2014

Computer Networks

EDA387 / DIT663

SP1 2014/2015

Internet Interconnections

Ali Salehson

Course Literature

- **Douglas Comer**

"Internetworking with TCP/IP"

Principles, Protocols, and Architectures

Volume 1, 5th edition Prentice Hall 2006

- **J. F. Kurose, K. W. Ross**

"Computer Networking"

A Top-Down Approach

6th edition, Pearson Education 2012

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Internetworking with TCP/IP

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Ch 2: Ethernet & MAC frame (review)

Ch 3: Internetworking Concept (review)

Ch 4: IPv4 Addressing

Ch 5: ARP protocol & operation

Ch 6: IPv4 Protocol (self-study)

Ch 7: Forwarding IP Datagrams

Ch 8: ICMP and TCP/IP Utilities (self-study)

Ch 9: IPv4 CIDR

Internetworking with TCP/IP

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Ch 23: Domain Name System (DNS)

Ch 31: IPv6 & ICMPv6

Internet Services

Practical Perspective (lab 4h)

- Domain Name System (DNS)
  - Using *dig* in Linux
  - DNS-client interacts with DNS-servers
- IPv6 and ICMPv6
  - Using *ping6* and *traceroute6* in Linux
  - Capturing IPv6 packets with *Wireshark*
  - *Neighbor Discovery* and *Autoconfig*

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Internet Interconnections

Underlying Network Technologies

Ethernet and MAC frames

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Network Technologies (review)

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Outline

- Review basic network concepts
- Examine physical networks
- Learn physical addressing
- Focus on Ethernet technology
- Study MAC frame

The TCP/IP Concept

- **Use existing network hardware**
- **Interconnect networks**

The challenge is to accommodate all possible network hardware.

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Basic Categories of Network

- **Connection-orieneted**

  circuit-switching or

  virtual-circuit packet-switching

- **Connectionless**

  datagram packet-switching

  frame broadcasting

Connection Oriented

Paradigm

- establish a ”connection” through the network
- send / receive data over the *same* connection
- terminate the connection

➢ Can guarantee bandwidth and reserve resources

➢ Works well with real-time applications *(e.g. voice)*

Examples

- PSTN and ISDN *(circuit-switching)*
- Frame Relay and ATM *(VC packet-switching)*

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Connectionless Networks

Paradigm

- form a ”packet” of data to transmit
- send packet *as soon as possible* over network

➢ Each packet travels as datagram independently

➢ Packet includes identification of the destination

➢ Each packet can be of a different size

➢ Works well with file transfer applications

Packet-switching Networks

- Local Area Network (LAN)
- Wide Area Network (WAN)

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Local Area Networks

- **Engineered for**
  - **Limited distance to a locale**
  - **Direct connection among computers**
- **Low cost**
- **High speed**
- **Need Medium Access Control (MAC)**

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Wide Area Networks

- **Engineered for**
  - **Long distances**
  - **Indirect connection via special-purpose hardware (DTE/DCE)**
- **Higher cost**
- **Lower capacity in shared links**
- **Need Intermediate Network Devices**

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Packet-switched Networks

- **Wide Area Networks**
  - ARPAnet, Internet
  - Common carrier services
- **Leased Line services**
  - Point-to-point connections
- **Local Area Networks**
  - Ethernet
  - Wi-Fi

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ARPAnet (1969-1989)

- Original backbone of Internet
- Wide area network around which TCP/IP was developed
- Funding from Advanced Research Project Agency (ARPA)

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WANs from Carriers

- Point-to-point digital circuits
  - T-lines (e.g. T1 = 1.544 Mbps)
  - E-lines (e.g. E1 = 2.048 Mbps)
  - OC-line (e.g. OC-3 = 155 Mbps)
- Packet-switching services also available by:
  - X.25, Frame Relay, ATM

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Point-to-Point Network

- **Any direct connection between two nodes**
  - Leased line
  - Connection between two routers
  - Dialup connection
  - DSL broadband connection
- **Link-level protocol required for framing**
- **TCP/IP views it as an independent network**

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LANs: Focus on Ethernet

- extremely cheap and popular
- can run over
  - copper (twisted pair)
  - optical fiber
- many physical standards
  - 10 Base T (Legacy Ethernet 10 Mbps)
  - 100 Base T (Fast Ethernet 100 Mbps)
  - 1000 Base T (Gigabit Ethernet 1 Gbps)
  - 10 Gigabit Ethernet over fiber
- one IEEE MAC standard 802.3

