CSE3213 Computer Network I

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Course page:
http://www.cse.yorku.ca/course/3213

Slides modified from Alberto Leon-Garcia and Indra Widjaja

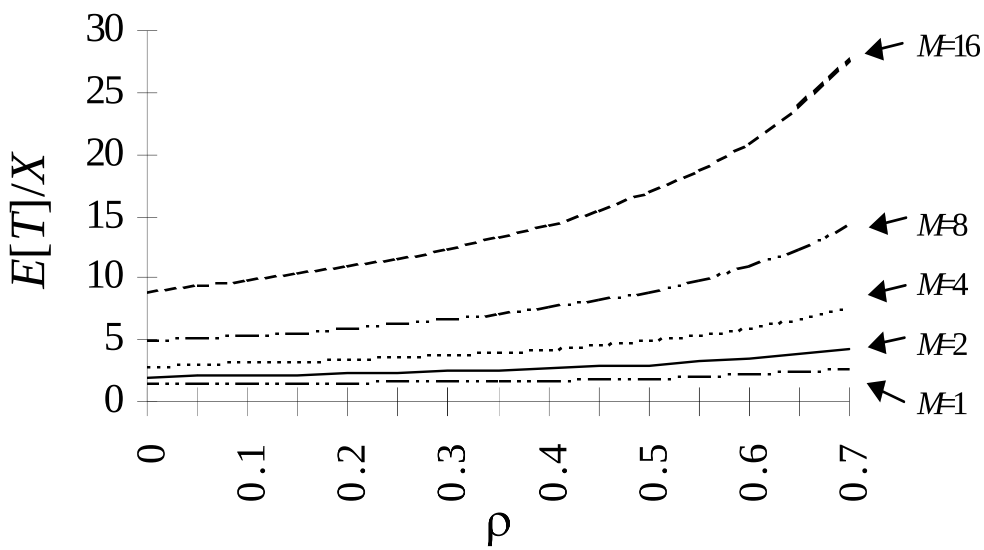
Channelization

Why Channelization?

- Channelization
  - Semi-static bandwidth allocation of portion of shared medium to a given user
- Highly efficient for constant-bit rate traffic
- Preferred approach in
  - Cellular telephone networks
  - Terrestrial & satellite broadcast radio & TV

Why not Channelization?

- Inflexible in allocation of bandwidth to users with different requirements
- Inefficient for bursty traffic
- Does not scale well to large numbers of users
  - Average transfer delay increases with number of users M
- Dynamic MAC much better at handling bursty traffic

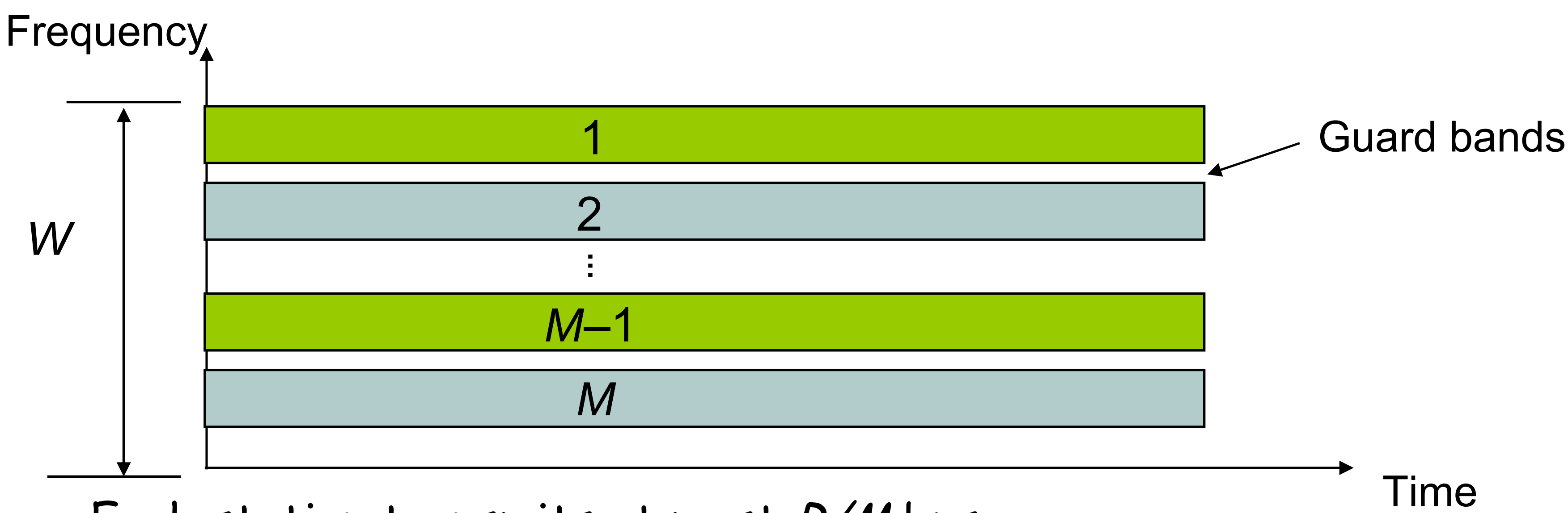


Channelization Approaches

- *Frequency Division Multiple Access* (FDMA)
  - Frequency band allocated to users
  - Broadcast radio & TV, analog cellular phone
- *Time Division Multiple Access* (TDMA)
  - Periodic time slots allocated to users
  - Telephone backbone, GSM digital cellular phone

Channelization: FDMA

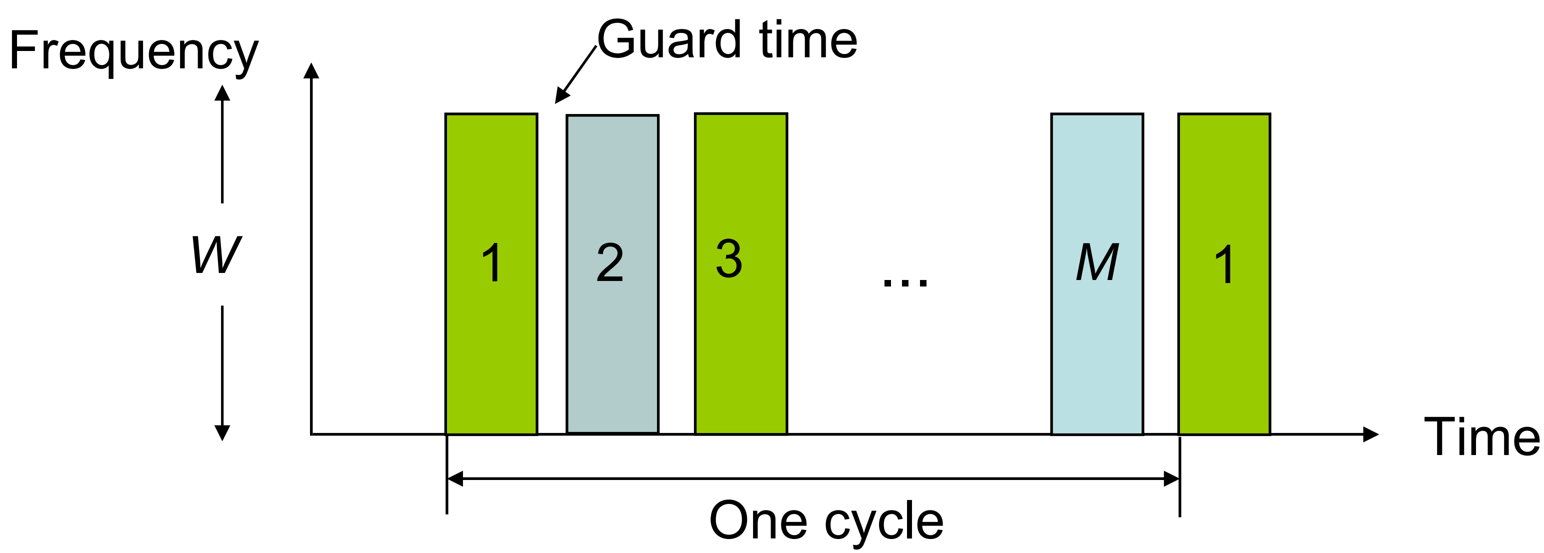
- Divide channel into *M* frequency bands
- Each station transmits and listens on assigned bands



- Each station transmits at most *R/M* bps
- Good for stream traffic; Used in connection-oriented systems
- Inefficient for bursty traffic

Channelization: TDMA

- Dedicate 1 slot per station in transmission cycles
- Stations transmit data burst at full channel bandwidth



- Each station transmits at R bps 1/M of the time
- Excellent for stream traffic; Used in connection-oriented systems
- Inefficient for bursty traffic due to unused dedicated slots

Guardbands

- FDMA
  - Frequency bands must be non-overlapping to prevent interference
  - Guardbands ensure separation; form of overhead
- TDMA
  - Stations must be synchronized to common clock
  - Time gaps between transmission bursts from different stations to prevent collisions; form of overhead
  - Must take into account propagation delays

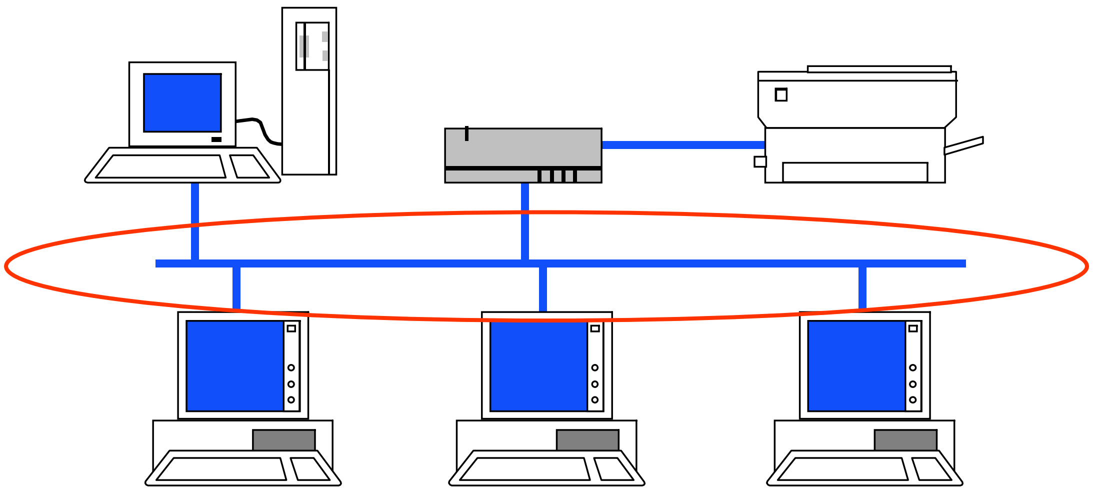
Overview of LANs

What is a LAN?

