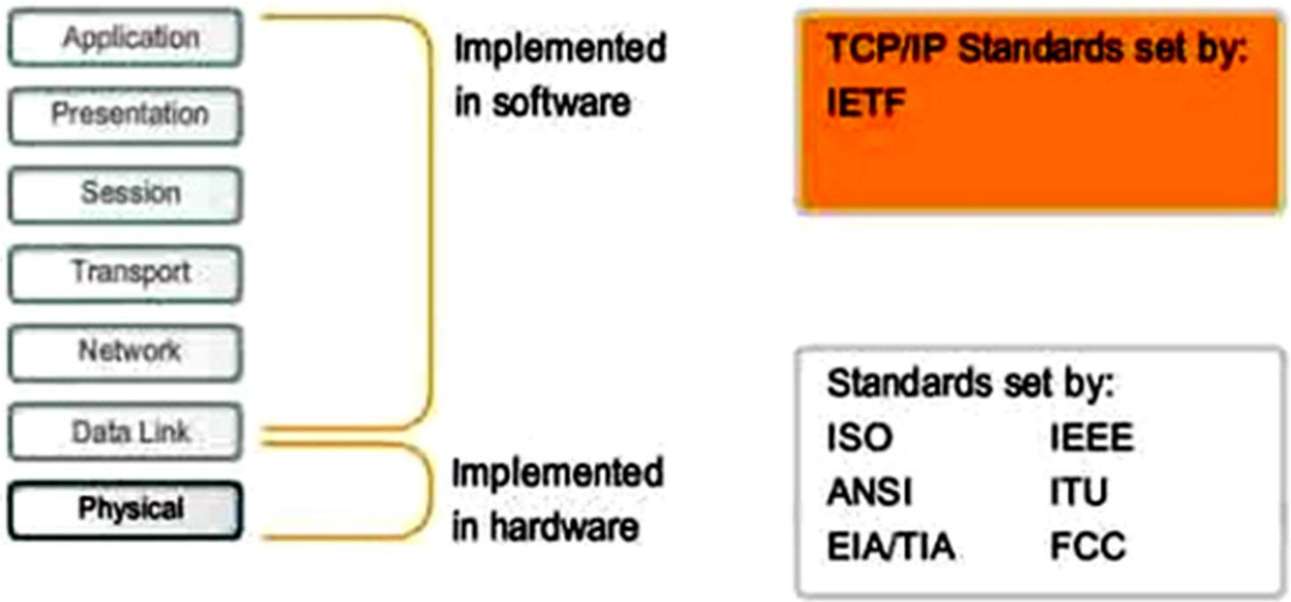
Comparison of Physical Layer Standards and Upper Layer Standards



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# 1.4. Physical layer Fundamental Principles

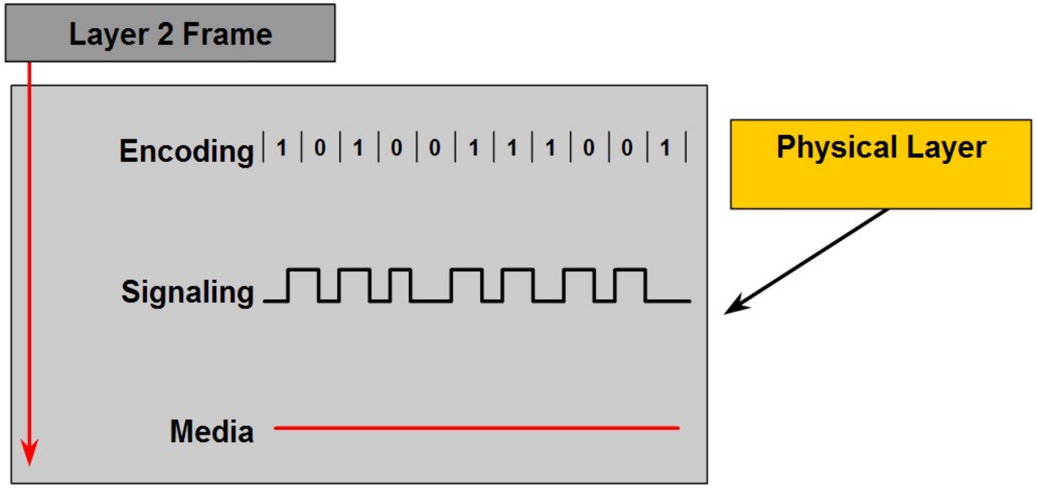
The three fundamental functions of the physical layer are:

•**The physical components:** the electronic hardware devices, media and connectors other that transmit and carry the signals to represent the bits

•**Data encoding:** a method of converting a stream of data bits into a predefined "code". Codes are groupings of bits used to provide a predictable pattern that can be recognized by both the sender and the receiver.

It may also provide codes for control purposes such as identifying the beginning and end of a frame.

•**Signaling:** The Physical layer must generate the electrical, optical, or wireless signals that represent the "1" and "0" on the media.



## 1.5. Physical Layer Signaling and Encoding

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- The Physical layer represents each of the bits in the frame as a signal.
- Each signal placed onto the media has a specific amount of time to occupy the media. This is referred to as its **bit time**.
- Successful delivery of the bits requires some method of synchronization between transmitter and receiver.
- The signals representing the bits must be examined at specific times during the bit time to properly determine if the signal represents a "1" or a "0".

## 1.5. Physical Layer Signaling and Encoding

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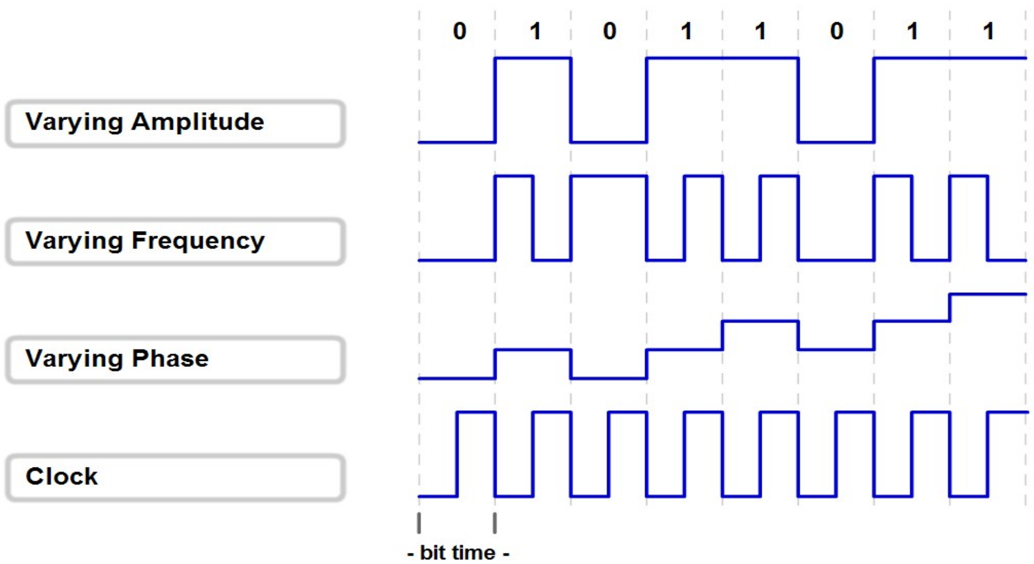
- Bits are represented on the medium by changing one or more of the following characteristics of a signal: Amplitude, Frequency, Phase.
- Explain that network communication at this layer consists of individual bits encoded onto the Physical layer and describe the basic encoding techniques.

Ways to Represent a Signal on the Medium



# 1.6. Signaling Methods

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- **Non-Return to Zero (NRZ),** a 0 may be represented by one voltage level on the media during the bit time and a 1 might be represented by a different voltage on the media during the bit time
- This simple method of signaling is only suited for slow speed data links.
- NRZ signaling uses bandwidth inefficiently and is susceptible to electromagnetic interference.
- The boundaries between individual bits can be lost when long strings of 1s or 0s are transmitted consecutively.

