2. LAN Topologies

- Two basic categories of network topologies exist:
  - *physical topologies* and
  - *logical topologies*.

- The **physical topology** of a network is the cabling layout used to link devices (aka **nodes**)

- This refers to the following:
  - the layout of **cabling**,  
  - the locations of nodes, and
  - the interconnections between the nodes and the cabling.

- The **logical topology** is the way that the signals act on the network media, or the way that the data passes through the network from one device to the next without regard to the physical interconnection of the devices.

- A network’s logical topology is not necessarily the same as its physical topology.
  - For example, the original twisted pair Ethernet using repeater hubs was a logical bus topology carried on a physical star topology.

- Some networks are able to dynamically change their logical topology through configuration changes to their **routers** and switches.

- Wired LANs are classified in one of the following topologies (page 227):
  - Bus topology
  - Ring topology
  - Star topology, and
  - Mesh topology

- Each of these topologies has advantages and disadvantages.
**Bus Topology**

- A network in this category consists of a single cable (bus) to which each computer is attached.
- Each computer attached to the bus can send a signal (message) through the bus that is received by all other computers attached to the bus:
  - If a computer address does not match the intended address for the data, the machine ignores the data.
  - Alternatively, if the data matches a computer address, the data is accepted.
- Computers attached to a bus network must coordinate to ensure that only one computer sends a signal at any time.

![Bus Network Topology](image)

**Ring Topology**

- A **ring topology** is a bus topology in a closed loop.
- Data travels around the ring in one direction.
- When one node sends data to another, the data passes through each intermediate node on the ring until it reaches its destination.
- The intermediate nodes repeat (re transmit) the data to keep the signal strong.
- If one node is unable to re transmit data, it severs communication between the nodes before and after it in the bus.
- In some networks in this category, each computer is connected to a small device and the cables (buses) connect those devices instead.
- This approach allows the network to continue to operate even if some of the computers are disconnected or fail.

![Ring Network Topology](image)
Mesh Topology

- A network in this category provides a direct connection between each pair of computers.
- The disadvantage of this approach is the large number of connections that is needed to connect all computers.
- If there are N computers in a network, the number of connections will be $N \times (N - 1)/2$.
- Few wired LANs employ this topology because physical connections are expensive.

![Mesh topology](image1)

Star Topology

- In *star topology*, every node (computer workstation or any other peripheral) is connected to a central node which may be a *hub*, a *router*, or a *switch*.
- All traffic that traverses the network passes through the central node.
- An advantage of the star topology is the simplicity of adding additional nodes.
- The primary disadvantage of the star topology is that the hub represents a single point of failure.
- A typical *hub* is an electronic device that accepts data from the sending computer and delivers it to the appropriate destination.

![Star network topology](image2)
3. Wired Network Communication and Addresses

- In a communication over a wired LAN, computers are identified in one of the following ways:
  - By using universally administered addresses which correspond to their MAC addresses, or
  - By using locally administered addresses which are 48-bit addresses assigned to each computing device by the network administrator (overriding their MAC addresses).

- A universally administered address is distinguished from a locally administered address by setting the second least significant bit of the left-most byte of the OUI:
  - to 0 for universally administered addresses, and
  - to 1 for locally administered addresses.

Examples:
- OUI of a universally administered address: 08-00-00 because \(8 = 1000\)
- OUI of a locally administered address: 06-00-00 because \(6 = 0110\)

Unicast, Broadcast, and Multicast Transmissions

- The IEEE has built in the following special address types to allow more than one network interface card to be addressed in a packet transmission:
  - **Unicast address**
    - A *unicast address* is a 48-bit address such that the least significant bit of the left-most byte is set to 0.
    - Example: 08-00-00-00-00-00 because \(8 = 1000\)
    - A copy of a packet with a *unicast address* should be delivered to only the computer with the address specified in the packet.
  - **Multicast address**
    - A *multicast address* is a 48-bit address such that the least significant bit of the left-most byte is set to 1.
    - Example: 09-00-00-00-00-00 because \(9 = 1001\)
    - A multicast address identifies a subset of the computers on a given network, and specifies that each computer in the subset should receive a copy of the packet.
  - **Broadcast address**
    - The broadcast address is the 48-bit address consisting of all 1s
    - Example: FF-FF-FF-FF-FF-FF
    - A copy of a packet with the *broadcast address* should be delivered to each computer on a LAN.
Frames and Byte Stuffing

- In a packet switching network, a frame corresponds to a packet and consists of the following two parts:
  - The **frame header**
    - that contains the information used to process the frame such as an address that specifies the intended recipients of the message.
  - The **payload**
    - that contains the message being sent.