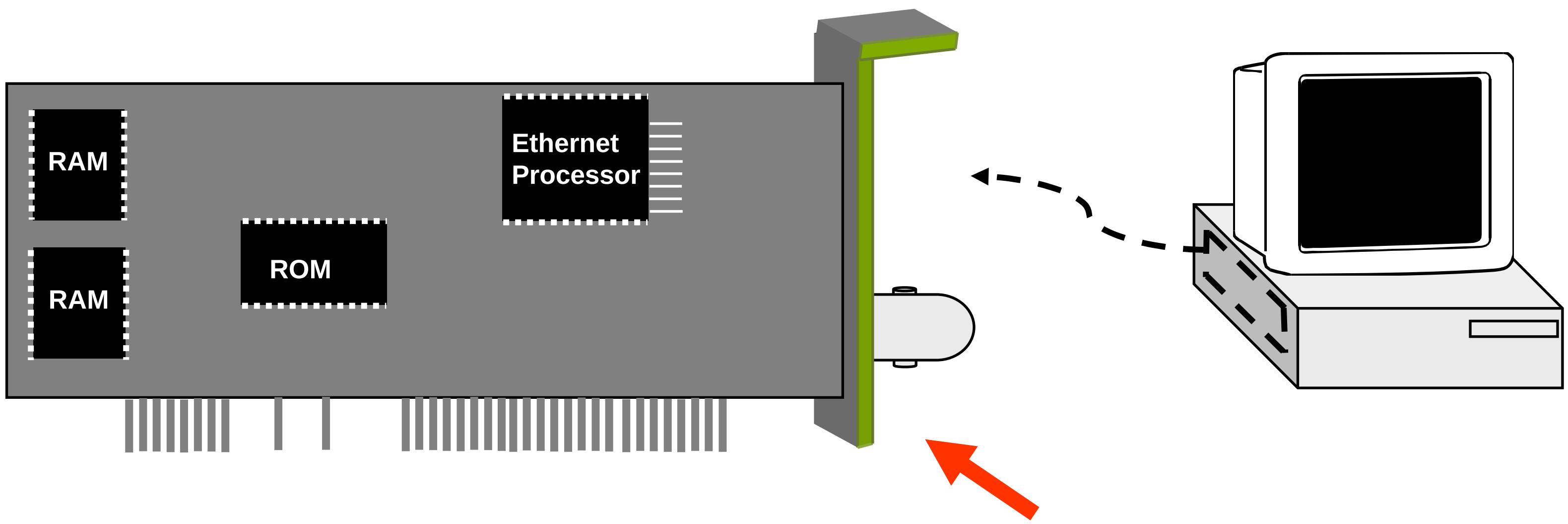
Local area means:

- Private ownership
  - freedom from regulatory constraints of WANs
- Short distance (~1km) between computers
  - low cost
  - very high-speed, relatively error-free communication
  - complex error control unnecessary
- Machines are constantly moved
  - Keeping track of location of computers a chore
  - Simply give each machine a unique address
  - ***Broadcast*** *all messages to all machines in the LAN*
- Need a *medium access control protocol*

Typical LAN Structure



- Transmission Medium
- Network Interface Card (NIC)
- *Unique MAC "physical" address*

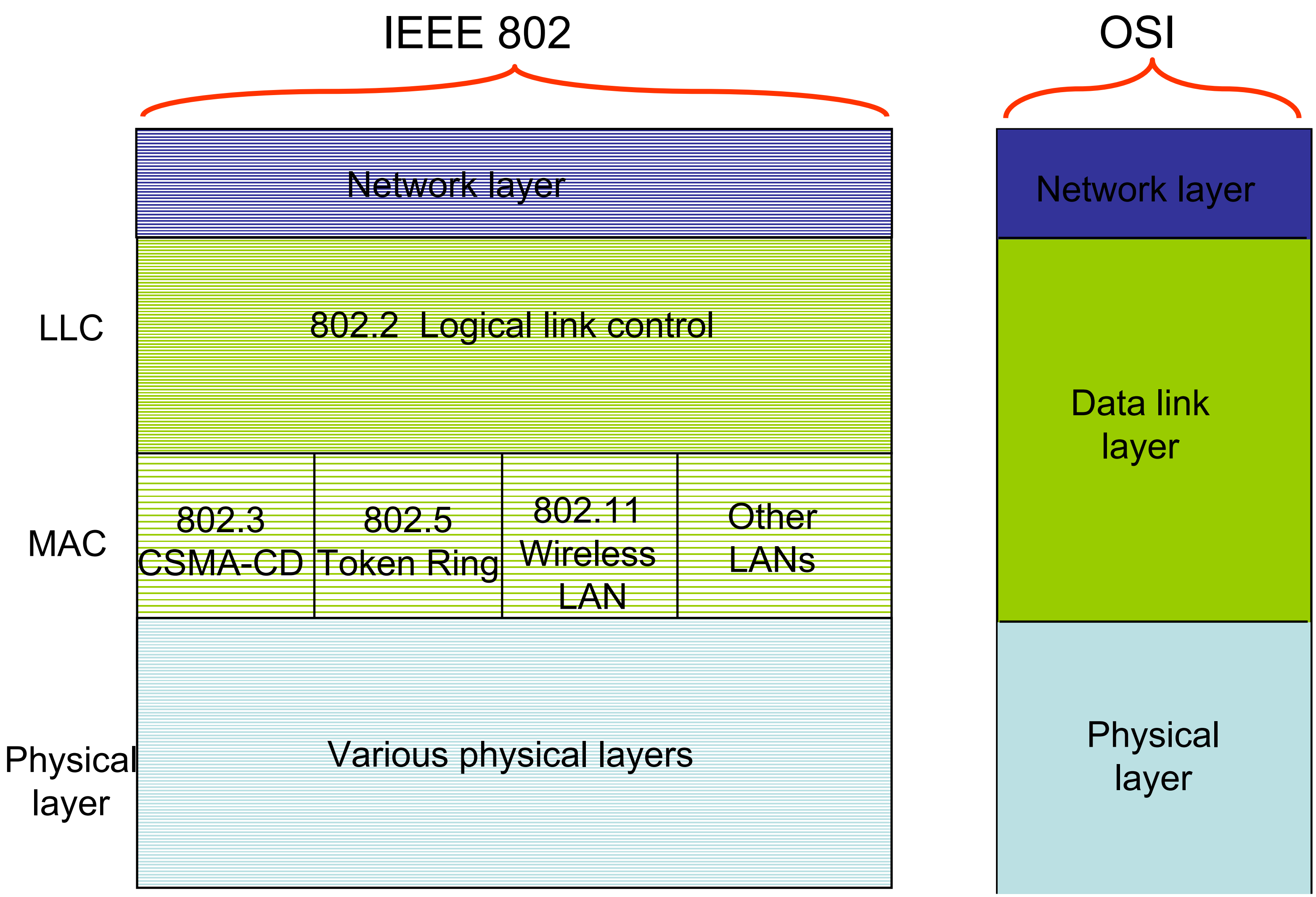


Medium Access Control Sublayer

- In IEEE 802.1, Data Link Layer divided into:

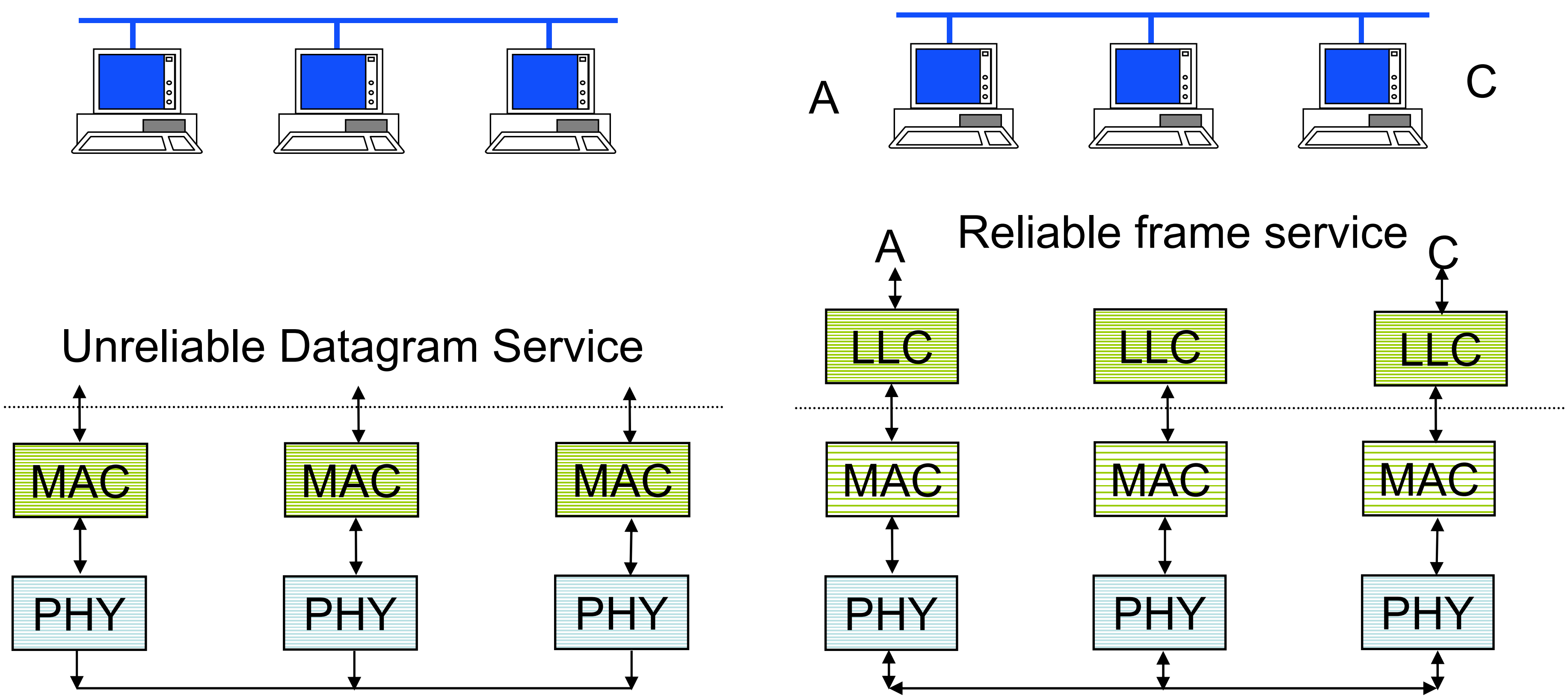
1. Medium Access Control Sublayer
   - Coordinate access to medium
   - Connectionless frame transfer service
   - Machines identified by MAC/physical address
   - Broadcast frames with MAC addresses
2. Logical Link Control Sublayer
   - Between Network layer & MAC sublayer

