
University of Colorado Boulder

Fundamentals of Data Communications CSCI 5010

Network Media & Technologies

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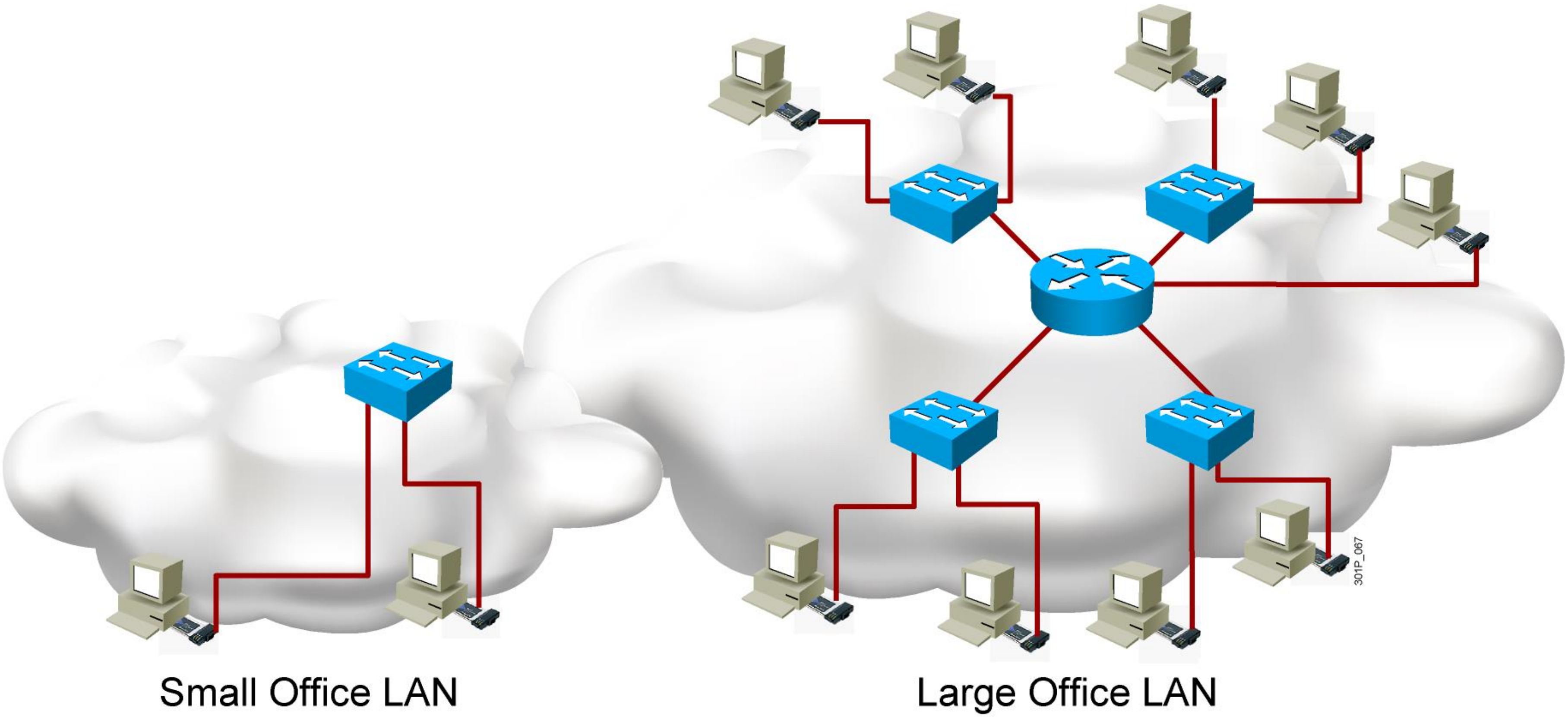
Review

Local Area Network (LAN)

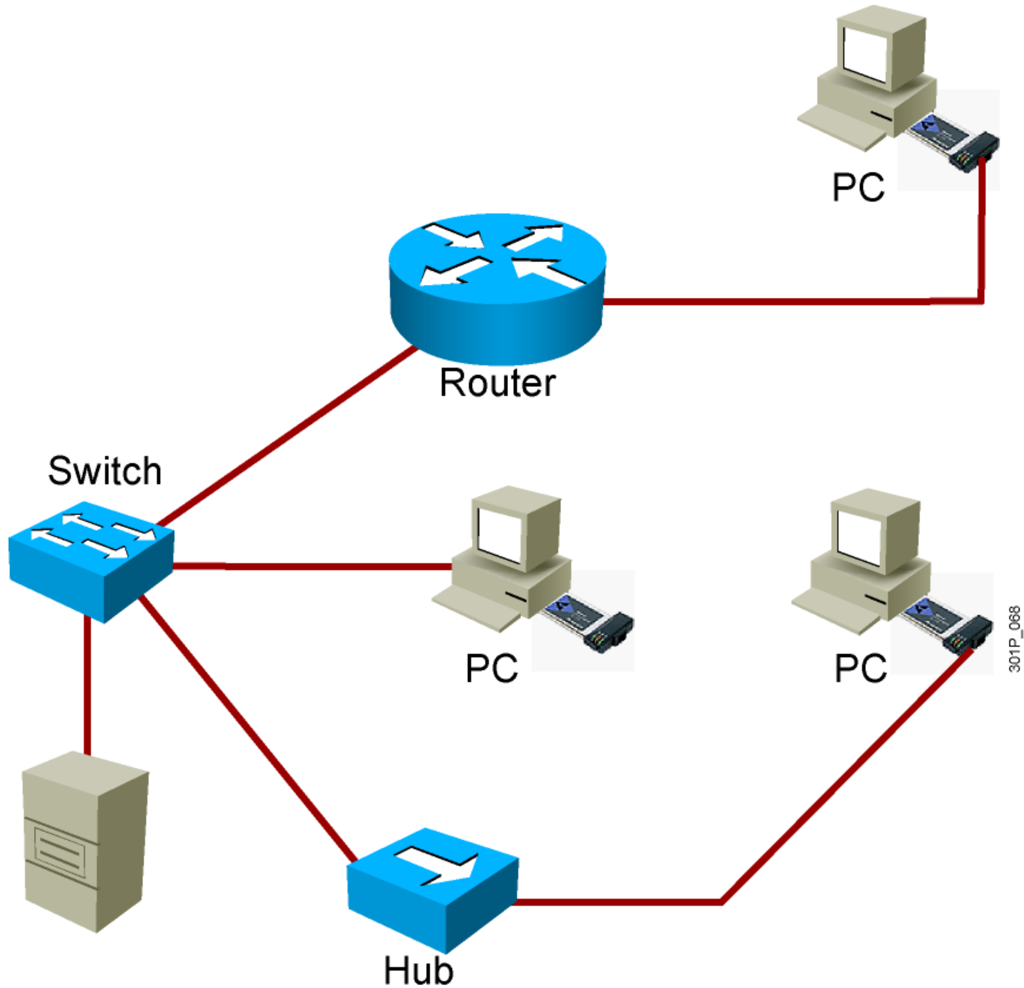
- A LAN is a network that is located in a limited area
- The computers and other components that are part of this network located relatively close together
- Fundamental components are required for the operation of a LAN:
    - ***Computers***
    - ***Interconnections***
    - ***Network devices***
    - ***Protocols***
- LANs provide both communication and resource-sharing functions for their users.
- LANs can be configured in various sizes, to accommodate environments from SOHO to enterprise.

