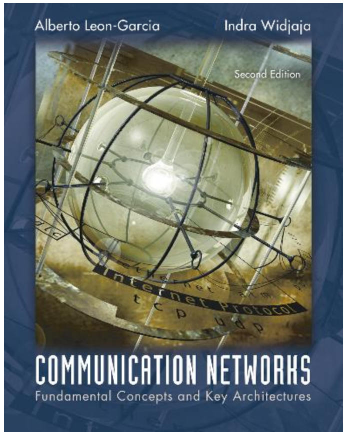
Chapter 6
Medium Access Control Protocols and Local Area Networks



Part I: Medium Access Control

Part II: Local Area Networks

Chapter Overview

- **Broadcast Networks**
  - All information sent to all users
  - No routing
  - Shared media
  - Radio
    - Cellular telephony
    - Wireless LANs
  - Copper & Optical
    - Ethernet LANs
    - Cable Modem

- ***Medium Access Control***
  - To coordinate access to shared medium
  - Data link layer since direct transfer of frames

- ***Local Area Networks***
  - High-speed, low-cost communications between co-located computers
  - Typically based on broadcast networks
  - Simple & cheap
  - Limited number of users

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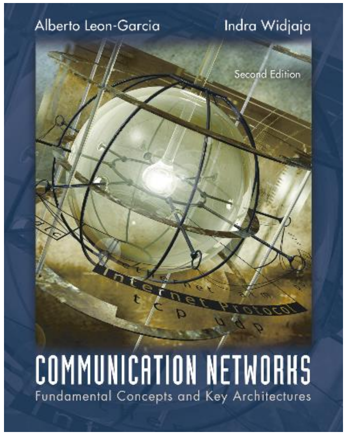

Part I: Medium Access Control

6.1 Multiple Access Communications
6.2 Random Access
Scheduling
Channelization
Delay Performance

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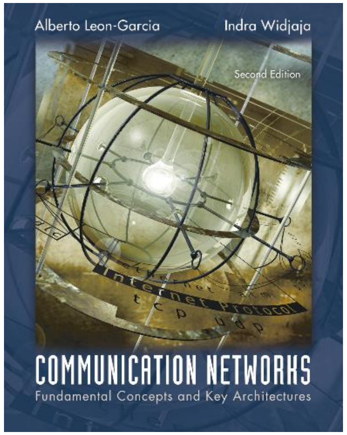
Medium Access Control Protocols and Local Area Networks



Part II: Local Area Networks

6.6 LAN Protocols

6.7 Ethernet and IEEE 802.3

Token Ring and FDDI

802.11 Wireless LAN

6.11 LAN Bridges

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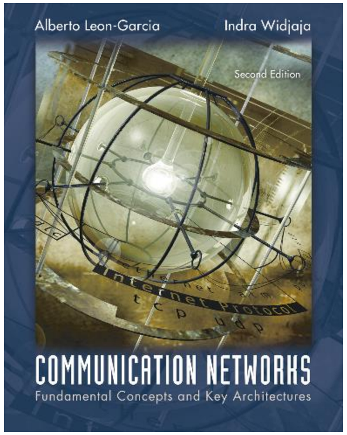
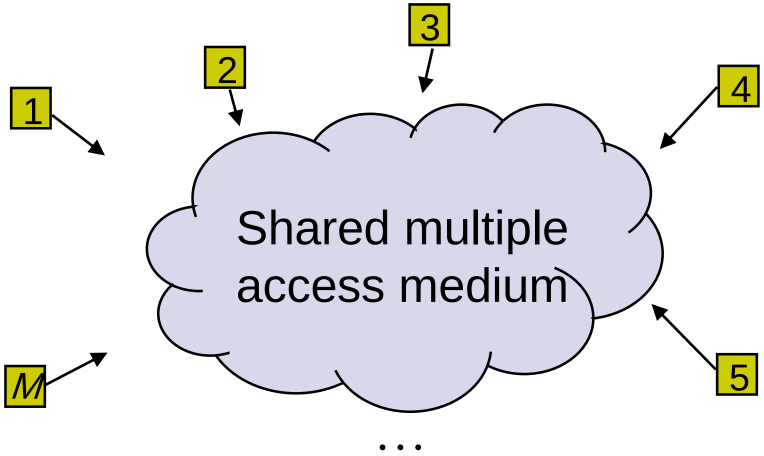
Medium Access Control Protocols and Local Area Networks



6.1 Multiple Access Communications

Multiple Access Communications

- Shared media basis for broadcast networks
  - Inexpensive: radio over air; copper or coaxial cable
  - M users communicate by broadcasting into medium
- Key issue: How to share the medium?



Approaches to Media Sharing

Medium sharing techniques

- Static channelization
- Dynamic medium access control
  - Scheduling
  - Random access

Static channelization

- Partition medium
- Dedicated allocation to users
- Satellite transmission
- Cellular Telephone

Scheduling

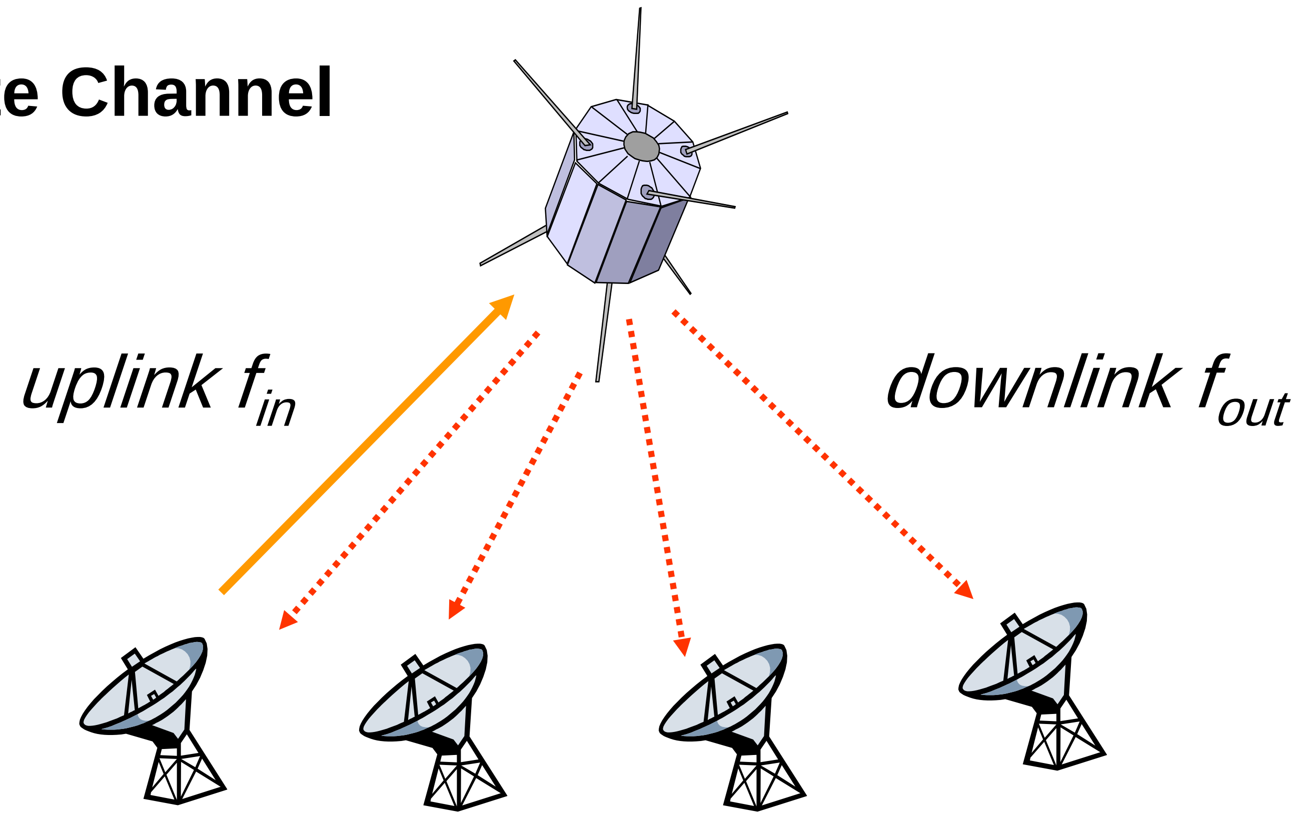
- Polling: take turns
- Request for slot in transmission schedule
- Token ring
- Wireless LANs