MAC Sub-layer

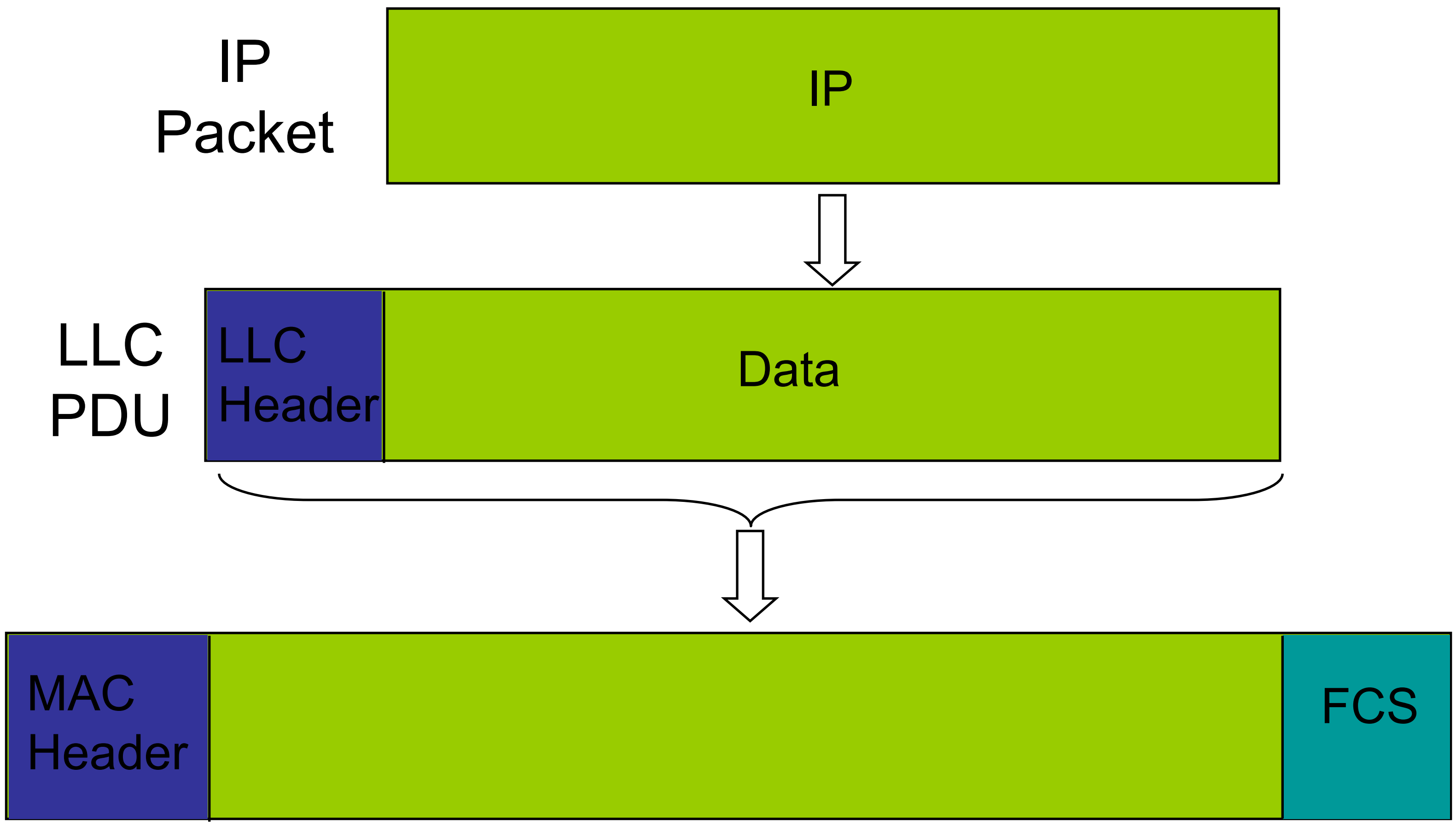


Logical Link Control Layer

- IEEE 802.2: LLC enhances service provided by MAC



Encapsulation of MAC frames



Ethernet

IEEE 802.3 MAC: Ethernet

MAC Protocol:

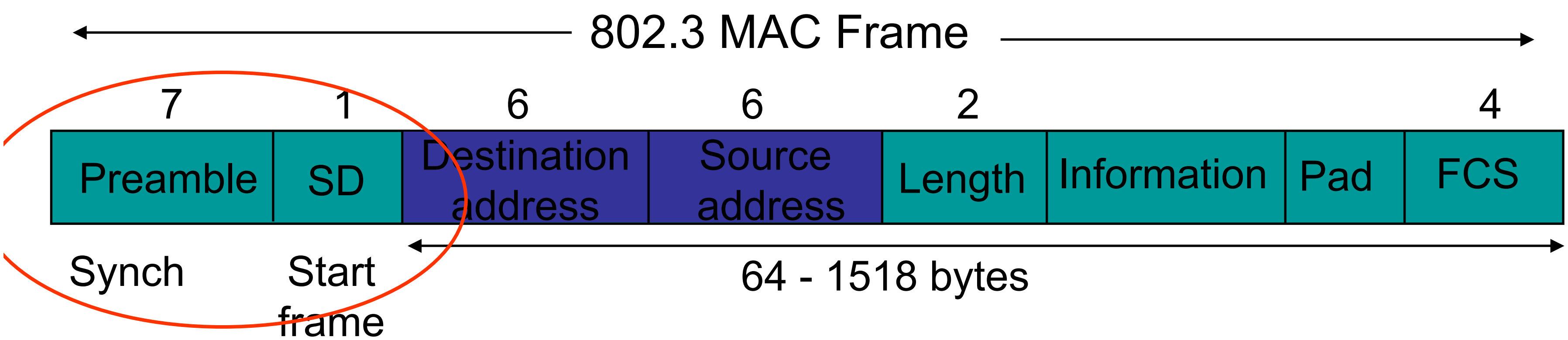
- CSMA/CD
- *Slot Time* is the critical system parameter
  - upper bound on time to detect collision
  - upper bound on time to acquire channel
  - upper bound on length of frame segment generated by collision
  - quantum for retransmission scheduling
  - max{round-trip propagation, MAC jam time}
- Truncated binary exponential backoff
  - for retransmission n: $0 < r < 2^k$, where k=min(n,10)
  - Give up after 16 retransmissions

IEEE 802.3 Original Parameters

- Transmission Rate: 10 Mbps
- Min Frame: 512 bits = 64 bytes
- Slot time: 512 bits/10 Mbps = 51.2 μsec
  - 51.2 μsec x 2×10^5 km/sec =10.24 km, 1 way
  - 5.12 km round trip distance
- Max Length: 2500 meters + 4 repeaters

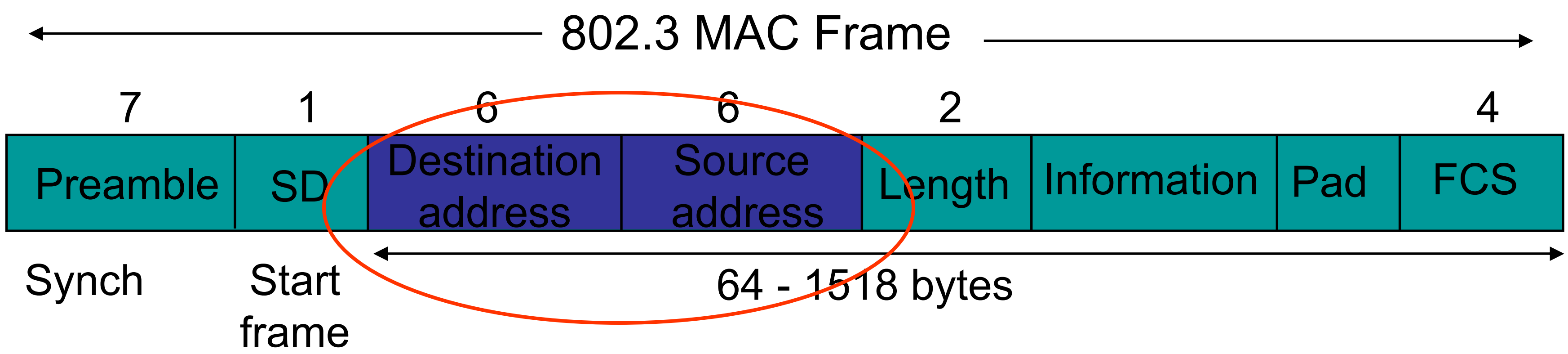
- *Each x10 increase in bit rate, must be accompanied by x10 decrease in distance*

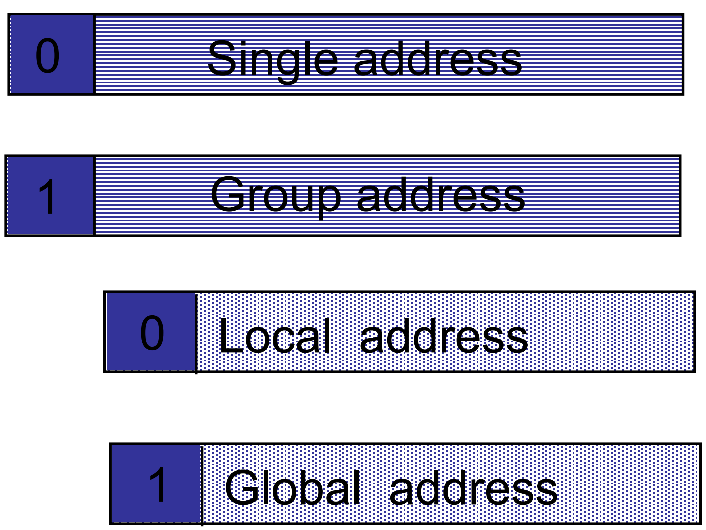
IEEE 802.3 MAC Frame



- Every frame transmission begins “from scratch”
- Preamble helps receivers synchronize their clocks to transmitter clock
- 7 bytes of 10101010 generate a square wave
- Start frame byte changes to 1010101**1**
- Receivers look for change in 10 pattern

IEEE 802.3 MAC Frame

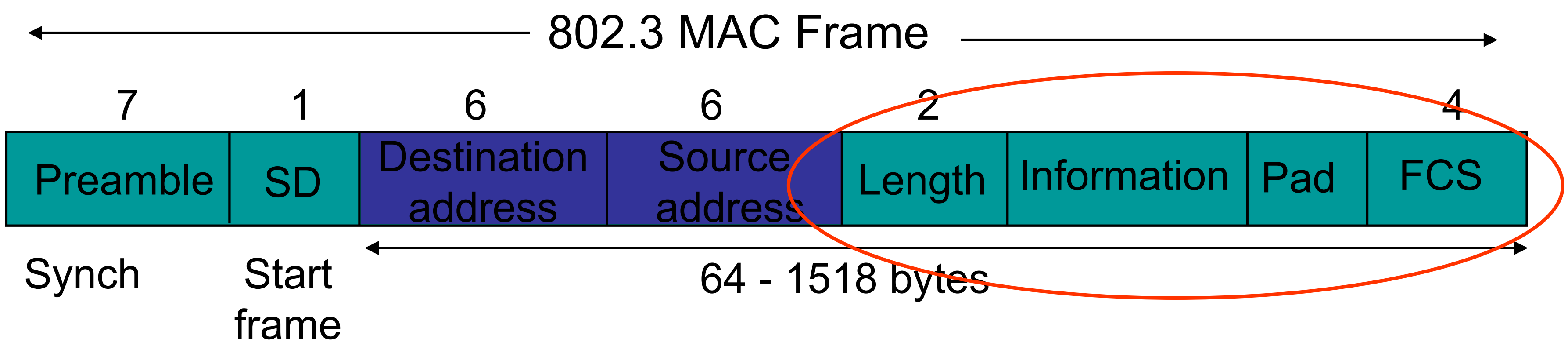




- Destination address
  - single address
  - group address
  - broadcast = 111...111

Addresses
  - local or global
- Global addresses
  - first 24 bits assigned to manufacturer;
  - next 24 bits assigned by manufacturer
  - Cisco 00-00-0C
  - 3COM 02-60-8C

IEEE 802.3 MAC Frame



- Length: # bytes in information field
  - Max frame 1518 bytes, excluding preamble & SD
  - Max information 1500 bytes: 05DC
- Pad: ensures min frame of 64 bytes
- FCS: CCITT-32 CRC, covers addresses, length, information, pad fields
  - NIC discards frames with improper lengths or failed CRC

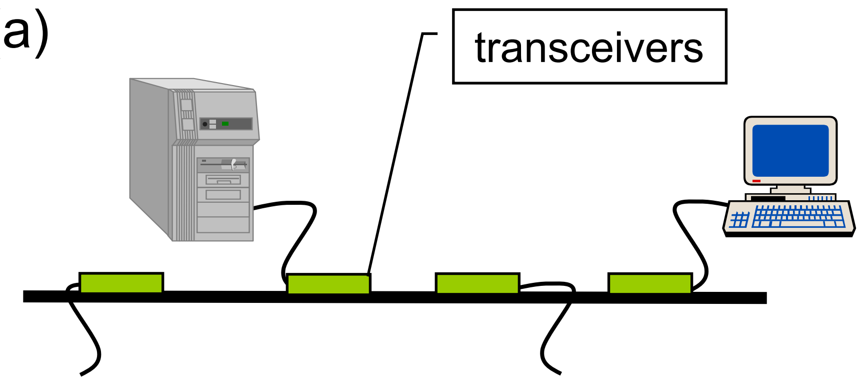
IEEE 802.3 Physical Layer

Table 6.2 IEEE 802.3 10 Mbps medium alternatives

	10base5	10base2	10baseT	10baseFX
Medium	Thick coax	Thin coax	Twisted pair	Optical fiber
Max. Segment Length	500 m	200 m	100 m	2 km
Topology	Bus	Bus	Star	Point-to-point link

Hubs & Switches!