Local Area Network



LAN Components

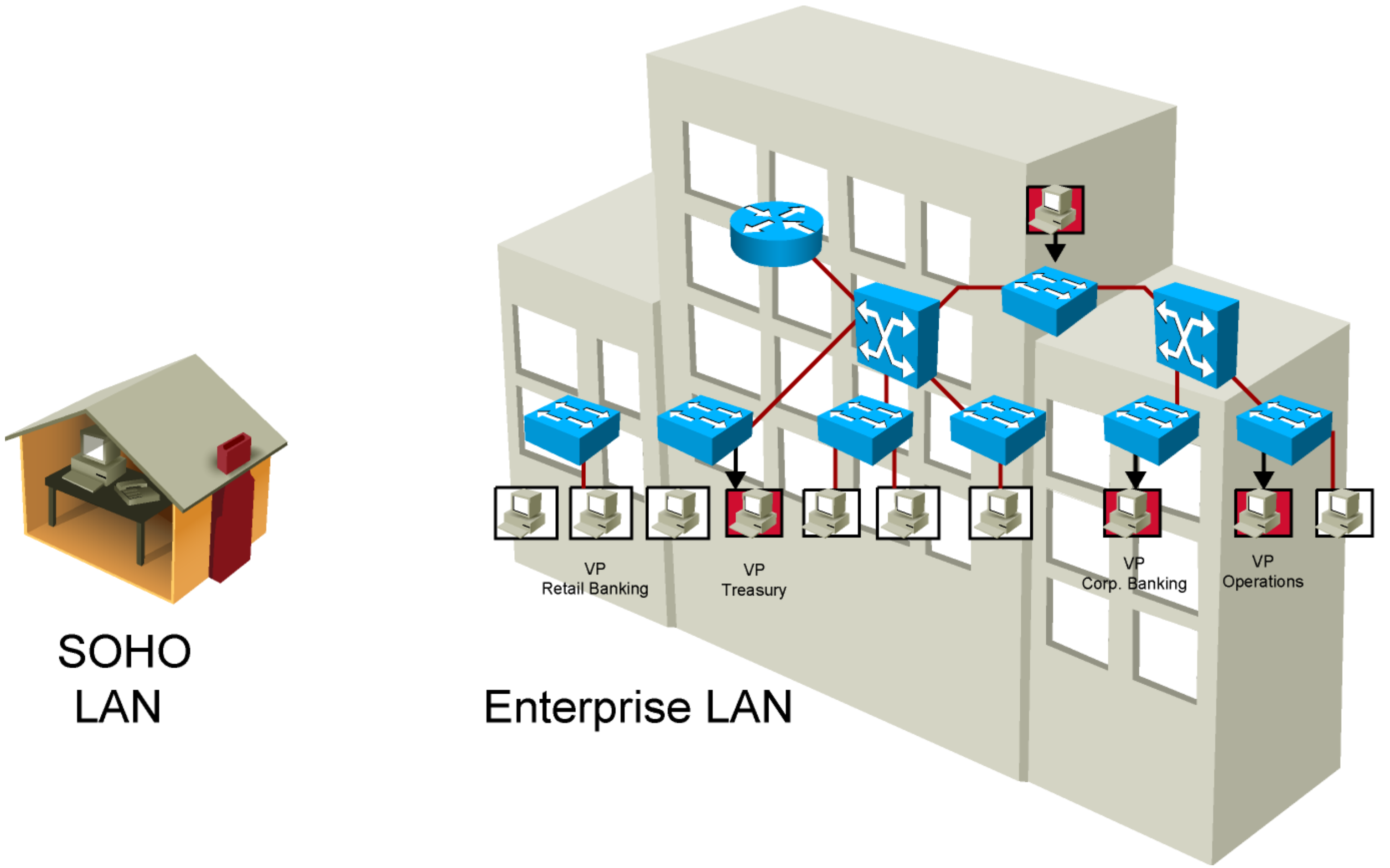
- **Computers**
  - PCs
  - Servers
- **Interconnections**
  - NICs
  - Media
- **Network devices**
  - Switches
  - Routers
- **Protocols**
  - Ethernet
  - IP
  - ARP
  - DHCP



Functions of a LAN

- Data and applications
- Share resources
- Provide communication path to other networks

LAN Sizes


VP
Retail Banking
VP
Treasury
VP
Corp. Banking
VP
Operations
301P_069
SOHO
LAN
Enterprise LAN

Ethernet

- Ethernet was originally developed in the 1970s by DEC, Intel, and Xerox, and was called DIX Ethernet.
- When a workgroup of this body (referred to as IEEE 802.3) defined new standards for Ethernet in the mid-1980s to define Ethernet-like networks for public use, the standards were called Ethernet 802.3 and 802.2.
- Ethernet LAN standards specify cabling and signaling at both the physical and data link layers of the OSI model.

Ethernet Evolution

Year	Ethernet Activity
1970	First packet radio network
1973	Ethernet invented at Xerox
1977	U.S. patent no. 4063220 issued
1982	DIX releases 10-Mb/_s Ethernet
1992	First stackable Ethernet hub
2002	IEEE approves 802.3ae; 10 billion bps

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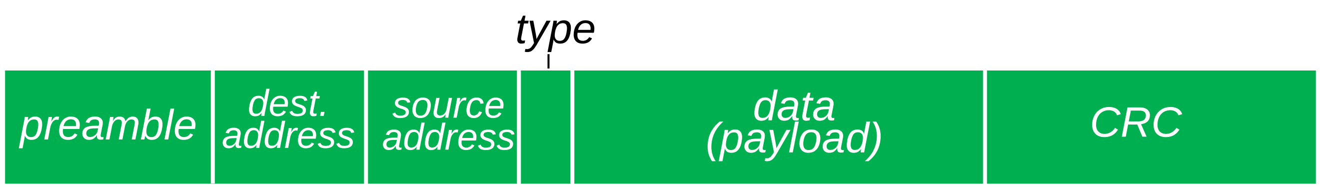
Ethernet Frame Structure

Sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame



Preamble:

- 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
- Used to synchronize receiver, sender clock rates

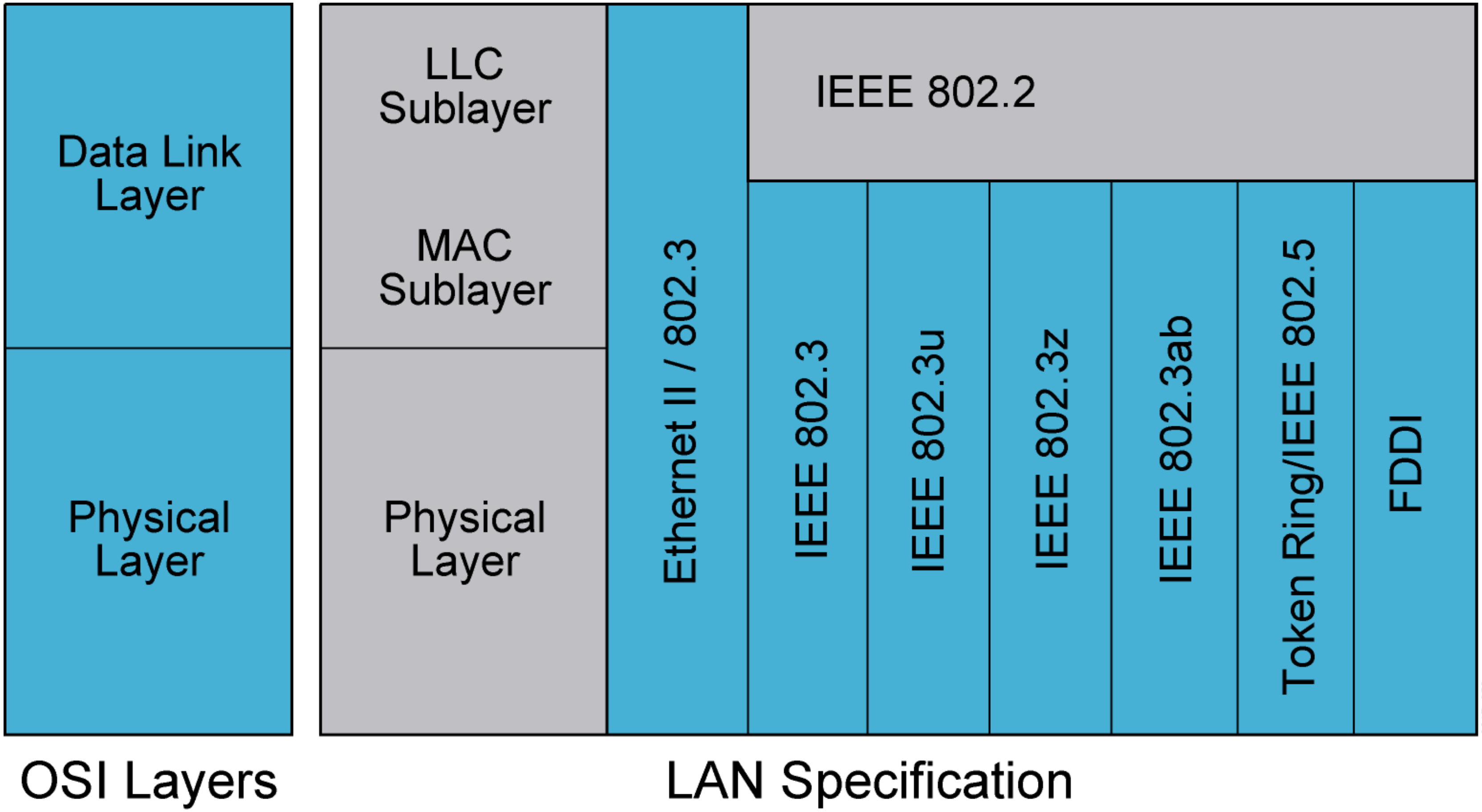
Ethernet frame structure (more)