Random access

- Loose coordination
- Send, wait, retry if necessary
- Aloha
- Ethernet

Channelization: Satellite

Satellite Channel

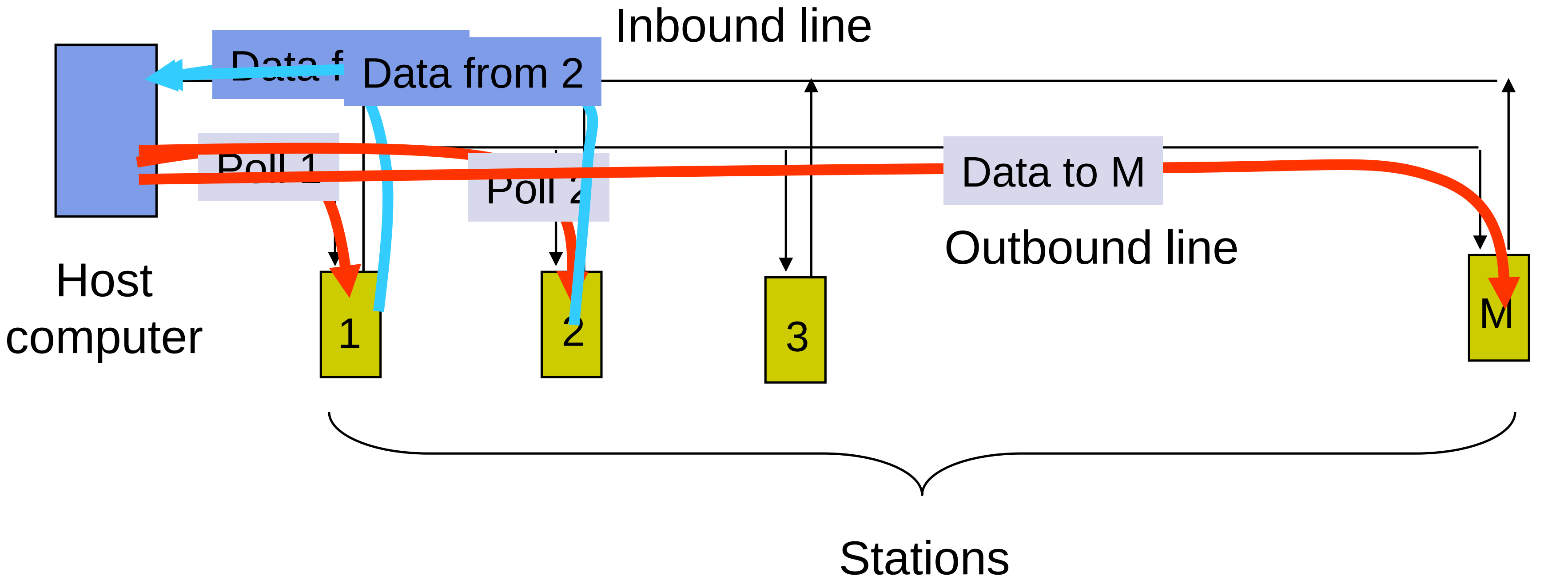


Channelization: Cellular

uplink f_1 ; *downlink* f_2

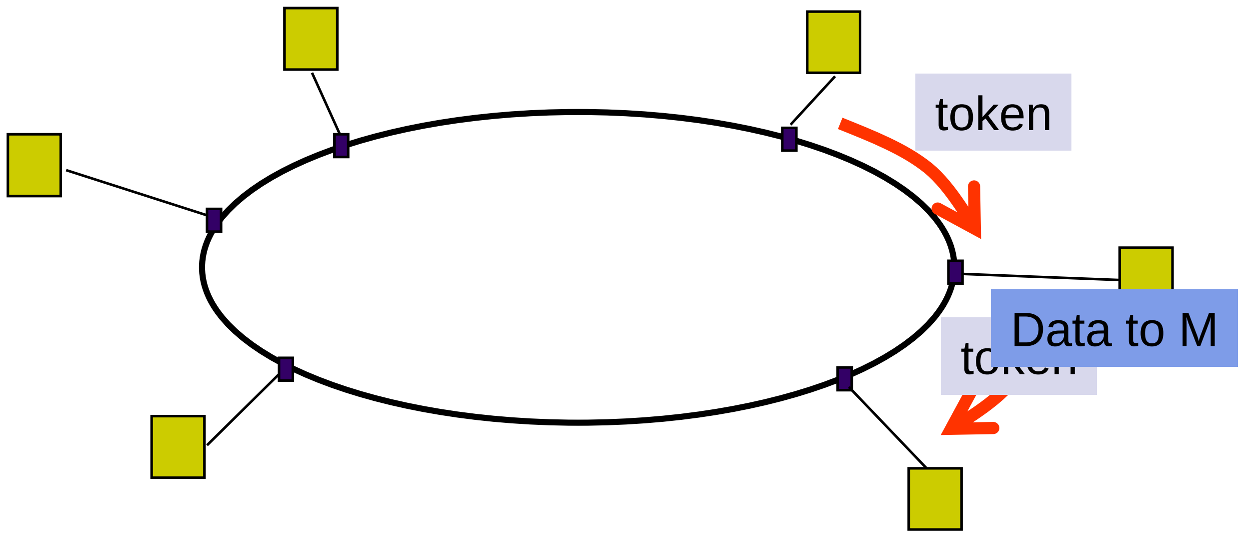
uplink f_3 ; *downlink* f_4

Scheduling: Polling



Scheduling: Token-Passing

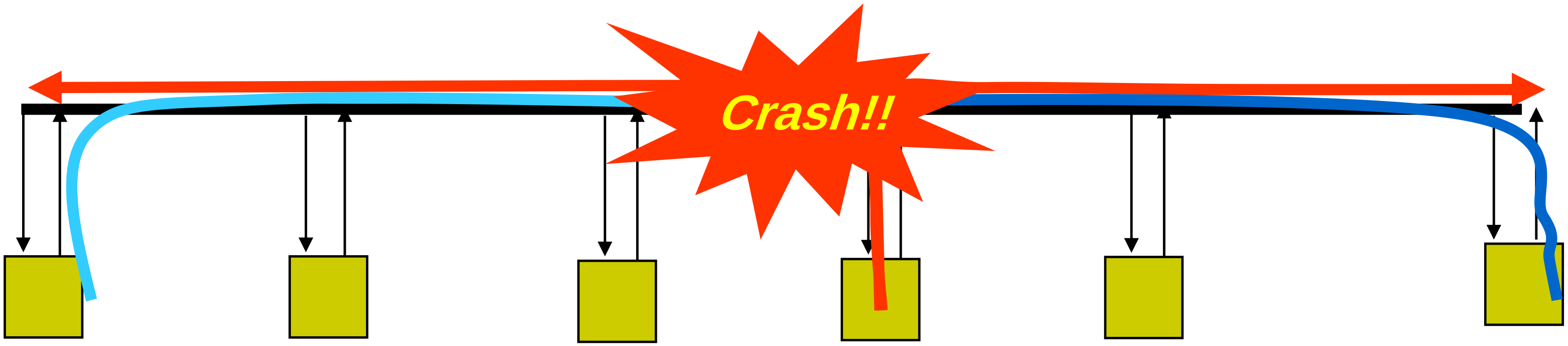
Ring networks



Station that holds token transmits into ring

Random Access

Multi-tapped Bus

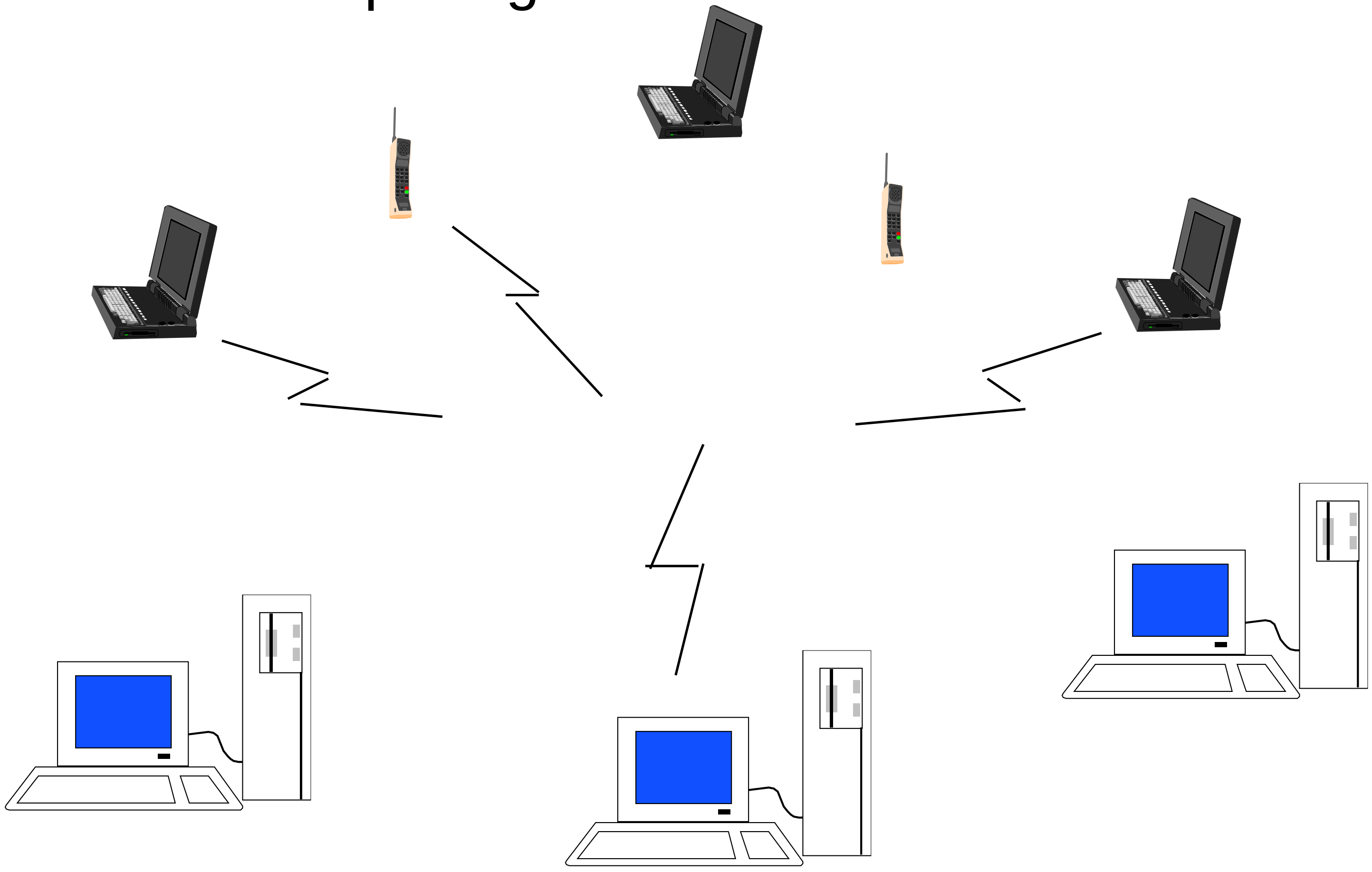


Transmit when ready

Transmissions can occur; need retransmission strategy

Wireless LAN

AdHoc: station-to-station
Infrastructure: stations to base station
Random access & polling



Selecting a Medium Access Control

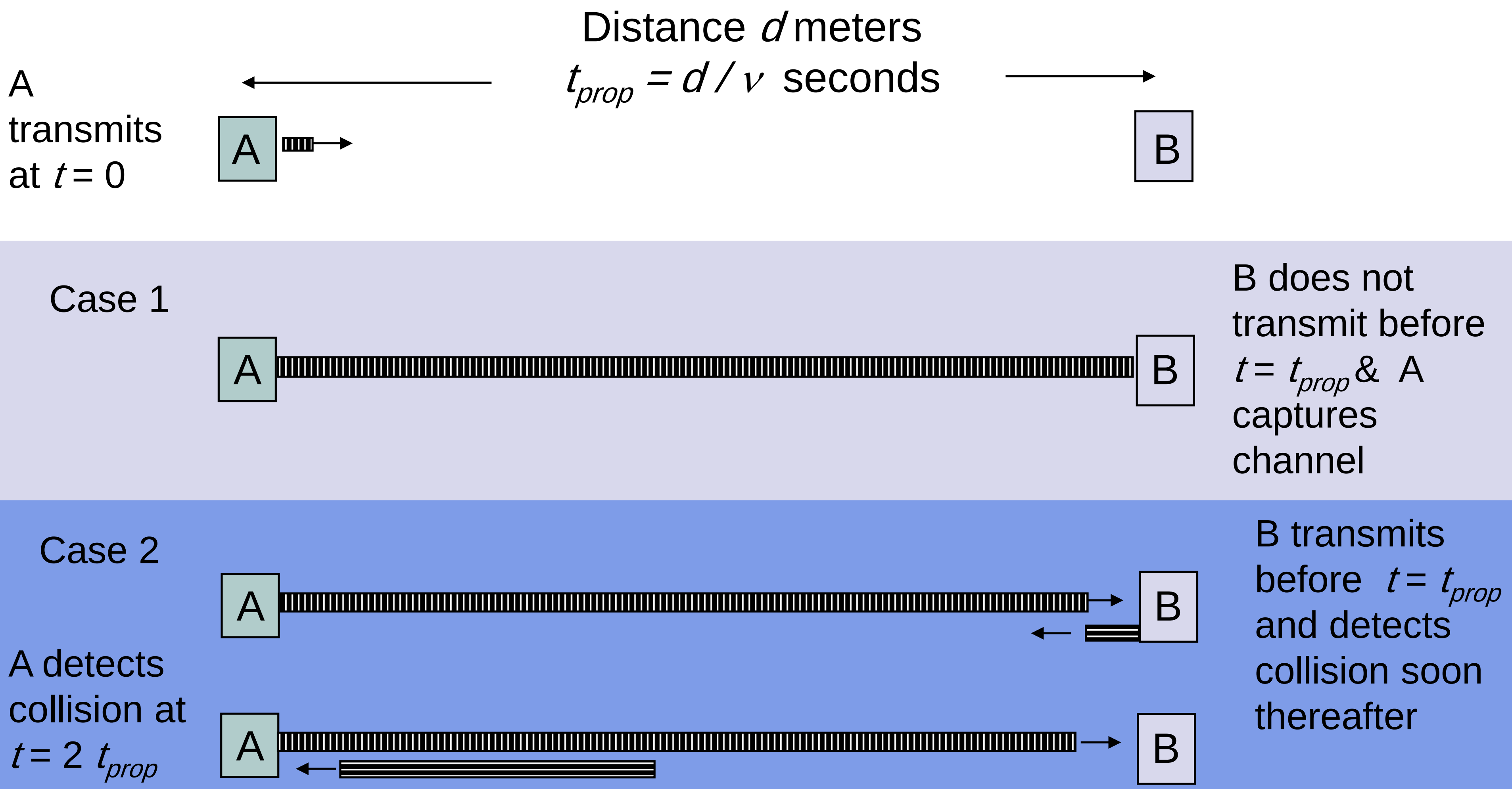
- Applications
  - What type of traffic?
  - Voice streams? Steady traffic, low delay/jitter
  - Data? Short messages? Web page downloads?
  - Enterprise or Consumer market? Reliability, cost
- Scale
  - How much traffic can be carried?
  - How many users can be supported?
- Current Examples:
  - Design MAC to provide wireless-DSL-equivalent access to rural communities
  - Design MAC to provide wireless-LAN-equivalent access to mobile users (user in car travelling at 100 km/hr)

Delay-Bandwidth Product

- ***Delay-bandwidth*** product is key parameter
  - Coordination in sharing medium involves using bandwidth (explicitly or implicitly)
  - <u>How many bits are enroute</u> from source to destination?→<u>Prop delay * bandwidth</u>
- Simple two-station example
  - Station with frame to send listens to medium and transmits if medium found idle
  - Station monitors medium to detect collision
  - If collision occurs, station that begin transmitting earlier retransmits

Two-Station MAC Example

Two stations are trying to share a common medium



Efficiency of Two-Station Example

- Each frame transmission requires $2t_{prop}$ of quiet time
  - Station B needs to be quiet t_{prop} before *and* after time when Station A transmits
  - *R* transmission bit rate
  - *L* bits/frame

$$Efficiency = \rho_{\max} = \frac{L}{L + 2t_{prop}R} = \frac{1}{1 + 2t_{prop}R/L} = \frac{1}{1+2a}$$

$$MaxThroughput = R_{eff} = \frac{L}{L/R + 2t_{prop}} = \frac{1}{1+2a}R \text{ bits/second}$$

Normalized Delay-Bandwidth Product

$$\boxed{a = \frac{t_{prop}}{L/R}}$$

Propagation delay

Time to transmit a frame

Typical MAC Efficiencies

Two-Station Example:

$$Efficiency = \frac{1}{1+2a}$$

CSMA-CD (Ethernet) protocol:

$$Efficiency = \frac{1}{1+6.44a}$$

Token-ring network

$$Efficiency = \frac{1}{1+a'}$$

a' = latency of the ring (bits)/average frame length

- If $a<<1$, then efficiency close to 100%
- As a approaches 1, the efficiency becomes low

Typical Delay-Bandwidth Products

Distance	10 Mbps	100 Mbps	1 Gbps	Network Type
1 m	3.33×10^{-02}	3.33×10^{-01}	3.33×10^{0}	Desk area network
100 m	3.33×10^{01}	3.33×10^{02}	3.33×10^{03}	Local area network
10 km	3.33×10^{02}	3.33×10^{03}	3.33×10^{04}	Metropolitan area network
1000 km	3.33×10^{04}	3.33×10^{05}	3.33×10^{06}	Wide area network
100000 km	3.33×10^{06}	3.33×10^{07}	3.33×10^{08}	Global area network

- Max size Ethernet frame: 1500 bytes = 12000 bits
- Long and/or fat pipes give large a

MAC protocol features

- Delay-bandwidth product
- Efficiency
- Transfer delay
- Fairness
- Reliability
- Capability to carry different types of traffic
- Quality of service
- Cost

MAC Delay Performance

- Frame transfer delay
  - From first bit of frame arrives at source MAC
  - To last bit of frame delivered at destination MAC
- Throughput
  - Actual transfer rate through the shared medium
  - Measured in frames/sec or bits/sec
- Parameters