# 1.6. Signaling Methods

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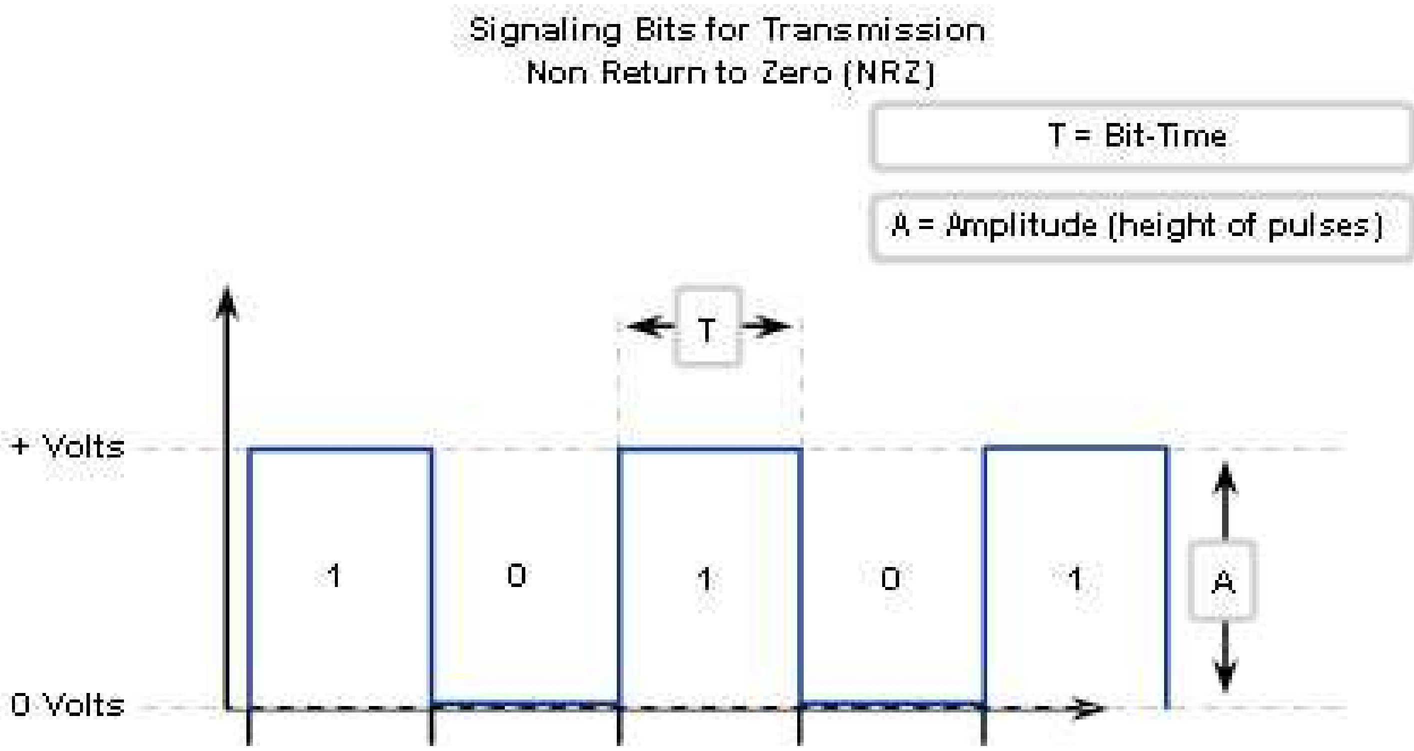


- Discrete pulses (not continuous)
- Can only have one of two states (1/0, on/off)
- Voltage jumps between levels

# 1.6. Signaling Methods

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- **Manchester Encoding** indicates a 0 by a high to low voltage transition in the middle of the bit time. For a 1 there is a low to high voltage transition in the middle of the bit time
- Although Manchester Encoding is not efficient enough to be used at higher signaling speeds, it is the signaling method employed by 10BaseT Ethernet (Ethernet running at 10 Megabits per second).

# 1.6. Signaling Methods

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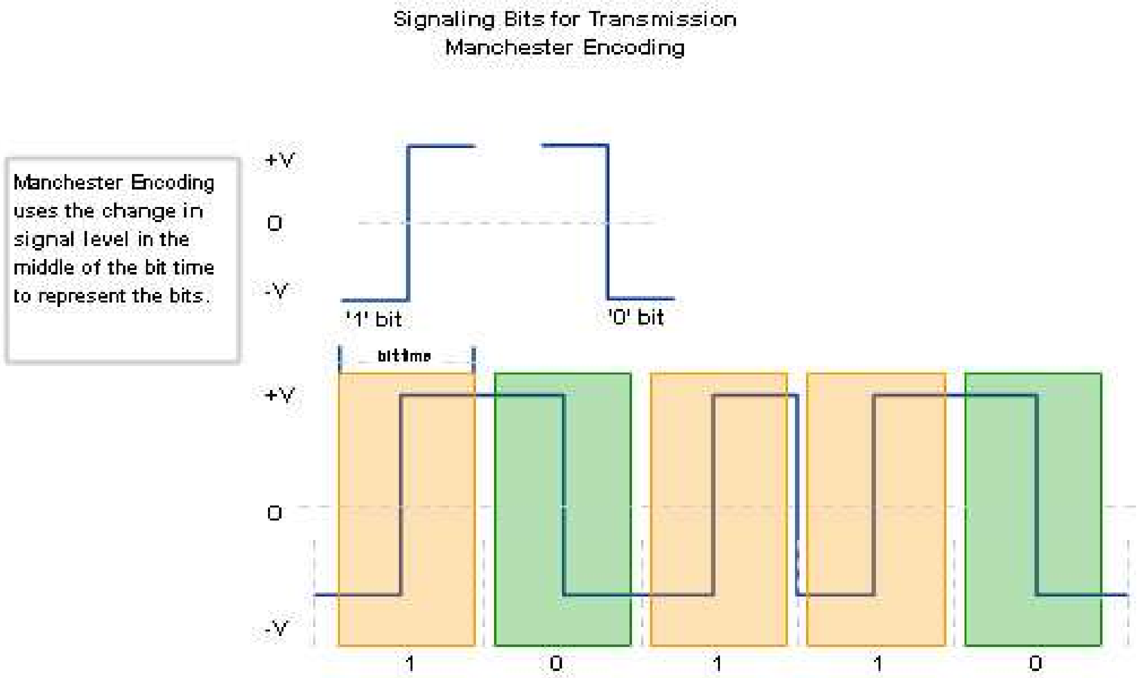


- The signaling method used must be compatible with a standard so that the receiver can detect the signals and decode them.

# 1.7. Encoding – Grouping Bits

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- By using an encoding step before the signals are placed on the media, we improve the efficiency at higher speed data transmission.
- Using media with higher speed, the possibility that data will corrupt is higher. By using the coding groups, we can detect errors more efficiently.
- As the demand for data speeds increase, we seek ways to represent more data across the media, by transmitting fewer bits. Coding groups provide a method of making this data representation.
- The Physical layer of a network device needs to be able to detect legitimate data signals and ignore random non-data signals that may also be on the physical medium.

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# 1.7. Encoding – Grouping Bits

- One way to provide frame detection is to begin each frame with a pattern of signals representing bits that the Physical layer recognizes as denoting the start of a frame.
- Another pattern of bits will signal the end of the frame.
- Signal bits not framed in this manner are ignored by the Physical layer standard being used.

