Network Layer Design Issues and Connecting devices

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Aim of the session

To familiarize students with the Design issues in the Network layer and network devices

Learning Outcomes

At the end of this session, you should be able to:

- Understand the design issues in the network layer
- Understand the services provided by the Network layer

Network Layer

- Network layer is concerned with getting datagram packets from the source all the way to the destination[1]
- This may require making many hops at intermediate routers along the way
- To achieve this goal network layer must
  - Learn about the topology of the network
  - Compute appropriate paths through it
  - Coordinate traffic flows across multiple networks

[1] Data link layer sends frames to immediate neighbours using MAC address

Services

- Functions: Logical Addressing, Routing (Path determination), Congestion control
- **Packetizing**: Encapsulating the data received from the upper layer at the source and decapsulating at the receiver.
  - The source host receives the payload from an upper-layer protocol, adds a header that contains the source and destination addresses
- **Routing**: Network layer is responsible for routing a packet from its source to the destination.
  - A physical network is a combination of networks (LANs and WANs) and routers that connect them. There is more than one route from the source to the destination.

- **Congestion Control**: Congestion in the network layer is a situation in which too many datagrams are present in an area of the Internet.
  - Congestion may occur if the number of datagrams sent by source computers is beyond the capacity of the network or routers
  - In such a situation, some routers may drop some of the datagrams

Network layer Design Issues

Some of the issues that the designers of the network layer must handle. These issues include the service provided to the transport layer and the internal design of the network. They are:

- Store-and-Forward Packet Switching
- Services Provided to the Transport Layer
- Implementation of Connectionless Service
- Implementation of Connection-Oriented Service

Design Issue: Store-and-Forward Packet Switching

Store-and-Forward Packet Switching

- A host with a packet transmits it to the nearest router, either on its own LAN or over a point-to-point link
- The packet is stored there until it has fully arrived and the link has finished its processing by verifying the checksum.
- Then it is forwarded to the next router along the path until it reaches the destination host
- This mechanism is store-and-forward packet switching