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Hardware Address

- Unique number assigned to each network interface (NIC) on a machine
- Used to identify destination for a frame
- Known as (all terms are almost equal!)
  - Physical address
  - Link-layer address (layer-2 address)
  - Hardware address
  - Medium Access Control (MAC) address

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Use of Hardware Address

- **Sender supplies**
  - Destination address
  - Source address (in most technologies)
- **Network Hardware**
  - Uses destination address to forward frame
  - Delivers frame to proper machine interface
- **Each network technology defines its own scheme of addressing**
  - **Static:** assigned by hardware vendor
  - **Configurable:** assigned by customer
  - **Dynamic:** assigned by software at startup

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LAN MAC Address

- **MAC (link-layer or physical) address:**
  - **used to get frame from one interface to another physically-connected interface (same network)**
  - **48-bit MAC address (for most LANs)**
  - **normally burned in the adapter ROM**
- **MAC address allocation administered by IEEE:** *Institute of Electrical and Electronics Engineers*
- **Manufacturer gets portion of MAC address space (to assure uniqueness)**
- **MAC addressing is flat, no hierarchy**
  - **LAN card may be moved from one LAN to another**

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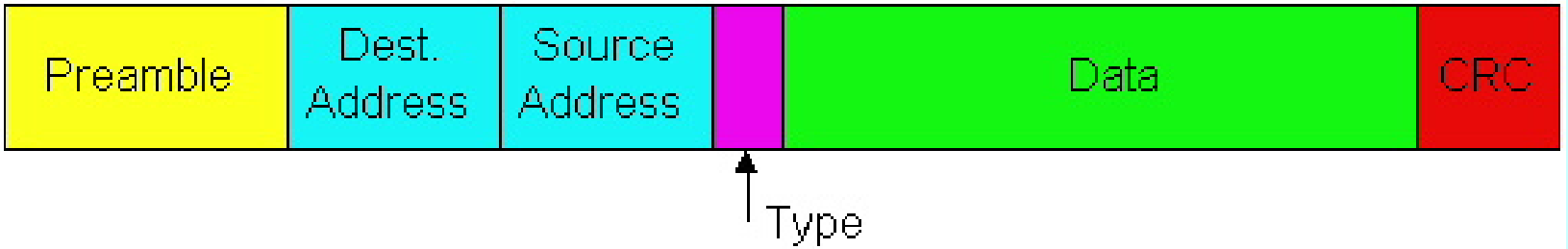
Ethernet Frame Format

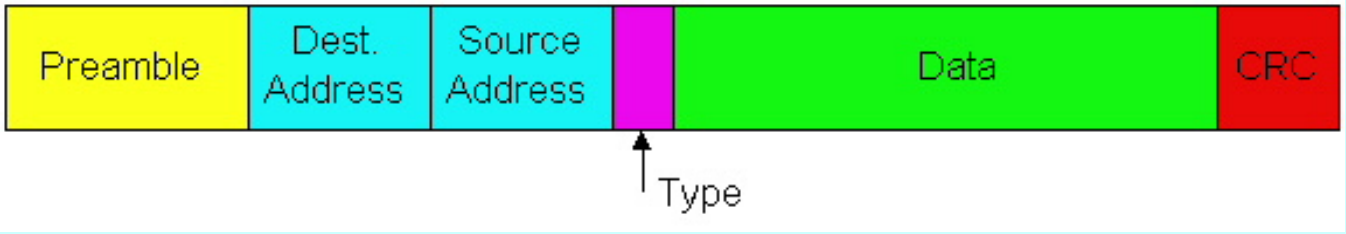
- Sending adapter encapsulates IP datagram (or other higher layer protocol data) in a frame

Sync | Header | Payload |Trailer



Preamble: (7 + 1) bytes
7 bytes with pattern 10101010 followed by one byte as:
Start of **F**rame **D**elimiter (**SFD**) with pattern 10101011 both used to synchronize receiver and sender clock rates and indicating the start of the frame.