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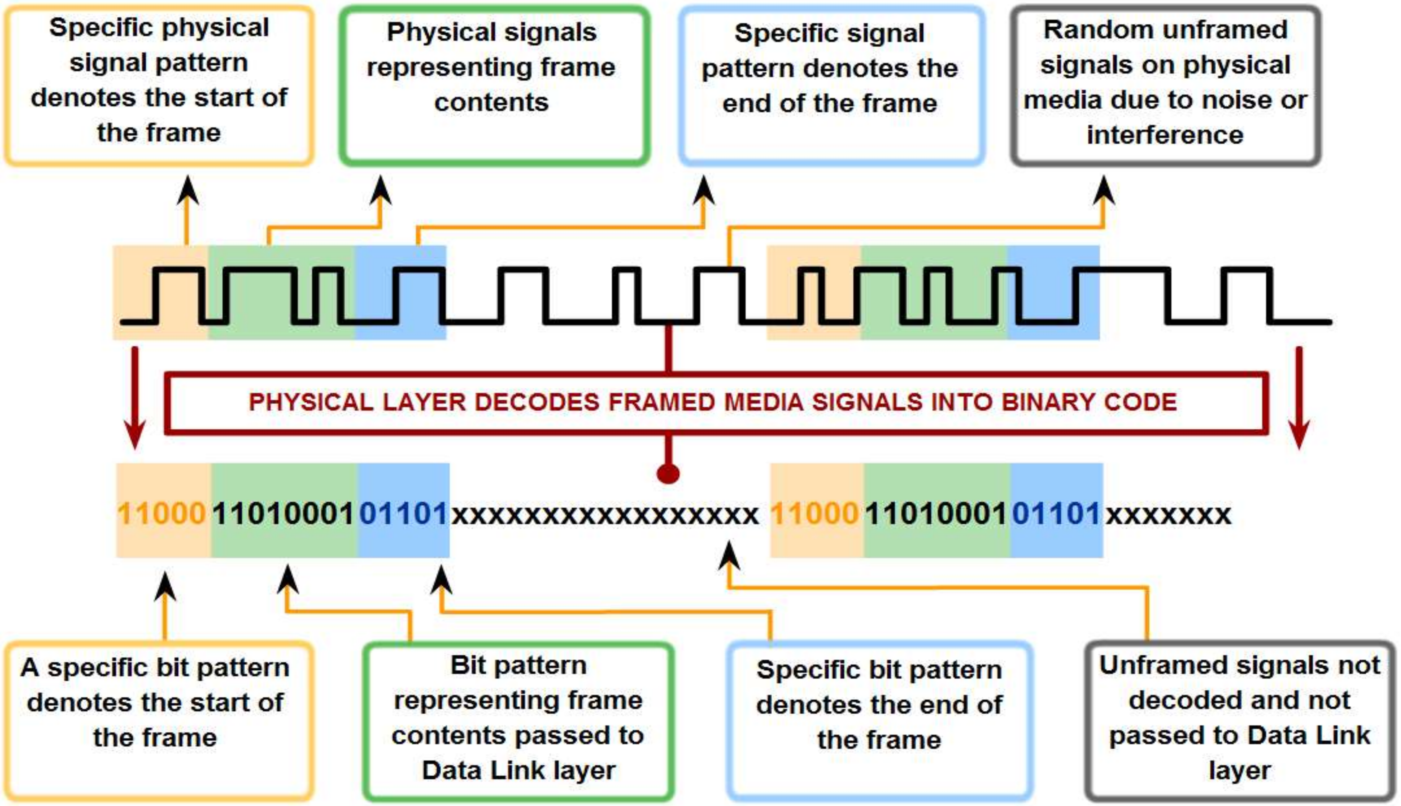
# 1.7. Encoding – Grouping Bits

Describe the role of encoding as it applies to the transmission of bits and explain the value of treating a collection of bits as a code.

**Recognizing Frame Signals**



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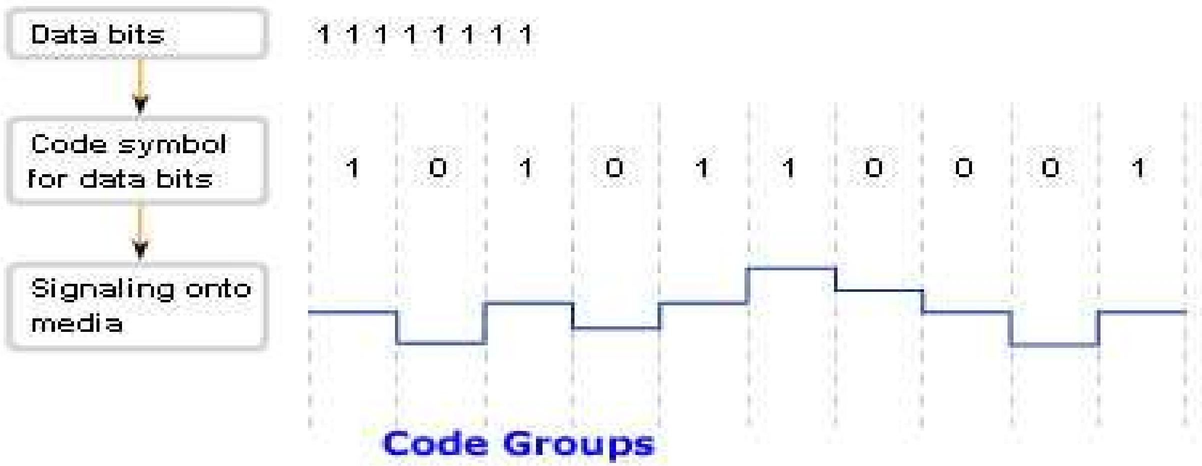
# 1.7. Encoding – Grouping Bits




•Encoding techniques use bit patterns called **symbols**.

•The Physical layer may use a set of encoded symbols - called **code groups** - to represent encoded data or control information.

•A code group is a successive sequence of code bits that are interpreted and mapped as data bit patterns. For example, code bits 10101 could represent the data bits 0011. Ex of Code group: 4B/5B

# 1.7. Encoding – Grouping Bits

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- **Example of code group: 4B/5B**

Start & End

Data Codes

| 4B Code | 5B Symbol |
|---|---|
| 0000 | 11110 |
| 0001 | 01001 |
| 0010 | 10100 |
| 0011 | 10101 |
| 0100 | 01010 |
| 0101 | 01011 |
| 0110 | 01110 |
| 0111 | 01111 |
| 1000 | 10010 |
| 1001 | 10011 |
| 1010 | 10110 |
| 1011 | 10111 |
| 1100 | 11010 |
| 1101 | 11011 |
| 1110 | 11100 |
| 1111 | 11101 |

Data

Invalid

Control and Invalid Codes

| 4B Code | 5B Symbol |
|---|---|
| idle | 11111 |
| start of stream | 11000 |
| start of stream | 10001 |
| end of stream | 01101 |
| end of stream | 00111 |
| transmit error | 00111 |
| invalid | 00000 |
| invalid | 00001 |
| invalid | 00010 |
| invalid | 00011 |
| invalid | 00100 |
| invalid | 00101 |
| invalid | 00110 |
| invalid | 01000 |
| invalid | 10000 |
| invalid | 11001 |

# 1.7. Encoding – Grouping Bits

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## 4B/5B

- Curriculum gives a simple code group called 4B/5B.
- NOTE: Code groups that are currently used in modern networks are generally more complex.
- In this technique, 4 bits of data are turned into 5-bit code symbols for transmission over the media system.
- In 4B/5B, each byte to be transmitted is broken into four-bit pieces or nibbles and encoded as five-bit values known as symbols. These symbols represent the data to be transmitted as well as a set of codes that help control transmission on the media.

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# 1.7. Encoding – Grouping Bits

Advantages using code groups include:

a) **Reducing bit level error**

more later using example

b) **Limiting the effective energy transmitted into the media**

The symbols ensure that the number of 1s and 0s in a string of symbols are evenly balanced. This prevents excessive amounts of energy from being injected into the media during transmission, thereby reducing the interference radiated from the media

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# 1.7. Encoding – Grouping Bits

c) **Helping to distinguish data bits from control bits**.

The code groups have 3 unique types of symbols:

i) Data symbols - Symbols that represent the data of the frame as it is passed down to the Physical layer.

ii) Control symbols - Special codes injected by the Physical layer used to control transmission.

iii) Invalid symbols - Symbols that have patterns not allowed on the media. The receipt of an invalid symbol indicates a frame error.

d) **Better media error detection**

Code groups can contain invalid symbols. The Physical layer can determine that there has been an error in data reception.

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## 1.7. Encoding – Grouping Bits

Different physical media support the transfer of bits at different speeds. Data transfer can be measured in three ways:

- Bandwith
  - Digital bandwidth measures the amount of information that can flow from one place to another in a given amount of time.
  - The practical bandwidth of a network is determined by a combination of factors: the properties of the physical media and the technologies chosen for signaling and detecting network signals.
  - Physical media properties, current technologies, and the laws of physics all play a role in determining available bandwidth.

| Unit of Bandwidth | Abbreviation | Equivalence |
|---|---|---|
| Bits per second | bps | 1 bps = fundamental unit of bandwidth |
| Kilobits per second | kbps | 1 kbps = 1,000 bps = 10^3 bps |
| Megabits per second | Mbps | 1 Mbps = 1,000,000 bps = 10^6 bps |
| Gigabits per second | Gbps | 1 Gbps = 1,000,000,000 bps = 10^9 bps |
| Terabits per second | Tbps | 1 Tbps = 1,000,000,000,000 bps = 10^12 bps |

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## 1.7. Encoding – Grouping Bits

Different physical media support the transfer of bits at different speeds. Data transfer can be measured in three ways:

- Bandwith
- Throughput

•Throughput is the measure of the transfer of bits across the media over a given period of time.

•Throughput usually does not match the specified bandwidth in Physical layer implementations such as Ethernet.