(a)



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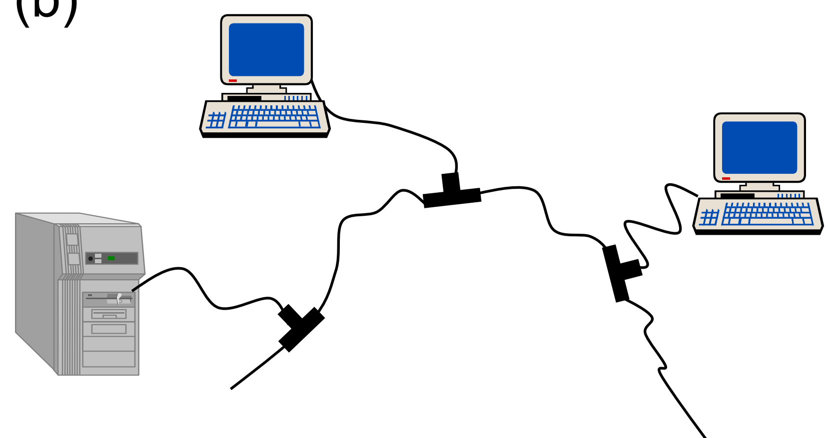
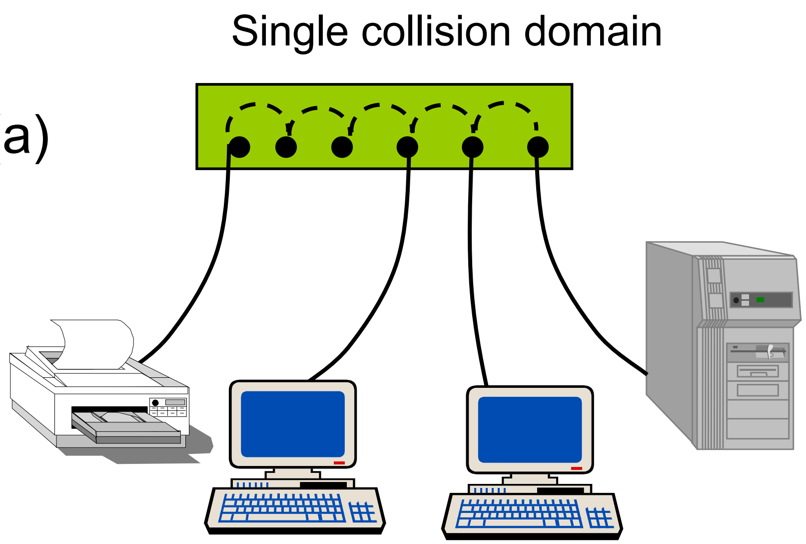


Thick Coax: Stiff, hard to work with

T connectors flaky

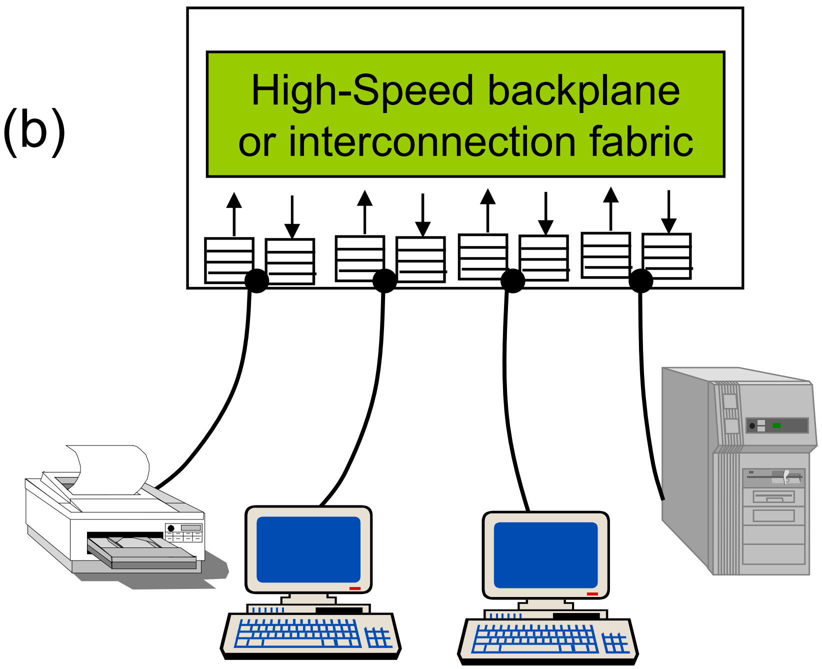
Ethernet Hubs & Switches

(a)



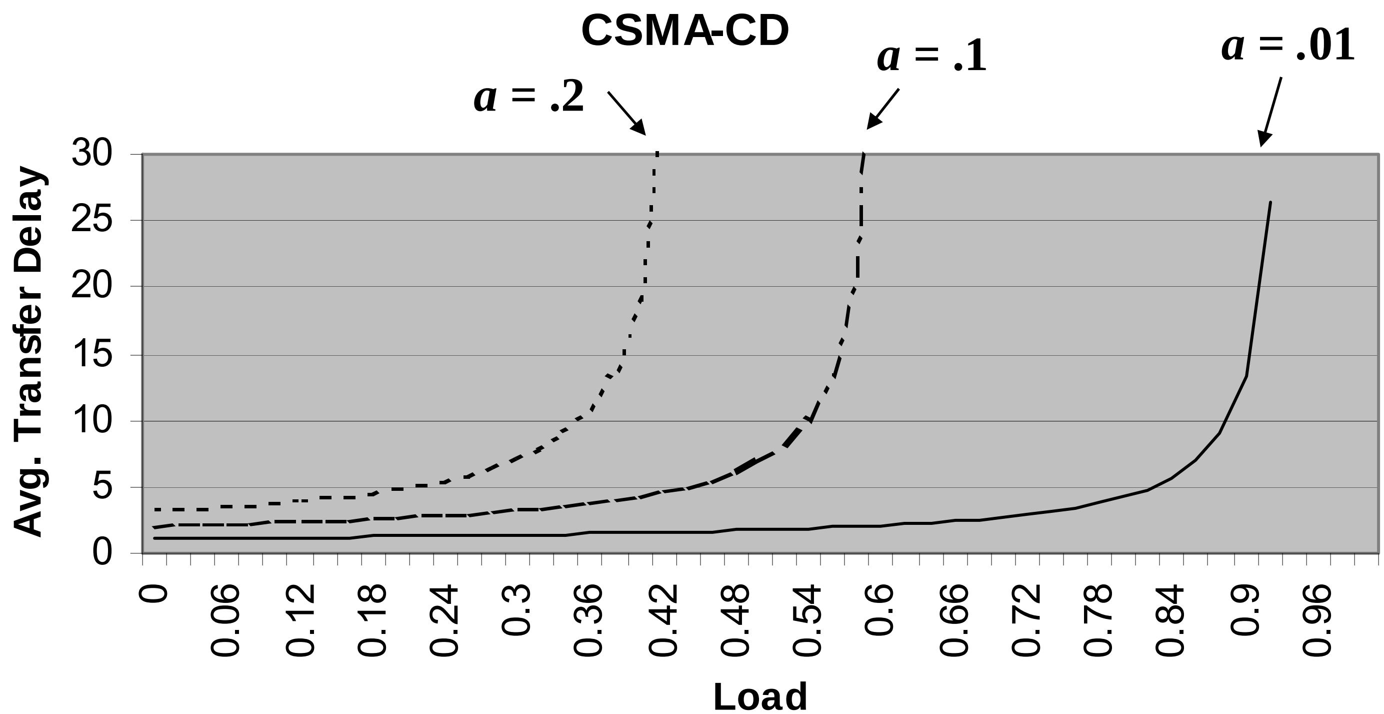
Twisted Pair Cheap
Easy to work with
Reliable
Star-topology CSMA-CD

(b)



Twisted Pair Cheap
Bridging increases scalability
Separate collision domains
Full duplex operation

Ethernet Scalability



- CSMA-CD maximum throughput depends on normalized delay-bandwidth product $a = t_{prop}/X$
- x10 increase in bit rate = x10 decrease in X
- To keep a constant need to either: decrease t_{prop} *(distance) by x10;* or increase frame length x10

Fast Ethernet

Table 6.4 IEEE 802.3 100 Mbps Ethernet medium alternatives

	100baseT4	**100baseT**	**100baseFX**
Medium	Twisted pair category 3 UTP 4 pairs	Twisted pair category 5 UTP two pairs	Optical fiber multimode Two strands
Max. Segment Length	100 m	100 m	2 km
Topology	Star	Star	Star

To preserve compatibility with 10 Mbps Ethernet:

- Same frame format, same interfaces, same protocols
- Hub topology only with twisted pair & fiber
- Bus topology & coaxial cable abandoned
- Category 3 twisted pair (ordinary telephone grade) requires 4 pairs
- Category 5 twisted pair requires 2 pairs (most popular)
- Most prevalent LAN today

Gigabit Ethernet

Table 6.3 IEEE 802.3 1 Gbps Fast Ethernet medium alternatives

	1000baseSX	**1000baseLX**	**1000baseCX**	**1000baseT**
Medium	Optical fiber multimode Two strands	Optical fiber single mode Two strands	Shielded copper cable	Twisted pair category 5 UTP
Max. Segment Length	550 m	5 km	25 m	100 m
Topology	Star	Star	Star	Star

- Slot time increased to *512 bytes*
- Small frames need to be extended to 512 B
- Frame bursting to allow stations to transmit burst of short frames
- Frame structure preserved but CSMA-CD essentially abandoned
- Extensive deployment in backbone of enterprise data networks and in server farms

10 Gigabit Ethernet

Table 6.5 IEEE 802.3 10 Gbps Ethernet medium alternatives

	10GbaseSR	10GBaseLR	10GbaseEW	10GbaseLX4
Medium	Two optical fibers Multimode at 850 nm 64B66B code	Two optical fibers Single-mode at 1310 nm 64B66B	Two optical fibers Single-mode at 1550 nm SONET compatibility	Two optical fibers multimode/single-mode with four wavelengths at 1310 nm band 8B10B code
Max. Segment Length	300 m	10 km	40 km	300 m – 10 km

- Frame structure preserved
- CSMA-CD protocol officially abandoned
- LAN PHY for local network applications
- WAN PHY for wide area interconnection using SONET OC-192c
- Extensive deployment in metro networks anticipated