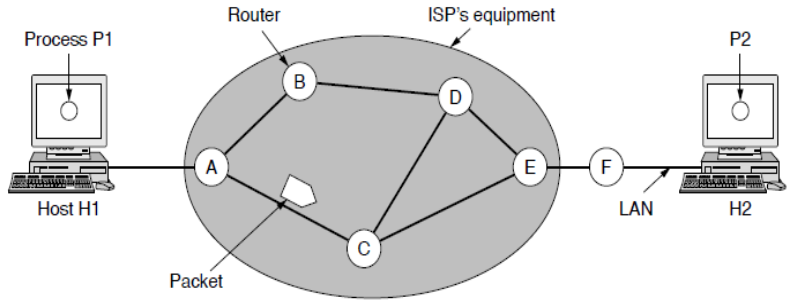


Figure: Environment of the network layer protocols

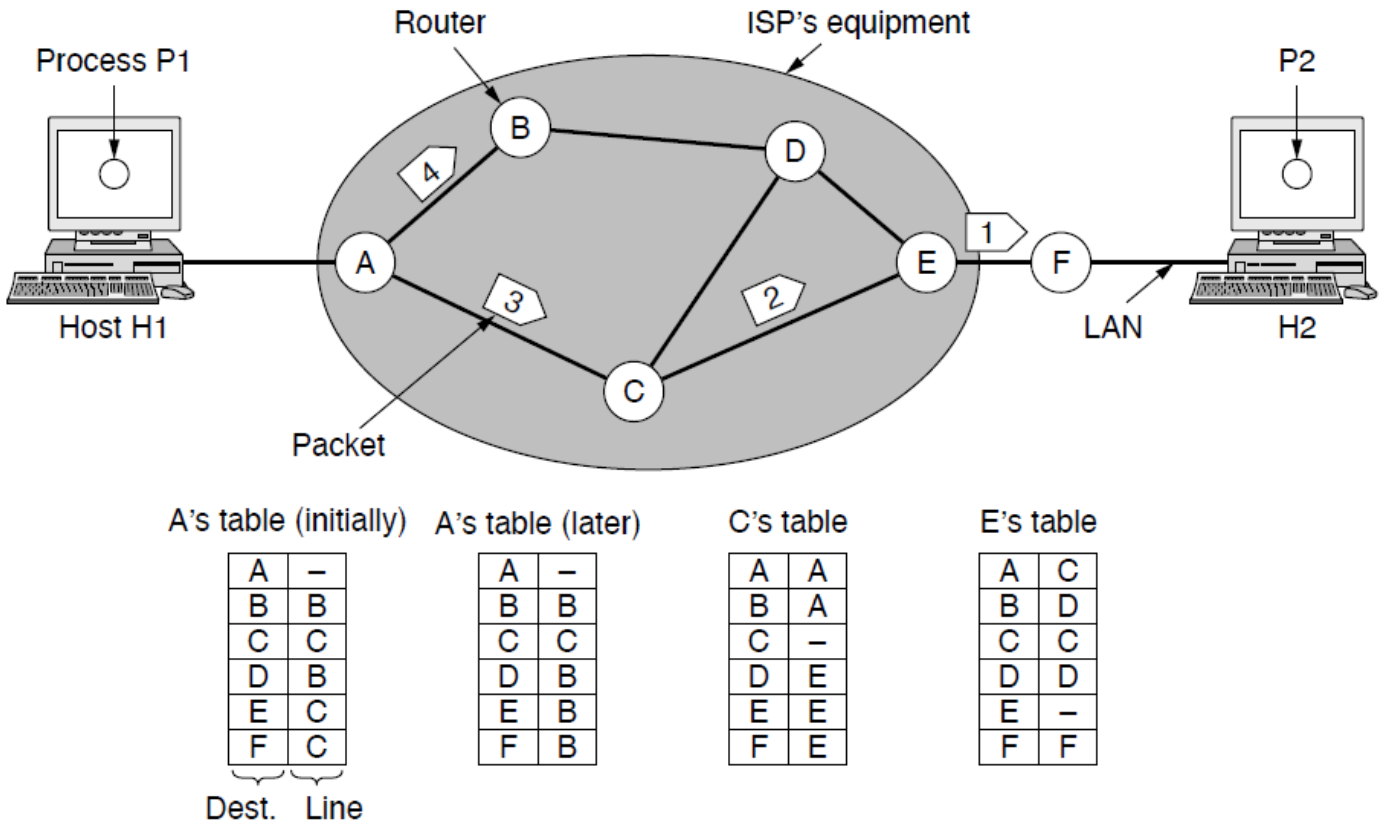
Design Issue: Services Provided to the Transport Layer

The services need to be carefully designed with the following goals in mind

- The services should be independent of the router technology
- The transport layer should be shielded from the number, type, and topology of the routers present.
- The network addresses made available to the transport layer should use a uniform numbering plan, even across LANs and WANs

Design Issue: Implementation of Connectionless Service

- The network-layer protocol treats each packet independently
- In this approach, the packets in a message may or may not travel the same path to their destination
- Each packet is routed based on the information contained in its header: source and destination addresses
- Packets are called **Datagrams**; Network is called **datagram network**
- The router in this case routes the packet based only on the destination address.
- The source address may be used to send an error message to the source if the packet is discarded.



A	–
B	B
C	C
D	B
E	C
F	C

A	–
B	B
C	C
D	B
E	B
F	B

A	A
B	A
C	–
D	E
E	E
F	E

A	C
B	D
C	C
D	D
E	–
F	F

Figure: Routing in datagram network

Datagram Network

- Host H1 has a long message for host H2
- The message is four times longer than the maximum packet size
  - So the network layer breaks the message into four packets
- Every router has an internal table telling it where to send packets for each of the possible destinations
- At A, packets (1-3) are stored briefly and had their checksums verified. Then each packet is forwarded according to A's table
  - Packet 1 Destination is F, so forward it to C
    - then forwarded to E and F. (Packets 2 and 3 follow the same route)
- Due to traffic in A-C-E path, A's table is updated and packet 4 is sent to router B.
- IP- The basis for the entire Internet, is the dominant example of a connectionless network service

Design Issue:Implementation of Connection-Oriented Service

- The path from the source router all the way to the destination router must be established before any data packets can be sent
- This connection is called a **VC (Virtual Circuit)**
- This network is called a **virtual-circuit network**
- In addition to source and destination address, packet contains a **flow label** (virtual-circuit identifier)