  R bits/sec & L bits/frame

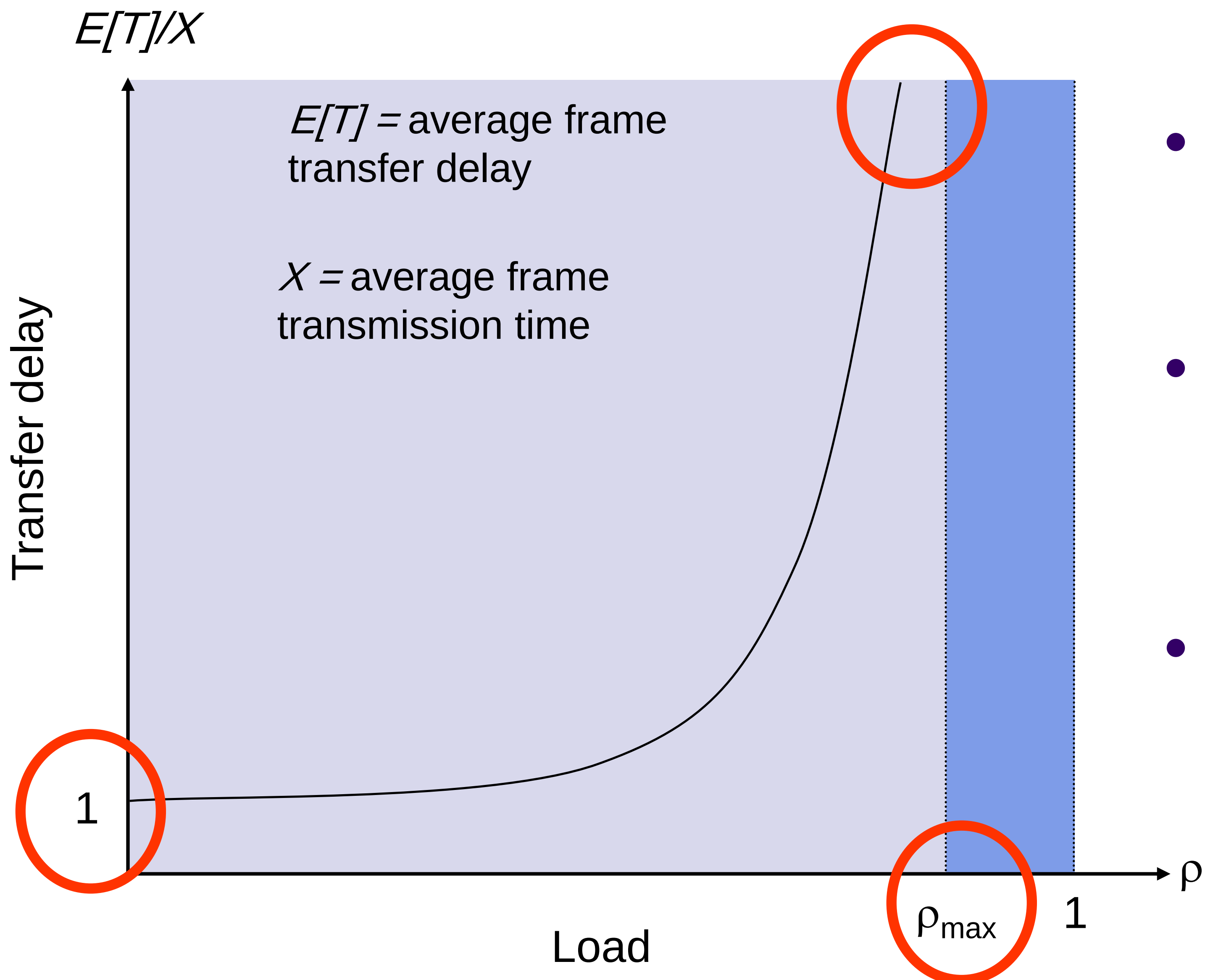
  $X=L/R$ seconds/frame

  λ frames/second average arrival rate

  Load $\rho = \lambda X$, rate at which “work” arrives

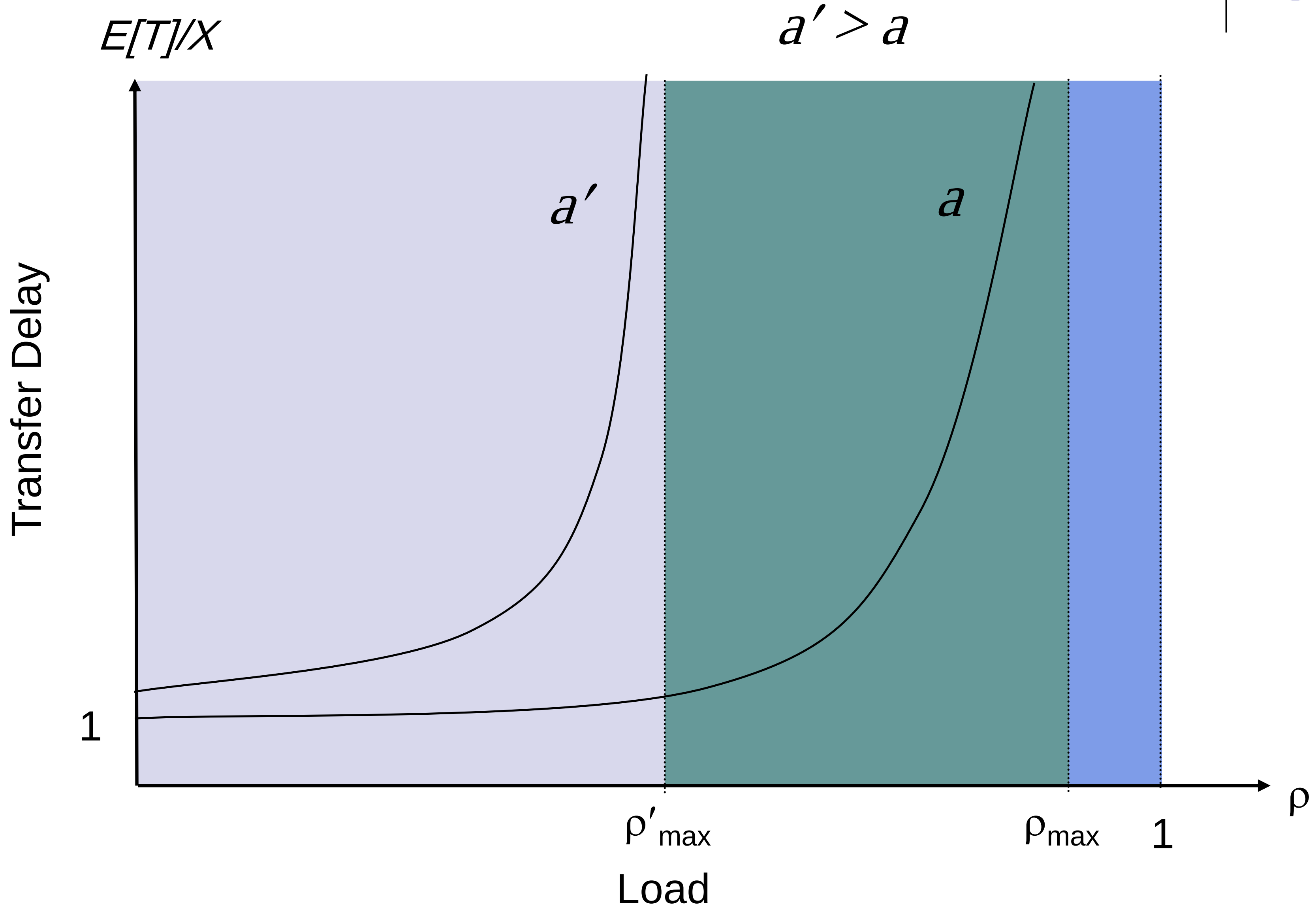
  Maximum throughput (@100% efficiency): R/L fr/sec

Normalized Delay versus Load



- At low arrival rate, only frame transmission time
- At high arrival rates, increasingly longer waits to access channel
- Max efficiency typically less than 100%

Dependence on Rt_{prop}/L



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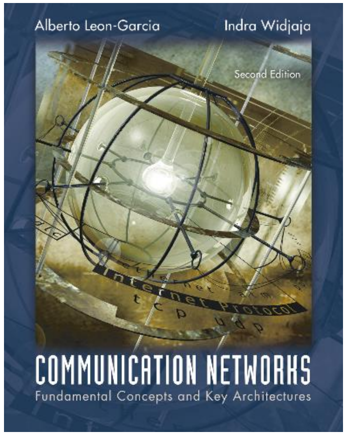
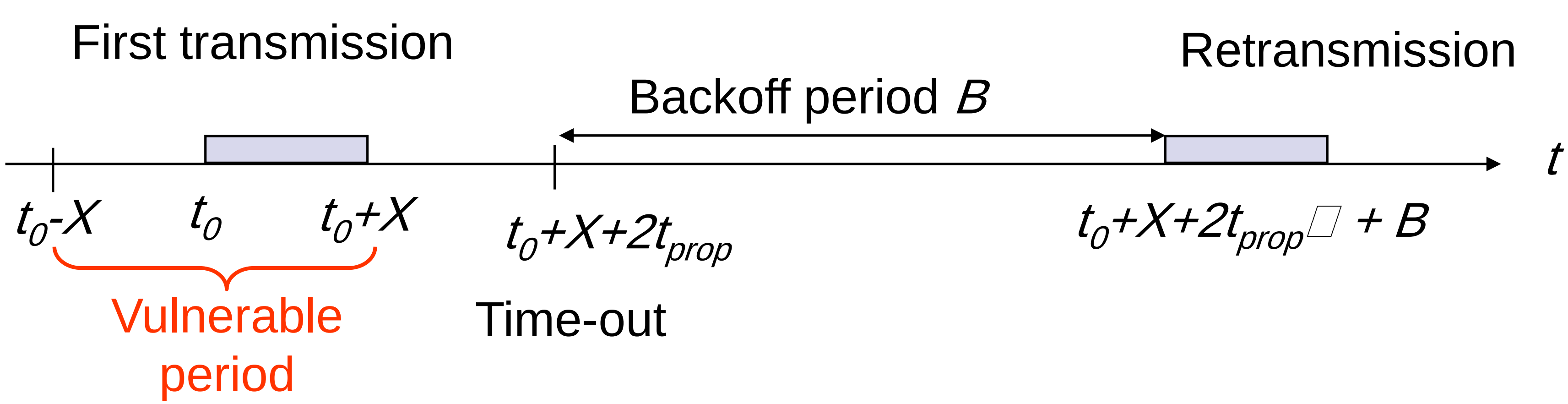


6.2 Random Access

ALOHA

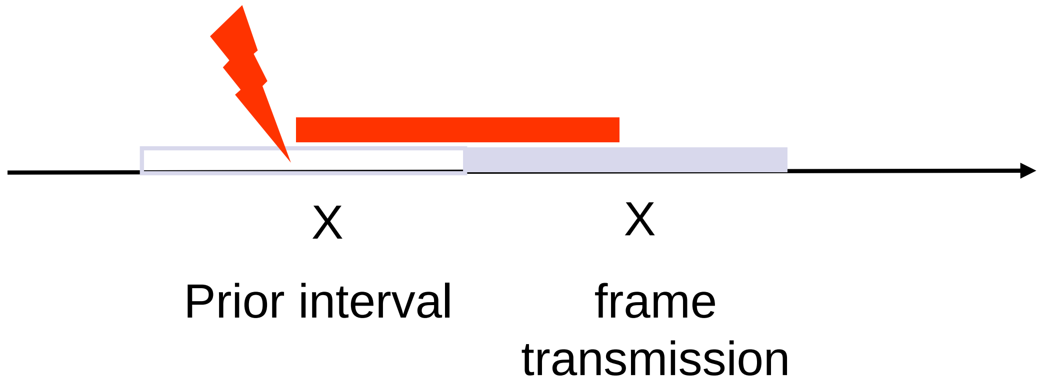
- Wireless link to provide data transfer between main campus & remote campuses of University of Hawaii
- Simplest solution: just do it
  - A station transmits whenever it has data to transmit
  - If more than one frames are transmitted, they interfere with each other (collide) and are lost
  - If ACK not received within timeout, then a station picks <u>random backoff time</u> (to avoid repeated collision)
  - Station retransmits frame after backoff time



ALOHA Model

- Definitions and assumptions
  - *X:* frame transmission time (assume constant)
  - *S*: throughput (average # of successful frame transmissions per *X* seconds)
  - *G*: load (average # of transmission attempts per X sec.)
  - $P_{success}$: probability a frame transmission is successful

$$S = GP_{success}$$



- Any transmission that begins during vulnerable period leads to collision
- Success if no arrivals during 2X seconds

Abramson's Assumption

- *What is probability of no arrivals in vulnerable period?*
- Abramson assumption: Effect of backoff algorithm is that frame arrivals are equally likely to occur at any time interval
- G is avg. # arrivals per X seconds
- Divide X into n intervals of duration $\Delta = X/n$
- $p =$ probability of arrival in Δ interval, then

  $G = n\,p$ since there are n intervals in X seconds

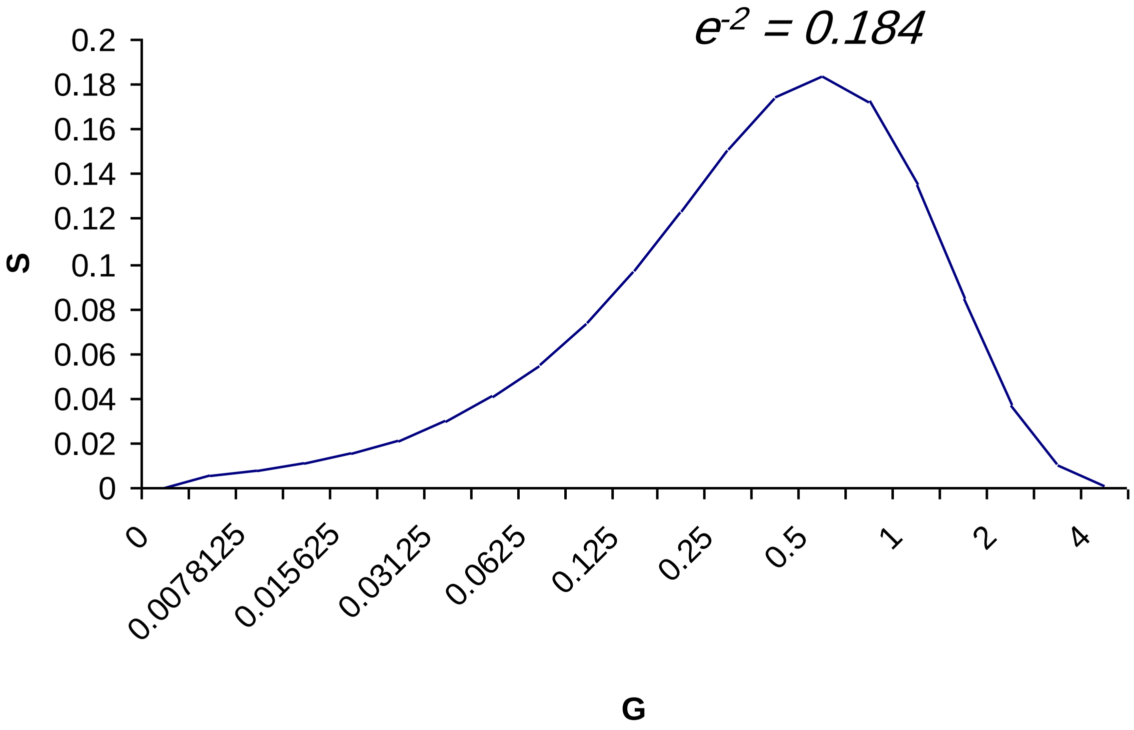
$$P_{success} = P[0 \text{ arrivals in } 2\text{X seconds}] =$$

$$= P[0 \text{ arrivals in } 2\text{n intervals}]$$

$$= (1-\text{p})^{2\text{n}} = (1 - \frac{G}{n})^{2n} \rightarrow e^{-2G} \quad \text{as n} \rightarrow \infty$$