- Some technologies delineate each frame by sending a short **prelude** before the frame and a short **postlude** after the frame.

- In the ASCII character set,
  - the **Start Of Header** (SOH) character marks the beginning of a frame and,
  - the **End Of Transmission** (EOT) character marks the end of a frame.

- A technique known as **byte stuffing** is used to make it possible to transmit a message that contains one or more of the character SOH and EOT.

- With **byte stuffing**, a third character such as the character ESC is selected such that each of these three character is replaced in the text of the message with a sequence of two characters.

  **For example:**

<table>
<thead>
<tr>
<th>Byte to be sent</th>
<th>Sequence sent</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOH</td>
<td>ESC A</td>
</tr>
<tr>
<td>EOT</td>
<td>ESC B</td>
</tr>
<tr>
<td>ESC</td>
<td>ESC C</td>
</tr>
</tbody>
</table>
4. Wired LAN Technology (Ethernet and IEEE 802.3)

- The Ethernet is the most common transmission technologies in use for wired local area networks.
- It was commercially introduced by Xerox PARC in 1980, and first standardized by IEEE in 1983 as IEEE 802.3.
- Over time, Ethernet has largely replaced competing wired LAN technologies such as:
  - token ring,
  - FDDI,
  - ARCNET, and
  - AppleTalk.
- Over the years, the hardware devices, cabling, and media used with Ethernet have changed dramatically.
- But newer versions of Ethernet remain backward compatible.

**Thick Ethernet (page 257)**

- The Thick Ethernet was the original Ethernet.
- It is also known as 10BASE5 or Thicknet.
- It uses a thick and stiff coaxial cable up to 500 meters (1,600 ft) in length.
- Up to 100 electronic devices called transceivers are connected to the Ethernet cable and handle:
  - carrier detection,
  - conversion of bits into appropriate voltage for transmission, and
  - conversion of incoming signals to bits
- Computers with NIC are attached to transceivers by a cable known as Attachment Unit Interface (AUI).
- The system is difficult to install and maintain.
**Thinnet Ethernet (page 257)**

- The second generation of Ethernet was known as **10BASE2**.
- It is also informally known as **Thinwire Ethernet** or **Thinnet**.
- It integrated transceiver on the Network Interface Card, and
- used a thinner and more flexible **RG-58** coaxial cable that runs from one computer to another.
- The major disadvantage is that if a user unplugs a segment of the network or relocates wires, or move a computer, the entire network will stop working.

- With **Thicknet** and **Thinnet**, since all communication happens on the same wire, any information sent by one computer is received by all, even if that information is intended for just one destination.
- The network interface card accept a message only if it is addressed to it and ignores it otherwise.
- A **collision** happens when two stations attempt to transmit at the same time: in this case, they corrupt transmitted data and require stations to re-transmit.
Twisted Pair Ethernet Wiring and Hubs (page 258)

- The third generation of Ethernet which is used today is informally known as **twisted pair Ethernet**.
- With the original version of **twisted pair Ethernet**, every node (computer workstation or any other peripheral) is connected by a twisted pair of wire to a central node called a **hub**.
- Electronic components in the hub emulate a physical cable, making the entire system operate like a conventional Ethernet.
- Each computer attached to the hub can send a signal (message) through the hub that is received by all other computers attached to the hub:
  - If a computer address does not match the intended address for the data, the machine ignores the data.
  - Alternatively, if the data matches a computer address, the data is accepted.
- Computers attached to a hub must coordinate to ensure that only one computer sends a signal at any time.
- Note that although the physical topology of the twisted pair Ethernet wiring is the star topology, its logical topology is in fact the bus topology.
- The following table lists the three types of twisted pair Ethernet and the cable used with each:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Name</th>
<th>Data Rate</th>
<th>Cable Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>10Base T</td>
<td>Twisted Pair Ethernet</td>
<td>10 Mbps</td>
<td>Category 5</td>
</tr>
<tr>
<td>100BaseT</td>
<td>Fast Ethernet</td>
<td>100 Mbps</td>
<td>Category 5E</td>
</tr>
<tr>
<td>100BaseT</td>
<td>Gigabit Ethernet</td>
<td>1 Gbps</td>
<td>Category 6</td>
</tr>
</tbody>
</table>