•Factors that influence throughput:

  •amount of traffic, the type of traffic, and the number of network devices encountered on the network being measured.

•throughput cannot be faster than the slowest link of the path from source to destination.

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## 1.7. Encoding – Grouping Bits

Different physical media support the transfer of bits at different speeds. Data transfer can be measured in three ways:

- Bandwith
- Throughput
- Goodput

•Goodput is the measure of usable data transferred over a given period of time, and is therefore the measure that is of most interest to network users.

•Unlike throughput, which measures the transfer of bits and not the transfer of usable data, goodput accounts for bits devoted to protocol overhead.

•Goodput is throughput minus traffic overhead for establishing sessions, acknowledgements, and encapsulation.

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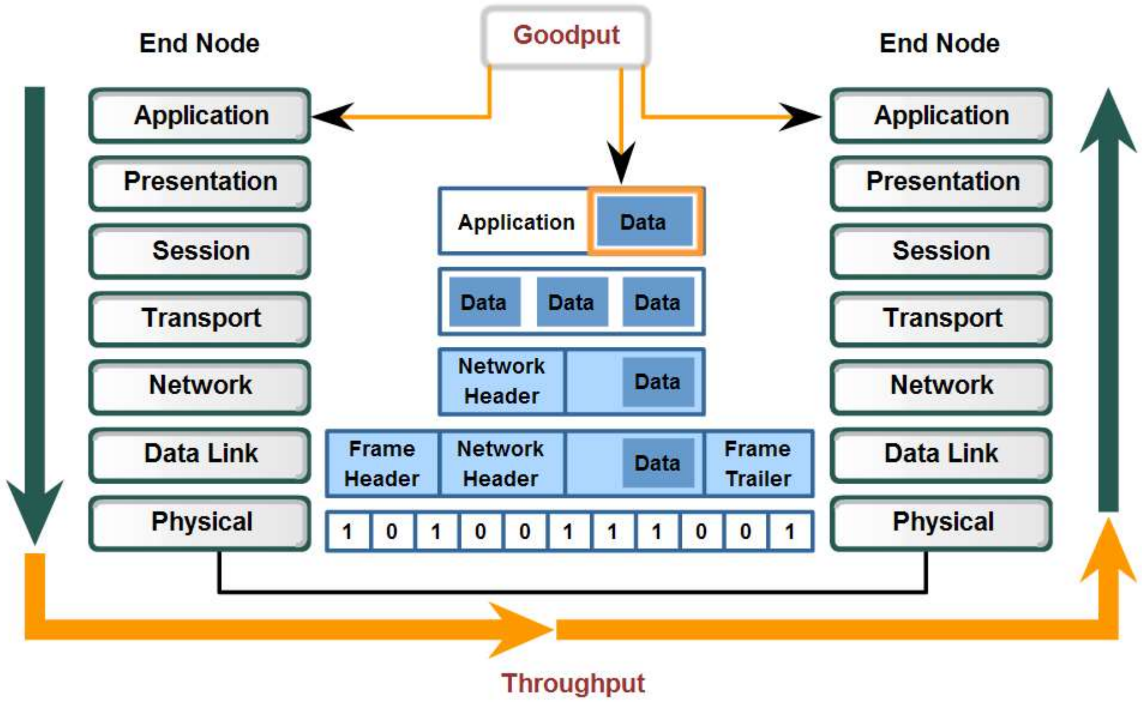
# 1.7. Encoding – Grouping Bits

Define the terms bandwidth, throughput, and goodput




**Data throughput is actual network performance. Goodput is a measure of the transfer of usable data after protocol overhead traffic has been removed.**

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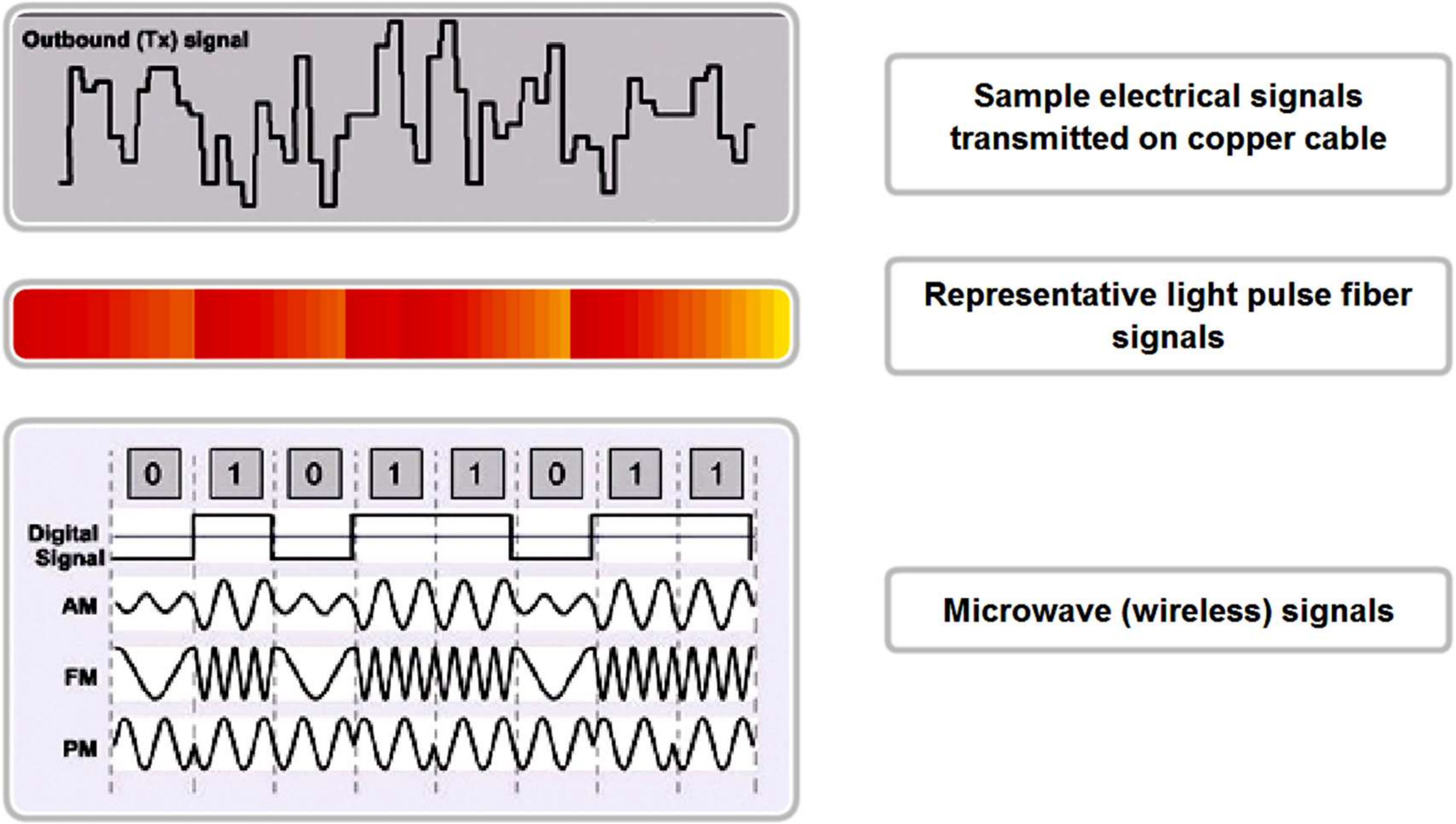
# 2. Network Media

- The media does not carry the frame as a single entity. The media carries signals, one at a time, to represent the bits