- *Addresses:* 6 byte source, destination MAC addresses
  - 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
  - otherwise, adapter discards frame
- *Type:* indicates higher layer protocol (mostly IP but others possible, e.g., Novell IPX, AppleTalk)
- *CRC:* cyclic redundancy check at receiver
  - error detected: frame is dropped

Error Detection and Correction

- **Cyclic Redundancy Check (CRC)**
  - Detects accidental changes to raw data
  - Enters = check value (*remainder of polynomial division of contents*)
  - Retrieval = calculation is repeated
    - ***If doesn't match data is corrupted and can be corrected***

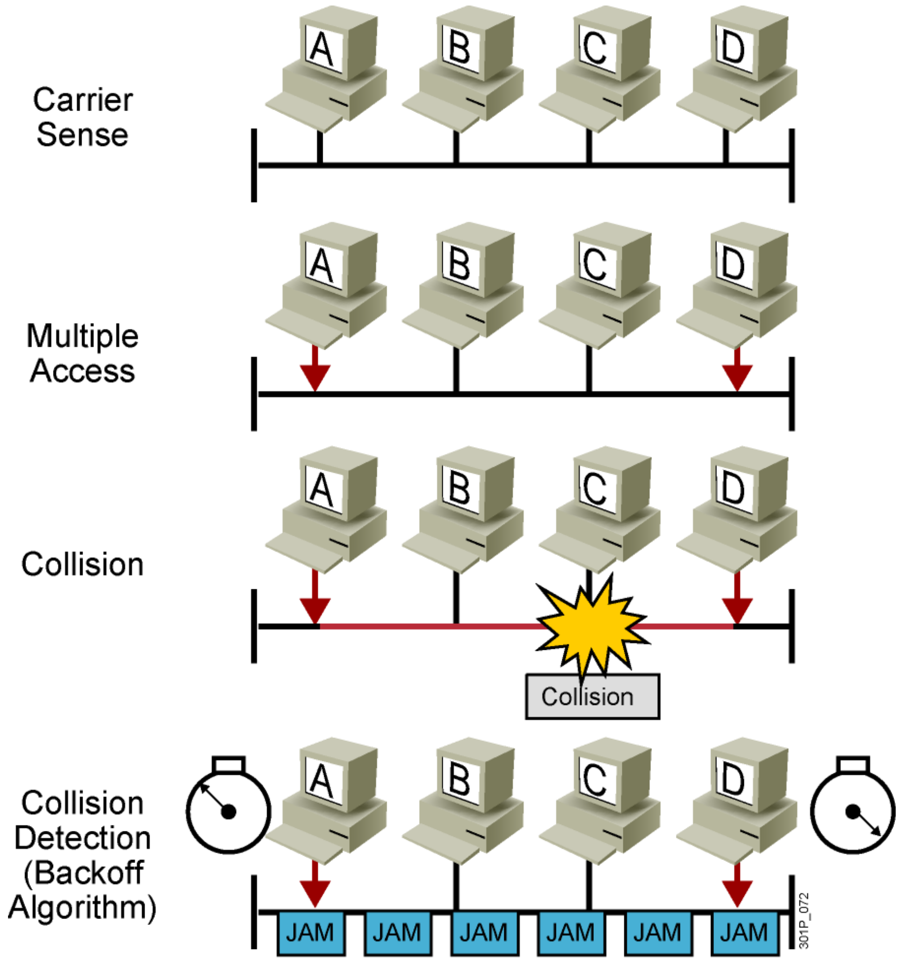
LAN Standards



Carrier-sense multiple access with collision detection (CSMA/CD)

- Stations on a CSMA/CD LAN can access the network at any time.
- Before sending data, CSMA/CD stations listen to the network to determine whether it is already in use.
- If it is in use, they wait.
- If the network is not in use, the stations transmit.
- A collision occurs when two stations listen for network traffic, hear none, and transmit simultaneously.