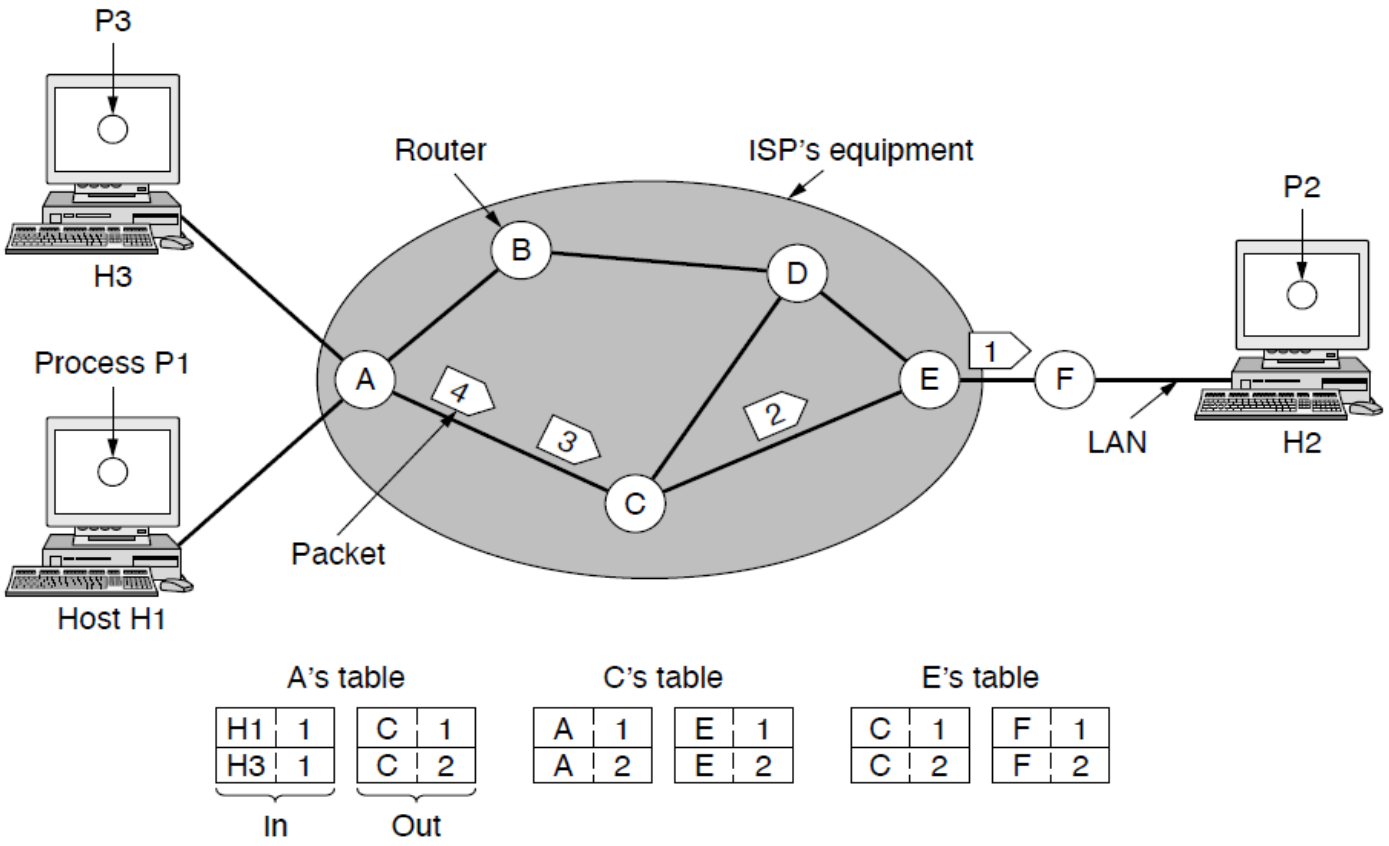


Figure: Routing in Virtual-circuit network

- Host H1 has established connection 1 with host H2
  - This connection is remembered as the first entry in each of the routing tables.
  - The first line of A's table says that
    - if a packet with connection identifier 1 comes from H1, it is to be sent to router C and given connection identifier 1.
    - Similarly, the first entry at C routes the packet to E, with connection identifier 1.
- Now consider H3 also wants to establish a connection to H2
  - It chooses connection identifier 1 (this is its only connection) and tells the network to establish the virtual circuit
  - A can easily distinguish connection 1 packets from H1 from connection 1 packets from H3, C cannot do this.
  - For this reason, A assigns a different connection identifier to the outgoing traffic for the second connection
- Example of a connection-oriented network service is MPLS (MultiProtocol Label Switching). It is used within ISP networks