**Representations of Signals on the Physical Media**



# 3. Data link layer Protocols

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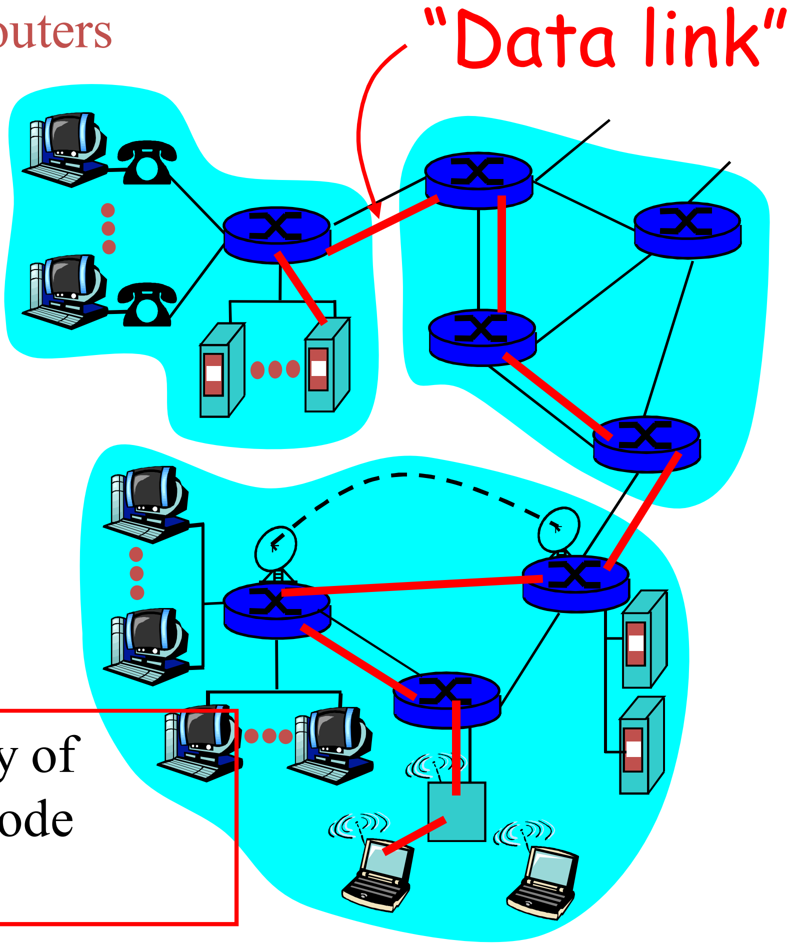
Some terminology:

- Hosts, bridges, switches and routers are **nodes**
- Communication channels that connect adjacent nodes along communication path are **links**
  - **wired links**
  - **wireless links**
  - **LANs**
- **frame**, encapsulates datagram




**Data link layer** has responsibility of transferring datagram from one node to adjacent node over a data link

# 3.1. Overview of Data Link Layer (DLL)

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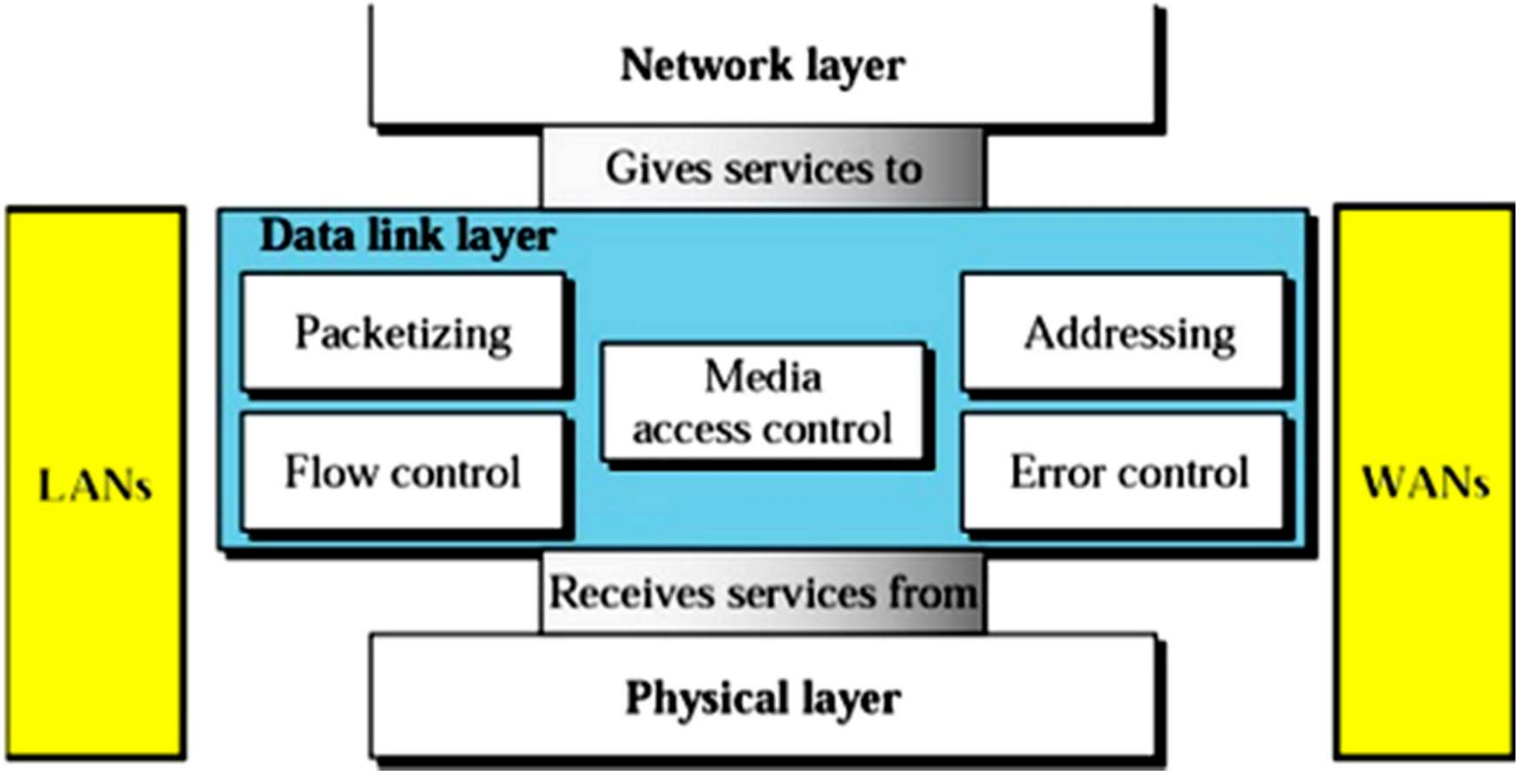
The data link layer transforms the physical layer, a raw transmission facility, to a link responsible for node-to-node (hop-to-hop) communication. Specific responsibilities of the data link layer include *framing*, *addressing*, *flow control*, *error control*, and *media access control*.



# 3. Data link layer Protocols

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1) **Services Provided to Network Layer**
   - The network layer wants to be able to send packets to its neighbors without worrying about the details of getting it there in one piece.
2) **Framing**
   - Group the physical layer bit stream into units called **frames.** Frames are nothing more than “packets” or “messages”. By convention, we use the term “frames” when discussing DLL.
3) **Frame synchronization**
   - Data are sent in blocks called frames. The beginning and end of each frame must be recognized.
4) **Error Control**
   - Sender checksums the frame and transmits checksum together with data. Receiver re-computes the checksum and compares it with the received value.

# 3. Data link layer Protocols

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5) **Flow Control**
   - Prevent a **fast sender** from overwhelming a **slower receiver**.
6) **Addressing**
   - On a multipoint line, such as a LAN, the identity of the two stations involved in a transmission must be specified.
7) **Link management**
   - The initiation, maintenance, and termination of a data exchange requires a fair amount of coordination and cooperation among stations.
8) **Multi-Access**
   - Hosts on shared link when tries to transfer data, has great probability of collision. Data-link layer provides mechanism like CSMA/CD to equip capability of accessing a shared media among multiple Systems

