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Networking Fundamentals

S. Hussain Ali

M.S. (Computer Engineering)

Department of Computer Engineering
King Fahd University of Petroleum and Minerals
Dhahran, Saudi Arabia



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Topics Covered in this Session

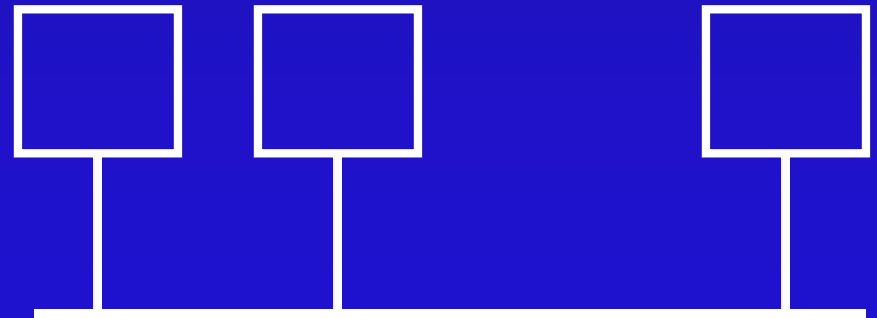
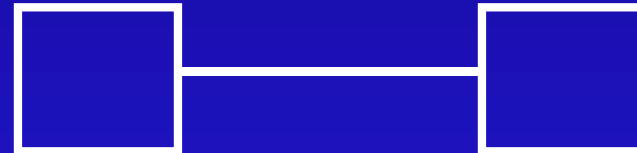
- Networking and Design concepts
- Layering: Reference Models
- Interconnection Devices

Information, Computers, Networks

- Information: anything that is represented in **bits**
 - » **Form** (can be represented) vs **substance** (cannot)
- Properties:
 - » Infinitely replicable
 - » Computers can %manipulate+information
 - » Networks create %access+to information
- Potential of networking:
 - » move bits **everywhere, cheaply**, and with desired **performance characteristics**

Connectivity...

- Building Blocks
 - » links: coax cable, optical fiber...
 - » nodes: general-purpose workstations...
- Direct connectivity:
 - » point-to-point
 - » multiple access



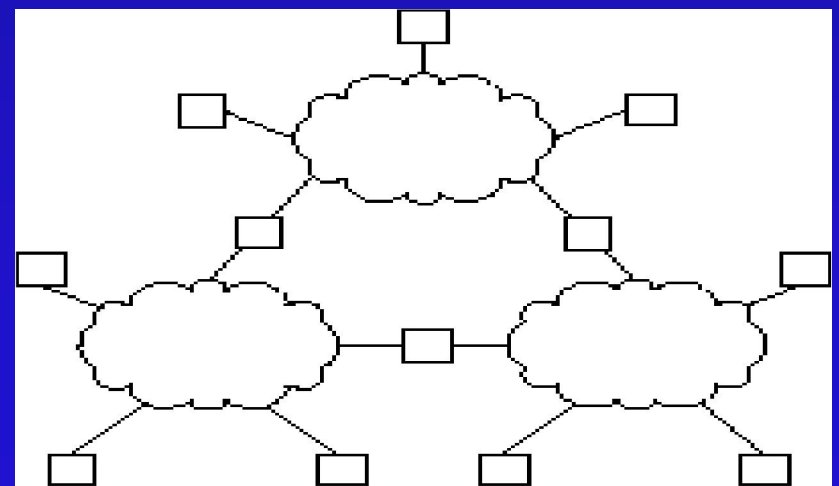
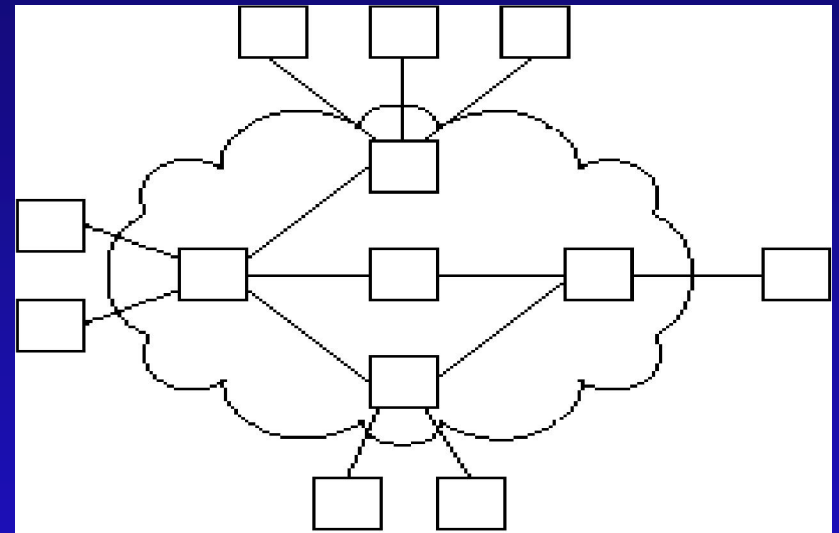
Connectivity... (Continued)