CSMA/CD

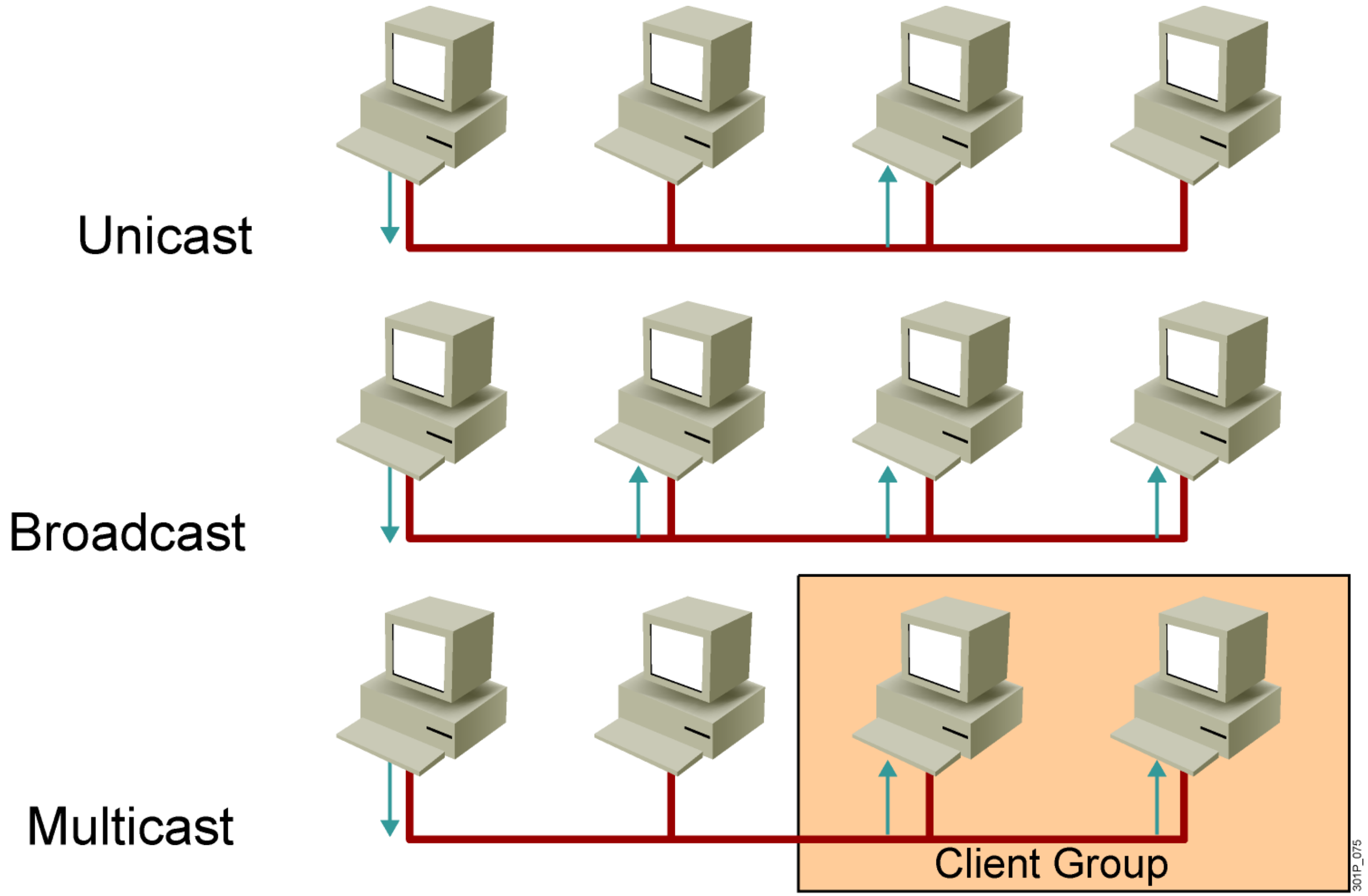


Carrier Sense Multiple Access Collision Detection (CSMA/CD)

Communication within the LAN

- There are three major kinds of communications in networks:
  - ***Unicast***
    - a frame is sent from one host addressed to one specific destination
  - ***Broadcast***
    - a frame is sent from one address to all other addresses
  - ***Multicast***
    - a destination addresses a specific group of devices

Communicating Within the LAN

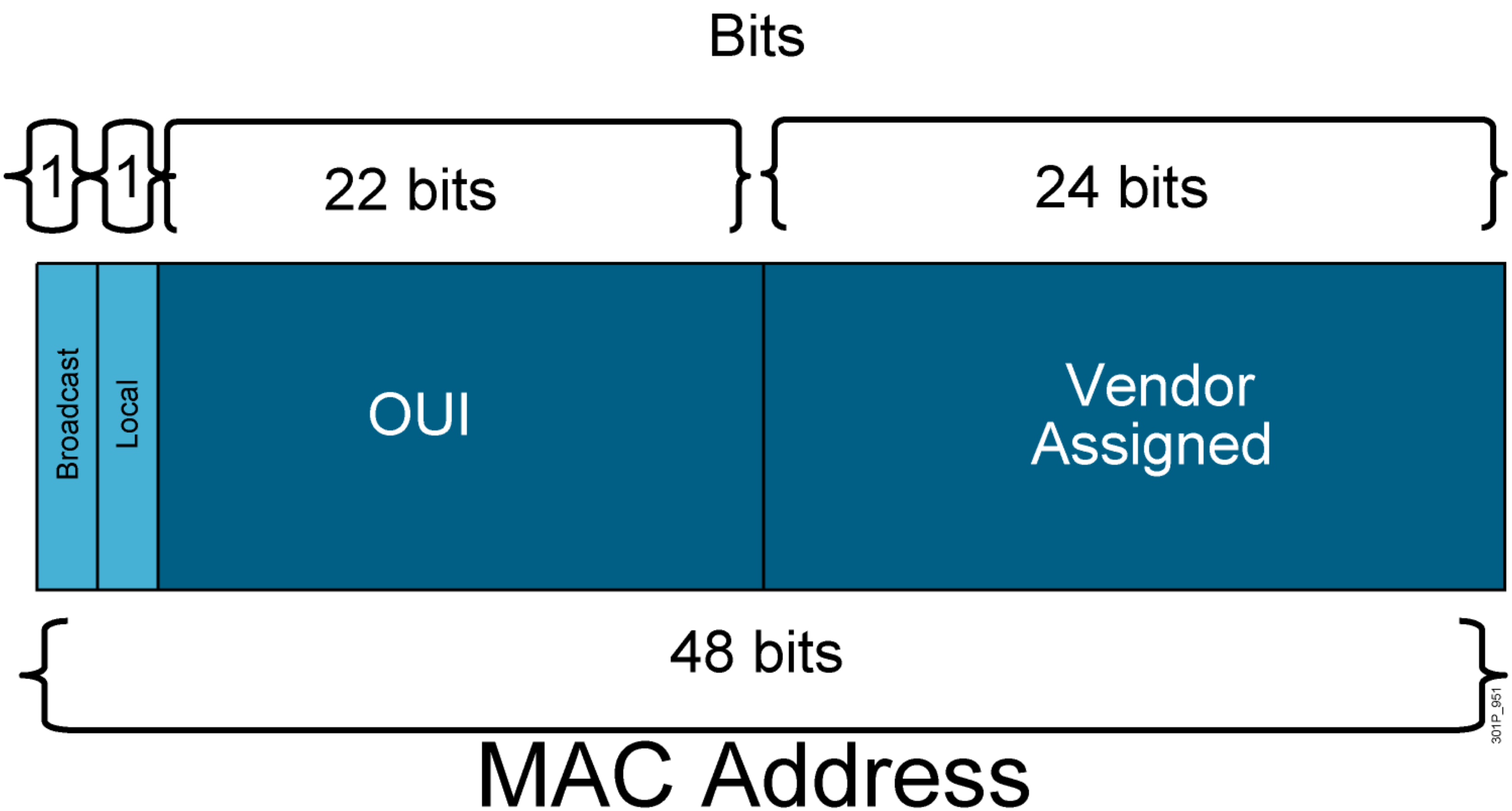


MAC Address

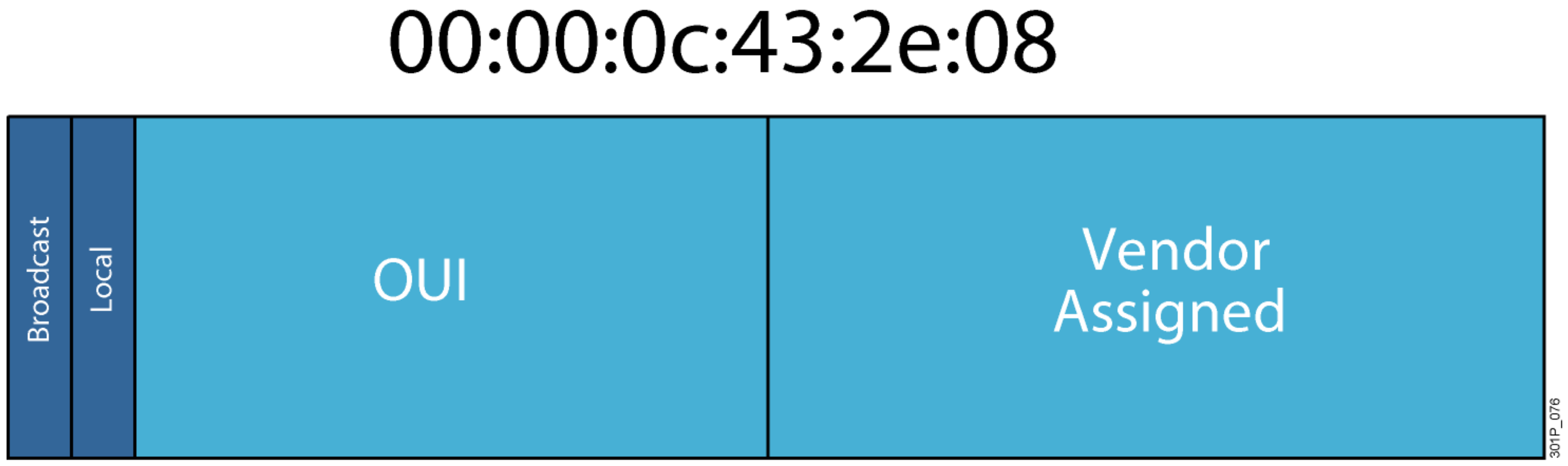
– The MAC address is burned onto each NIC by the manufacturer