Ethernet Frame Format



Addresses: 2 x 6 bytes

if adapter receives frame with matching destination address, or with broadcast address (e.g. ARP packet), it passes data in frame to network layer protocol

Type/Length: 2 bytes (0x0800 for IP) / (0x002E → 0x05DC)

in Ethernet type II, indicates higher layer protocol (mostly IP)

in IEEE 802.3 indicates length of data field (LLC frame)

Data: 46 – 1500 bytes (variable)

Min. length makes sure collisions are always detected

Max. length indicates Maximum Transmission Unit (MTU) on Ethernet

CRC: 4 bytes

at sender inserted FCS bits, to check for errors at receiver

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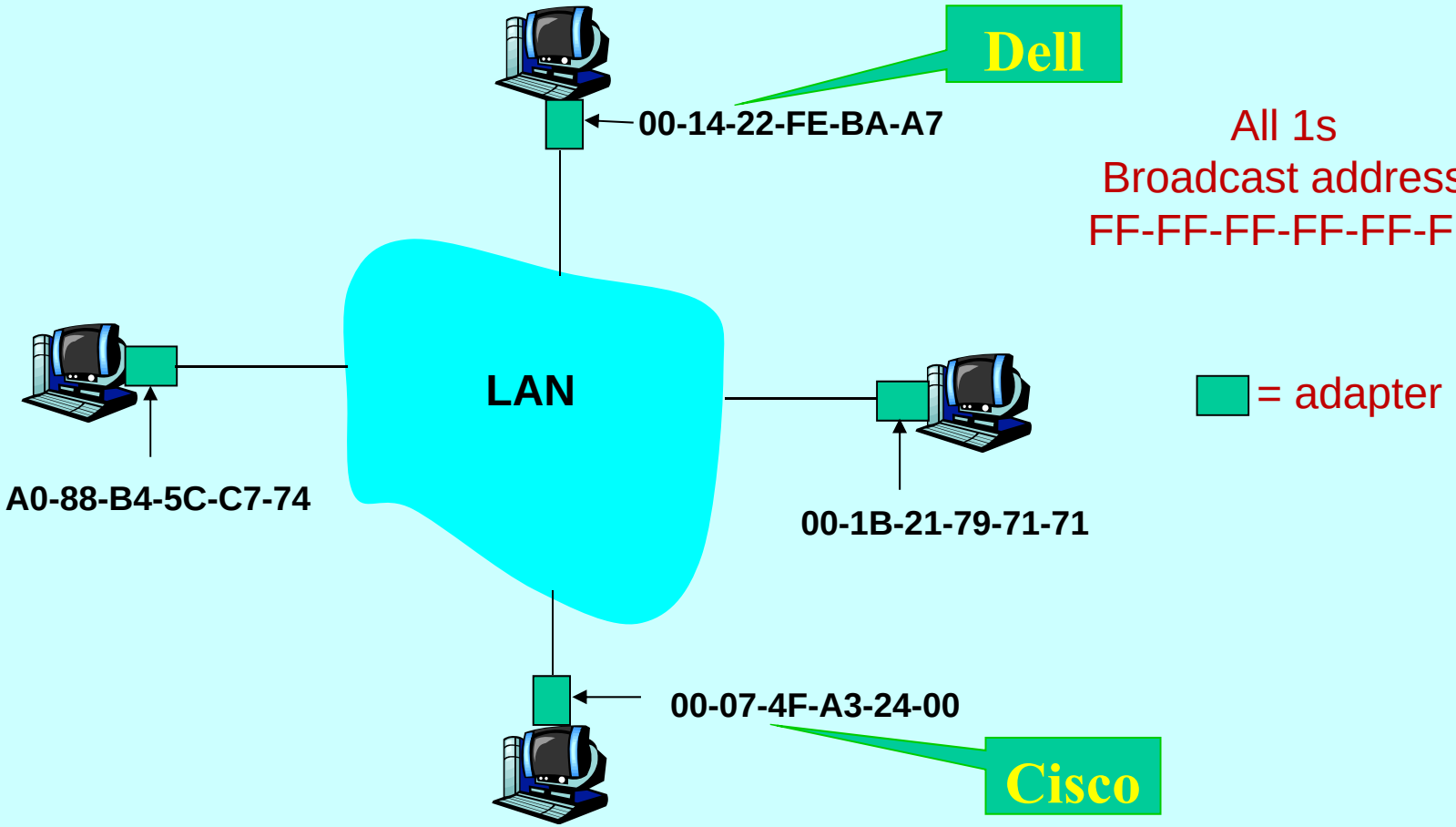
MAC Addresses

- The 48-bit MAC address is given as 6 bytes, separated by periods (hyphens or colons) and each byte is presented as two hexadecimal digits



MAC Unicast Address

- Ethernet hardware addresses are 48 bits, expressed as 12 hexadecimal digits (0-9, A-F often capitalized).
- The first (left) 6 digits should match the vendor of the Ethernet interface. These high-order 3 octets (6 hex digits) are also known as the Organizationally Unique Identifier (OUI).
- The last (right) 6 digits specify the serial number given for the interface by that vendor.
- These addresses are physical unicast addresses, and not *multicast* nor *broadcast*, so the second hex digit (reading from the left) will be even, not odd.