Throughput of ALOHA

$$S = GP_{success} = Ge^{-2G}$$



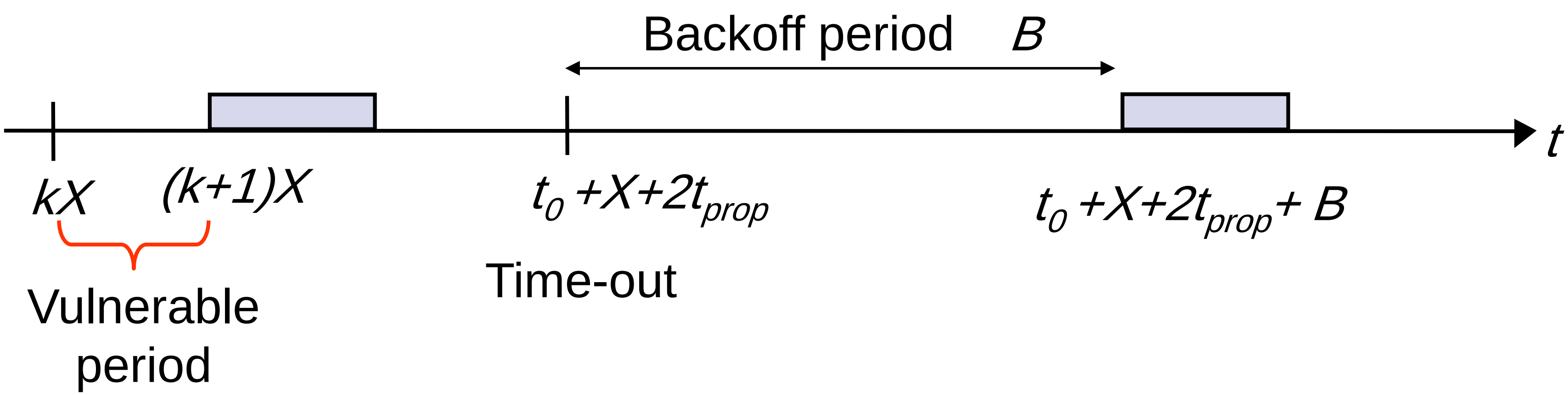
- Collisions are means for coordinating access
- Max throughput is ρ_{max}= 1/2*e (18.4%)*
- Bimodal behavior:

  Small G, S≈G

  Large G, S↓0
- Collisions can snowball and drop throughput to zero

Slotted ALOHA

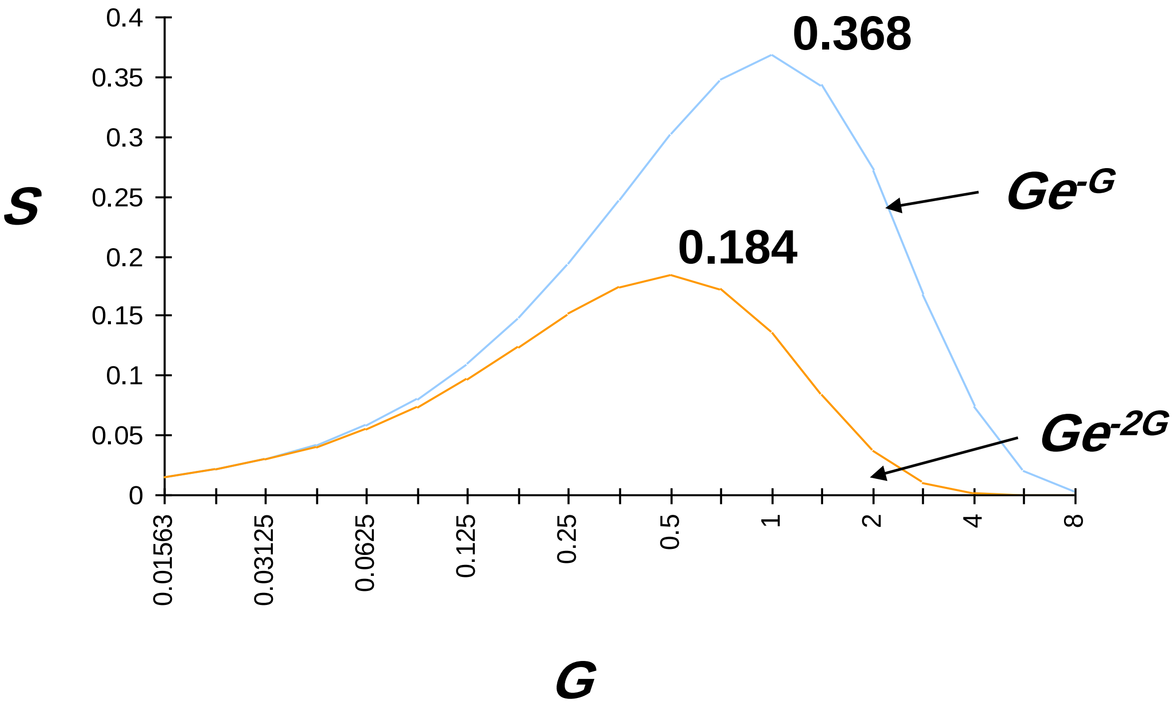
- Time is slotted in X seconds slots
- Stations synchronized to frame times
- Stations transmit frames in first slot after frame arrival
- Backoff intervals in multiples of slots



Only frames that arrive during prior X seconds collide

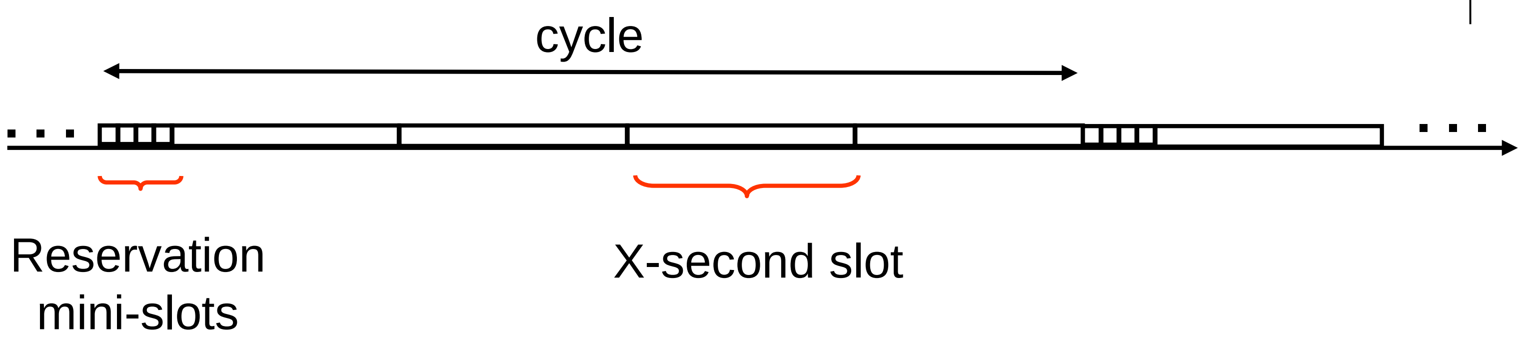
Throughput of Slotted ALOHA

$$S = GP_{success} = GP[\text{no arrivals in X seconds}]$$
$$= GP[\text{no arrivals in n intervals}]$$
$$= G(1-p)^n = G(1-\frac{G}{n})^n \rightarrow Ge^{-G}$$



- Max throughput is ρ_{max}= *e (36.8%)*

Application of Slotted Aloha



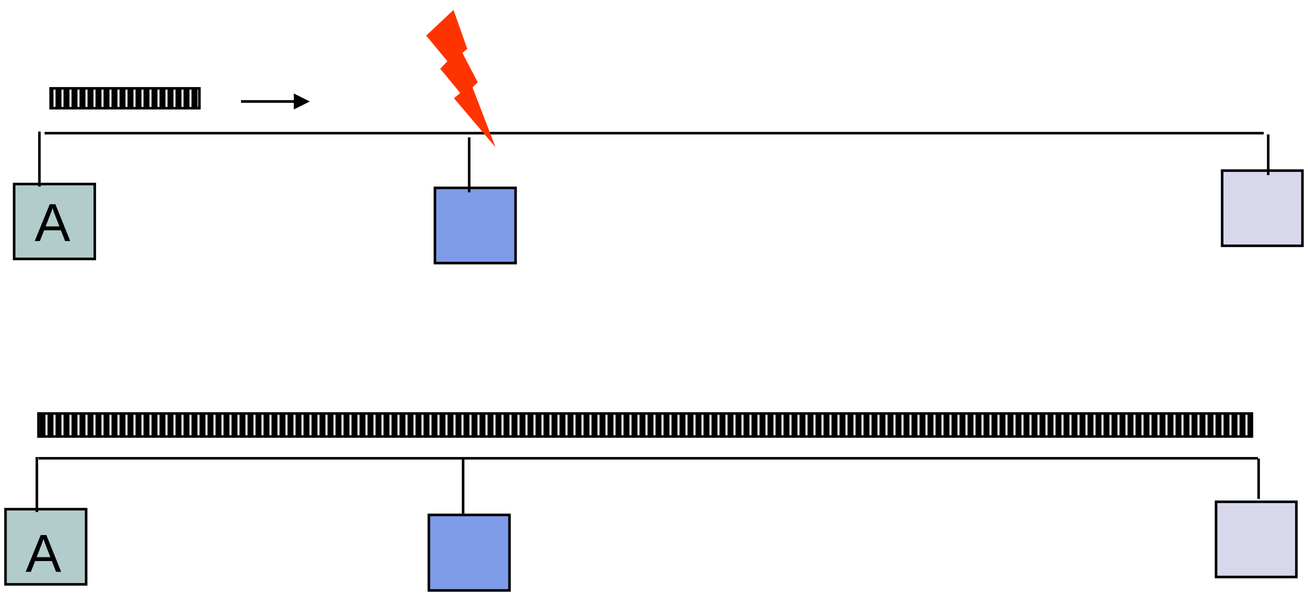
- Reservation protocol allows a large number of stations with infrequent traffic to reserve slots to transmit their frames in future cycles
- Each cycle has mini-slots allocated for making reservations
- Stations use slotted Aloha during mini-slots to request slots

Carrier Sensing Multiple Access (CSMA)

- A station senses the channel before it starts transmission
  - If busy, either wait or schedule backoff (different options)
  - If idle, start transmission
  - Vulnerable period is reduced to t_{prop} (due to *channel capture* effect)
  - When collisions occur they involve entire frame transmission times
  - If t_{prop} >X (or if a>1), no gain compared to ALOHA or slotted ALOHA

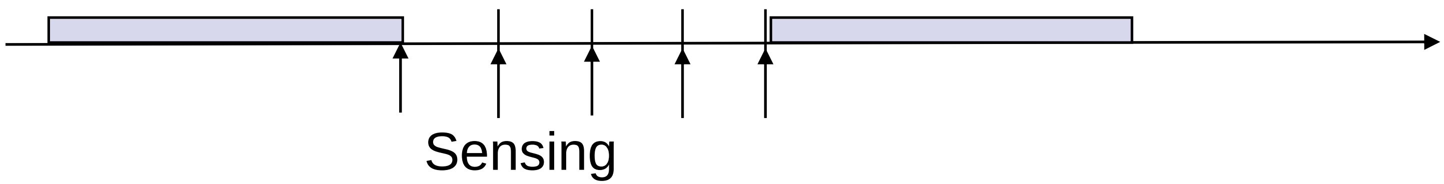
Station A begins transmission at $t = 0$

Station A captures channel at $t = t_{prop}$

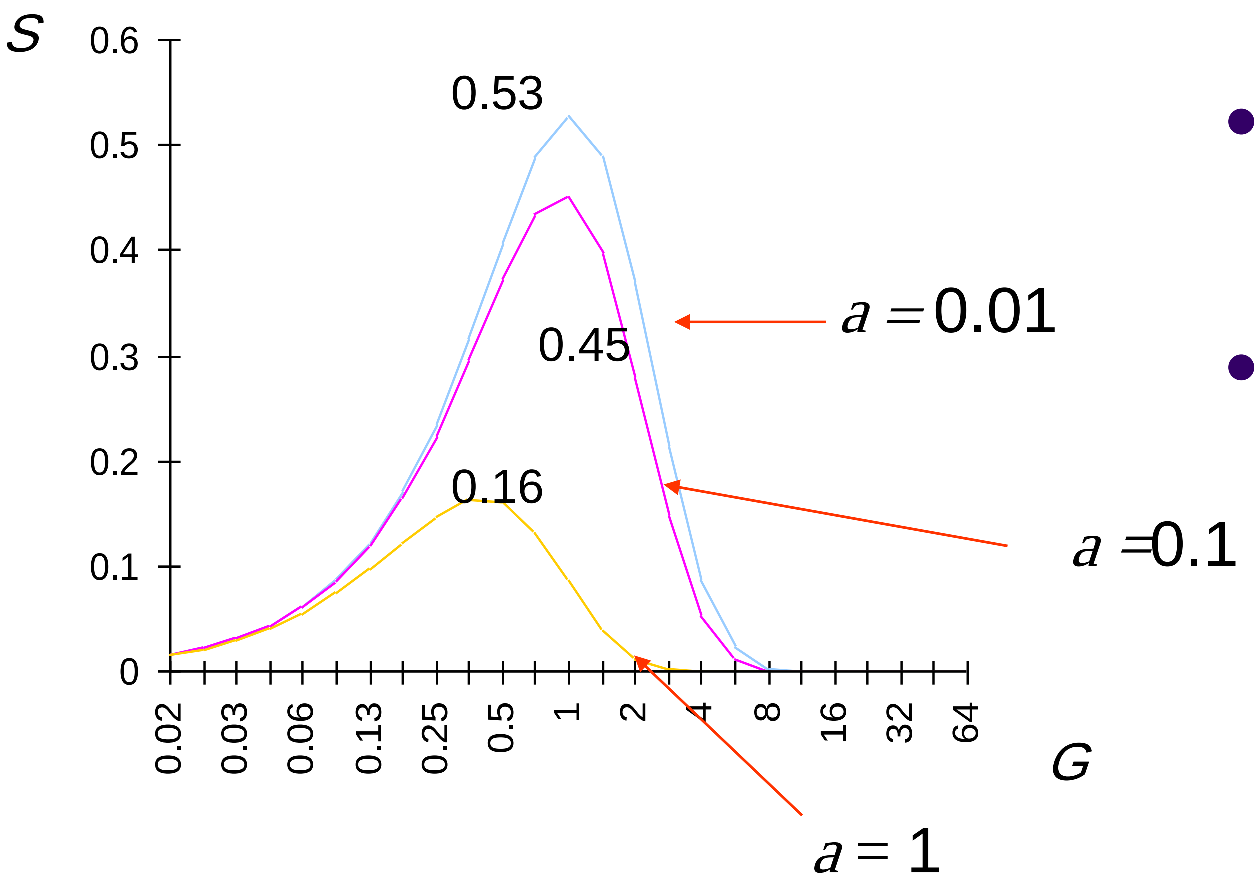


CSMA Options

- Transmitter behavior when busy channel is sensed
  - 1-persistent CSMA (most greedy)
    - Start transmission as soon as the channel becomes idle
    - Low delay and low efficiency
  - Non-persistent CSMA (least greedy)
    - Wait a backoff period, then sense carrier again
    - High delay and high efficiency
  - p-persistent CSMA (adjustable greedy)
    - Wait till channel becomes idle, transmit with prob. p; or wait one mini-slot time & re-sense with probability 1-*p*
    - Delay and efficiency can be balanced