- Indirect Connectivity
 - » switched networks

⇒ switches

- » inter-networks

⇒ routers



What is “Connectivity” ?

- Direct or indirect access to every other node in the network
- Connectivity is the magic needed to communicate if you do not have a link.
- Internet:
 - » Best-effort (no performance guarantees)
 - » Packet-by-packet
- A pt-pt link:
 - » Always-connected
 - » Fixed bandwidth
 - » Fixed delay & Zero-jitter

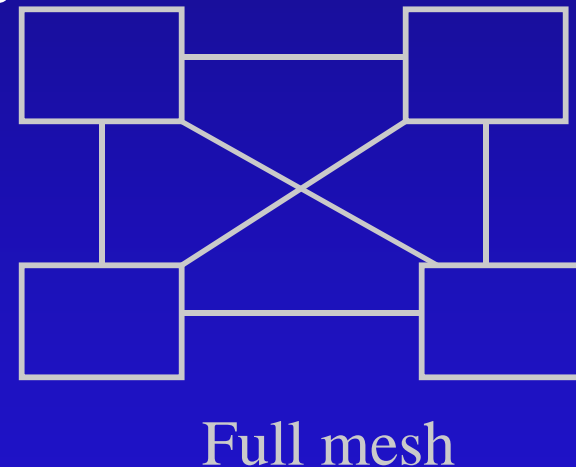
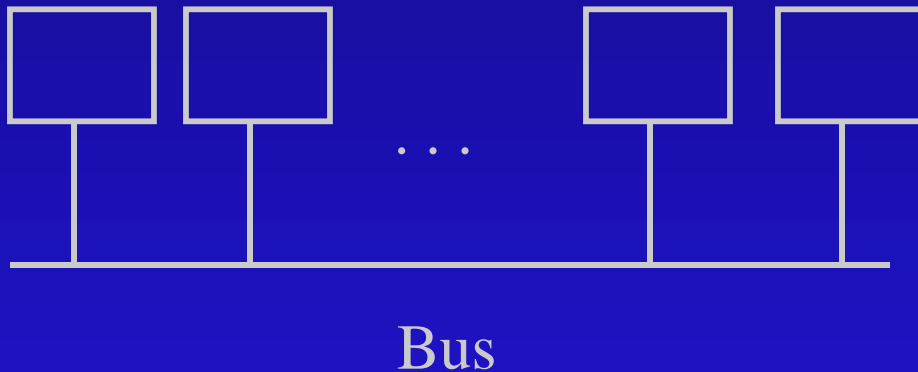
Point-to-Point Connectivity Issues



- Physical layer: coding, modulation etc
- Link layer needed if the link is shared between apps; is unreliable; and is used sporadically
- No need for protocol concepts like addressing, names, routers, hubs, forwarding, filtering etc
- What if I want to build a network with N nodes and let N increase ?

Connecting N users: *Directly* ...