– Provides a unique, physical network address that permits the device to participate in the network

MAC Address Components



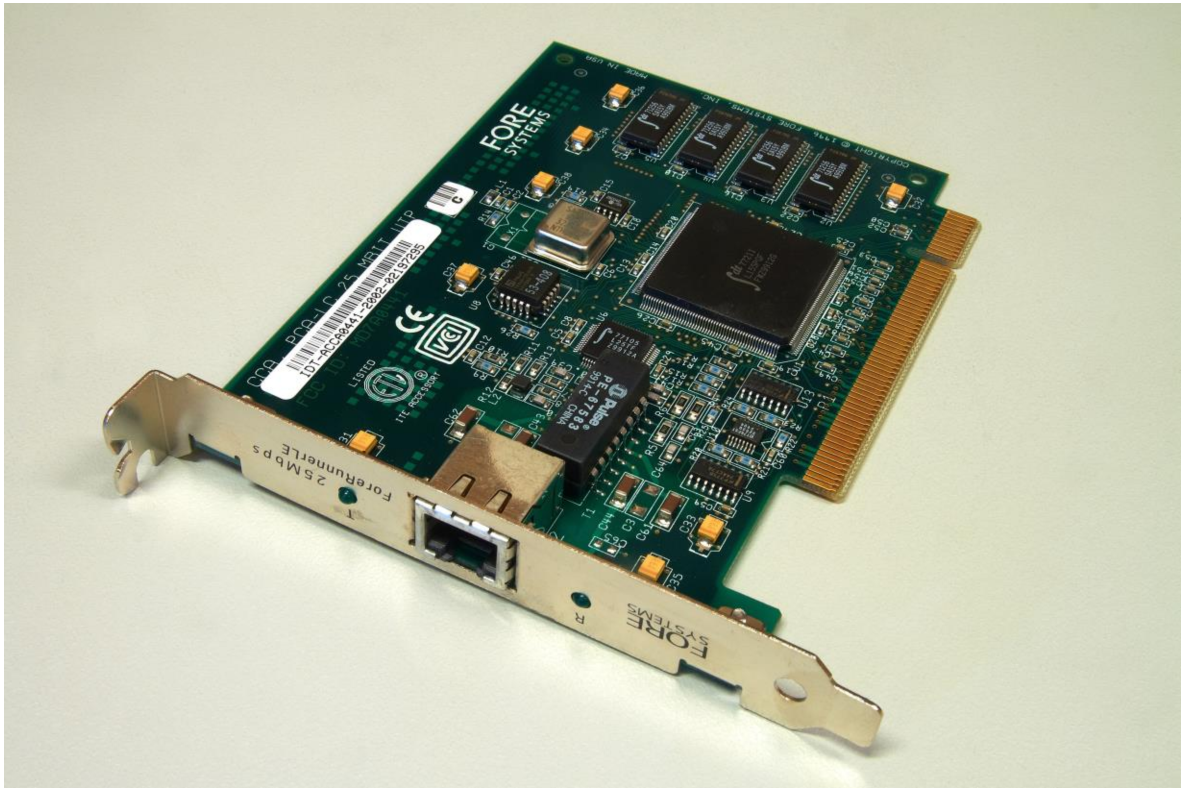
MAC Addresses



Network Interface Card (NIC)

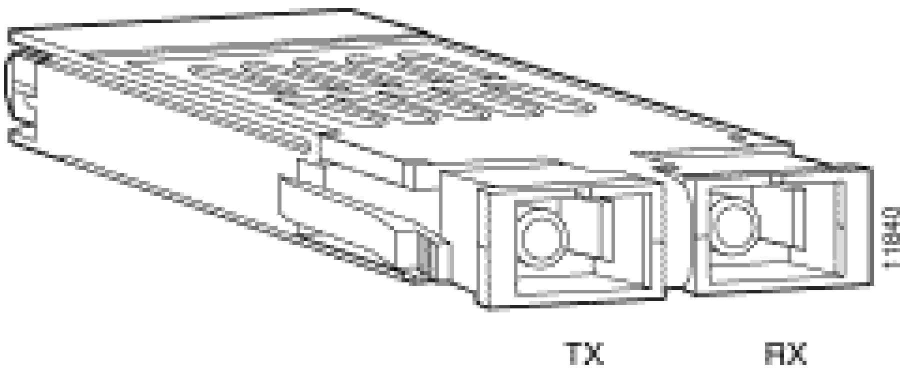
- Also called a LAN adapter, the NIC plugs (or is typically built into a laptop) into a motherboard and provides a port for connecting to the network.

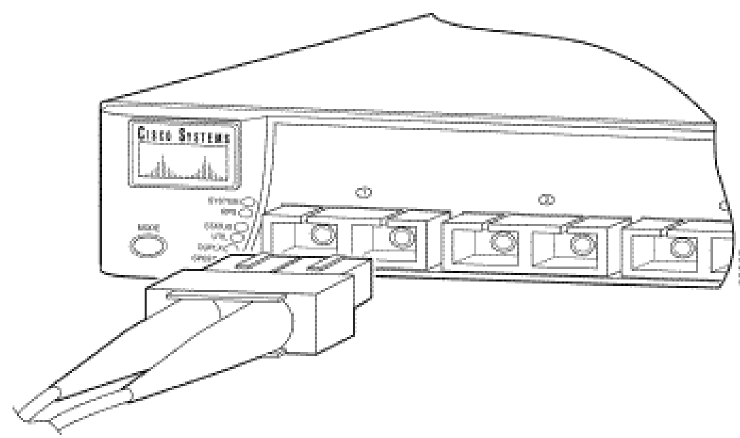
Network Interface Card



Fiber-Optic GBICs

– Short wavelength (1000BASE-SX)
– Long wavelength/long haul (1000BASE-LX/LH)
– Extended distance (1000BASE-ZX)





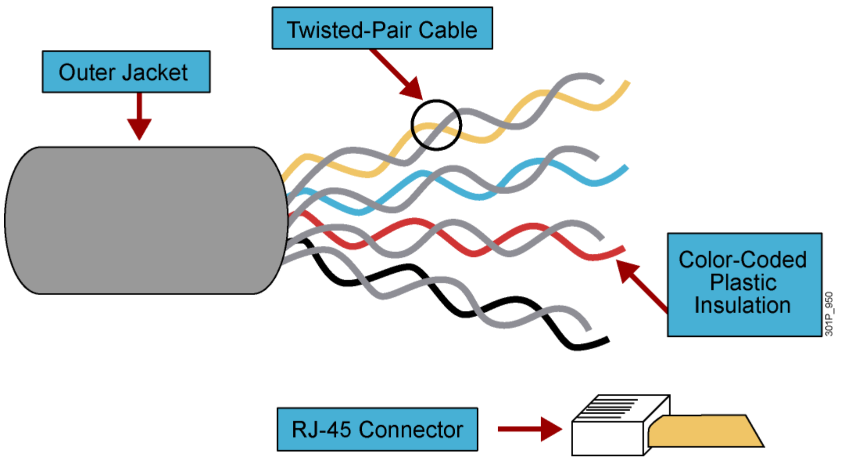
Unshielded Twisted-Pair (UTP) Cable

– UTP cable is a four-pair wire

– Each of the eight individual copper wires in UTP cable is covered by an insulating material