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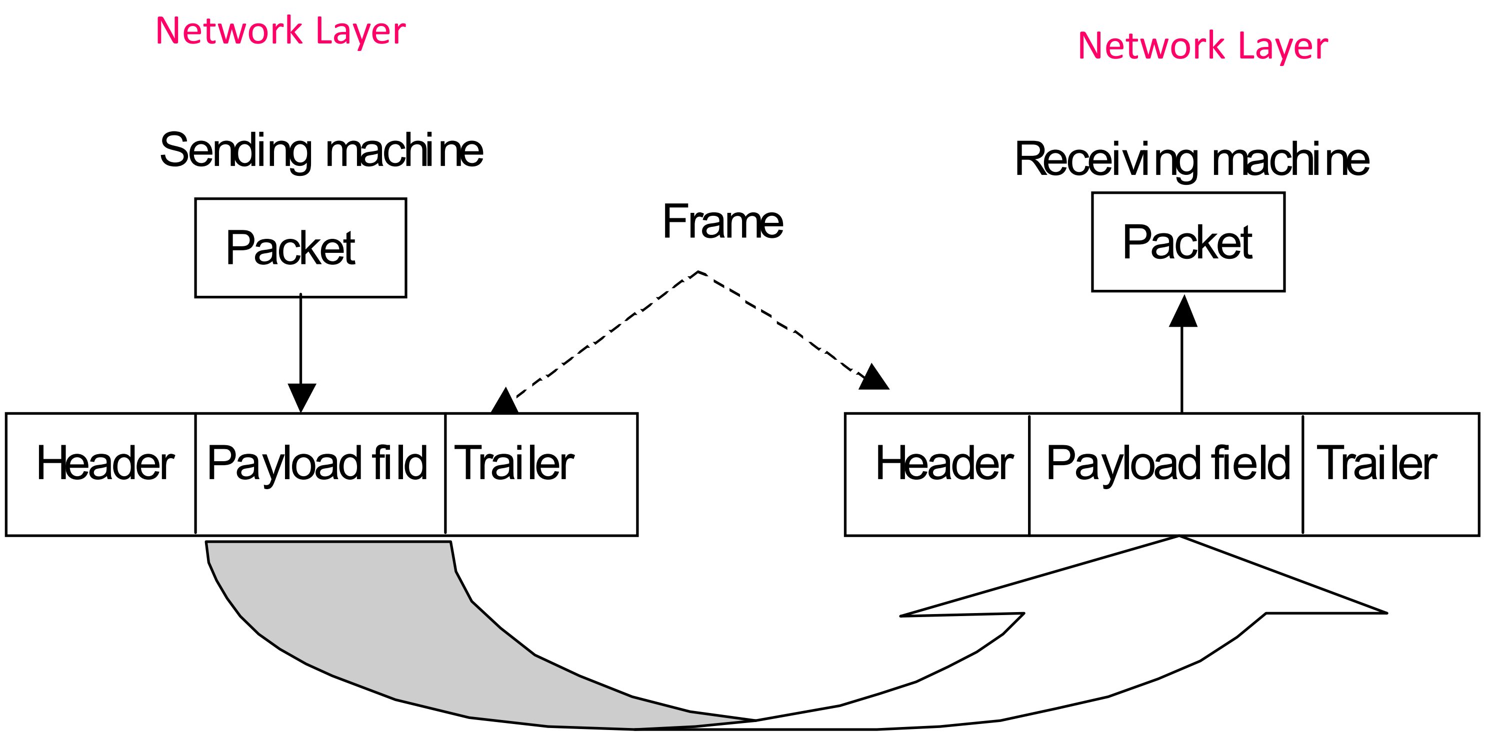

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Fields of a Data Link Layer Frame

A data link layer frame has the following parts:

•**Frame Header**: It contains the source and the destination addresses of the frame and the control bytes.

•**Payload field**: It contains the message to be delivered.

•**Trailer**: It contains the error detection and error correction bits. It is also called a Frame Check Sequence (FCS).

•**Flag**: Two flag at the two ends mark the beginning and the end of the frame.

**In some cases, functions of error control and flow control are allocated in transport or other upper layer protocols and not in the DLL, but principles are pretty much the same.**

# Protocol layering and data

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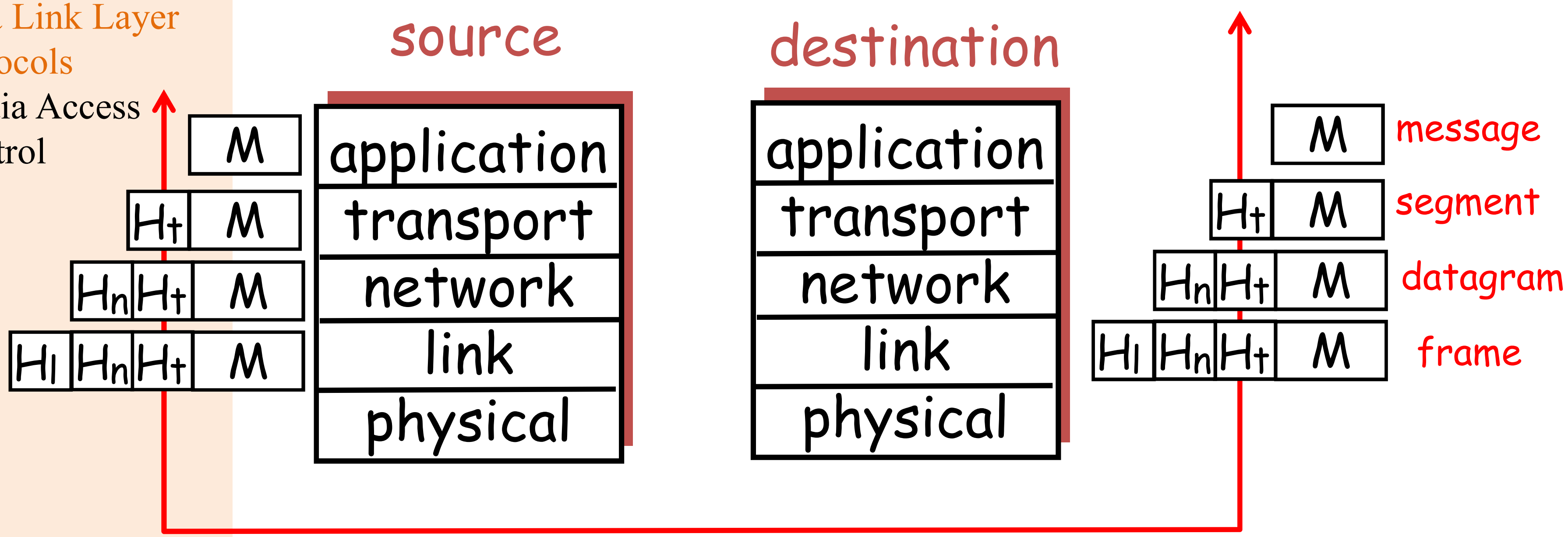
Each layer takes data from above

- adds header information to create new data unit
- passes new data unit to layer below



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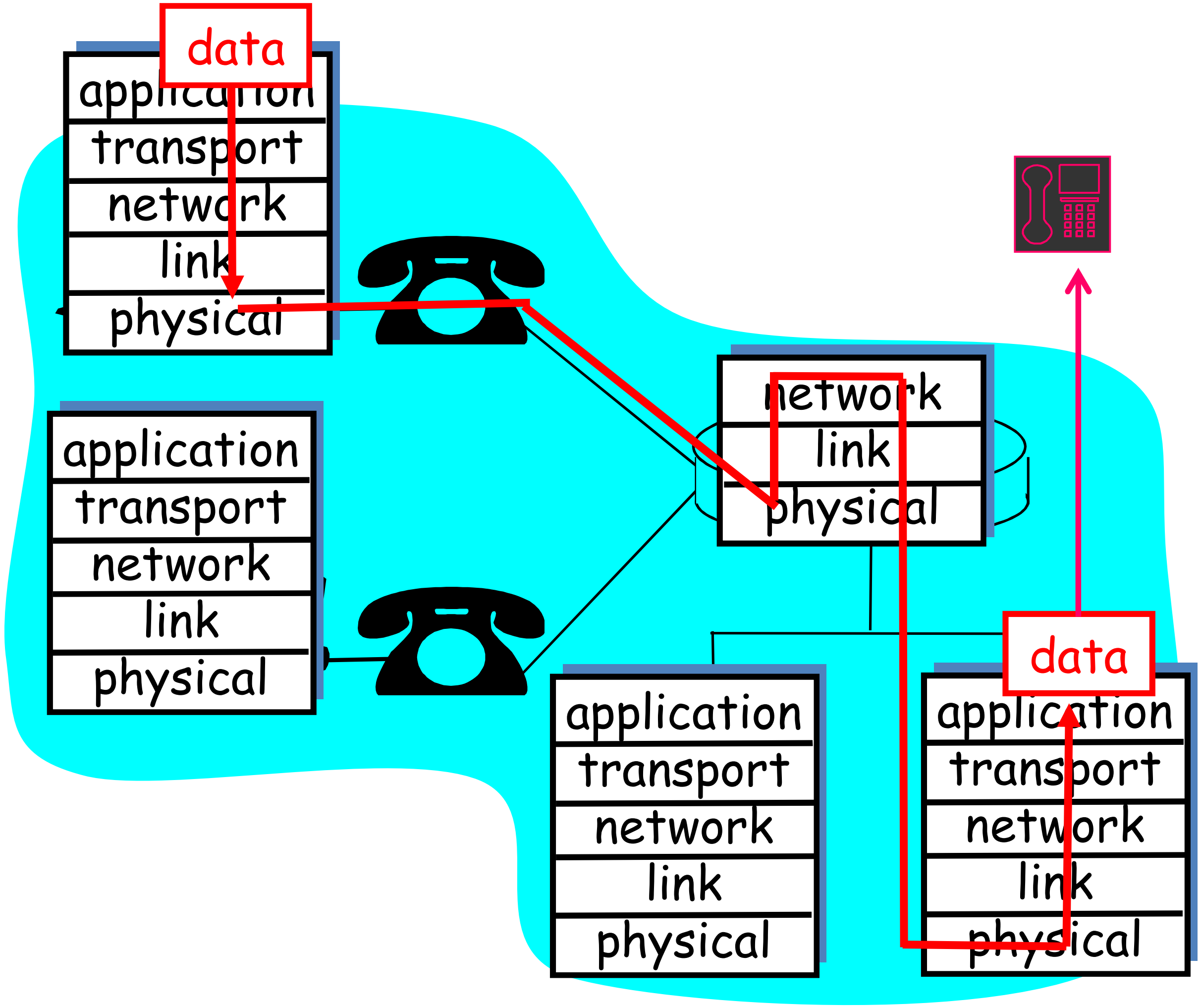

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# 3.2. Error Detection and Correction

✓There are many reasons such as noise, cross-talk etc., which may help data to get corrupted during transmission.