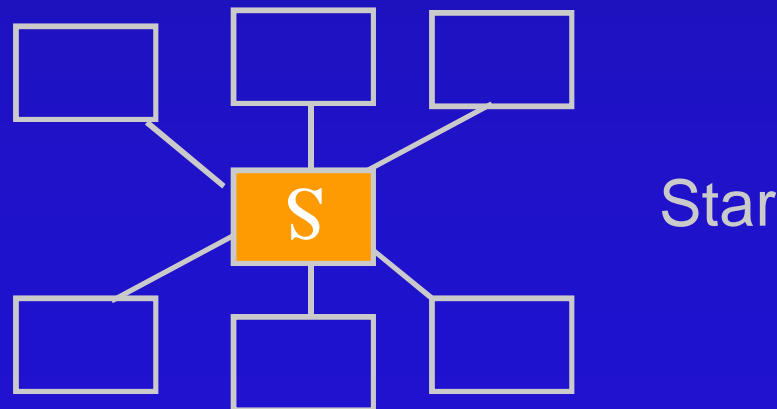
- **Bus:** broadcast, collisions, media access control
- **Full mesh:** Cost, simplicity



- ❑ Address concept needed if we want the receiver alone to consume the packet
- ❑ Required in all topologies

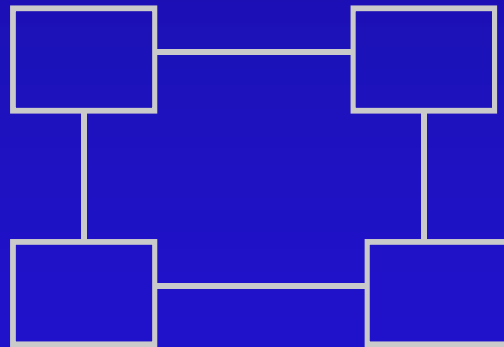
Connecting N users: *Indirectly ...*

- **Star:** One-hop path to any node, reliability, forwarding function
- %Switch+S.can filter and forward!
 - » Switch may forward multiple pkts in parallel !
- Forwarding without filtering => %hub+
 - » Emulates %hub++ needs filtering at hosts



Connecting N users: *Indirectly ...*

- **Ring:** Reliability to link failure, near-minimal links
- All nodes need %forwarding+and %filtering+
- Sophistication of forward/filter lesser than switch