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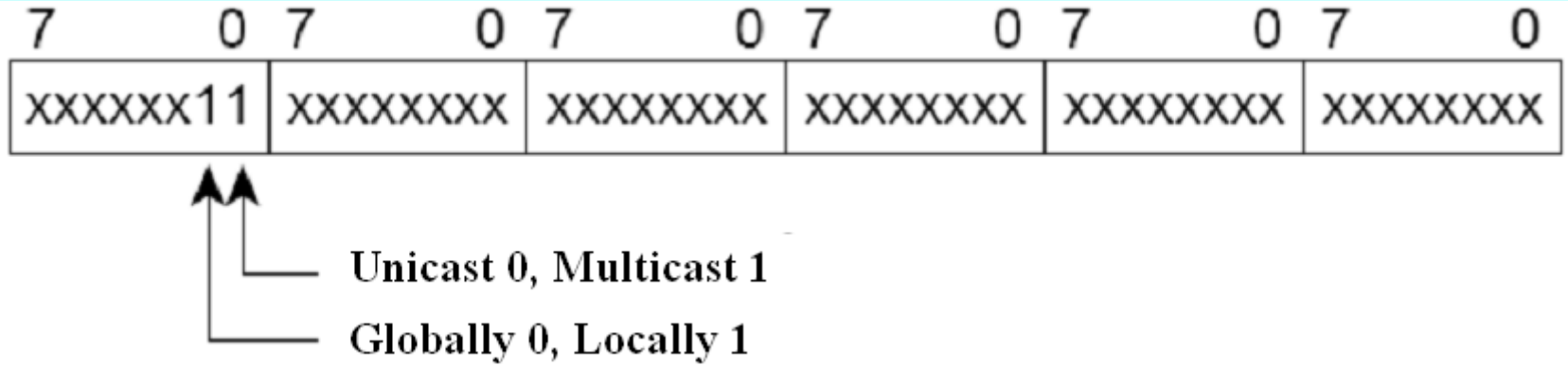
MAC Multicast Address

- An Ethernet multicast address consists of the multicast bit, the 23-bit vendor component, and the 24-bit group identifier assigned by the vendor.
- For example, DEC is assigned the vendor component (first 3 bytes) 08-00-2B, so multicast addresses assigned by DEC will have the first 24-bits 09-00-2B.
- The multicast bit is the low-order bit of the first byte, which is "the first bit on the wire".



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MAC Multicast Address

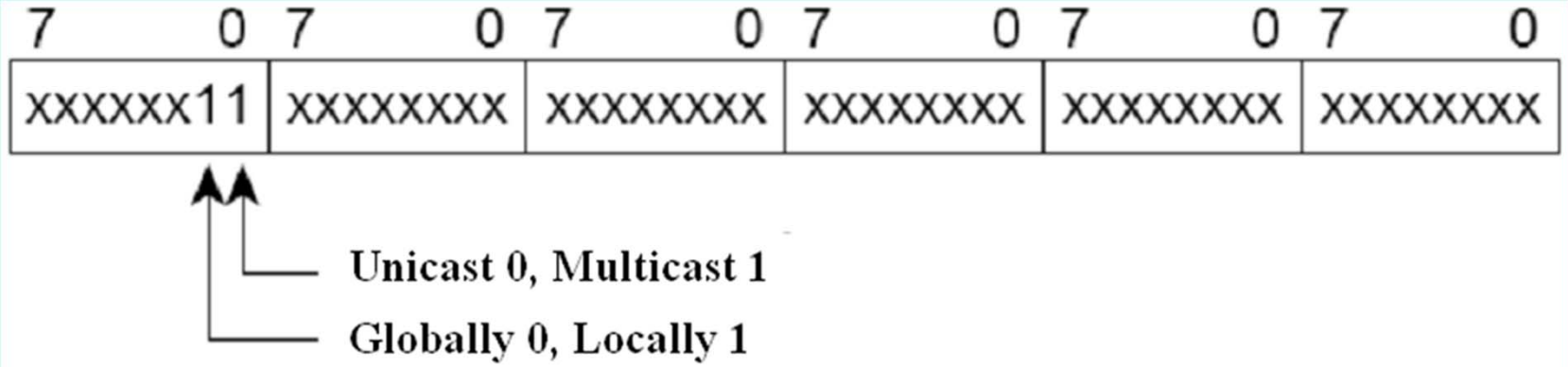
ONLY destination address

Examples:

01-80-C2-00-00-00 used by Spanning Tree Protocol

01-00-5E-00-00-00 is the Internet Multicast

Octets transmitted left-to-right, and within octets:
on the wire, bits transmitted from right to left (LSB)
in memory, bits placed from left to right (MSB)



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CSMA/Collision Detection

1. Adapter receives datagram from network layer and creates frame

2. Adapter waits until it senses channel idle, plus 96 bit times, then transmits frame.

3. If adapter transmits entire frame without detecting another transmission, the adapter is done with frame.

4. If adapter detects another transmission while it is self transmitting, aborts and sends jam signal (48 bits) to warn other nodes about **collision**

5. After aborting, adapter enters **exponential backoff**: after *m*th collision, adapter chooses *K* at random from {0,1,2,…,2^m-1} until K is max 1023 (m = 10).

   Adapter waits K*512 bit times, and returns to Step 2

Bit time is 10 ns for 100 Mbps

for K = 1023,
max. wait time is about 5 ms

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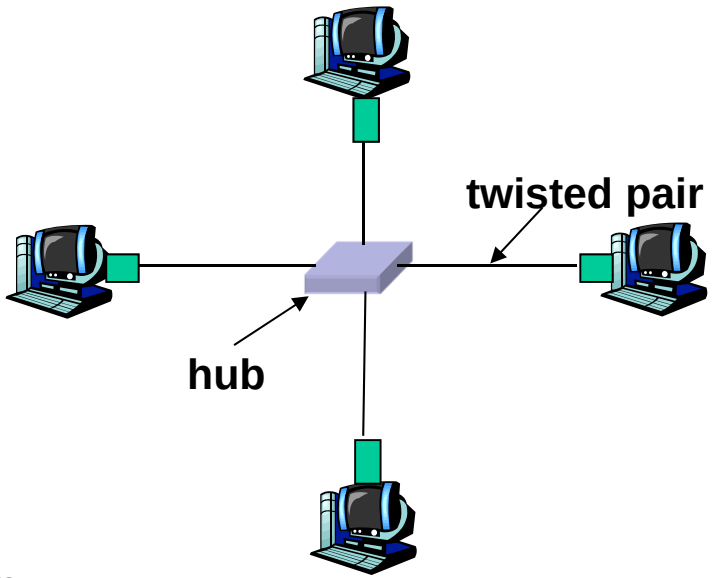
Shared Ethernet: Hubs

Hubs are essentially physical-layer multiport repeaters:

- **bits coming in one link repeated out *all* other links**
- **at same rate**
- **no frame buffering**
- **adapters detect collisions and do CSMA/CD**



LAN Bridge

- Hardware device that connects two LAN segments and makes them appear to be a single LAN
- Inspects frames to learn which computers are on which side of the bridge
- Uses hardware addresses to filter
- Repeats frames from one LAN segment to another
- Introduces delay of 1 frame-time (store-and-forward)
- Does not forward collisions or noise (checks CRC and performs CSMA/CD)
- Called Layer 2 device

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Switched Ethernet

- **link-layer device**
  - multi-port LAN bridge
  - store and forward Ethernet frames
  - examine frame header and selectively forward frame based on MAC destination address
- **Auto-negotiation**
  - detection of devices and their communication capabilities
- **Transparent**
  - hosts are unaware of presence of switches
- **Plug-and-play, self-learning**
  - The switch forwarding table does not need to be configured

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Self Learning

- Switch learns which MAC addresses of hosts can be reached through which interface
  - When frame received, switch "learns" location of sender i.e. incoming LAN segment
  - Records sender/location pair in switch table
- Entry in switch table

  [MAC Address, Interface, Time Stamp]
- Stale entries in table dropped (aging time may be configured or set to a default)

Summary

- TCP/IP is designed to use all types of networks
  - Connection-oriented
  - Connectionless
  - Local Area Network (LAN)
  - Wide Area Network (WAN)
  - Point-to-point link
  - Set of bridged networks
- Recall: each technology can define its own addressing scheme
- Heterogeneous networks imply potential for heterogeneous addressing
- Conclusion: cannot rely on hardware addressing

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Questions?

Thank You!