Virtual-Circuit N/W Vs Datagram Networks

Issue	Datagram network	Virtual-circuit network
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

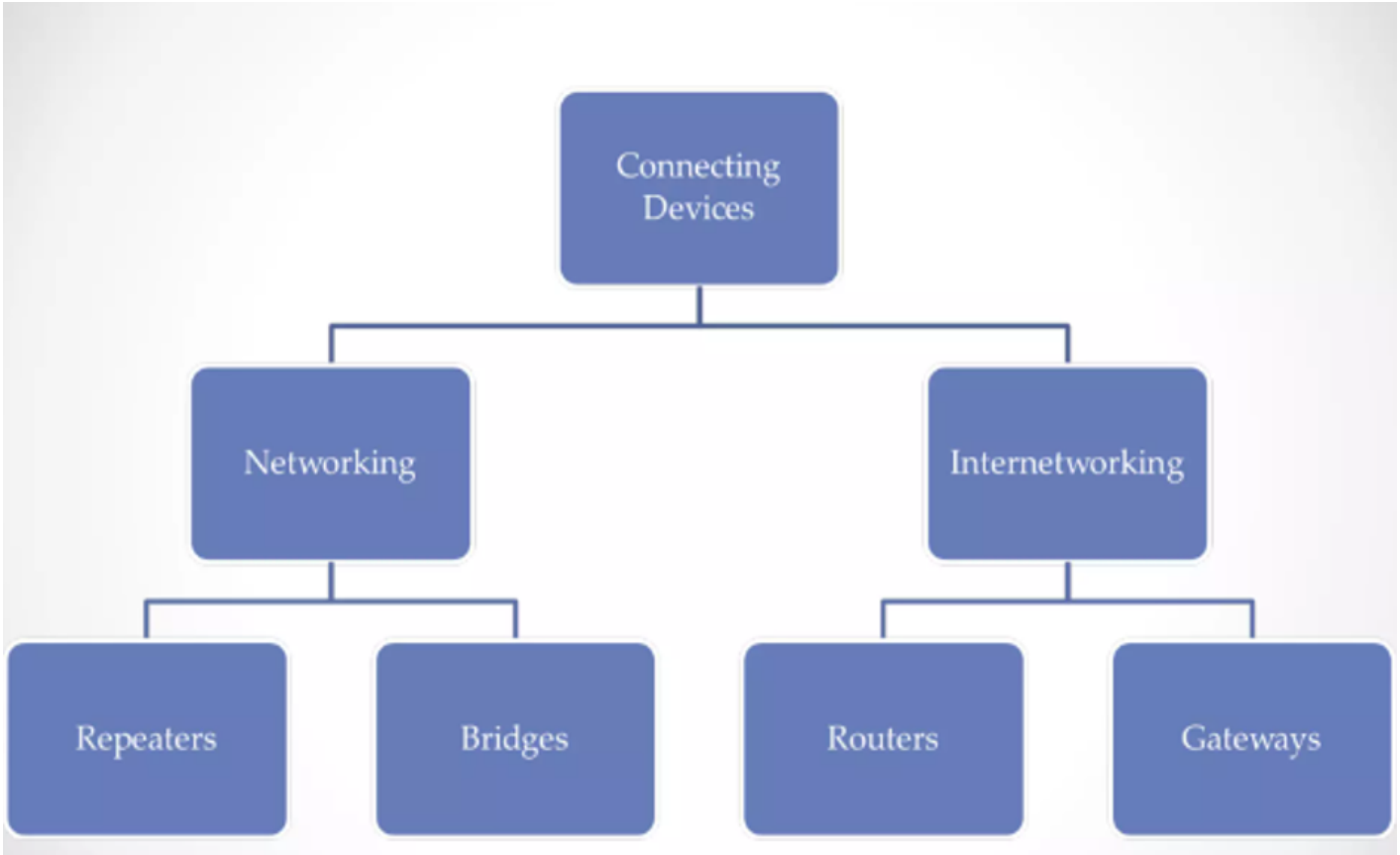
Figure: Comparison of datagram and virtual-circuit networks