Ring

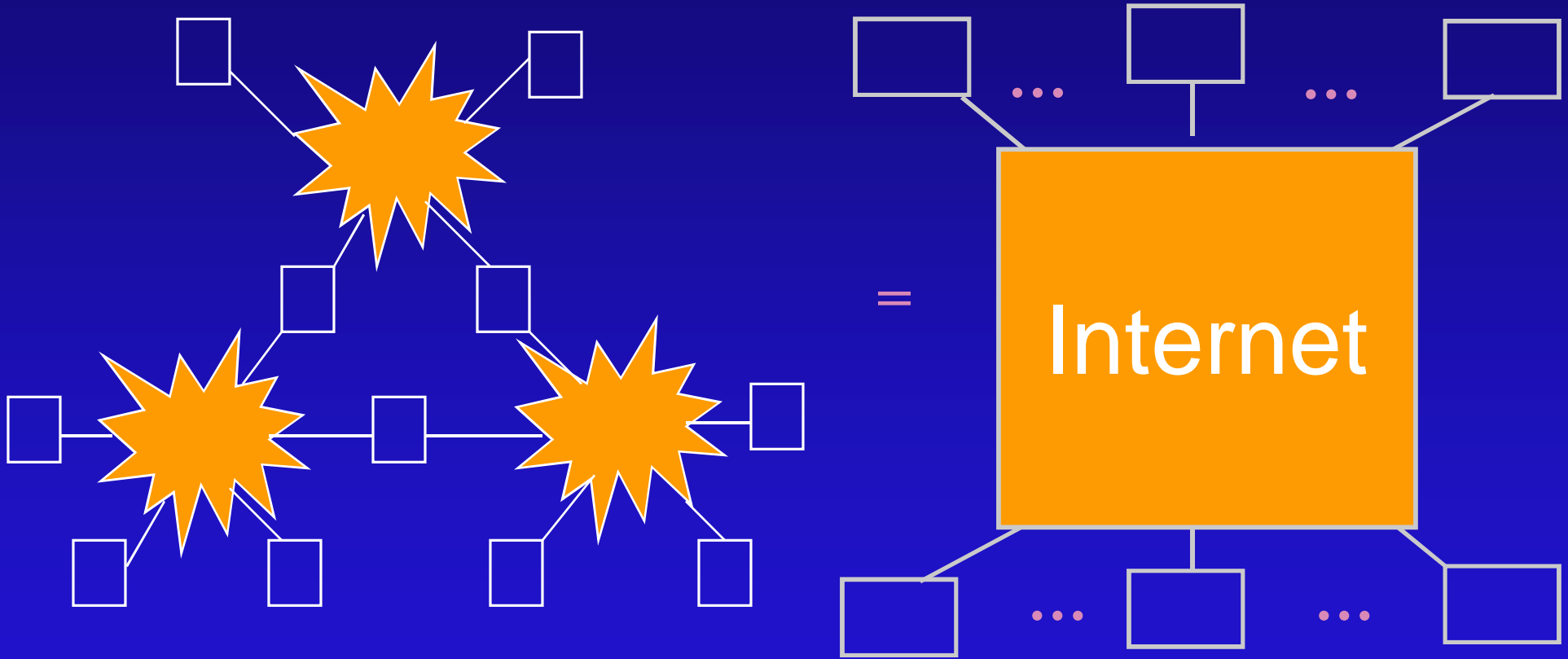
Multi-Access LANs

- **Hybrid topologies:** direct & indirect
 - » Limited scalability due to limited filtering
- Topology issues: Cost, reliability, manageability, deployability, scalability, complexity
- Medium Access Protocols:
 - » CSMA/CD (Ethernet), Token Ring
 - » Key: Use a single protocol in network
- Concepts: address, forwarding (and forwarding table), bridge, switch, hub, token, medium access control (MAC) protocols

Networks: Networks of Networks

- What is it ?
 - » Connect **many** disparate physical networks and make them function as a coordinated unit ÷ +- Douglas Comer
 - » Many => scale
 - » Disparate => heterogeneity
- Result: Universal connectivity!
 - » The inter-network looks like one large switch, i.e.
 - » User interface is sub-network independent

Networks: Networks of Networks

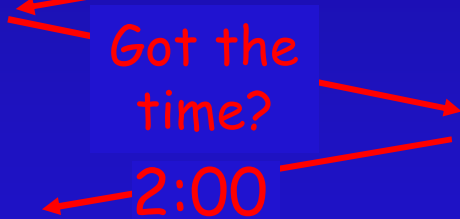
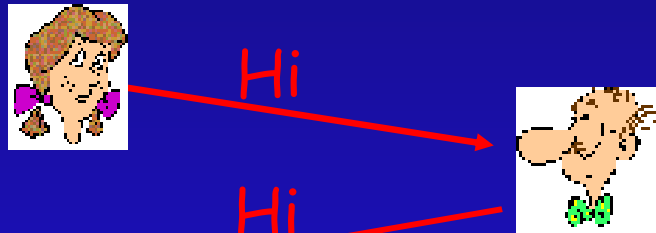