– The wires in each pair are twisted around each other

Unshielded Twisted-Pair Cable



– Average cost per node: Least expensive

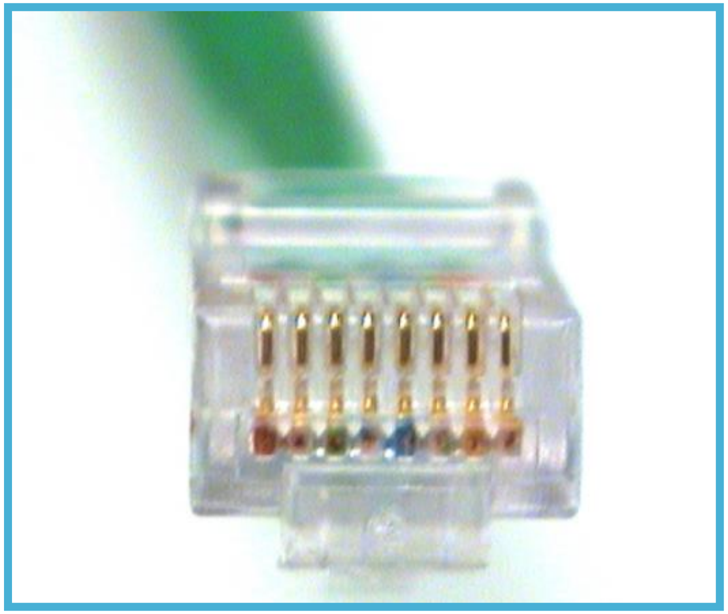
– Media and connector size: Small

– Maximum cable length: Varies

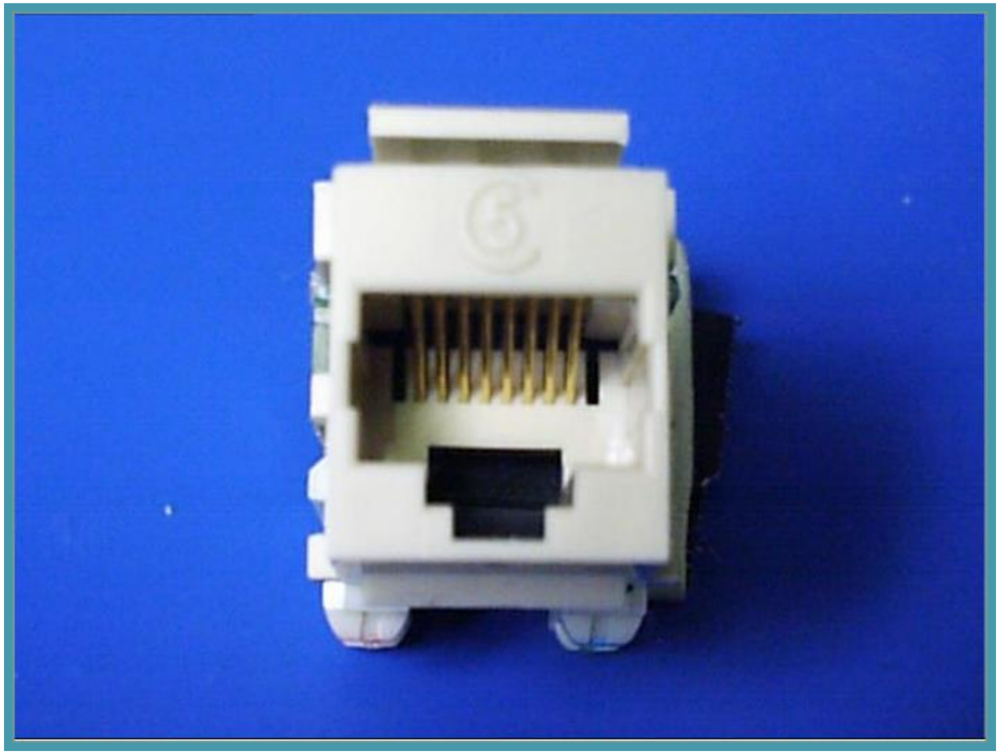
UTP Categories - Copper Cable

UTP Category	Data Rate	Max. Length	Cable Type	Application
CAT1	Up to 1Mbps	-	Twisted Pair	Old Telephone Cable
CAT2	Up to 4Mbps	-	Twisted Pair	Token Ring Networks
CAT3	Up to 10Mbps	100m	Twisted Pair	Token Rink & 10BASE-T Ethernet
CAT4	Up to 16Mbps	100m	Twisted Pair	Token Ring Networks
CAT5	Up to 100Mbps	100m	Twisted Pair	Ethernet, FastEthernet, Token Ring
CAT5e	Up to 1 Gbps	100m	Twisted Pair	Ethernet, FastEthernet, Gigabit Ethernet
CAT6	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT6a	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT7	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (100 meters)

RJ-45 Connector



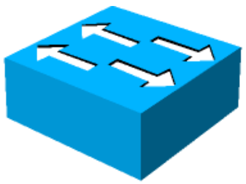
RJ-45 Jack



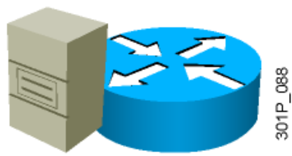
UTP Implementation (Straight-Through)

Cable 10BASE-T/
100BASE-TX Straight-Through

Straight-Through Cable



Hub/Switch



Server/Router

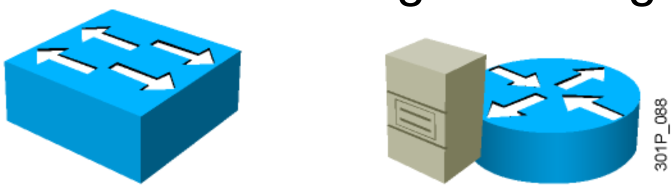
Pin	Label	Pin	Label
1	TX+	1	TX+
2	TX-	2	TX-
3	RX+	3	RX+
4	NC	4	NC
5	NC	5	NC
6	RX-	6	RX-
7	NC	7	NC
8	NC	8	NC

Wires on cable ends
are in same order.

UTP Implementation (Crossover)

Cable 10BASE-T or
100BASE-TX Straight-Through

Crossover Cable



Hub/Switch Server/Router

Pin	Label	Pin	Label
1	TX+	1	TX+
2	TX-	2	TX-
3	RX+	3	RX+
4	NC	4	NC
5	NC	5	NC
6	RX-	6	RX-
7	NC	7	NC
8	NC	8	NC