Network devices

- Hub ,Repeater
- Bridge
- Switch
- Router
- Gateway

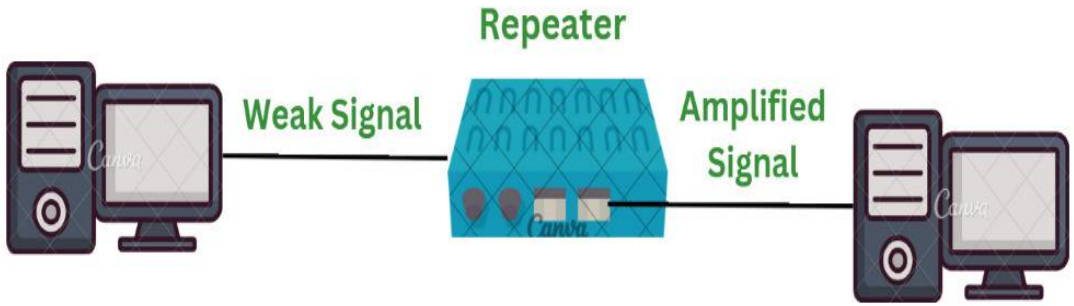
Application layer	Application gateway
Transport layer	Transport gateway
Network layer	Router
Data link layer	Bridge, switch
Physical layer	Repeater, hub

Figure: Device-Layer Mapping


Connecting Devices
Networking
Internetworking
Repeaters
Bridges
Routers
Gateways

Repeater

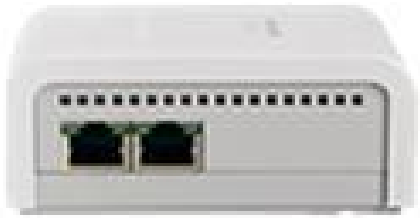
- A **repeater** receives a signal and, before it becomes too weak or corrupted *regenerates* the original bit pattern (amplifying)
- Repeaters do not understand frames, packets, or headers
- A repeater operates at the physical layer
- **A repeater has no filtering capability.**



Hub

- A hub is a physical device used to join multiple devices on the same LAN.
- A hub is a device that operates only in the physical layer
- A hub must connect to a router or switch in order to communicate outside its LAN.
- Frames arriving on any of the lines are sent out on all the others.
- They do not examine the link layer addresses or use them
- Hubs differ from repeaters
  - Hubs do not (usually) amplify the incoming signals
  - Hubs are designed for multiple input lines,
- Ethernet LANs use star topology.
  - In a star topology, a repeater is a multiport device, often called a *hub*