Internet Interconnections

Internetworking Concept

Architectural Model

Review

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The TCP/IP Internet Concept

- Use available physical networks
- Interconnect underlying networks
  - Network of networks
  - Providing universal communication
- Devise abstractions that hide
  - Underlying architecture
  - Hardware addresses
  - Routes and alternative paths

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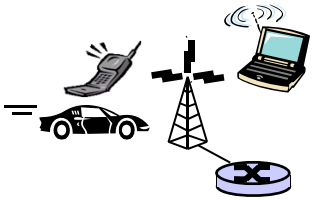
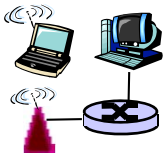
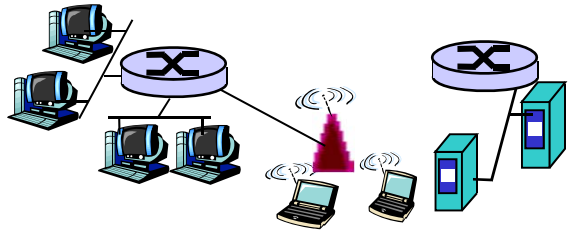
Internet Interconnection

- Network uses active intermediate system
- Each network sees an additional computer system attached
- IS is an IP router (originally called IP gateway)



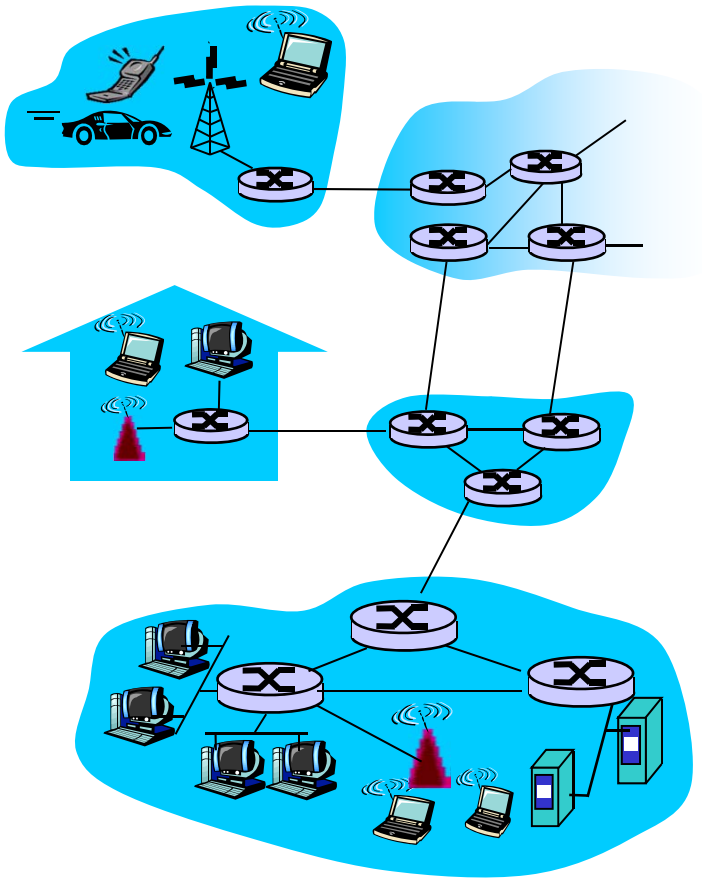




In a TCP/IP internet, special computers called **IP routers** *or* **IP gateways** *provide interconnections among physical networks.*

Internetworking

- Uses multiple IP routers
- Ensures that each network is reachable
- Do not need router between *each* pair of networks (packets may be passed through other networks)



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Packet Transmission Paradigm

- Source computer
  - Generates a packet
  - Sends across one network to a router
- Intermediate router
  - Forwards packet to “next” router
- Final router
  - Delivers packet to destination

Routers use the destination network, not the destination computer, when forwarding packets.

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Architectural Terminology

- End-user System (ES) is called ***host***
  - Connects to physical network
  - Normally many hosts per network
  - Possibly more than one network connection per host (multi-homed)
- Dedicated systems called ***IP gateways*** or ***IP routers*** interconnect networks
  - Router connects two or more networks

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Summary

- TCP/IP Internet is set of interconnected (possibly heterogeneous) networks
- Routers provide interconnection
- End-user systems are called host computers
- Internetworking introduces abstractions that hide details of underlying networks

Needs:

- Addressing model and relationship to hardware addresses
- Format of packet as it travels through Internet

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Questions?

Thank You!