✓The upper layers work on some generalized view of network architecture and are not aware of actual hardware data processing.

✓So, upper layers expect error-free transmission between systems.

✓Data-link layer uses some error control mechanism to ensure that frames (data bit streams) are transmitted with certain level of accuracy.

✓But to understand how errors is controlled, it is essential to know what types of errors may occur.

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# 3.2.Error Detection and Correction

There may be three types of errors:

1) **Single bit error:**

In a frame, there is only one bit, anywhere though, which is corrupt.


2) **Multiple bits error:**

Frame is received with more than one bits in corrupted state.


3) **Burst error:**

Frame contains more than1 consecutive bits corrupted

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# 3.2. Error Detection and Correction

Error control mechanism may involve two possible ways:

- ❑ Error detection
- ❑ Error correction

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# 3.2. Error Detection and Correction

Error control mechanism may involve two possible ways:

- ❑ **Error detection**
- ❑ Error correction

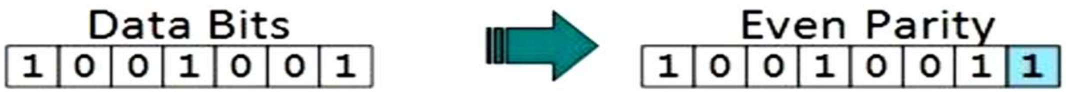
Errors in the received frames are detected by means of Parity Check and CRC (Cyclic Redundancy Check).

In both scenario, few extra bits are sent along with actual data to confirm that bits received at other end are same as they were sent.

If the checks at receiver's end fails, the bits are corrupted.

**Parity check**

One extra bit is sent along with the original bits to make number of 1s either even, in case of even parity or odd, in case of odd parity.




[*Image: Even Parity*]

If a single bit flips in transit, the receiver can detect it by counting the number of 1s. But when more than one bits are in error it is very hard for the receiver to detect the error.

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# 3.2. Error Detection and Correction

Error control mechanism may involve two possible ways:

- ❑ **Error detection**
- ❑ Error correction

**Cyclic redundancy check**

This technique involves binary division of the data bits being sent. The divisor is generated using polynomials. The sender performs a division operation on the bits being sent and calculates the remainder.

Before sending the actual bits, the sender adds the remainder at the end of the actual bits. Actual data bits plus the remainder is called a codeword. The sender transmits data bits as codewords.

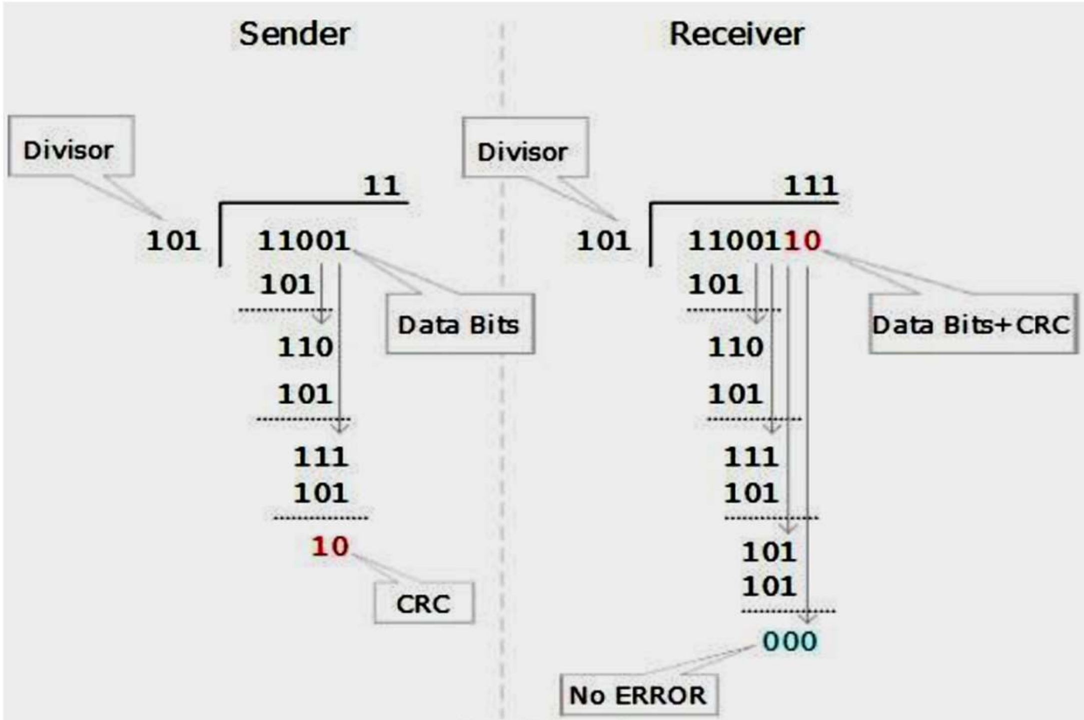
**Outlines**

- Introduction
- Physical Layer Protocols
- Network Media
- Data Link Layer Protocols
- Media Access Control

# 3.2. Error Detection and Correction

Error control mechanism may involve two possible ways:

- ❑ **Error detection**
- ❑ Error correction




[*Image: CRC in action*]

At the other end, the receiver performs division operation on codewords using the same CRC divisor. If the remainder contains all zeros the data bits are accepted, otherwise there has been some data corruption occurred in transit.

**Outlines**

- Introduction
- Physical Layer Protocols
- Network Media
- Data Link Layer Protocols
- Media Access Control

# 3.2. Error Detection and Correction

Error control mechanism may involve two possible ways:

- ❑ Error detection
- ❑ **Error correction**

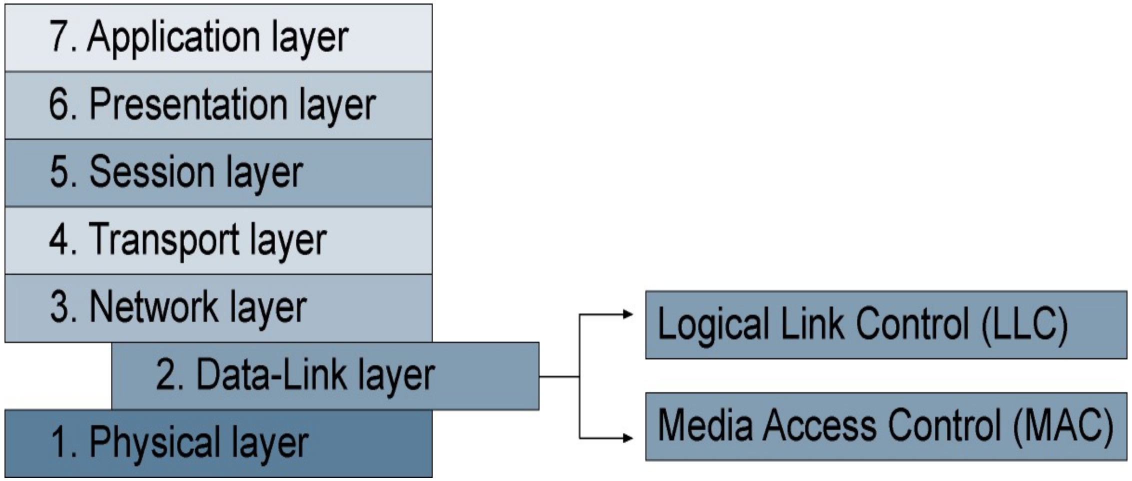
In digital world, error correction can be done in two ways:

- *Backward Error Correction:* When the receiver detects an error in the data received, it requests back the sender to retransmit the data unit.
    - used where retransmitting is not expensive, for example fiber optics.
- *Forward Error Correction:* When the receiver detects some error in the data received, it uses an error-correcting code, which helps it to auto-recover and correct some kinds of errors.