Networks: Networks of Networks

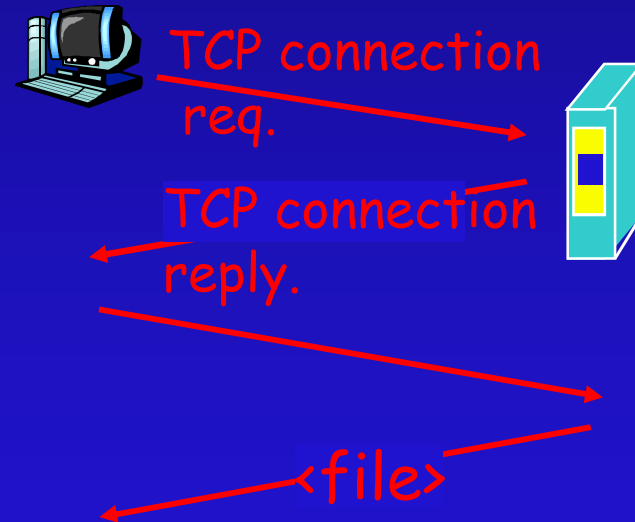
- Internetworking involves two fundamental problems: **heterogeneity and scale**
- **Concepts:**
 - » Translation, overlays, address & name resolution, fragmentation: to handle heterogeneity
 - » Hierarchical addressing, routing, naming, address allocation, administration: to handle scaling

Formal Framework: *Protocols*

Human protocol vs Computer network protocol:



time

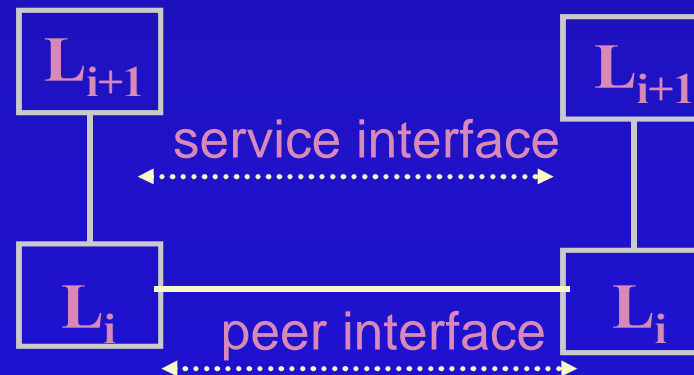


So, why layering?

- Explicit structure allows identification, relationship of complex systems & pieces
 - » layered reference model
- Modularization eases maintenance, updating of system
 - » change of implementation of layers & service transparent to rest of system
 - » e.g., change in gate procedure doesn't affect rest of system

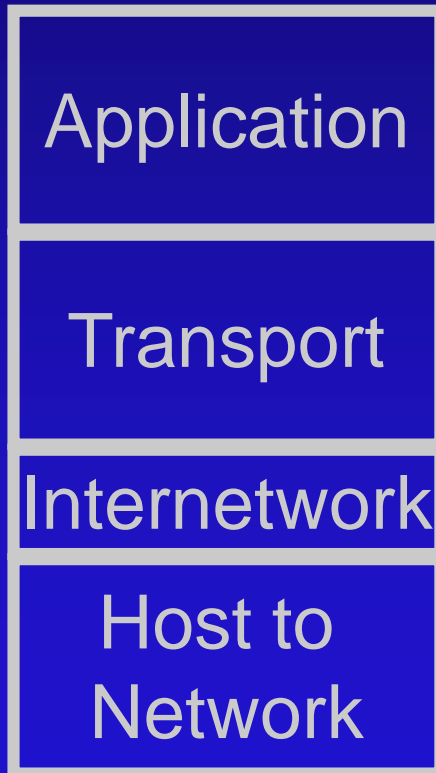
Formal Framework: *Protocols*

- Building blocks of a network architecture
- Each protocol object has two different interfaces
 - » service interface: defines operations on this protocol
 - » peer-to-peer interface: defines messages exchanged with peer