HUB and Repeater

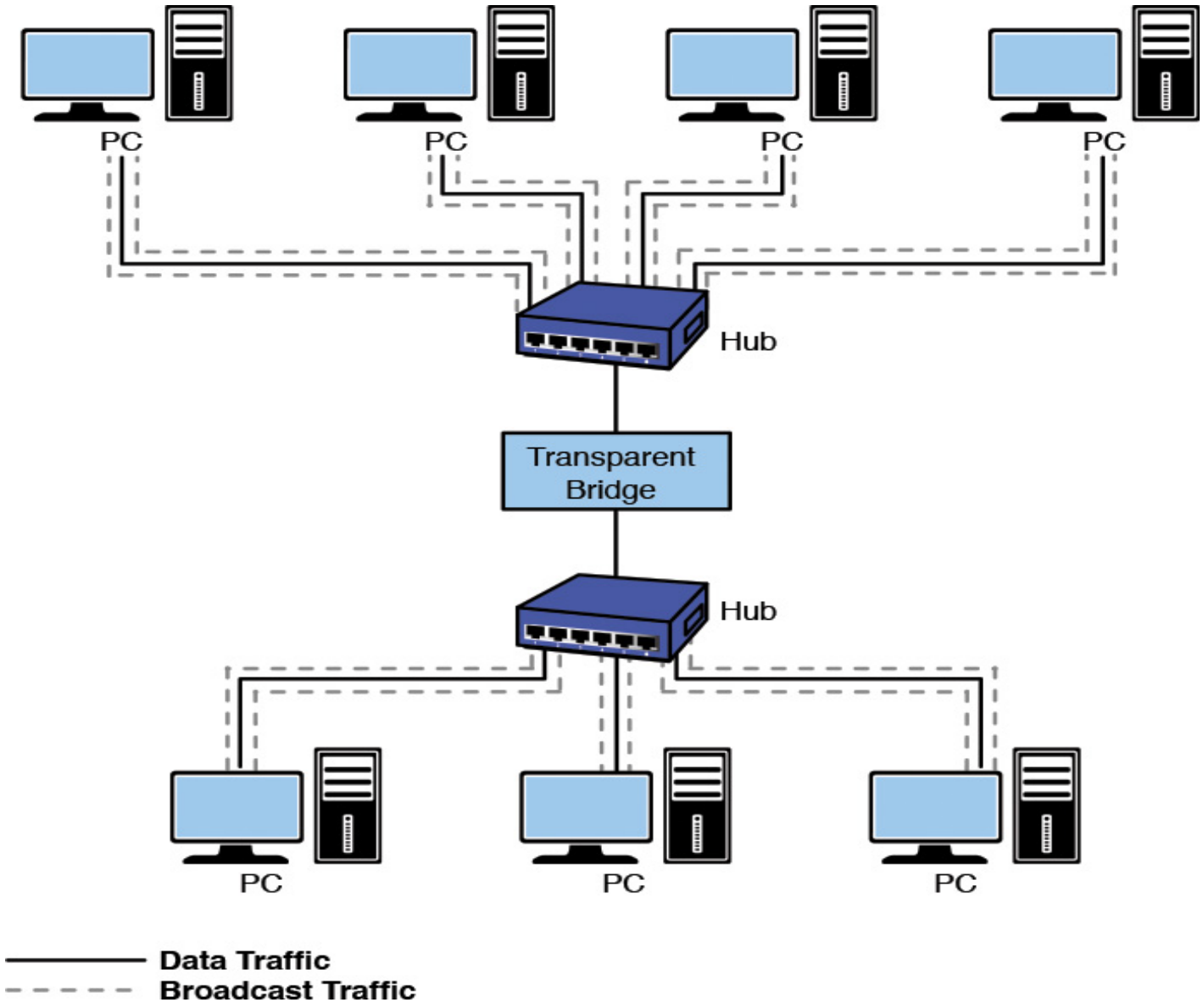


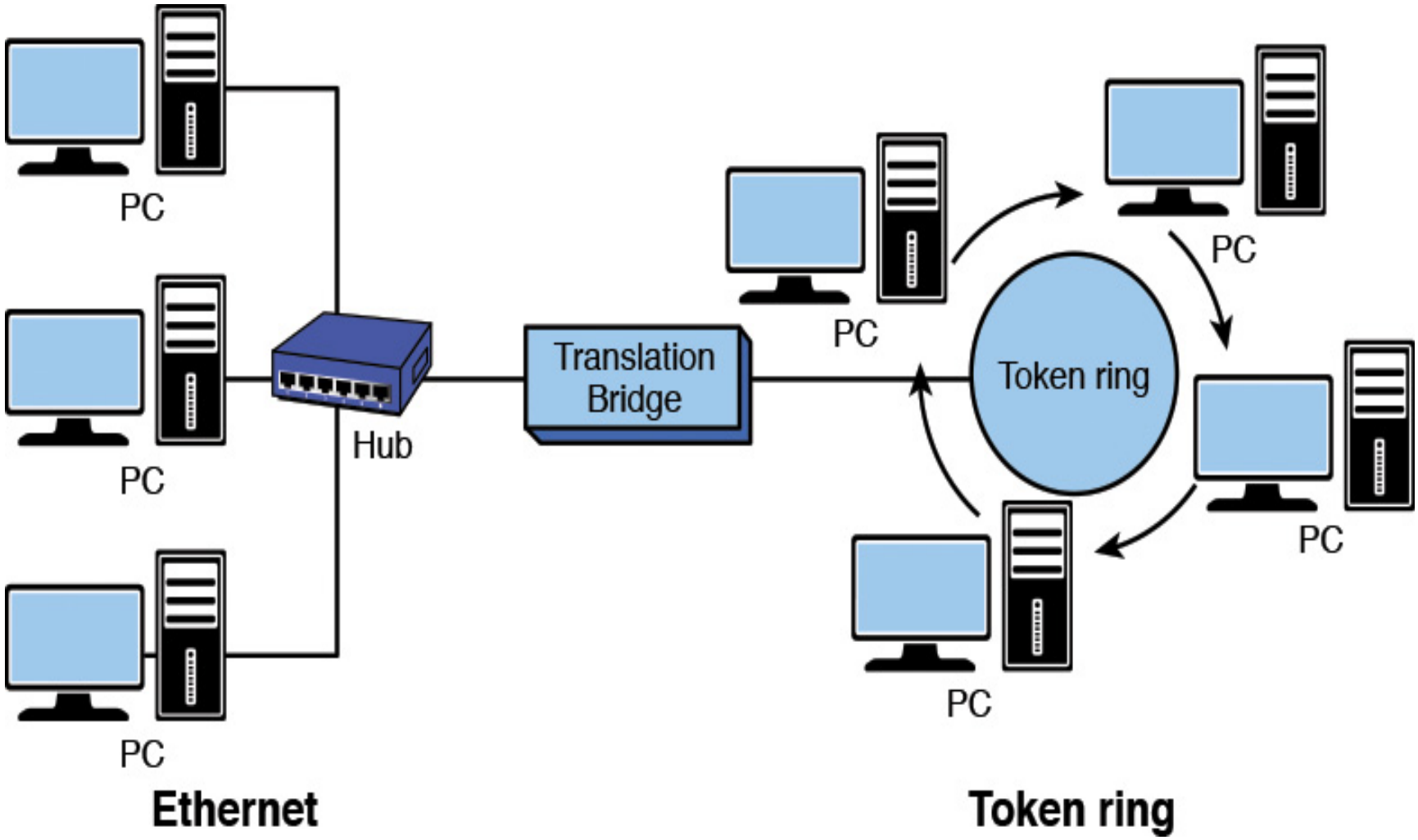
Repeater

Hub

Bridge

- To provides a **means of interconnecting similar LANs**
- A **transparent bridge** interconnects LANs that use the **same protocol suite**
- A **translation bridge** joins LANs that use **different protocols**.
- A network device model with filtering and forwarding capabilities
- The bridge extracts the destination address from the frame header and looks it up in a table to see where to send the frame.
- Bridges were originally intended to be able to join different kinds of LANs. However, this never worked well because of differences between the LANs
  - Different frame formats require copying and reformatting, which takes CPU time, requires a new checksum calculation


PC
PC
PC
PC
Hub
Transparent Bridge
Hub
PC
PC
PC
Data Traffic
Broadcast Traffic



https://www.javatpoint.com/token-ring-in-computer-networks

Switch

- Switches are modern bridges by another name
- The switch will tend to have many ports (than a bridge)
  - Modern installations all use point-to-point links to plug directly into a switch
- A switch allocates bandwidth for each port.