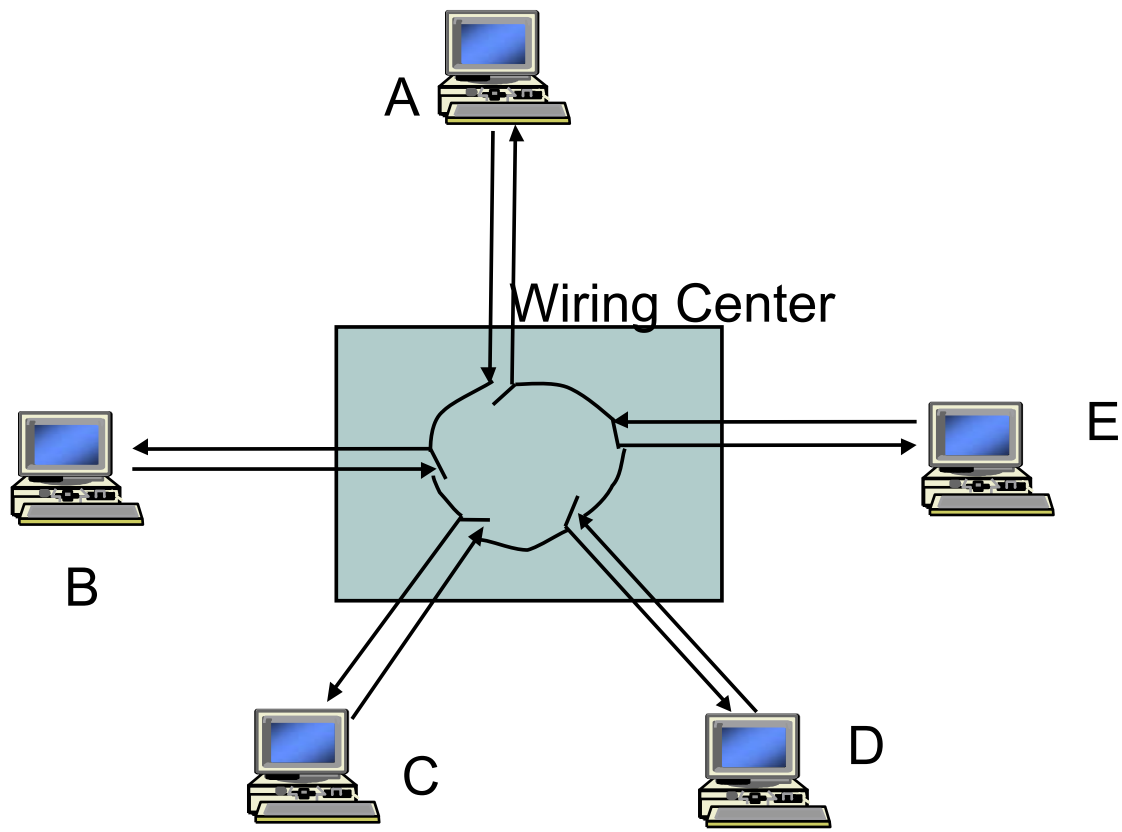
Token Ring

IEEE 802.5 Ring LAN

- Unidirectional ring network
- 4 Mbps and 16 Mbps on twisted pair
  - Differential Manchester line coding
- Token passing protocol provides access
  - ✓ Fairness
  - ✓ Access priorities
  - ✗ Breaks in ring bring entire network down
- Reliability by using star topology

Star Topology Ring LAN

- Stations connected in star fashion to wiring closet
  - Use existing telephone wiring
- Ring implemented inside equipment box
- Relays can bypass failed links or stations



Token Frame Format

Data frame format

SD	AC	FC	Destination address	Source address	Information	FCS	ED	FS
1	1	1	6	6		4	1	1

Token frame format

SD	AC	ED

Starting delimiter

J	K	0	J	K	0	0	0

J, K nondata symbols (line code)
J begins as "0" but no transition
K begins as "1" but no transition

Access control

P P P	T	M	R R R

PPP=priority; **T=token bit**
M=monitor bit; RRR=reservation
T=0 token; T=1 data

Ending delimiter

J	K	1	J	K	1	I	E

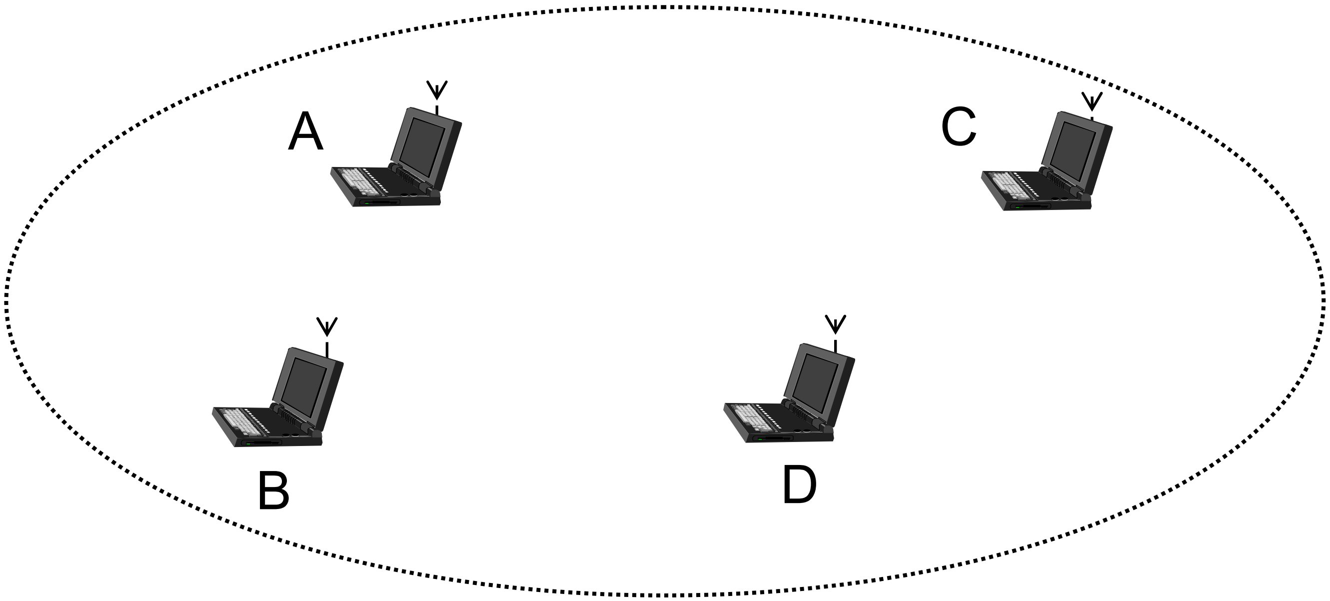
I = intermediate-frame bit
E = error-detection bit

802.11 Wireless LAN

Wireless Data Communications

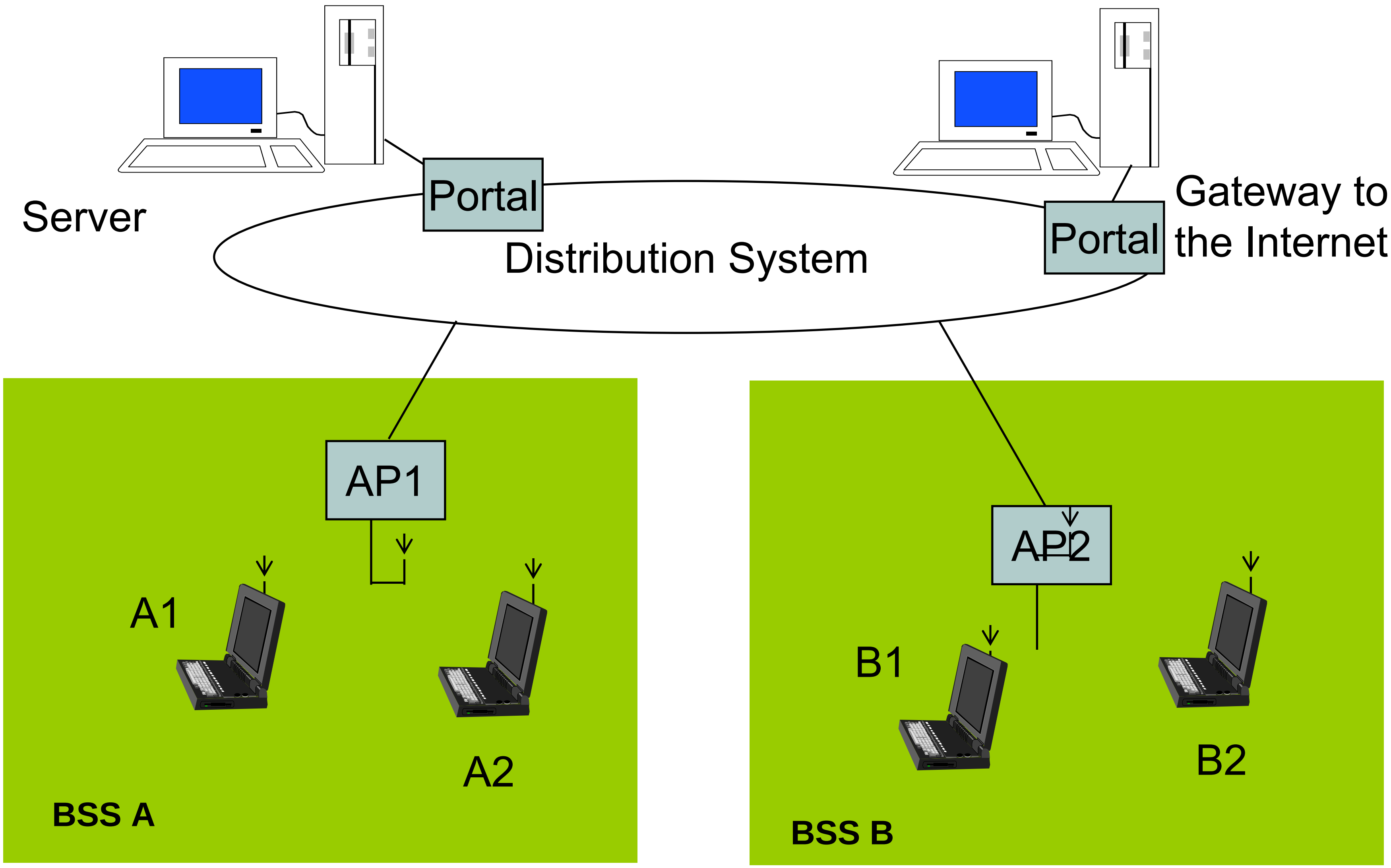
- Wireless communications compelling
  - ✓ Easy, low-cost deployment
  - ✓ Mobility & roaming: Access information anywhere
  - ✓ Supports personal devices
    - ✓ PDAs, laptops, data-cell-phones
  - ✓ Supports communicating devices
    - ✓ Cameras, location devices, wireless identification
  - ✗ Signal strength varies in space & time
  - ✗ Signal can be captured by snoopers
  - ✗ Spectrum is limited & usually regulated