**Notes:**

- Higher speed Ethernet technologies use an electronic device known as a **switch** instead of a **hub**.
- To remain backward compatible, standards for the higher speed versions specify that interfaces should automatically sense the speed at which a connection can operate and slow down to accommodate older devices.
- A twisted pair Ethernet cable uses RJ45 connectors.
- There are two types of twisted pair Ethernet cable: **straight** and **crossed**:
  - A **crossed cable** is used to connect two switches: it connects each pin of the RJ45 on one end of the cable to a different pin on the RJ45 attached on the other end.
  - A **straight cable** is used to connect a computer to a switch: it connects each pin of the RJ45 attached on one end of the cable to the same pin on the RJ45 attached on the other end.
  - Some sophisticated interface hardware can detect an incorrect cable and adapt. However, most hardware will not function correctly if a crossed cable is used when a straight cable is required.
The Ethernet Frame Format

- The header of an Ethernet frame consists of the following:
  - A 48-bit destination address field that contains the address of the intended recipient(s) of the message, which is followed by
  - A 48-bit source address field that contains the address of the computer that sent the frame, and which is followed by
  - A 16-bit type field.
- Its payload has a variable length of 46 to 1500 bytes.
- The Cycle Redundancy Check (CRC) is a 4-byte code that follows the payload.
  - It is an error-correcting code that is designed to protect against common types of errors on communication channels.

Ethernet frame type field

- The Ethernet frame type is also referred to as the EtherType.
- It is used by the sender to indicate which protocol is encapsulated in the payload of the frame:
  - Each such protocol has a code, and
  - When the frame arrives at its destination, the receiver uses that code to determine which software module should be used to process the frame.
IEEE’s Version of the Ethernet (802.3) (Page 255)

- In 1983, the IEEE developed a standard for Ethernet (referred to as 802.3 Ethernet) and attempt to redefine the Ethernet frame format.
- However, most installations still use the original frame format.
- The major difference between conventional Ethernet and the 802.3 Ethernet follows:
  - The 802.3 Ethernet interprets the type field as a packet length, and
  - It adds an extra 8-byte header that contains the packet type. This extra header is referred to as Logical Link Control/Sub-Network Attachment Point (LLC/SNAP) header.
  - The 802.3 Ethernet reduced the payload maximum size from 1500 bytes to 1492 (1500 – 8) bytes.
- To keep the two versions of Ethernet compatible, we can think of the LLC/SNAP (or SNAP) header as the first 8 bytes of the payload and then use the following convention:
  1. If bytes 13-14 of frame contain a numeric value less than 1500 then
     a. The field is interpreted as a packet length and the 802.3 standard applies.
  2. Otherwise
     a. The field is a type field and the original Ethernet standard applies.
Extending a LAN across a Long Distance: Fiber Modems, Repeaters, Bridges, and Switches

- A typical LAN technology is designed to span a few hundred meters: it works well within a single building or a small campus.
- One limitation on distance is due to the fact that the hardware is designed to emit a fixed amount of energy, and
- If the wiring is extended beyond the design limits, stations will not receive a sufficiently strong signal, and errors will occur.
- The following mechanisms are used to extend a LAN across a long distance:
  - Fiber modem extensions,
  - Repeaters,
  - Bridges, and
  - Switches
- As a general rule, these extension mechanisms do not increase the strength of signals or extend cables.
- They insert additional hardware components that can relay signals across longer distances.
- An Ethernet extender (also network extender or LAN extender) is any device used to extend an Ethernet or network segment beyond its inherent distance limitation which is approximately 100 meters (330 ft) for most common forms of twisted pair Ethernet.
- These devices employ a variety of transmission technologies and physical media (wireless, copper wire, fiber-optic cable, coaxial cable).
- Ethernet extenders are the perfect solutions for:
  - point-of-sale terminals,
  - IP cameras,
  - wireless access points,
  - campus environments,
  - warehouses and other industrial installations,
  - remote offices or outposts, and
  - any number of applications that require broadband speeds to be carried over distances exceeding the 328 foot limit of network cable.
- There are many types of commercial Ethernet extenders available today.
Fiber Modem Extensions

- This mechanism consists of a pair of fiber modems and an optical fiber that are used to connect a computer to a remote Ethernet (refer to Figure 17.1 in page 292).
- Each of the modems performs two tasks:
  - Accept packets from the computer and send them over the optical fiber to the Ethernet hub/switch, and
  - Accept packets that arrive from the Ethernet hub/switch and send them to the computer.