Routers

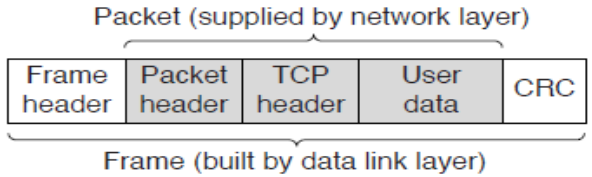


Figure: Frames, Packets and headers

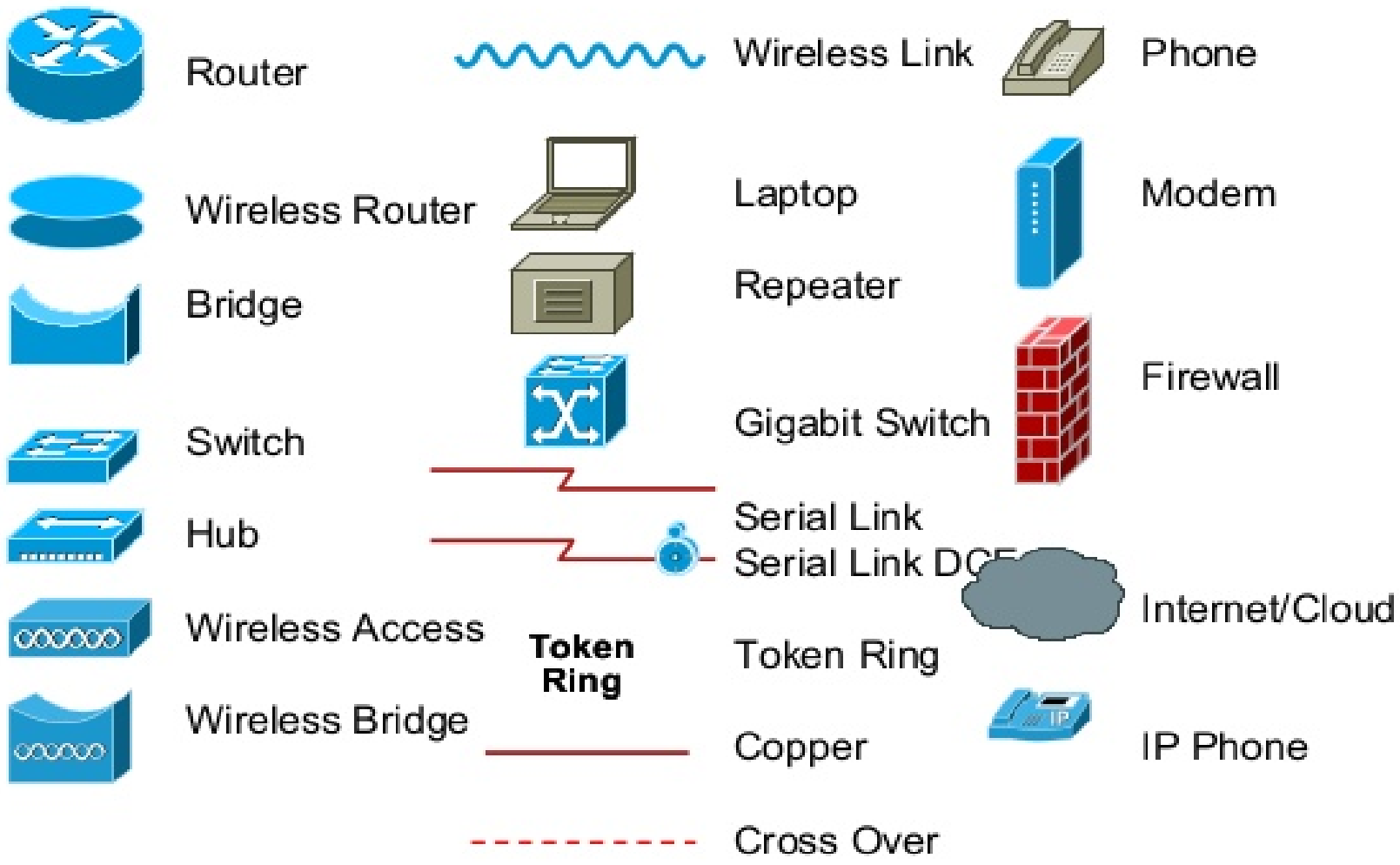
- A router determines a packet's future path by examining the destination IP address
- A **router** is a three-layer device; it operates in the physical, data-link, and network layers
  - Physical layer: It regenerates the signal it receives.
  - Link-layer device: It checks the physical (MAC) address
  - Network-layer device: It checks the network-layer addresses
- A router changes the link-layer address of the packet (both source and destination) when it forwards the packet.

Gateways

- A **Transport gateway** is a device used to connect networks [2]
- They connect two computers that use different connection-oriented transport protocols (PC1(TCP/IP)$\longleftrightarrow$PC2(SCTP))
- Historically, gateways and routers have been separate devices.
  - However, it's becoming more common for their functions to be combined and simply called a router.
- **Application gateways** understand the format and contents of the data and can translate messages from one format to another
  - An email gateway could translate Internet messages into SMS messages for mobile phones

[2] while a router typically delivers data within a network.

Common Data Network Symbols



Layer 2 Switches

Hub

Multi Layer Switches

Firewalls

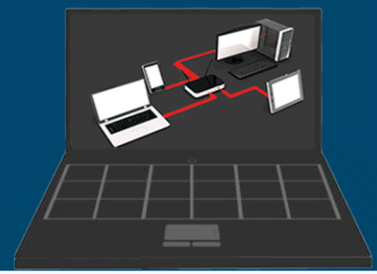
Modems

Routers

Bridges

Repeater

TYPES OF NETWORK DEVICES



REPEATER

A repeater is a two-port network device that regenerates the signal over a network before it becomes weak or gets damaged.

BRIDGE

A bridge is a device that joins any two networks or host segments together.

MODEM

Modems are devices that transform digital signals into the form of analog signals that are of various frequencies

NETWORK HUB

A network hub is a multiport repeater that connects multiple wires from different branches.

NETWORK SWITCH

Switches play a more important role than hubs. A switch is a multi-port device that enhances network efficiency.

GATEWAY

As the name suggests, the gateway is a passage that interlinks two networks together.

ACCESS POINT

An AP or Access Point is a wireless appliance that operates on the OSI model's second layer. It can be used in two ways.

Acknowledge various sources for the images.
Thankyou