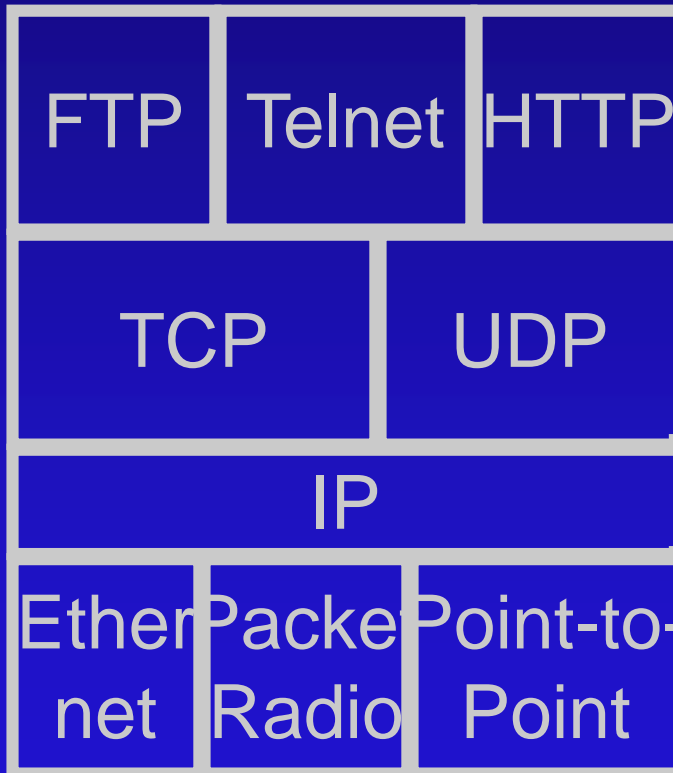


Reference Models for Layering

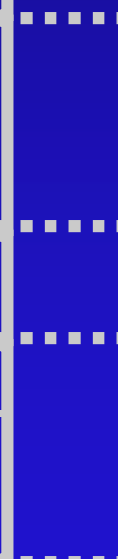
TCP/IP Model



TCP/IP Protocols



OSI Ref Model



Framework: *Interface Design*

- Interface between layers is also called the **architecture+**
 - » Use abstractions to hide complexity
 - » Allows a subroutine abstraction between a layer and its adjacent layers.
- Interface design crucial because **interface outlives the technology** used to implement the interface.

Review: *Multiple Access Protocols*

- Aloha at University of Hawaii:
Transmit whenever you like
Worst case utilization = $1/(2e) = 18\%$
- CSMA: Carrier Sense Multiple Access
Listen before you transmit
- CSMA/CD: CSMA with Collision Detection
Listen while transmitting.
Stop if you hear someone else.
- Ethernet uses CSMA/CD.
Standardized by IEEE 802.3 committee.