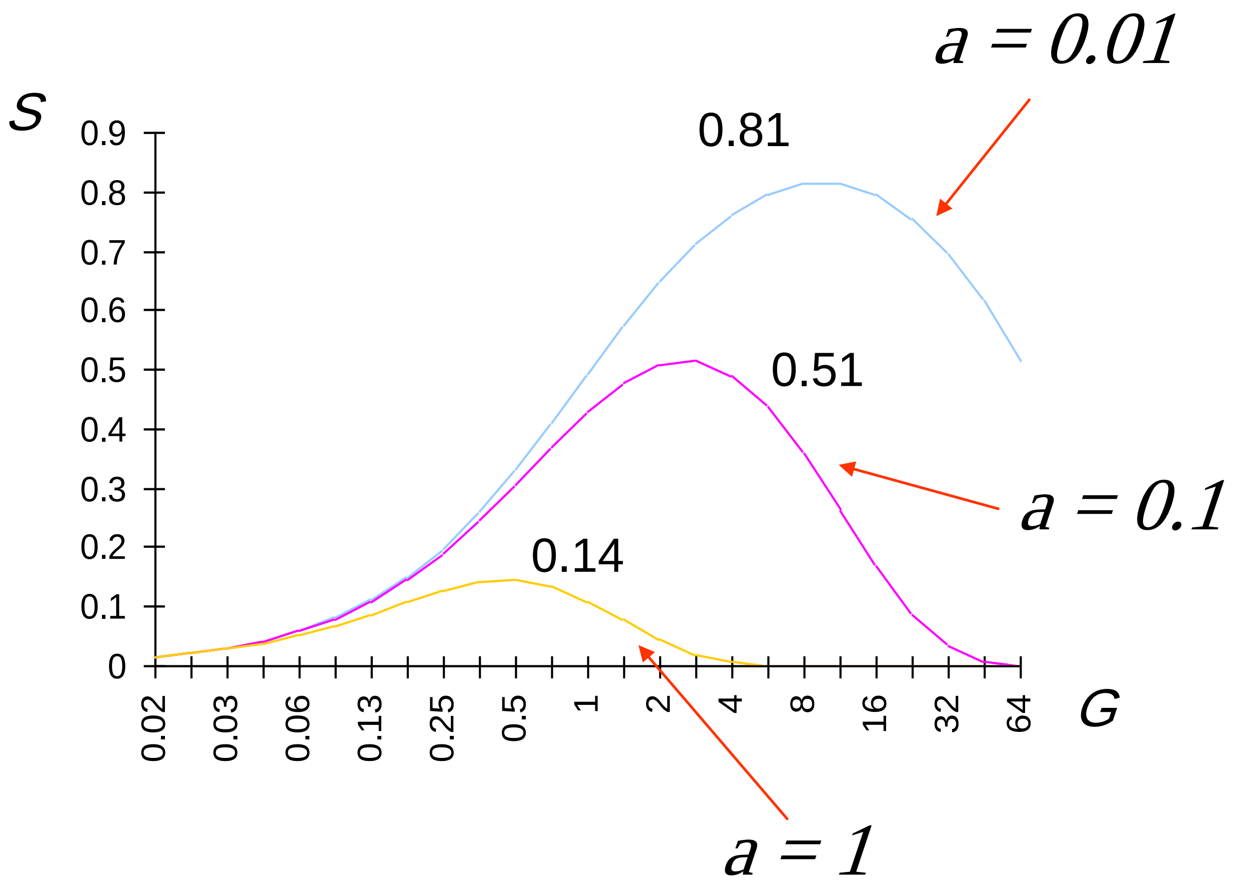


1-Persistent CSMA Throughput



- Better than Aloha & slotted Aloha for small a
- Worse than Aloha for $a > 1$

Non-Persistent CSMA Throughput



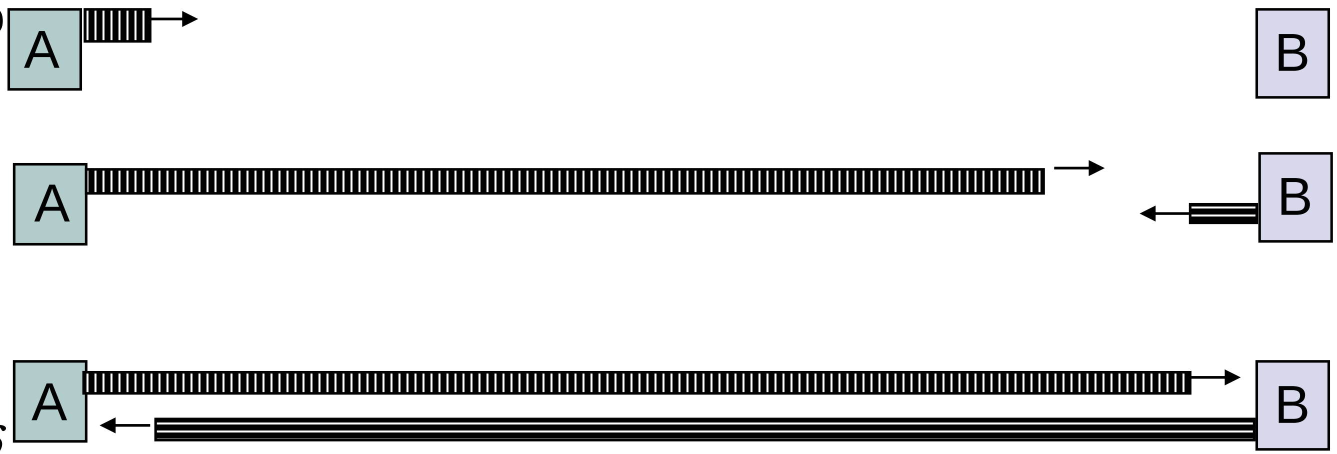
- Higher maximum throughput than 1-persistent for small *a*
- Worse than Aloha for *a* > *1*

CSMA with Collision Detection (CSMA/CD)

- Monitor for collisions & abort transmission
  - Stations with frames to send, first do carrier sensing
  - After beginning transmissions, stations continue listening to the medium to detect collisions
  - If collisions detected, all stations involved stop transmission, reschedule random backoff times, and try again at scheduled times
- In CSMA, collisions result in wastage of X seconds spent transmitting an entire frame
- CSMA-CD reduces wastage to time to detect collision and abort transmission

CSMA/CD reaction time

A begins to transmit at $t = 0$



B begins to transmit at $t = t_{prop} - \delta$;

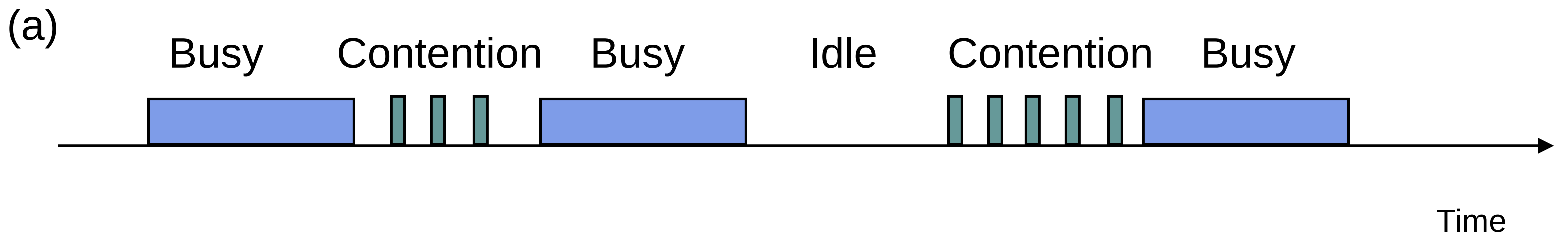
B detects collision at $t = t_{prop}$

A detects collision at $t = 2\ t_{prop} - \delta$

It takes $2\ t_{prop}$ to find out if channel has been captured

CSMA-CD Model

- Assumptions
  - Collisions can be detected and resolved in $2t_{prop}$
  - Time slotted in $2t_{prop}$ slots during contention periods
  - Assume n busy stations, and each may transmit with probability p in each contention time slot
  - Once the contention period is over (a station successfully occupies the channel), it takes X seconds for a frame to be transmitted
  - It takes t_{prop} before the next contention period starts.



Contention Resolution

- How long does it take to resolve contention?
- Contention is resolved (“success’) if exactly 1 station transmits in a slot:

$$P_{success} = np(1-p)^{n-1}$$

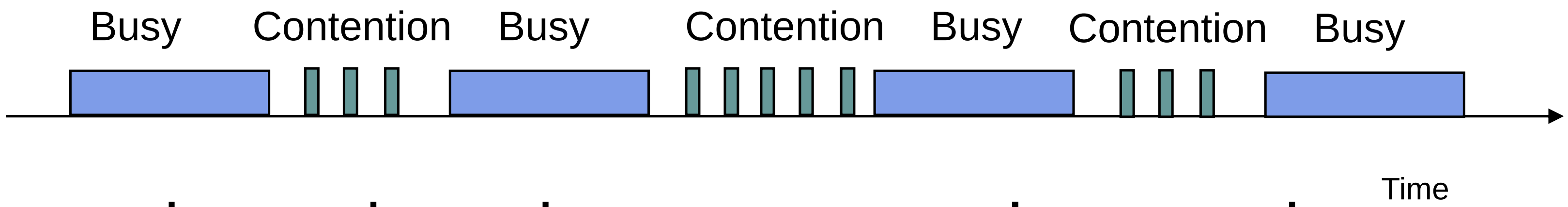
- By taking derivative of $P_{success}$ we find max occurs at p=1/n

$$P_{success}^{\max} = n\frac{1}{n}(1-\frac{1}{n})^{n-1} = (1-\frac{1}{n})^{n-1} \to \frac{1}{e}$$

- On average, $1/P^{\max} = e = 2.718$ time slots to resolve contention

$$\textit{Average Contention Period} = 2t_{prop}e \textit{ seconds}$$

CSMA/CD Throughput



- At maximum throughput, systems alternates between contention periods and frame transmission times

$$\rho_{\max} = \frac{X}{X + t_{prop} + 2et_{prop}} = \frac{1}{1 + (2e+1)a} = \frac{1}{1 + (2e+1)Rd / \nu L}$$

- where:

  R bits/sec, *L* bits/frame, X=*L/R* seconds/frame

  $a = t_{prop}/X$

  ν meters/sec. speed of light in medium

  d meters is diameter of system

  2*e*+1 = 6.44

CSMA-CD Application: Ethernet

- First Ethernet LAN standard used CSMA-CD
  - 1-persistent Carrier Sensing
  - R = 10 Mbps
  - t_{prop} = 51.2 microseconds
    - 512 bits = 64 byte slot
    - accommodates up to 2.5 km using 4 repeaters
  - Uses Binary Exponential Backoff
    - After nth collision, select backoff from $\{0, 1,\ldots, 2^k - 1\}$, where k=min(n, 10)

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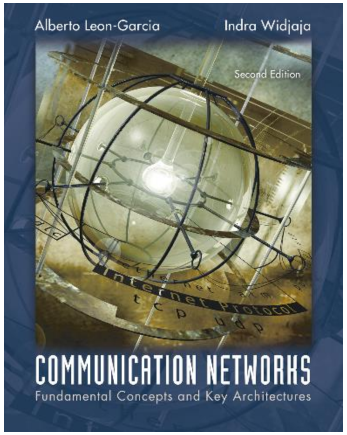

Part II: Local Area Networks

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6.7 Ethernet and IEEE 802.3

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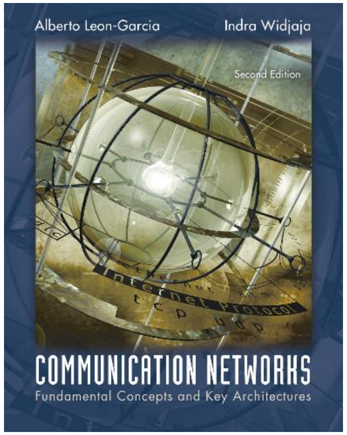


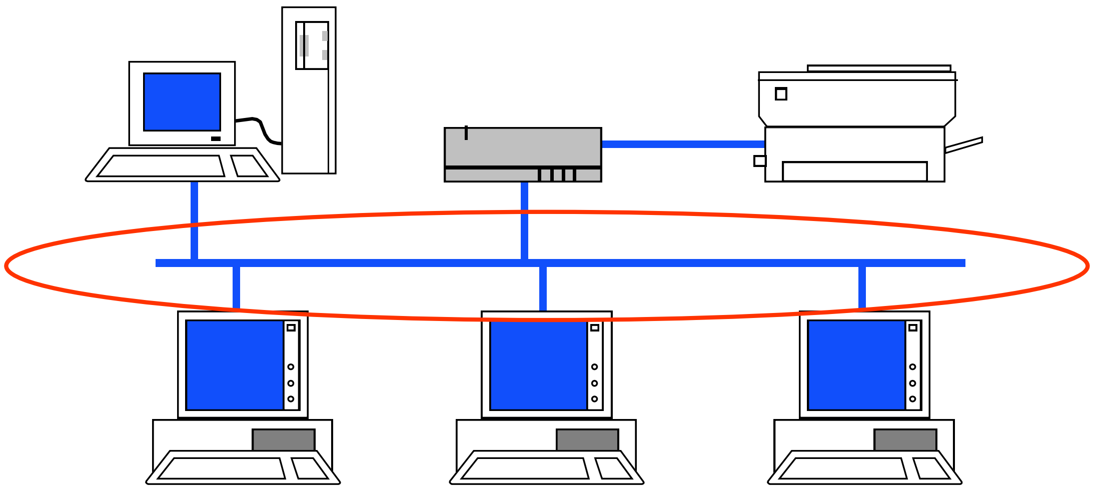
Overview of LANs

What is a LAN?