Repeaters

- A repeater is an analog device that is used to extend a LAN by propagating LAN signals over long distances (refer to Figure 17.2 in page 293).
- It amplifies the signal received from the LAN and transmits the amplified version as output.
- Repeaters were used extensively with the original Ethernet.

Bridges and Bridging

- A bridge is a mechanism that is used to connect two LAN segments and to forward packets from one segment to another (refer to Figure 17.3 in page 294).
- Two LAN segments connected by a bridge behave like a single LAN:
  - A computer on a bridged network cannot distinguish one segment of the network from the other.
  - It can send a frame to any computer on both segments, and
  - A broadcast frame is delivered to all computers on both segments.
- A bridge receives a copy of every frame sent on a bridged LAN and then does the following:
  a) Extract the destination MAC address and the source MAC address from the header, and
  b) If both addresses belong to the same segment,
     - Then the packet is ignored by the bridge.
     - Otherwise, it is forwarded to the other segment.
- Most bridges are called adaptive or learning bridges because they learn the locations of computers automatically as follows:
  - When a frame arrives from a given segment, the bridge extracts the source address from the header, and adds it to a list of computers attached to that segment.
Notes:

1. A bridge allows simultaneous activities on attached segments:
   - A pair of computers on one segment can communicate at the same time as a pair of computers on another segment.

2. Although vendors no longer sell stand-alone bridge devices, the concept of bridging has been incorporated in other network devices such as modems and wireless routers:

   **Example 1:**
   - A DSL or cable modem provides a form of bridging that isolates the local network at the subscriber’s premise from the network at the ISP:
     - A packet is sent to the ISP only if it is not sent to a local destination on the subscriber’s network.

   **Example 2:**
   - Many wireless routers incorporate an *Ethernet switch* that provides bridging functionality as follows:
     - The Ethernet switch in a wireless router has ports (switch ports are labelled *local* to distinguish them from the *Internet* port that connects to the ISP’s modem) to which computers can be connected.
     - If two computers connected to the switch communicate, the wireless router will send the packets between them without sending them to the ISP network.
Switching and Layer 2 Switches

- **Switching** is a mechanism that forms the basis of modern Ethernets.

- An **Ethernet switch** (also called **Layer 2 switch**) is an electronic device that provides multiple ports to which computers are attached just like a *hub*:
  - Every node (computer workstation or any other peripheral) is connected by a twisted pair of wire to an Ethernet switch (which is the central node) (refer to Figure 15.6, page 258).

- It allows computers attached to its ports to send packages to one another.

- The difference between a *hub* and an Ethernet switch follows:
  - A *hub* operates as an analog device that forwards signals from one computer attached to it to all other computers attached to it, whereas,
  - An Ethernet switch is a digital device that forwards an Ethernet frame from one computer to the computer(s) at the destination address in the frame.
  - A *hub* can be viewed as a communication medium that connects all the computers attached to it (logical bus topology), whereas,
  - An Ethernet switch can be viewed as a bridged LAN with one computer per LAN segment (logical star topology) (refer to Figure 17.6, page 298).

- An **Ethernet switch** consists of the following (refer to Figure 17.7, page 299):
  - An intelligent **interface** attached to each port, and
  - A central **fabric** that provides simultaneous transfer of packets between pairs of interfaces.

- An **interface** contains the following parts:
  - A processor
  - A memory, and
  - The hardware devices needed to transfer packets.

- It performs the following tasks:
  - accept an incoming packet
  - consult a forwarding table, and
  - send the packet across the **fabric** to the correct output port.

- It also accepts packets from the **fabric** and transmits them out the port.
Note:
- Because it has a memory, an *interface* can buffer arriving packets when an output port is busy.
- So, if computer 1 and computer 2 want to send packets to computer 3 at the same time, either interface 1 or interface 2 will hold its packet while the other is transmitting.

- The major advantage of using a *switched* LAN instead of a *hub* is parallelism:
  - A *hub* can only support one transmission at a time whereas
  - An *Ethernet switch* permits multiple independent transfers to occur at the same time: If a switch has $N$ ports, $N/2$ independent transfers can occur at the same time.

- *Ethernet switches* are available in many sizes:
  - The smallest consists of an inexpensive, stand-alone device that provides four connections which are sufficient to interconnect:
    - A computer,
    - A printer, and
    - Two other devices such as a scanner and a backup disk.
  - Larger switches are used in major corporations to connect tens of thousands of computers and other devices throughout a company.
Ethernet switches are often interconnected to form a single large network.