Inter-connection Devices

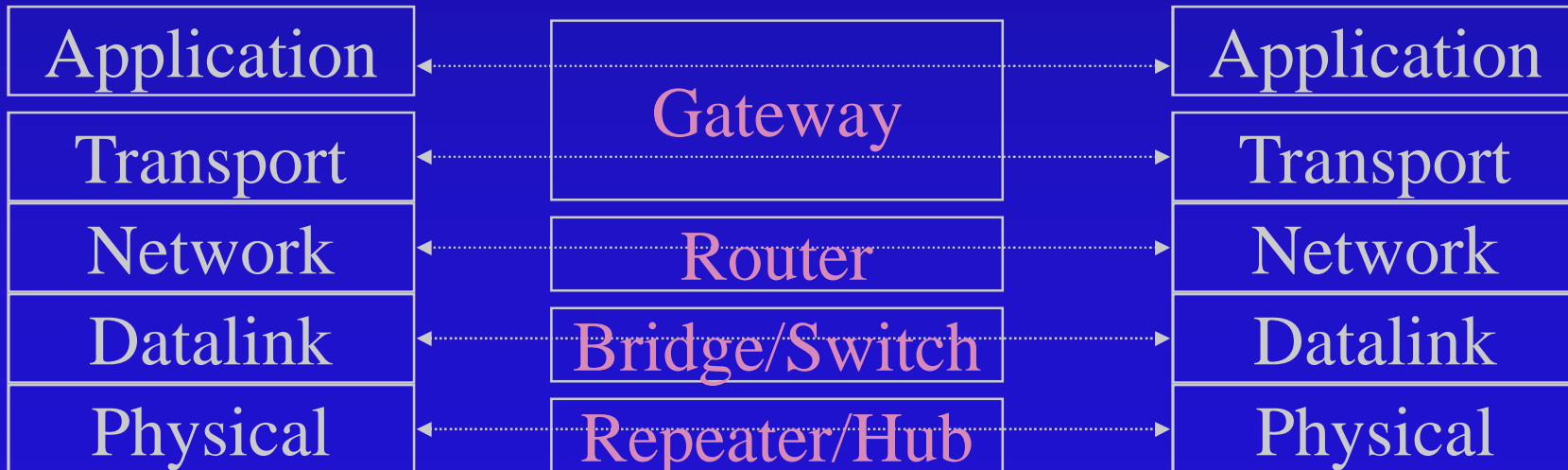
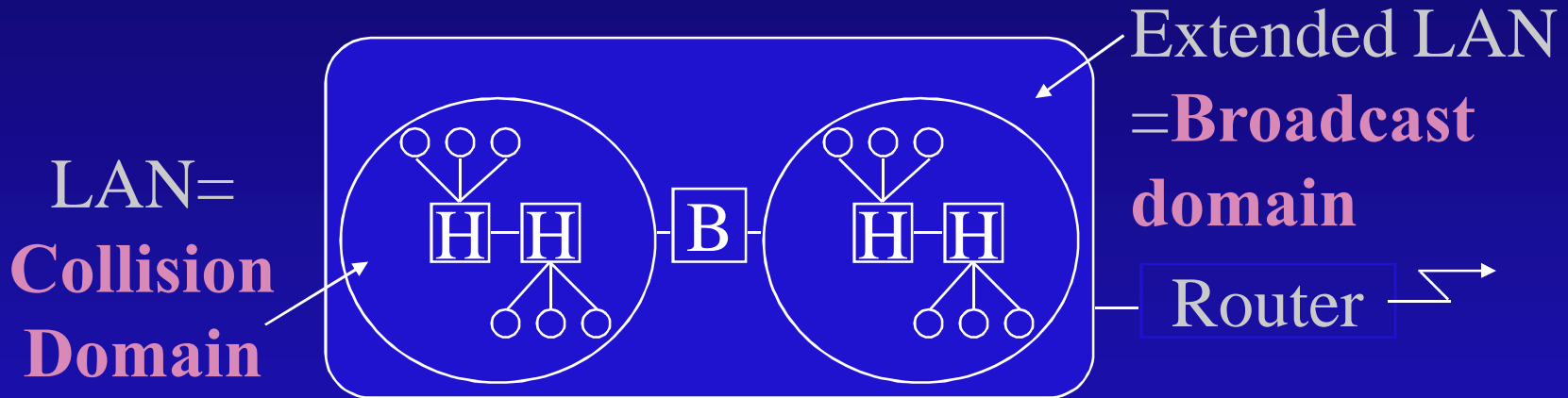
- **Repeater**: Layer 1 (PHY) device that restores data and collision signals: a digital amplifier
- **Hub**: Multi-port repeater + fault detection
 - » Note: broadcast at layer 1
- **Bridge**: Layer 2 (Data link) device connecting two or more **collision domains**.
 - » MAC multicasts are propagated throughout **extended LAN**.
 - » Note: Limited filtering and forwarding at layer 2

Connection Devices (Continued)

- **Router**: Network layer device. IP, IPX, AppleTalk. Interconnects **broadcast domains**.
 - » Does not propagate MAC multicasts.
- **Switch**:
 - » **Key**: has a switch fabric that allows parallel forwarding paths
 - » **Layer 2 switch**: Multi-port bridge w/ fabric
 - » **Layer 3 switch**: Router w/ fabric and per-port ASICs

These are functions. Packaging varies.

Interconnection *Devices*



Summary

- Connectivity among computers
 - » Direct
 - . Point-to-point &
 - . Multiple access
 - . ALOHA, CSMA/CD, Token Ring are examples of multiple access protocols.
 - » Indirect
 - . Switch
 - . Inter-Networks

Summary

- Inter-Networking issues
 - » heterogeneity and scale
 - Solution Layered Protocols
 - TCP/IP a four layered protocol for Internet connectivity.
 - OSI a seven layer protocol model for study.
 - » Interconnection devices at different layers