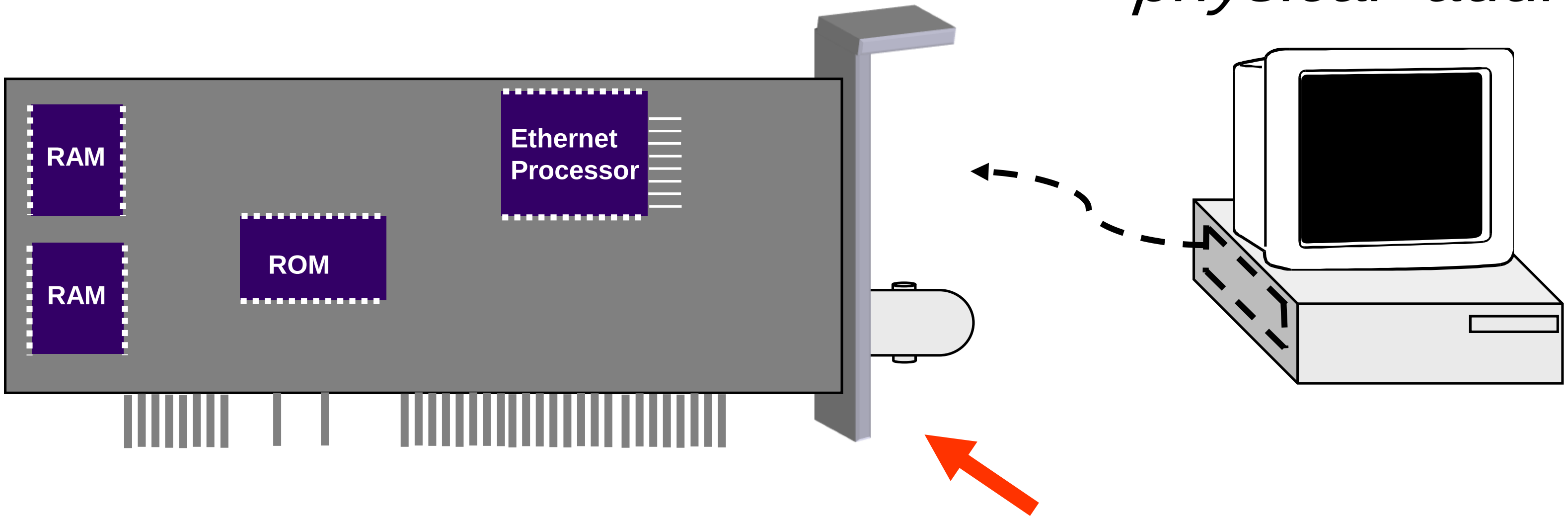
Local area means:

- 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*
- Needs a *medium access control protocol*

Typical LAN Structure



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

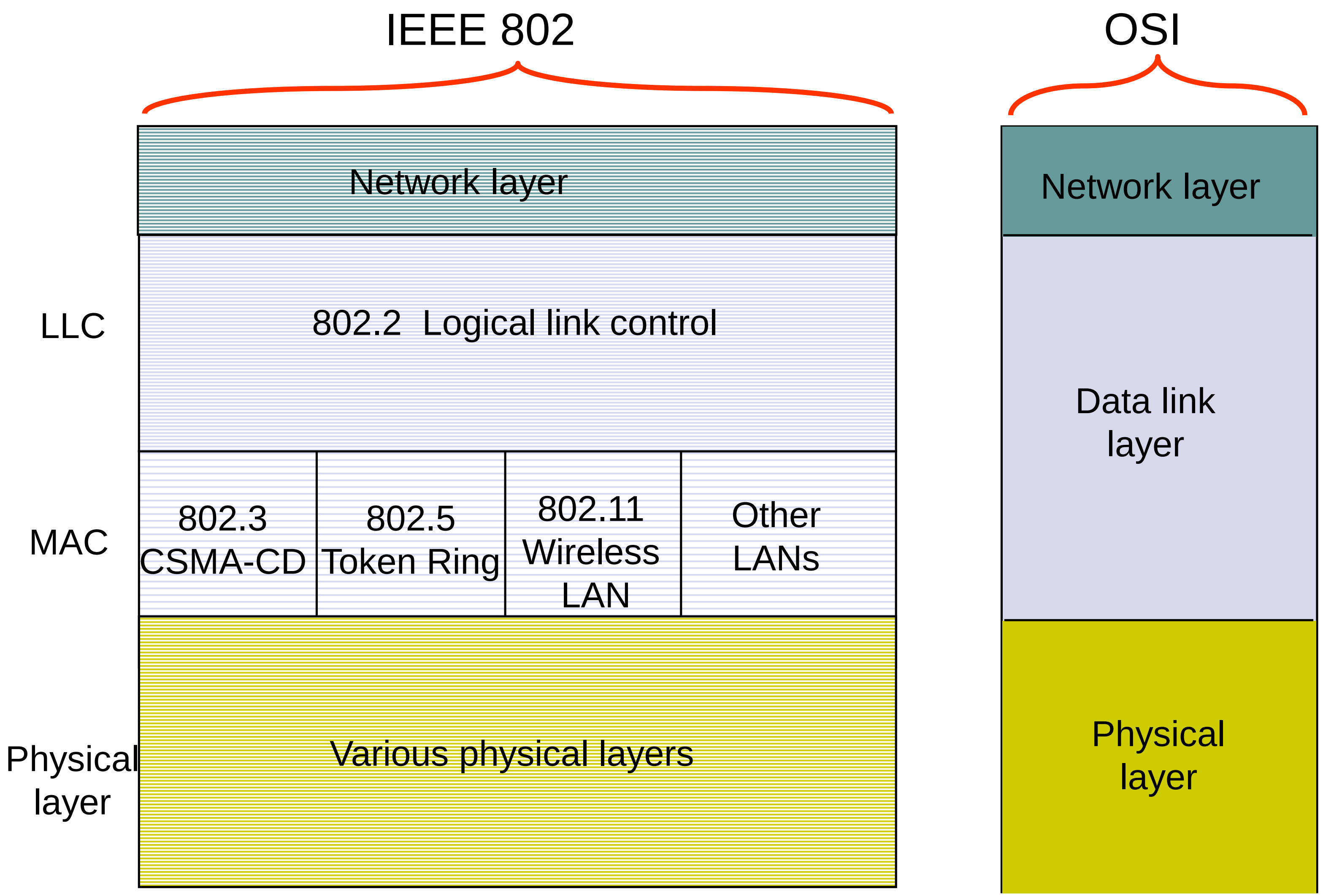


Medium Access Control Sublayer

- In IEEE 802, Data Link Layer divided into:

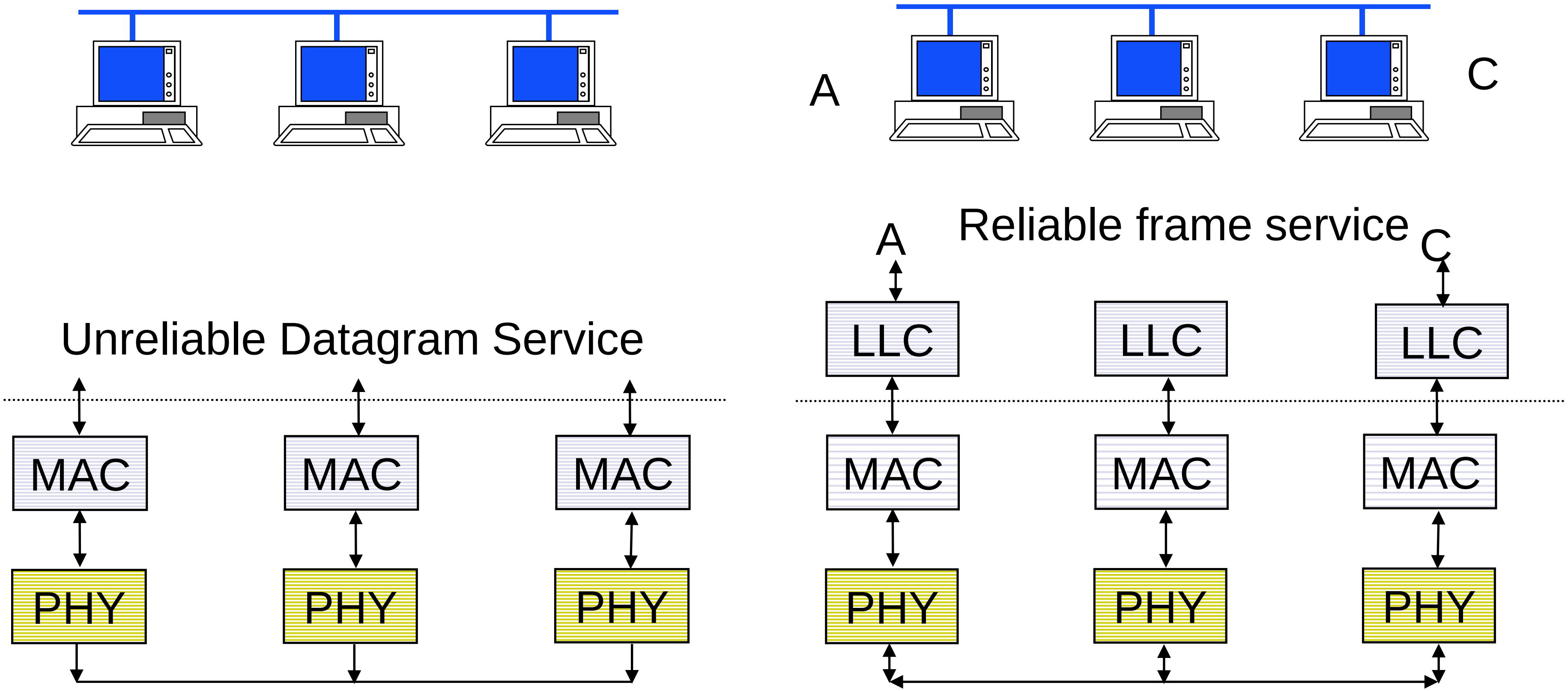
1. Medium Access Control Sublayer
   - Coordinate access to medium
   - Connectionless frame transfer service
   - Machines identified by MAC/physical address
   - Broadcast frames with MAC addresses
2. Logical Link Control Sublayer
   - Between Network layer & MAC sublayer

MAC Sub-layer



Logical Link Control Layer

- IEEE 802.2: LLC enhances service provided by MAC

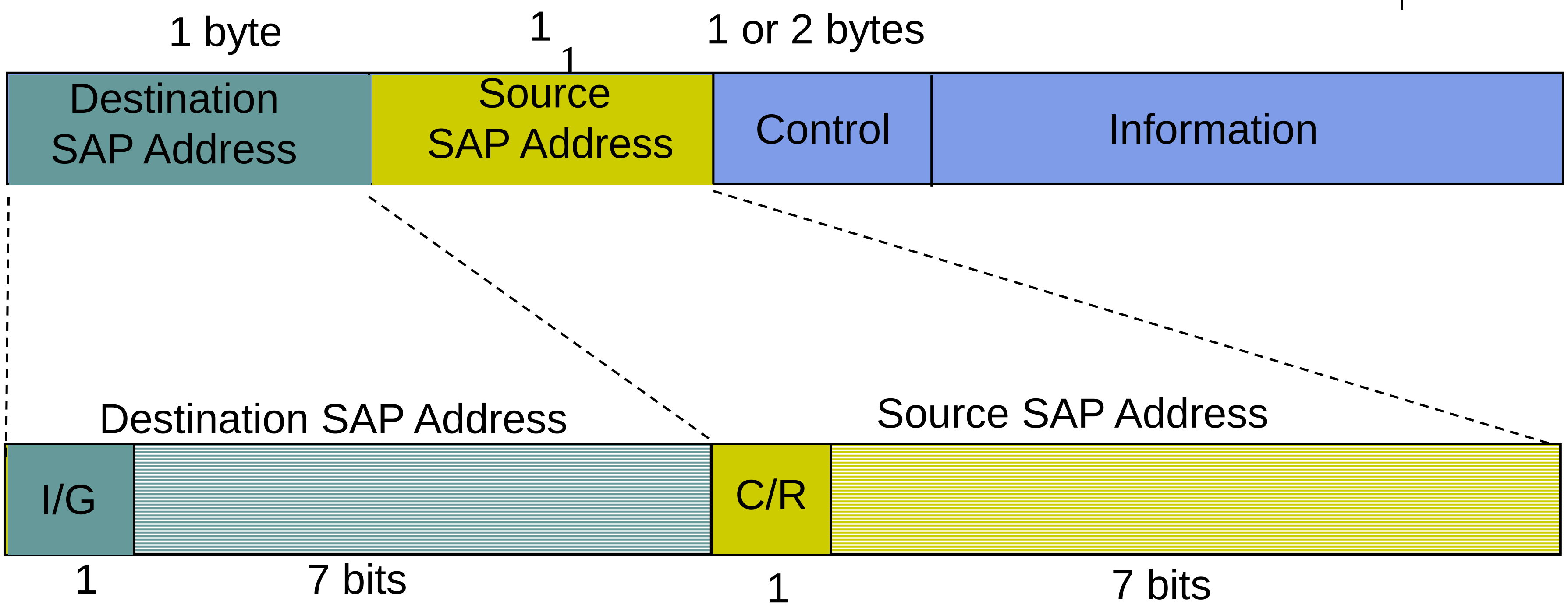


Logical Link Control Services

- Type 1: Unacknowledged connectionless service
  - Unnumbered frame mode of HDLC
- Type 2: Reliable connection-oriented service
  - Asynchronous balanced mode of HDLC
- Type 3: Acknowledged connectionless service

- Additional addressing
  - A workstation has a single MAC physical address
  - Can handle several logical connections, distinguished by their SAP (service access points)