Ad Hoc Communications



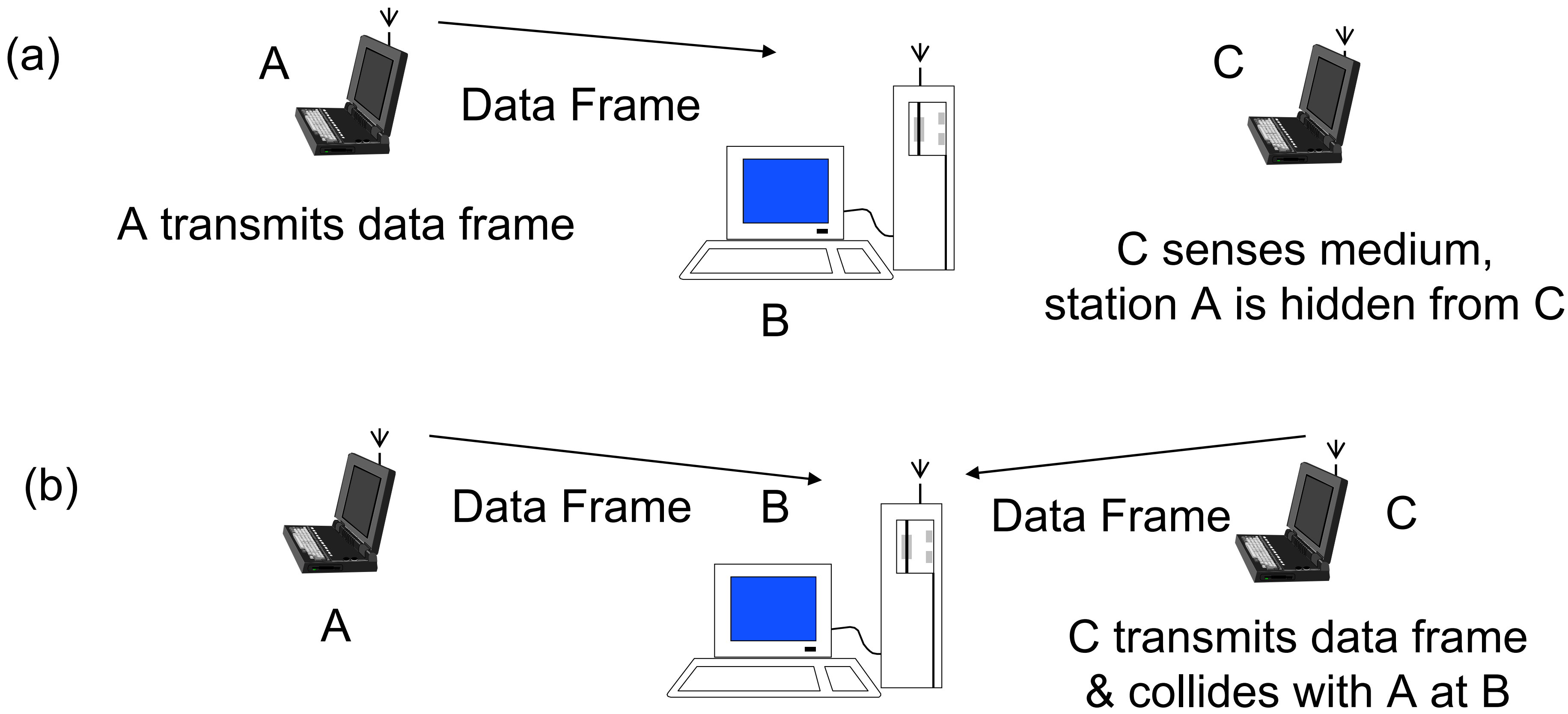
- Temporary association of group of stations
  - Within range of each other
  - Need to exchange information
  - E.g. Presentation in meeting, or distributed computer game, or both

Infrastructure Network



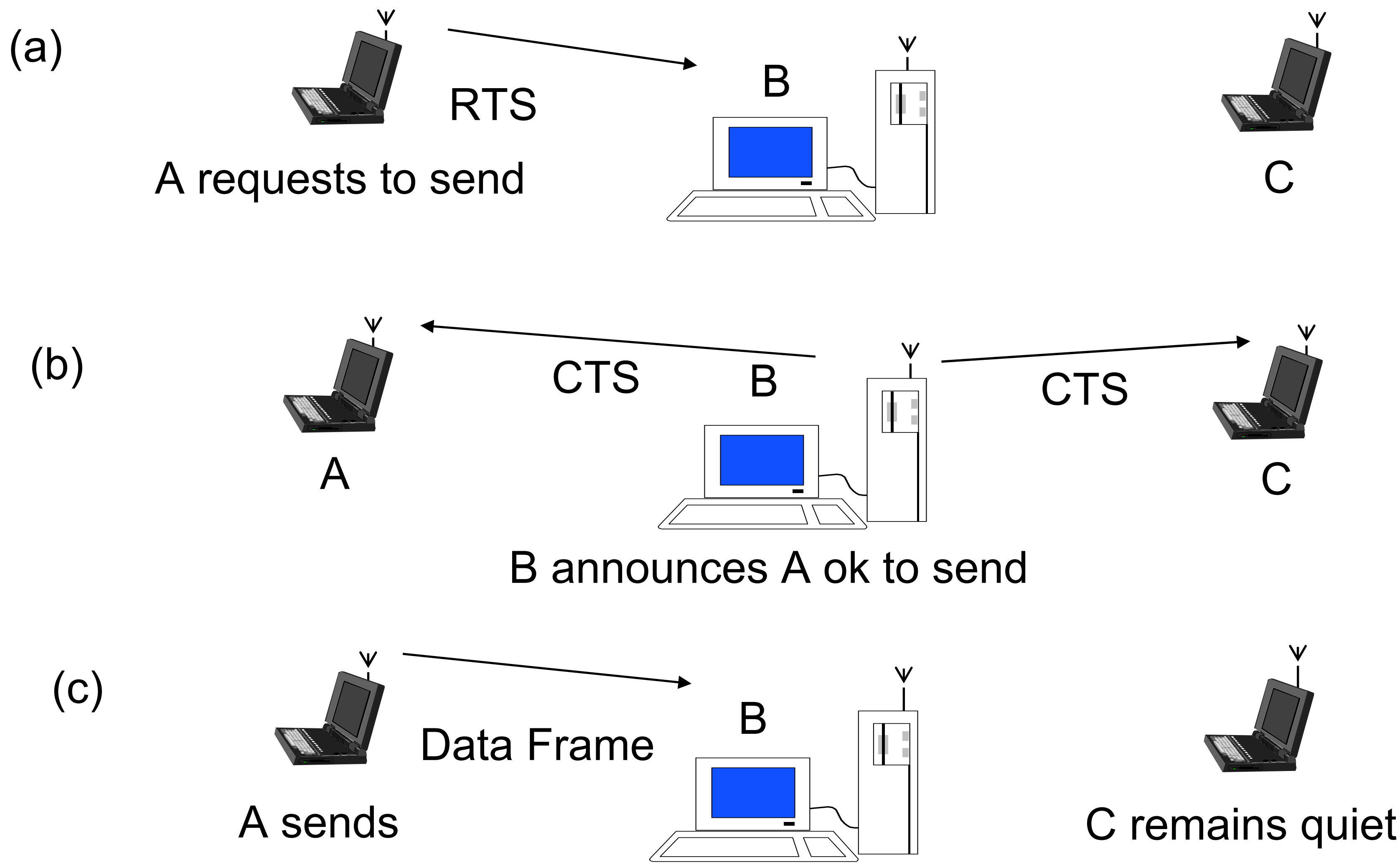
- Permanent Access Points provide access to Internet

Hidden Terminal Problem



- New MAC: CSMA with *Collision Avoidance*

CSMA with Collision Avoidance



IEEE 802.11 Physical Layer Options

	Frequency Band	Bit Rate	Modulation Scheme
802.11	2.4 GHz	1-2 Mbps	Frequency-Hopping Spread Spectrum, Direct Sequence Spread Spectrum
802.11b	2.4 GHz	11 Mbps	Complementary Code Keying & QPSK
802.11g	2.4 GHz	54 Mbps	Orthogonal Frequency Division Multiplexing & CCK for backward compatibility with 802.11b
802.11a	5-6 GHz	54 Mbps	Orthogonal Frequency Division Multiplexing

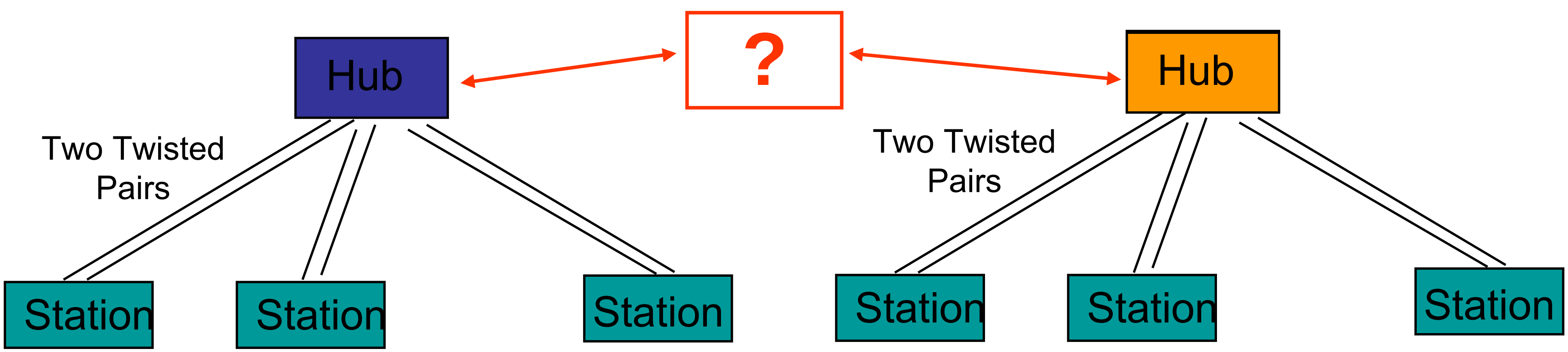
LAN Bridges

Hubs, Bridges & Routers

- Hub: Active central element in a star topology
  - Twisted Pair: inexpensive, easy to insall
  - Simple repeater in Ethernet LANs
  - "Intelligent hub": fault isolation, net configuration, statistics
  - Requirements that arise:

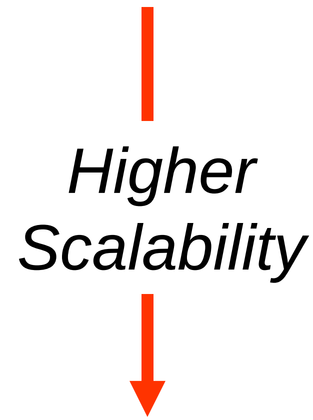
User community grows, need to interconnect hubs