Modern Ethernet implementation: switched connection, collision-free. Each computer communicates only with its own switch, without competition for the cable with others.
VLAN Switches

- **Virtual Local Area Network switches (VLAN switches)** are an extension of *Ethernet switches* with virtualization.

- It allows a manager to configure a single switch to emulate multiple, independent switches as follows:
  - It specifies a set of ports on the switch and designates them to be on virtual LAN 1.
  - Virtual LAN 2, virtual LAN 3, . . . etc are created in the same way.

- When a computer broadcasts a packet, only the computers on the same virtual LAN as this computer can receive it.

- A VLAN switch acts like a set of smaller switches.

- Dividing computers into separate broadcasting domains is important in certain large companies or service providers where it may be important to guarantee that a set of computers can communicate without others receiving the packets and without receiving packets from outsiders.

Multiple Ethernet Switches and Shared VLANS

- IEEE has extended the Ethernet standard to make it possible to configure VLANS that cross multiple Ethernet switches as follows (standard IEEE 802.1Q):
  - Each VLAN is assigned a unique identification number, and
  - An extra 16-bit field (known as *VLAN tag*) is added to the header of each frame to hold the identification number of the VLAN to which the computer sending the frame belongs.
  - The VLAN tag is inserted by the switch into the frame whenever it receives a frame from a computer.
  - This frame is sent from one switch to another, but
  - Before the frame is delivered to a destination computer by a switch, it removes the VLAN tag from it.

- When a computer broadcasts a frame,
  - The switch to which this computer is attached does the following:
    a. deliver a copy of the frame to each of its ports that is part of the VLAN.
    b. It insert the VLAN tag of the VLAN to which this computer belongs to the frame.
    c. It then sends the resulting frame across the inter-switch link.
  - The other switches do the following:
    a. receive the frame,
    b. extract the VLAN tag from it, and
    c. deliver a copy of the frame to each connected computer that is part of the VLAN.
Exercises:

Page 263: 15.1, 15.2, 15.3, 15.4, 15.6, 15.7, 15.8, 15.9, 15.10, 15.11, 15.12
Pages 302 & 303: 17.1, 17.3, 17.4, 17.11.

13.8 What are the four basic LAN topologies?
- bus topology, ring topology, mesh topology, and star topology.

13.10 In a mesh topology, how many connections are required among 20 computers?
- \(20 \times 19 / 2 = 190\).

13.11 The least significant bit of the left-most byte is set to 0. Example: 8-00-00-00-00-00 because \(8 = 100\).

13.12
- **Unicast address**: a packet with a unicast address as the destination address is delivered to only the host with that address.
- **Multicast address**: A multicast address identifies a subset of computers on a given LAN, and a copy of a packet with a multicast address as the destination address is delivered to each computer in that subset.
- **Broadcast address**: a copy of a packet with a broadcast address as the destination address is delivered to all the hosts (except the sending computer) on the LAN.

13.13 It decides to accept a packet if the destination address on that packet is its address, or if it is a multicast address of a subset of computers in which it belongs or it is a broadcast address.

13.14 Header

13.15 A frame consists of the header that contains metadata such as a destination address and source address, and the payload that contains the data being sent.

13.16 It is needed so that a character that is used as the SOH (start of the header) character or the EOT (end of transmission) character can be part of the data that is being sent.

15.1
- 6 bytes destination address
- 6 bytes source address
- 2 bytes type
- 46 – 1500 byte of payload
4 bytes CRC
Maximum (total) 1518

15.2
It is used by the destination host to determine which application program to use to process the package.

15.3
The maximum payload is 1492
With the 802.3 Ethernet frame, a new header of 8 bytes called the Logical Link Control or the Sub-Network Attachment Point (LLC/SNAP) is added to the frame.

15.4
If bytes 13-14 of the frame contains a numeric value less than 1500, then it is an 802.3 Ethernet frame; otherwise, it is an original Ethernet frame.

15.6
By using an Attachment Unit Interface (AUI) cable that connects NIC to a transceiver that is connected to the Ethernet cable.

15.7
Transceivers are integrated into the NIC in a computer, and the coaxial cable runs from computer to computer.

15.8
A hub is a central electronic device that provides multiple ports to which each computer of a LAN is attached. It emulates a bus topology.

5.9
A switch. Because with a switch, a packet sent to a host is not seen by all other hosts.

15.10
A twisted pair wiring with a hub.

15.11
A twisted pair wiring with a hub.

15.12

10 Mbps category 5
100 Mbps category 5E
1000 Mbps category 6