LLC PDU Structure

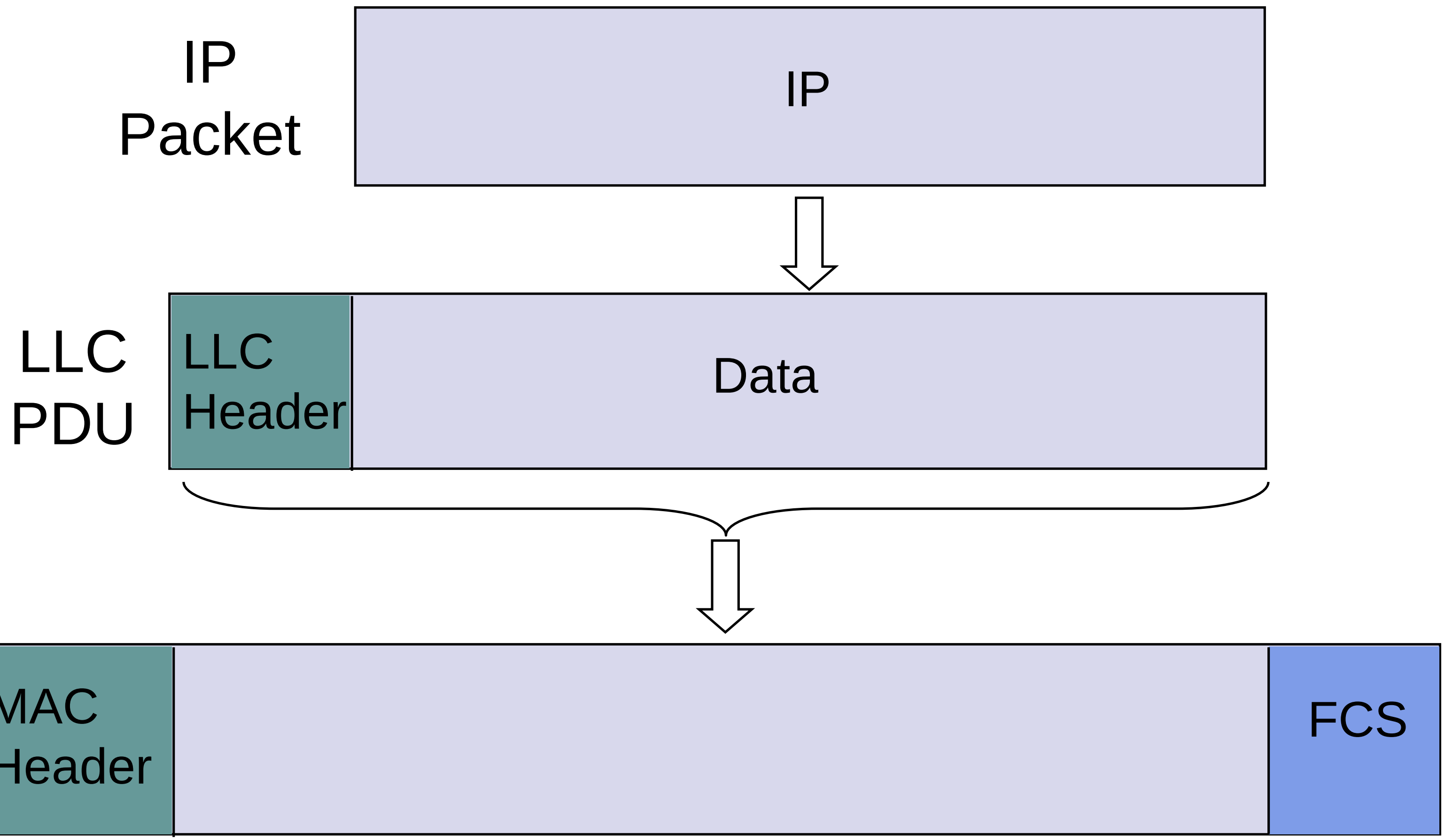


I/G = Individual or group address
C/R = Command or response frame

Examples of SAP Addresses:

06 IP packet
E0 Novell IPX
FE OSI packet
AA SubNetwork Access protocol (SNAP)

Encapsulation of MAC frames



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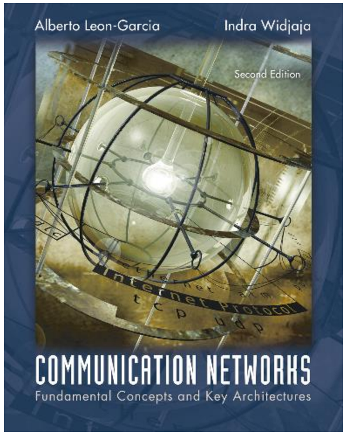
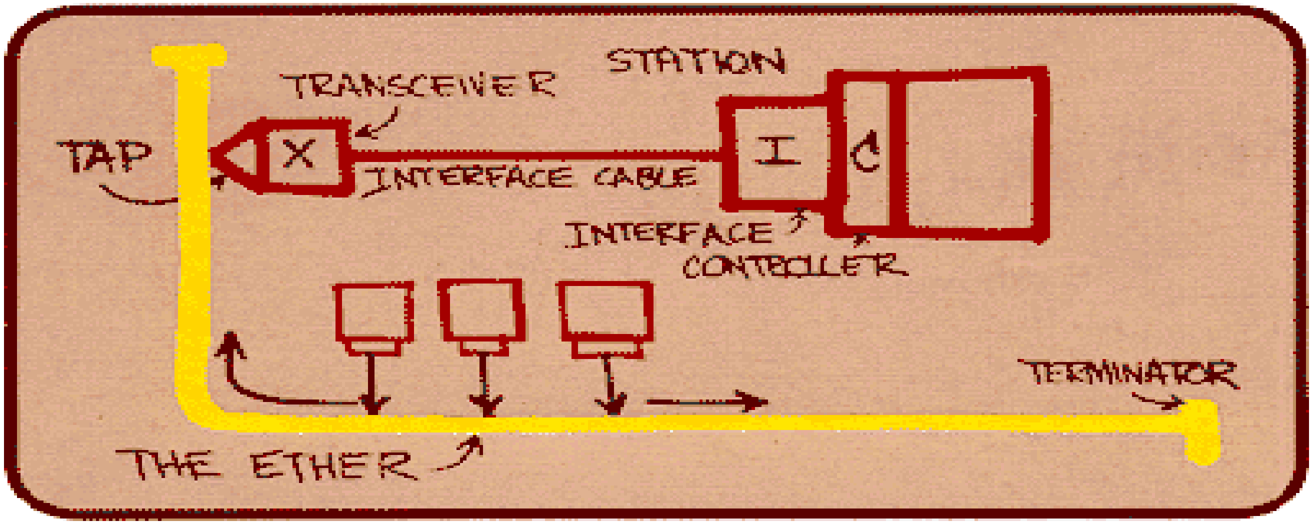


Ethernet and IEEE 802.3

A bit of history…

- 1970 ALOHAnet radio network deployed in Hawaiian islands
- 1973 Metcalf and Boggs invent Ethernet, random access in wired net
- 1979 DIX Ethernet II Standard
- 1985 IEEE 802.3 LAN Standard (10 Mbps)
- 1995 Fast Ethernet (100 Mbps)
- 1998 Gigabit Ethernet
- 2002 10 Gigabit Ethernet
- Ethernet is the dominant LAN standard today

Metcalf's Sketch



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 generated by collision
  - quantum for retransmission scheduling
  - max{round-trip propagation, MAC jam time}

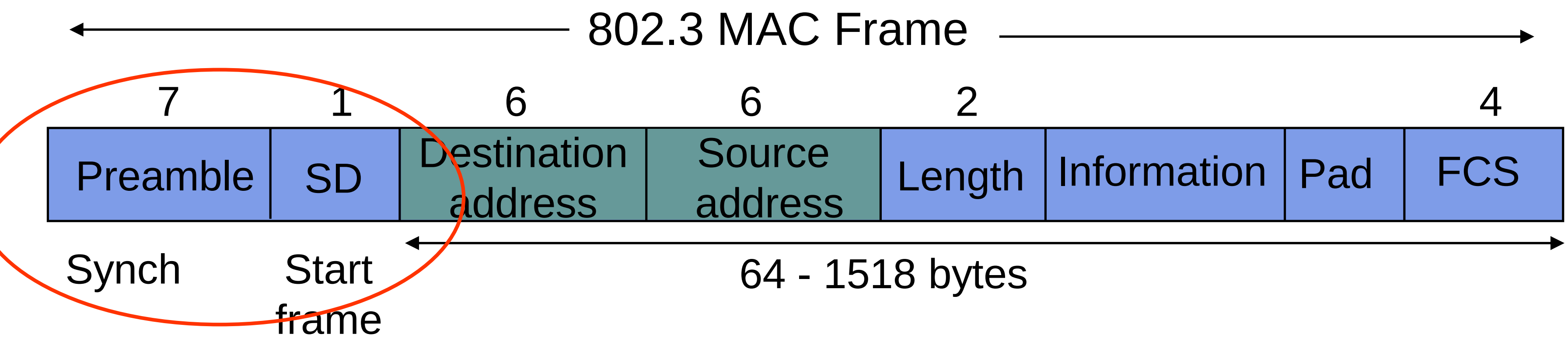
- binary exponential backoff
  - for retransmission n: $0 < r < 2^k$, where k=min(n,10)
  - Give up after 16 retransmissions

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 $2x10^5$ km/sec =10.24 km, 1 way
  - 5.12 km round trip distance
- Max Length: 2500 meters using 4 repeaters

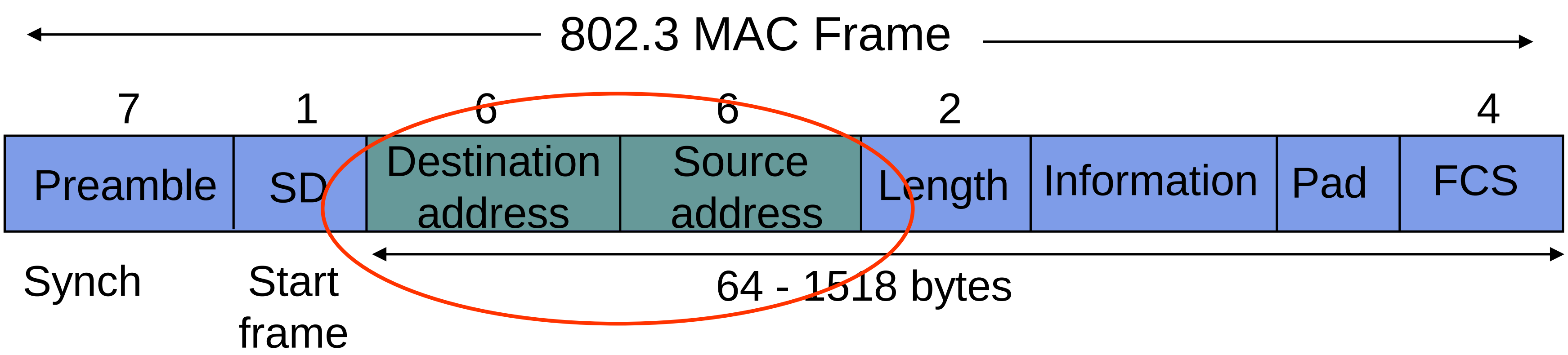
- *Each x10 increase in bit rate, must be accompanied by x10 decrease in distance*

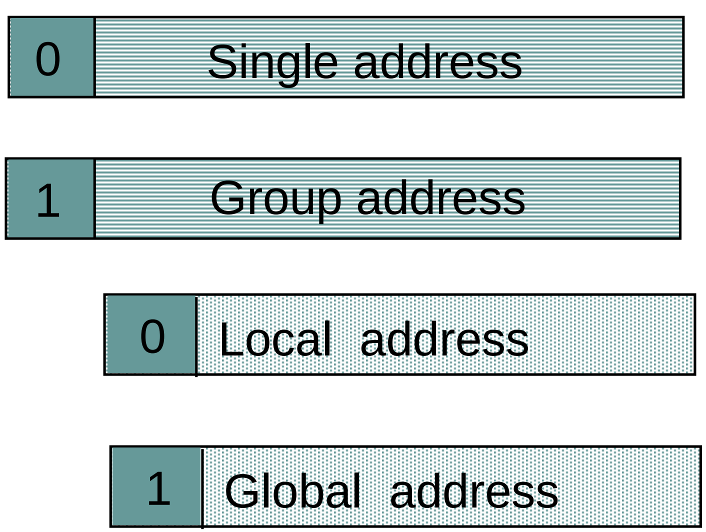
IEEE 802.3 MAC Frame



- 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

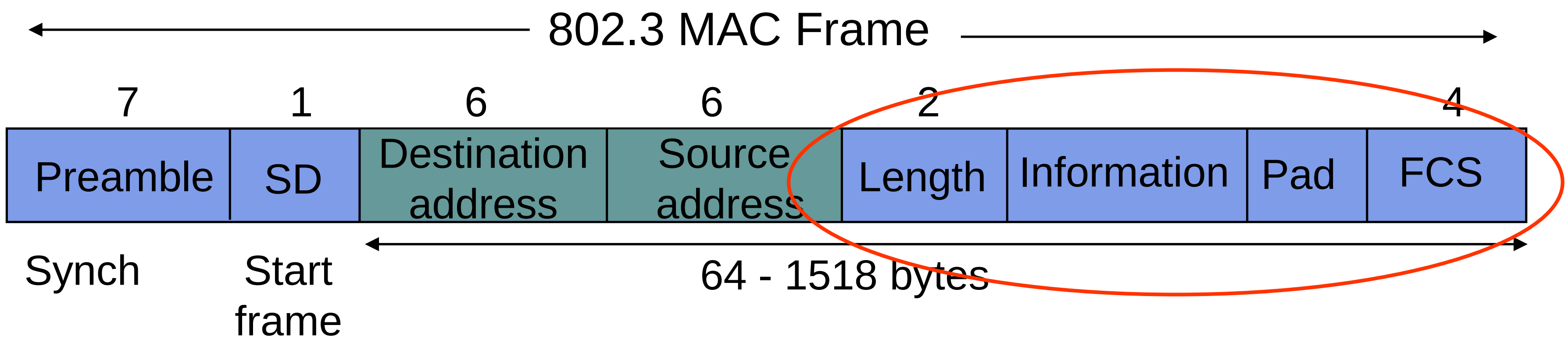




- Destination address
  - single address
  - group address
  - broadcast = 111...111

  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 minimum frame of 64 bytes
- FCS: CCITT-32 CRC, covers addresses, length, information, pad fields

  - NIC discards frames with improper lengths or failed CRC

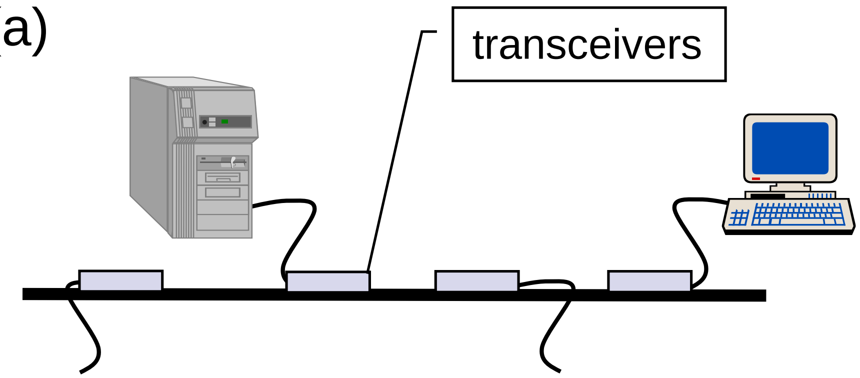
IEEE 802.3 Physical Layer

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

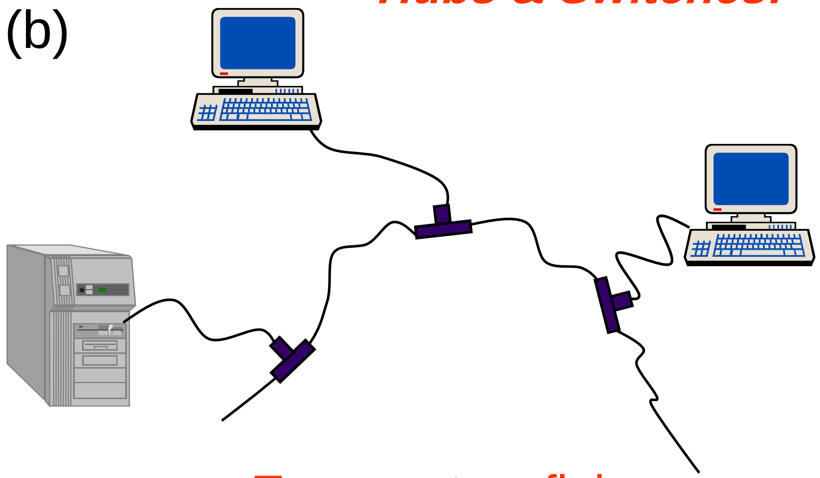
Hubs & Switches!