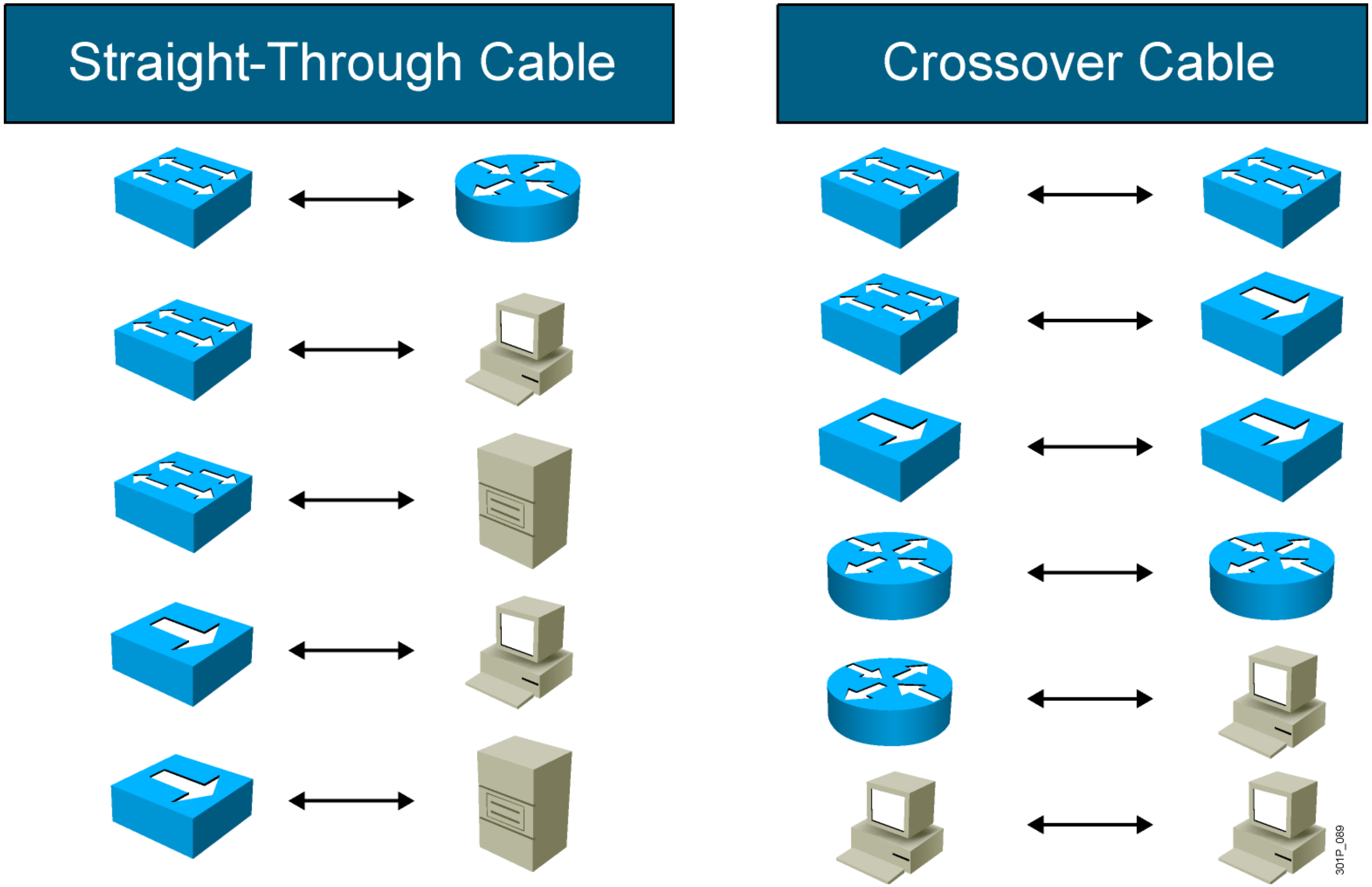
Some wires on cable
ends are crossed.

Straight-Through vs. Crossover

– A crossover cable is used to connect between similar devices:
  - ***switch to switch***
  - ***router to router***
  - ***PC to PC***
  - ***PC to router***

– A straight-through cable is used to connect between dissimilar devices:
  - ***switch to router***
  - ***switch to PC***

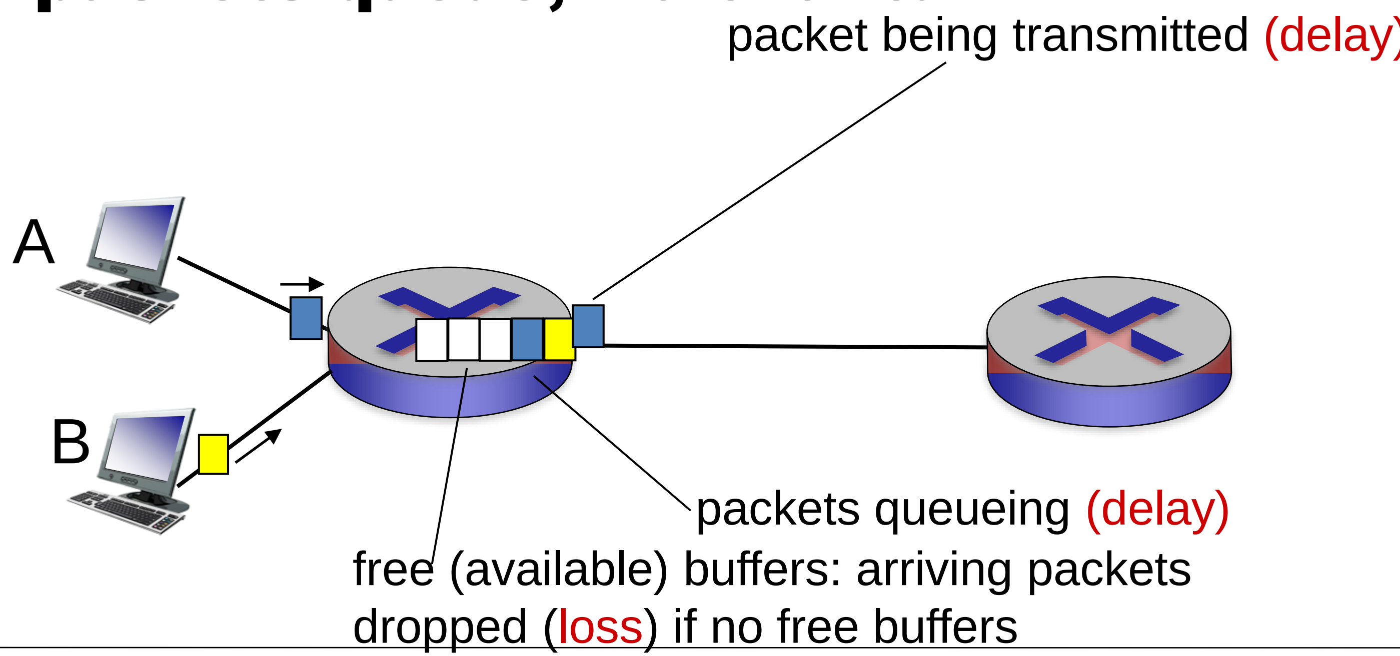
UTP Implementation: Straight-Through vs. Crossover



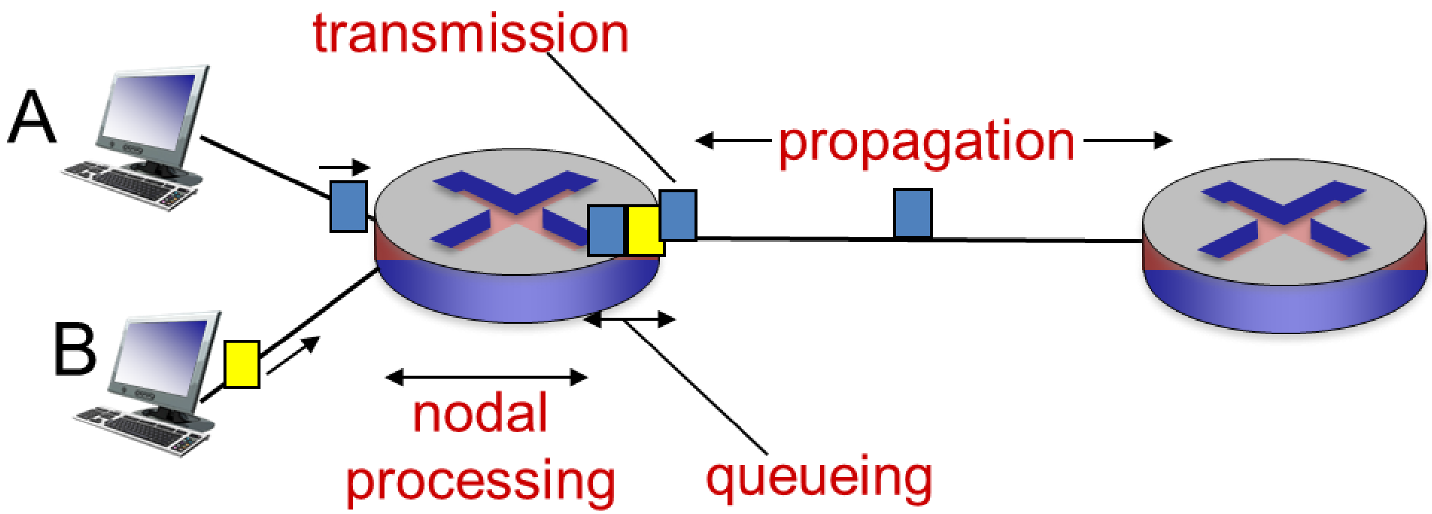
How do loss and delay occur?