# 3.3. DLL Sublayers

**Outlines**

- Introduction
- Physical Layer Protocols
- Network Media
- Data Link Layer Protocols
- Media Access Control




**LLC** – Interface to layer 3. Controls frame synchronization, flow control, and error checking

**MAC** – Interface to layer 1. Controls how PC accesses and transmits data and specifies the **Media Access Technique** used.

**Outlines**

- Introduction
- Physical Layer Protocols
- Network Media
- Data Link Layer Protocols
- Media Access Control

# 4. Media Access Control

## 4.1. What is MAC?

- MAC stands for **M**edia **A**ccess **C**ontrol (or Multiple Access Control). A MAC layer protocol is the protocol that controls access to the physical transmission medium on a LAN.
- It tries to ensure that no two nodes are interfering with each other’s transmissions, and deals with the situation when they do.
- CSMA/CD architecture used in Ethernet is a common MAC layer standard.
- It acts as an interface between the Logical Link Control sublayer and the network's Physical layer.

**Outlines**

- Introduction
- Physical Layer Protocols
- Network Media
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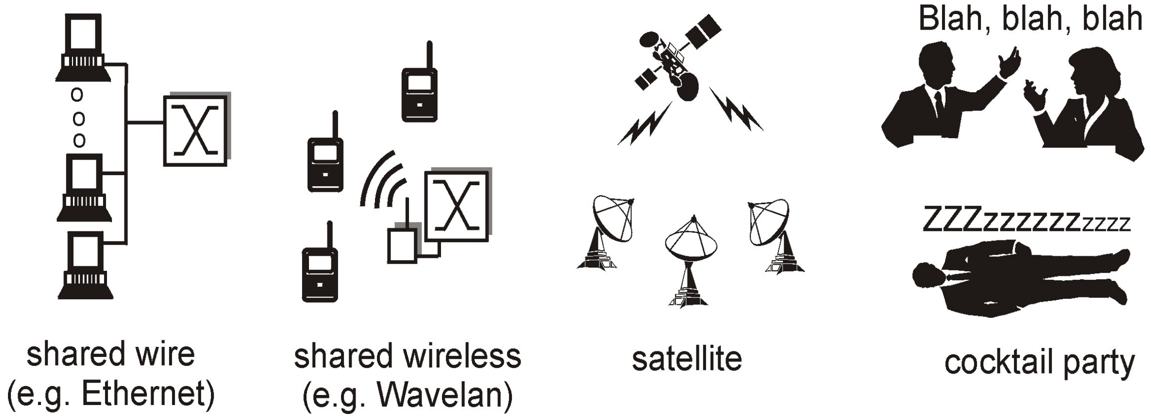
- Media Access Control

- Single shared broadcast channel; collision



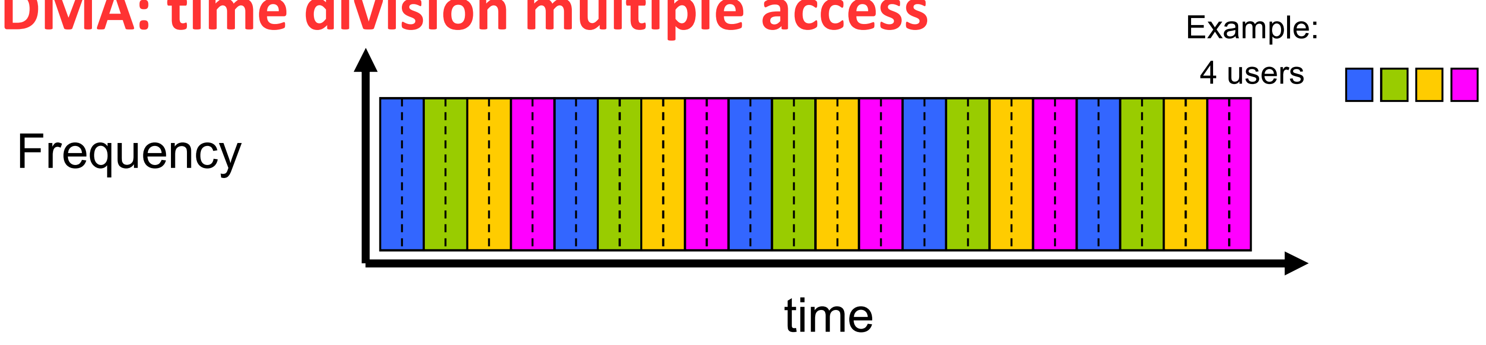

- Multiple access protocol
  - Distributed algorithm that determines how nodes share channel, i.e., determine when a node can transmit
- Two broad classes:
  - **Channel partitioning and**
  - **Random access**

## Outlines

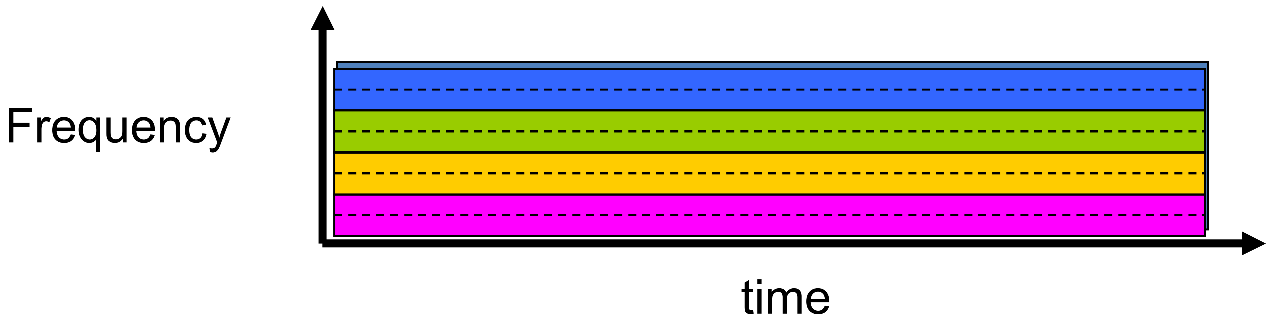

- Introduction
- Physical Layer Protocols
- Network Media
- Data Link Layer Protocols
- Media Access Control


- Two broad classes:
  - **Channel partitioning**
  - Random access

## TDMA: time division multiple access




## FDMA: frequency division multiple access




## CDMA: code division multiple access

- Same frequency and time but different codes.

**Outlines**

- Introduction
- Physical Layer Protocols
- Network Media
- Data Link Layer Protocols
- Media Access Control

- Two broad classes:
  - **Channel partitioning**
  - **Random access**

**Listen before transmit**

- When node has packet to send
  - Sense the channel.
  - If it is busy, wait for **random** amount of time and then retry.
  - no ***a priori*** coordination among nodes.
  - All nodes use the same time, frequency and code.
- Two or more transmitting nodes ➜ “collision”
  - Random access MAC protocol specifies how to recover from collisions -> Exponential backoff.
- Examples of random access MAC protocols:
  - **CSMA, CSMA/CA, CSMA/CD**

## Outlines

- Introduction
- Physical Layer Protocols
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- Media Access Control

- Two broad classes:
  - **Channel partitioning**
  - **Random access**

**Comparaison**

Channel partitioning MAC protocols:

- share channel efficiently and fairly at high load
- inefficient at low load: delay in channel access, 1/N bandwidth allocated even if only 1 active node

Random access MAC protocols

- efficient at low load: single node can fully utilize channel
- high load: collision overhead

**Both these types of protocols have been used in sensor networks depending on the application needs.**

# 3.2. MAC Requirements in Sensor Networks

**Outlines**

- Introduction
- Physical Layer Protocols
- Network Media
- Data Link Layer Protocols
- Media Access Control

- Important requirements of MAC protocols
  - **Energy efficiency**
  - Collision avoidance
  - Scalability & Adaptivity
  - Latency (response time)
  - Fairness
  - Throughput
  - Bandwidth utilization

Primary

Secondary