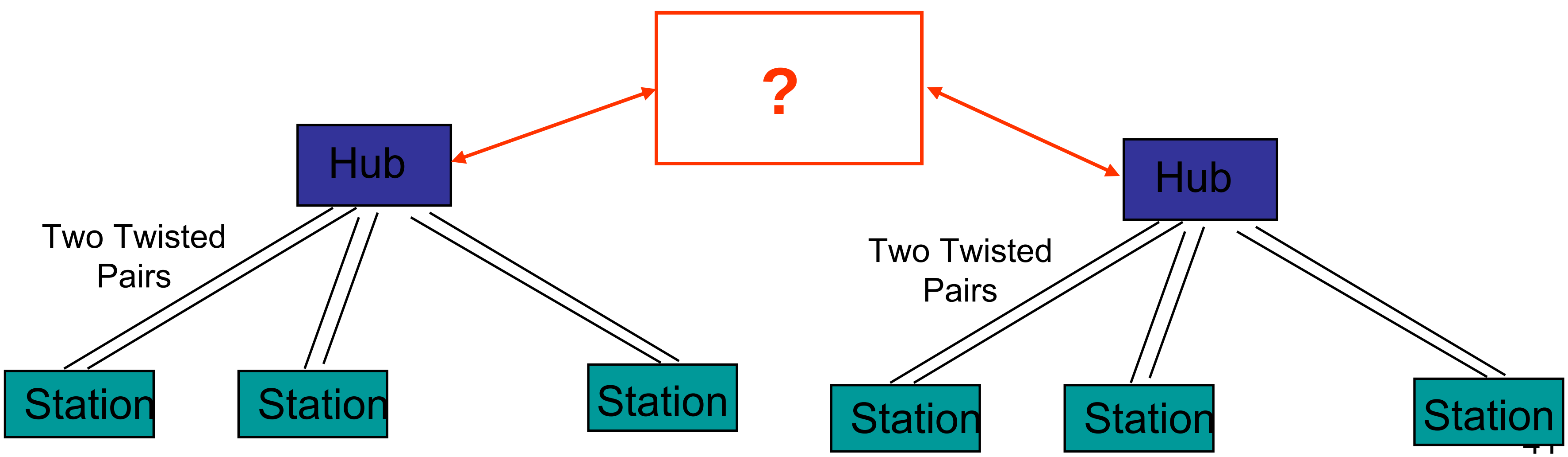
Hubs are for different types of LANs



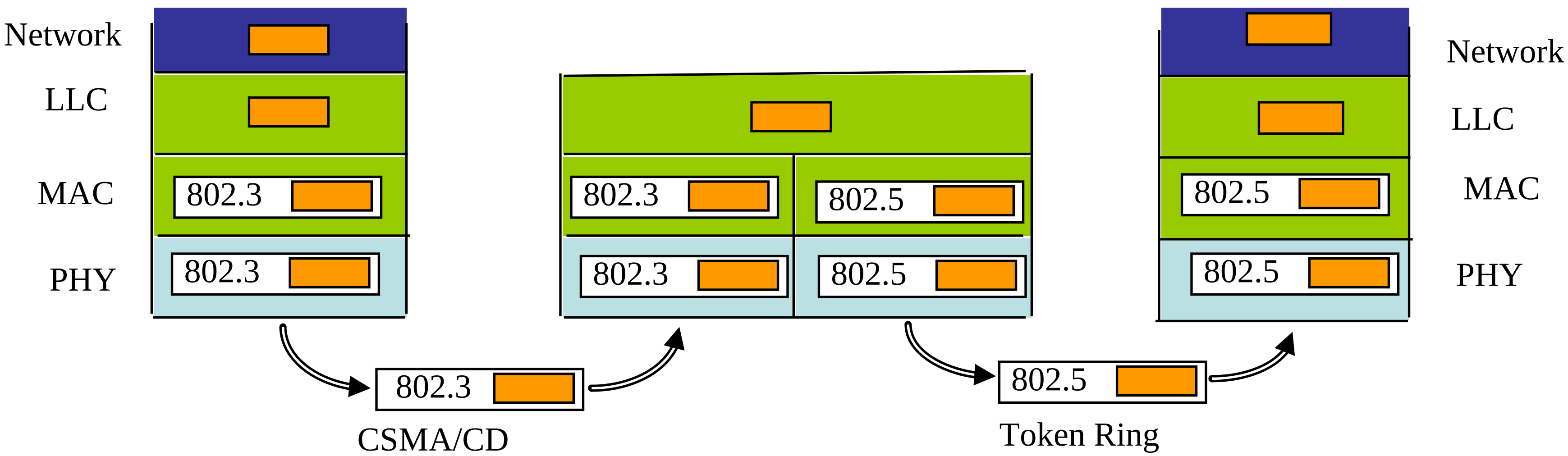
Hubs, Bridges & Routers

- Interconnecting Hubs
  - Repeater: Signal regeneration
    - All traffic appears in both LANs
  - Bridge: MAC address filtering
    - Local traffic stays in own LAN
  - Routers: Internet routing
    - All traffic stays in own LAN



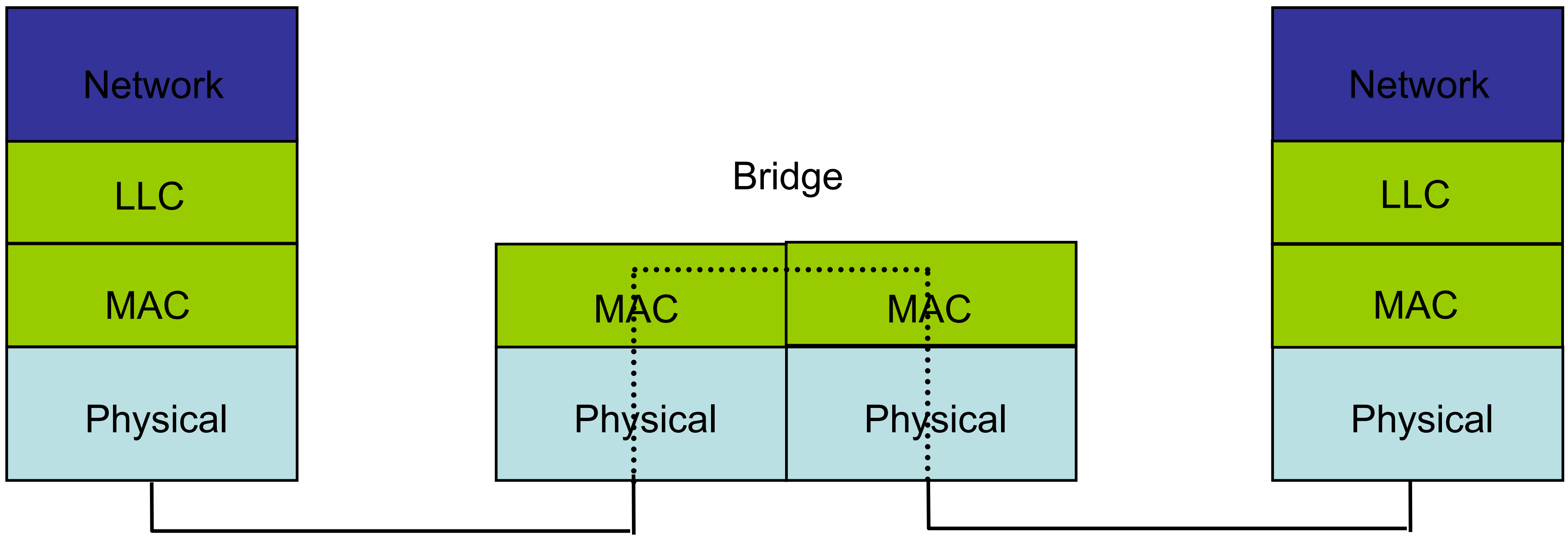


General Bridge Issues



- Operation at data link level implies capability to work with multiple network layers
- However, must deal with
  - Difference in MAC formats
  - Difference in data rates; buffering; timers
  - Difference in maximum frame length

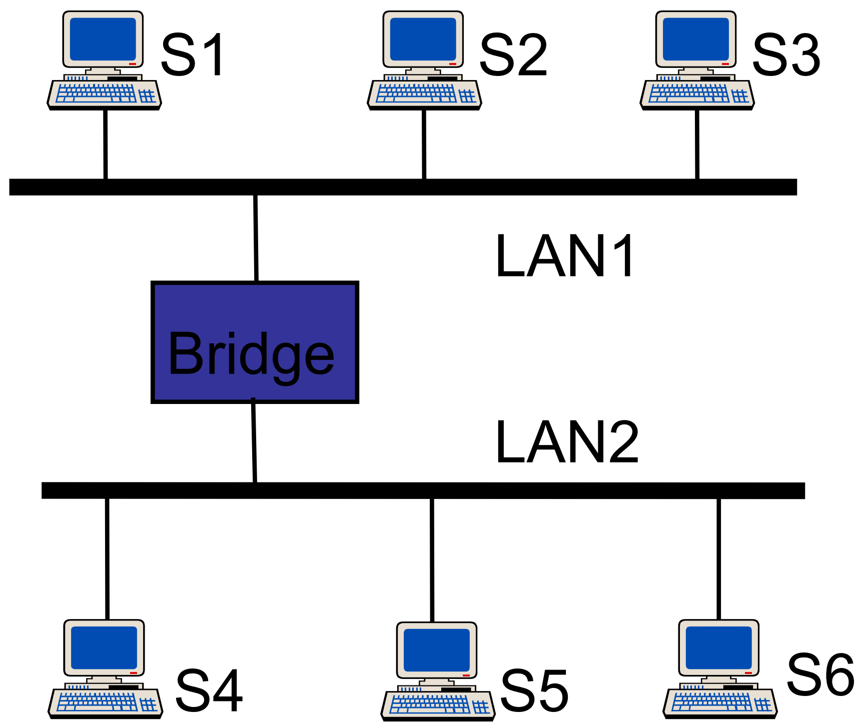
Bridges of Same Type

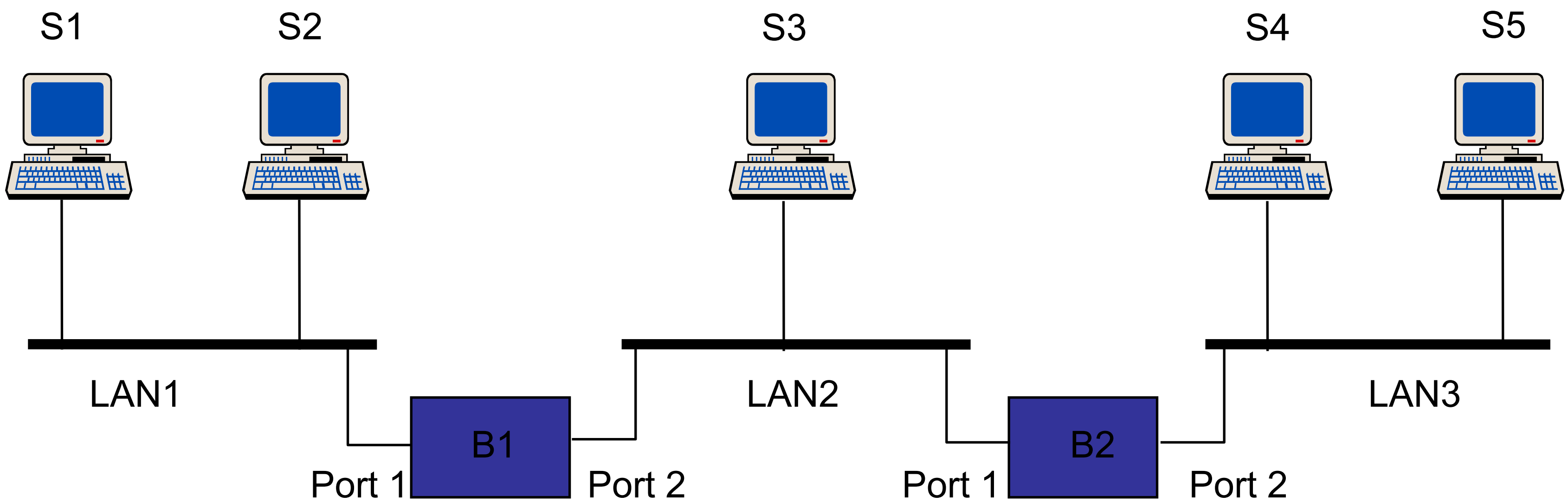


- Common case involves LANs of same type
- Bridging is done at MAC level

Transparent Bridges

- Interconnection of IEEE LANs with complete transparency
- Use table lookup, and
  - discard frame, if source & destination in same LAN
  - forward frame, if source & destination in different LAN
  - use flooding, if destination unknown
- Use backward learning to build table
  - observe source address of arriving LANs
  - handle topology changes by removing old entries