Packets *queue* in router buffers

- **packet arrival rate to link (temporarily) exceeds output link capacity**
- **packets queue, wait for turn**



Four Sources of Packet Delay



$$d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

Four Sources of Packet Delay

d_{proc}: nodal processing

- check bit errors
- determine output link
- typically < msec

d_{queue}: queueing delay

- time waiting at output link for transmission
- depends on congestion level of router

d_{trans}: transmission delay:

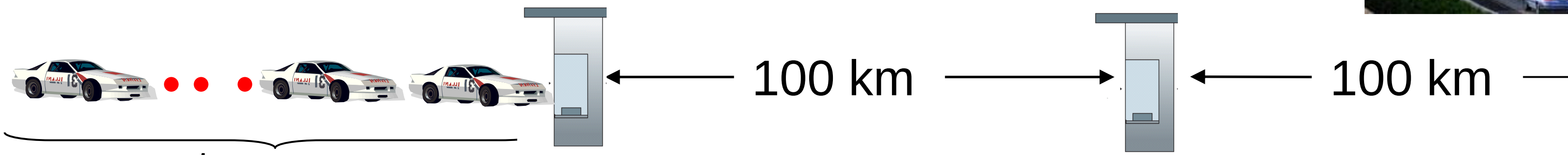
- *L*: packet length (bits)
- *R*: link *bandwidth (bps)*
- $d_{trans} = L/R$

d_{trans} and d_{prop}
very different

d_{prop}: propagation delay:

- *d*: length of physical link
- *s*: propagation speed (~2×10^8 m/sec)
- $d_{prop} = d/s$

Caravan analogy

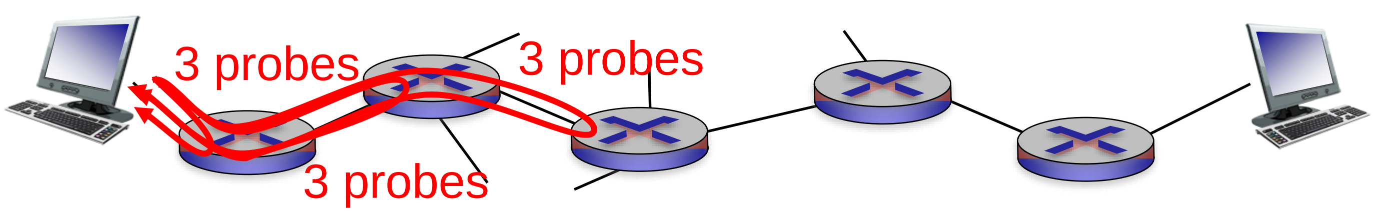


- **cars "propagate" at 100 km/hr**
- **toll booth takes 12 sec to service car (bit transmission time)**
- **car ~ bit; caravan ~ packet**
- ***Q:* How long until caravan is lined up before 2nd toll booth?**

- **time to "push" entire caravan through toll booth onto highway = 12*10 = 120 sec**
- **time for last car to propagate from 1st to 2nd toll both: 100km/(100km/hr)= 1 hr**
- ***A:* 62 minutes**

"Real" Internet Delays and Routes

- **What do "real" Internet delay & loss look like?**
- `traceroute` **program: provides delay measurement from source to router along end-end Internet path towards destination. For all *i*:**
  - sends three packets that will reach router *i* on path towards destination
  - router *i* will return packets to sender
  - sender times interval between transmission and reply



traceroute: gaia.cs.umass.edu to www.eurecom.fr

3 delay measurements from
gaia.cs.umass.edu to cs-gw.cs.umass.edu

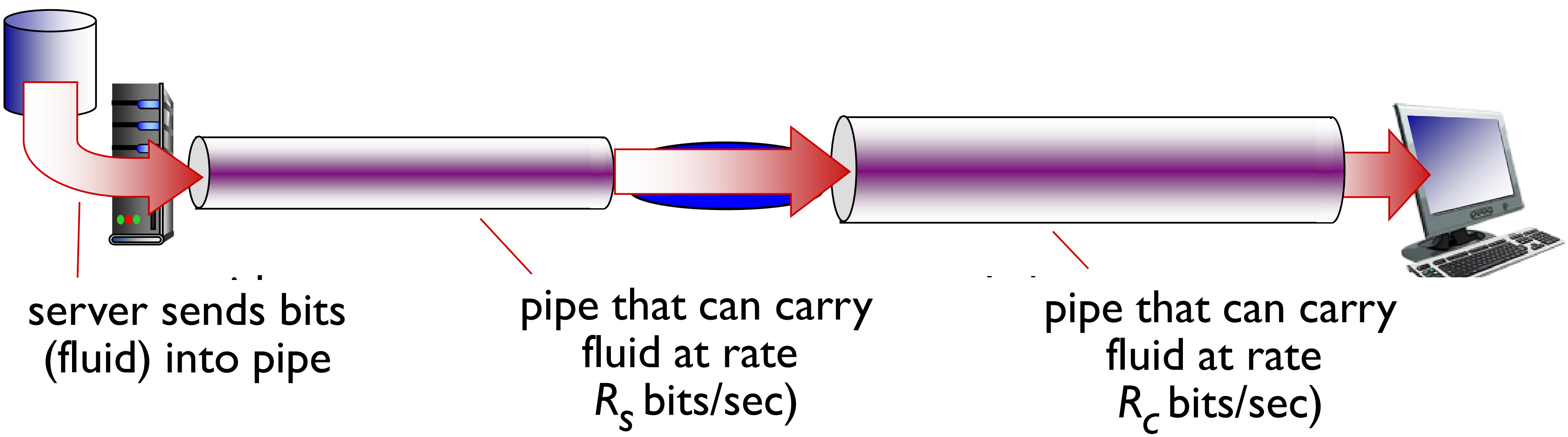
1 cs-gw (128.119.240.254) 1 ms 1 ms 2 ms
2 border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145) 1 ms 1 ms 2 ms
3 cht-vbns.gw.umass.edu (128.119.3.130) 6 ms 5 ms 5 ms
4 jn1-at1-0-0-19.wor.vbns.net (204.147.132.129) 16 ms 11 ms 13 ms
5 jn1-so7-0-0-0.wae.vbns.net (204.147.136.136) 21 ms 18 ms 18 ms
6 abilene-vbns.abilene.ucaid.edu (198.32.11.9) 22 ms 18 ms 22 ms
7 nycm-wash.abilene.ucaid.edu (198.32.8.46) 22 ms 22 ms 22 ms
8 62.40.103.253 (62.40.103.253) 104 ms 109 ms 106 ms
9 de2-1.de1.de.geant.net (62.40.96.129) 109 ms 102 ms 104 ms
10 de.fr1.fr.geant.net (62.40.96.50) 113 ms 121 ms 114 ms
11 renater-gw.fr1.fr.geant.net (62.40.103.54) 112 ms 114 ms 112 ms
12 nio-n2.cssi.renater.fr (193.51.206.13) 111 ms 114 ms 116 ms
13 nice.cssi.renater.fr (195.220.98.102) 123 ms 125 ms 124 ms
14 r3t2-nice.cssi.renater.fr (195.220.98.110) 126 ms 126 ms 124 ms
15 eurecom-valbonne.r3t2.ft.net (193.48.50.54) 135 ms 128 ms 133 ms
16 194.214.211.25 (194.214.211.25) 126 ms 128 ms 126 ms
17 * * *
18 * * *
19 fantasia.eurecom.fr (193.55.113.142) 132 ms 128 ms 136 ms

trans-oceanic link

* means no response (probe lost, router not replying)

Throughput

- ***throughput:*** **rate (bits/time unit) at which bits transferred between sender/receiver**
  - *instantaneous:* rate at given point in time
  - *average:* rate over longer period of time
- **bottleneck**



Questions?

Lab