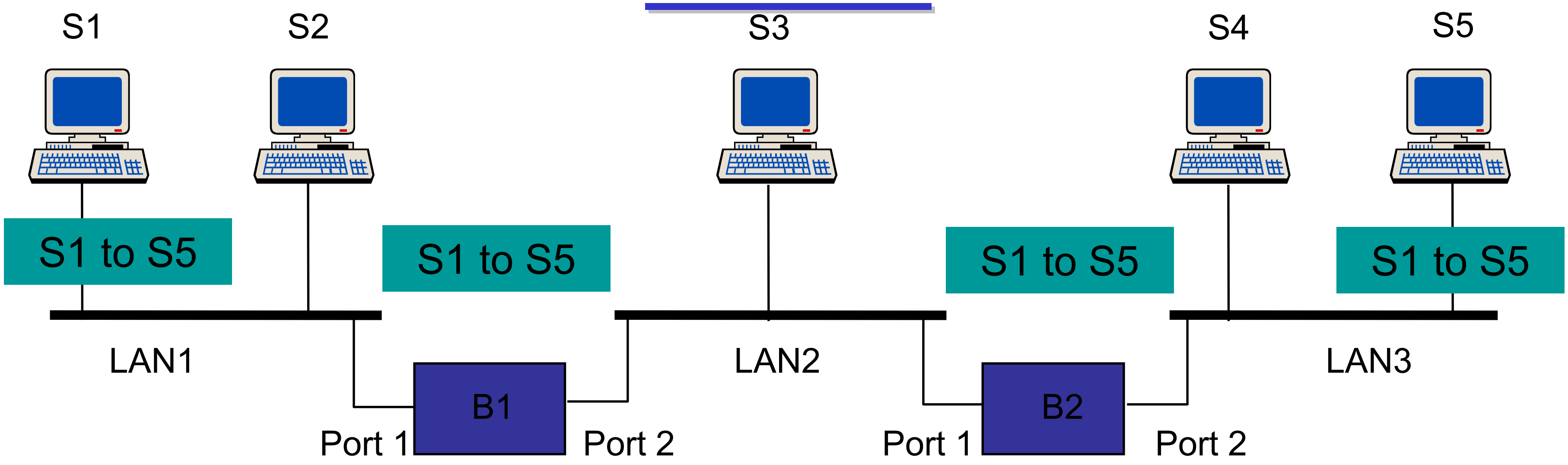




Address	Port

Address	Port

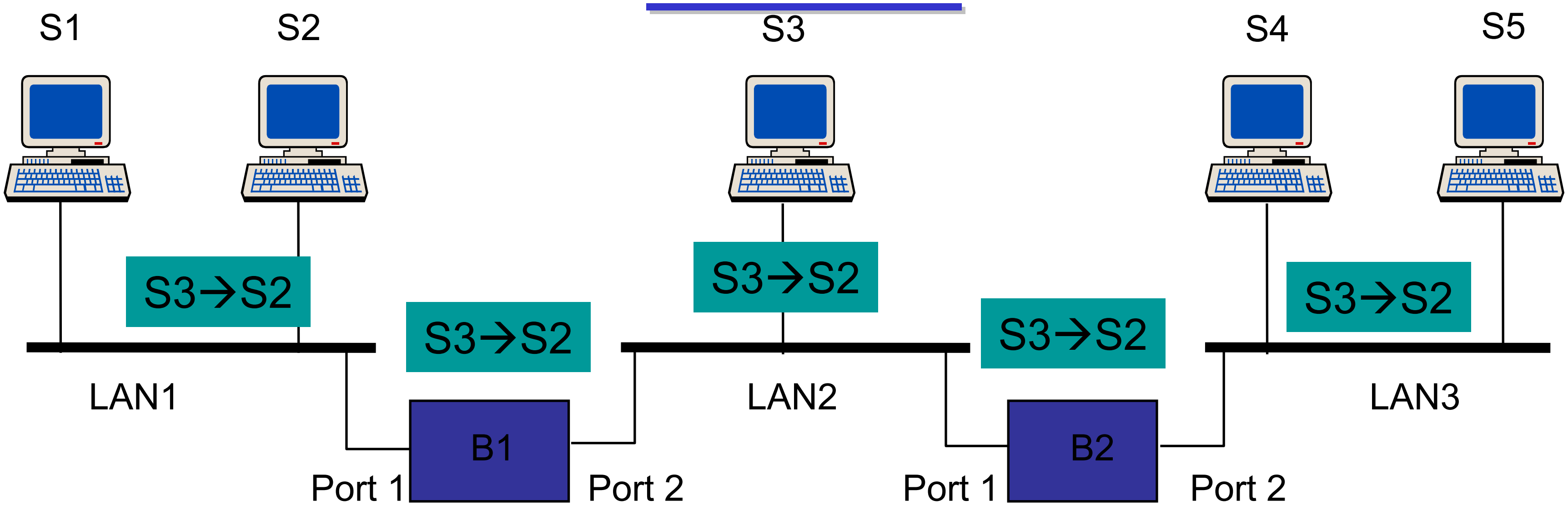
S1→S5



Address	Port
S1	1

Address	Port
S1	1

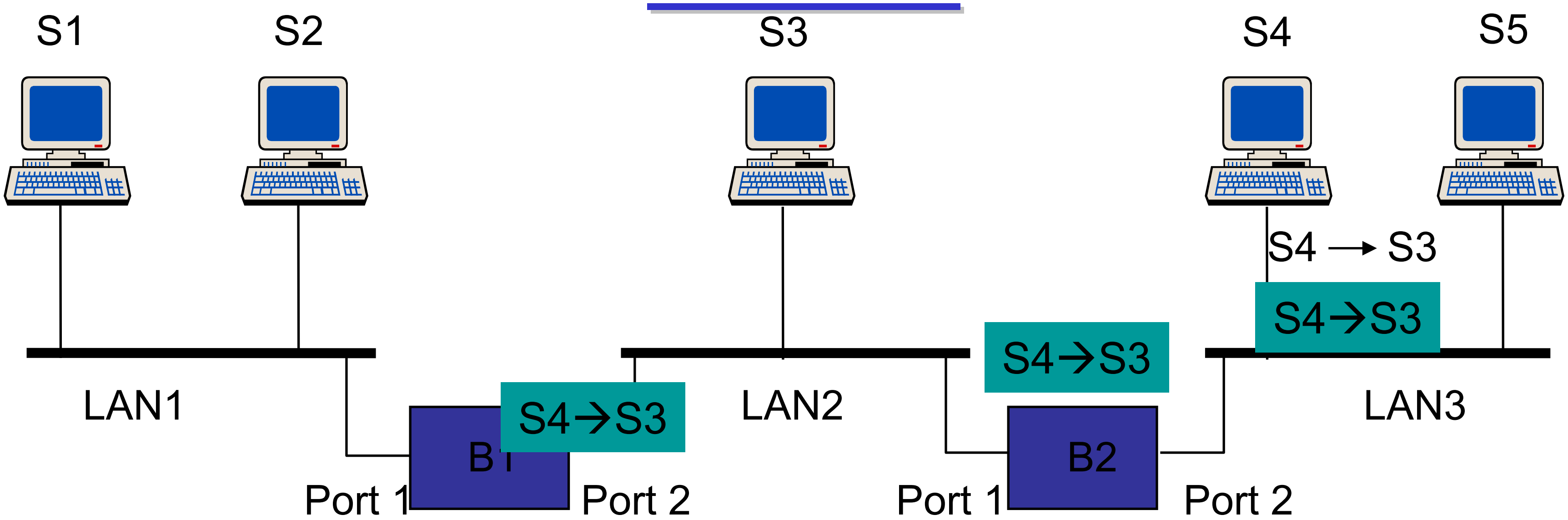
S3→S2



Address	Port
S1	1
S3	1

Address	Port
S1	1
S3	1

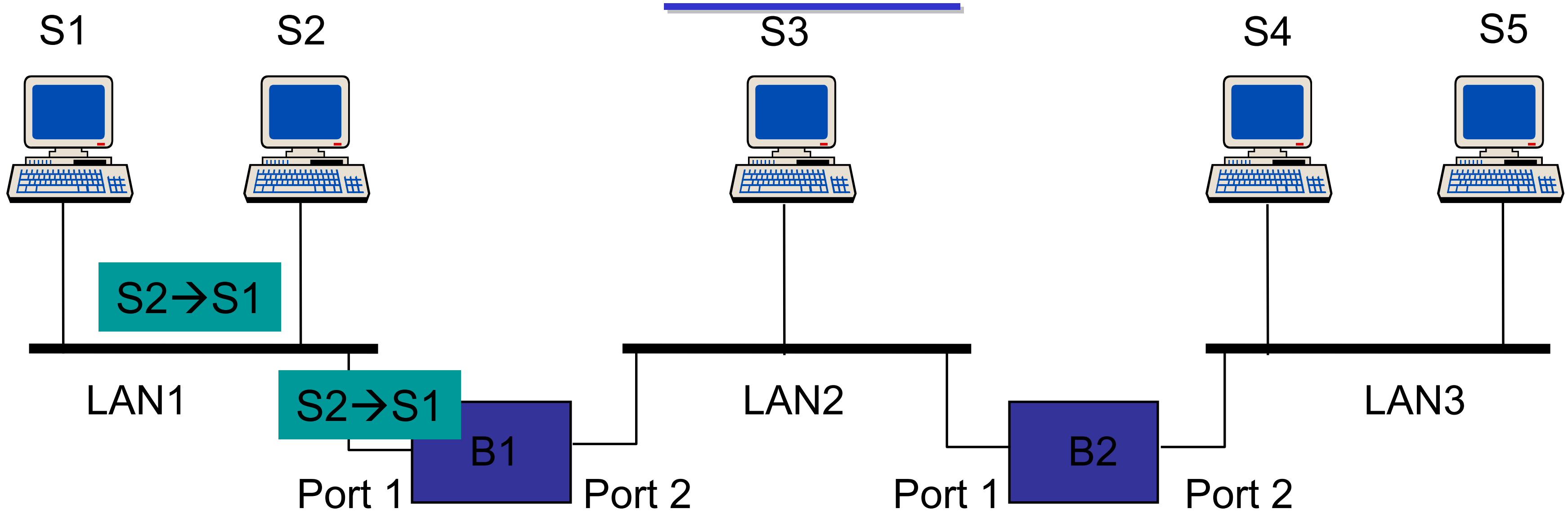
S4→S3



Address	Port
S1	1
S3	2
S4	2

Address	Port
S1	1
S3	1
S4	2

S2→S1



Address	Port
S1	1
S3	2
S4	2
S2	1

Address	Port
S1	1
S3	1
S4	2

Adaptive Learning

- In a static network, tables eventually store all addresses & learning stops
- In practice, stations are added & moved all the time
  - Introduce timer (minutes) to age each entry & force it to be relearned periodically
  - If frame arrives on port that differs from frame address & port in table, update immediately