(a)



Thick Coax: Stiff, hard to work with

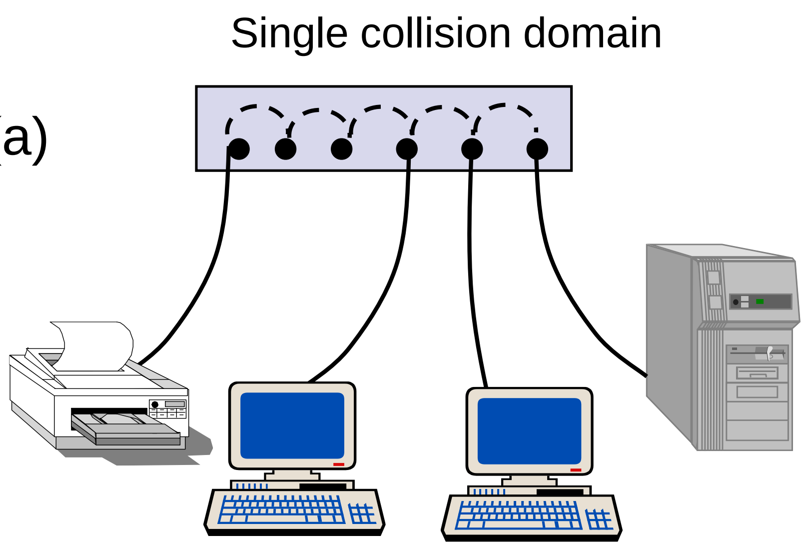
(b)



T connectors flaky

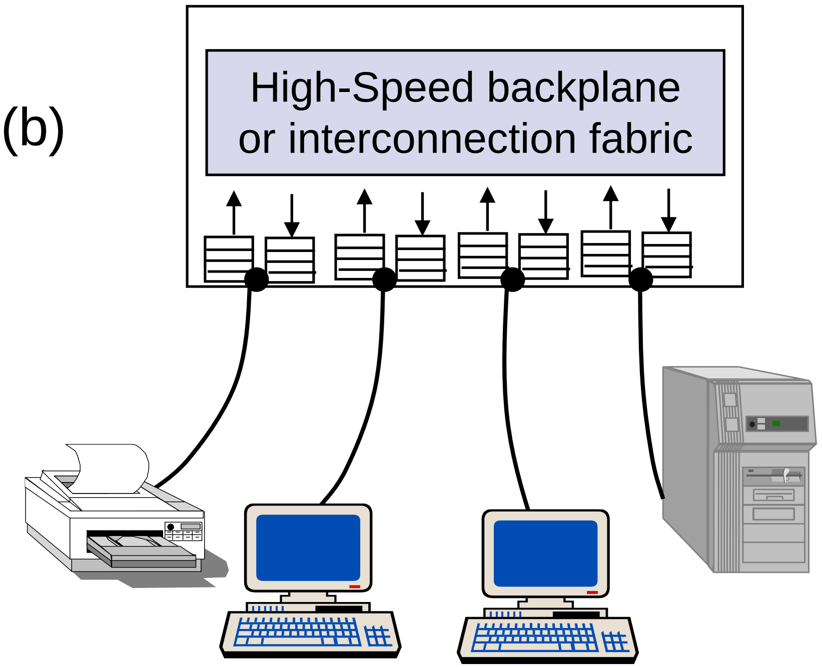
Ethernet Hubs & Switches

(a)



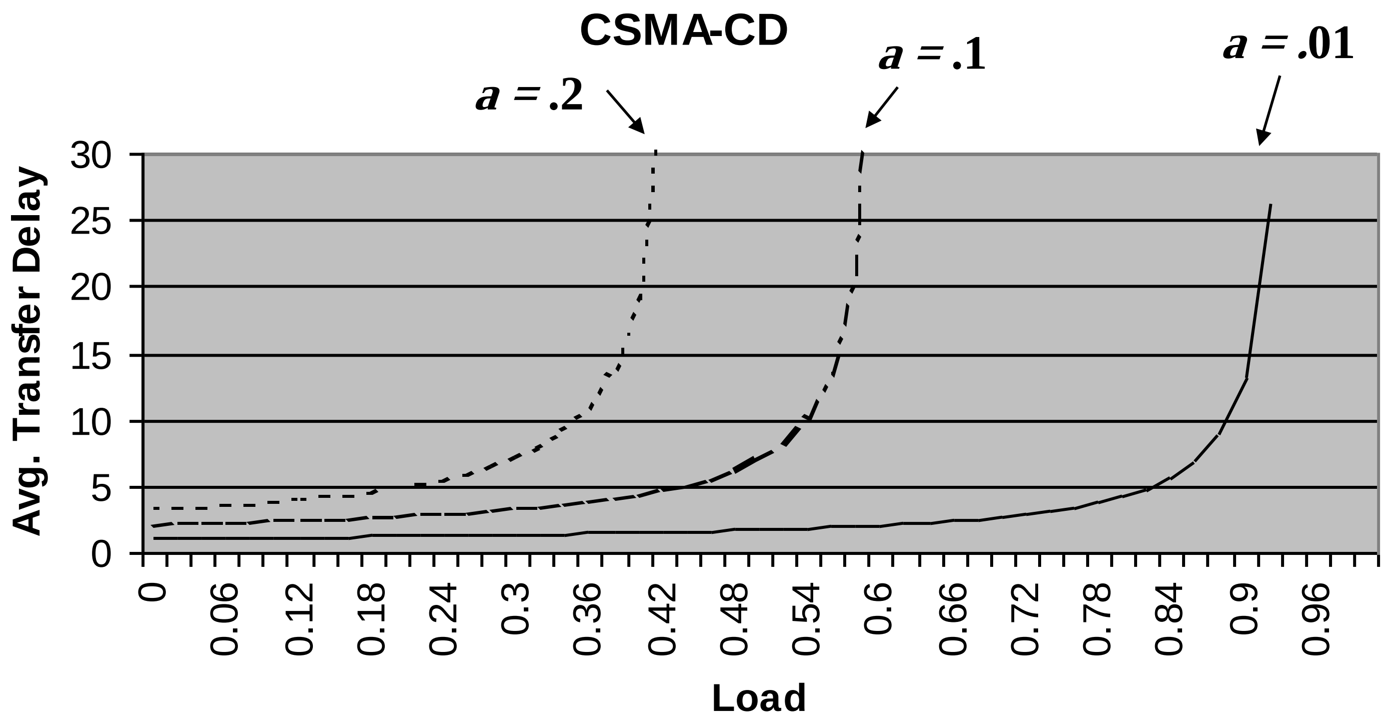
- Twisted Pair Cheap
- Easy to work with
- Reliable
- Star-topology CSMA-CD

(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 2 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 Ethernet (GE) 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 bytes (by padding)
- 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

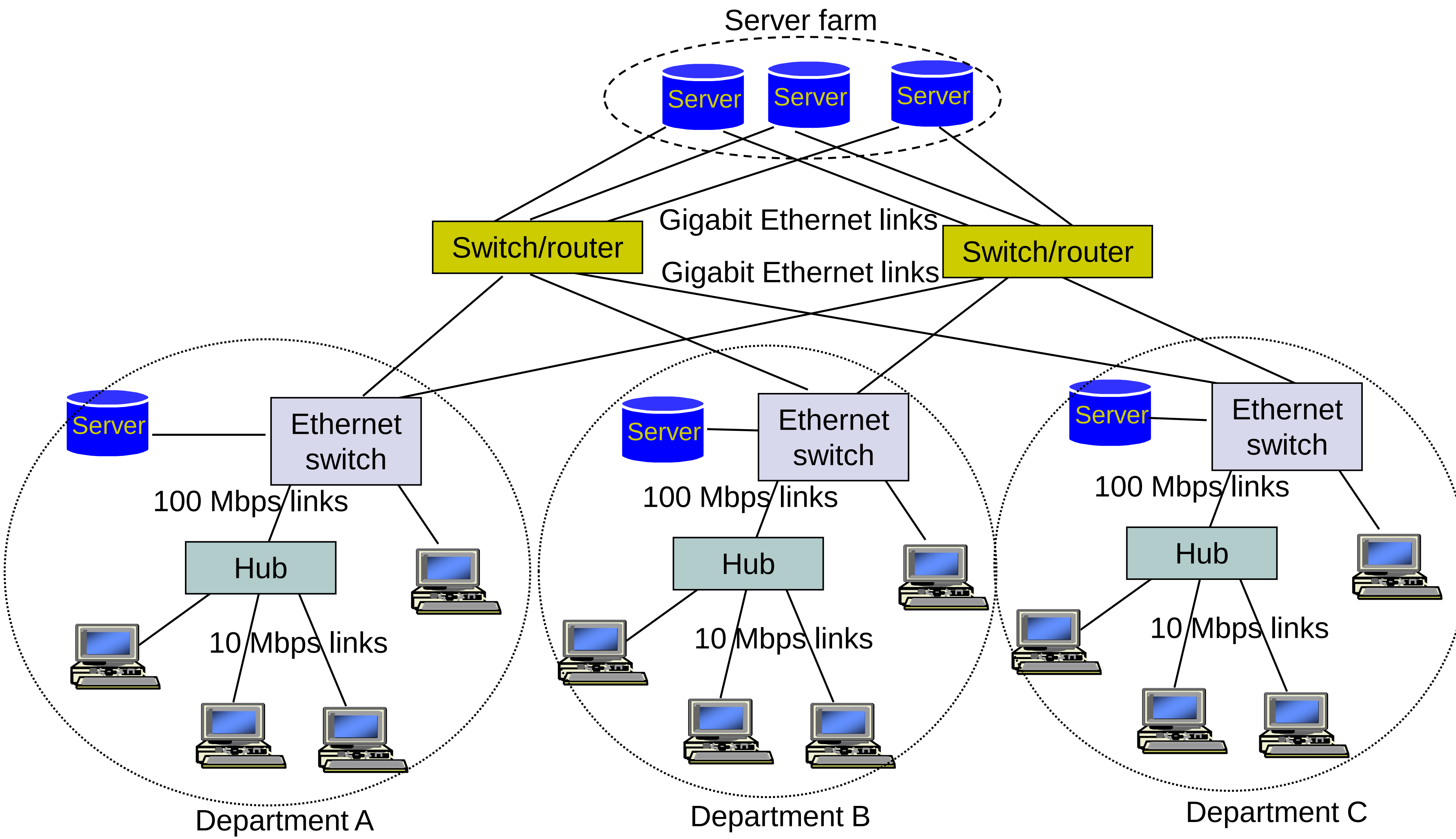
10 Gigabit Ethernet

Table 6.5 IEEE 802.3 10 Gbps Ethernet medium alternatives

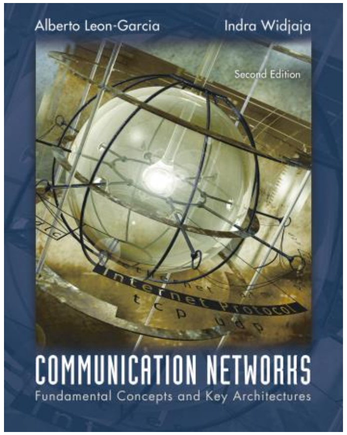
	10GbaseSR	10GBaseLR	10GbaseEW	10GbaseLX4
Medium	Two optical fibers Multimode at 850 nm 64B66B code	Two optical fibers Single-mode at 1310 nm 64B66B	Two optical fibers Single-mode at 1550 nm SONET compatibility	Two optical fibers multimode/single-mode with four wavelengths at 1310 nm band 8B10B code
Max.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

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

Typical Ethernet Deployment



Chapter 6
Medium Access Control Protocols and Local Area Networks

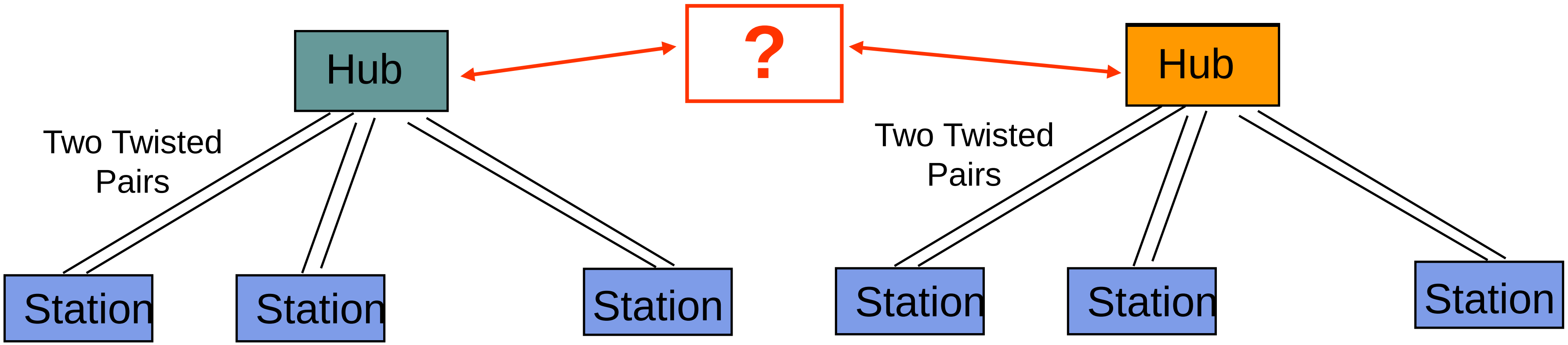


LAN Bridges

Hubs, Bridges & Routers

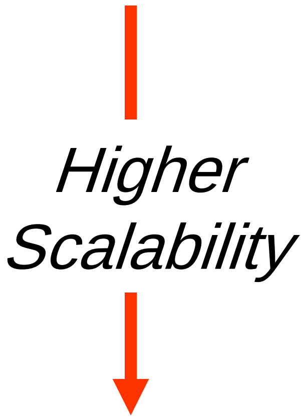
- Hub: Active central element in a star topology
  - Twisted Pair: inexpensive, easy to install
  - Simple repeater in Ethernet LANs
  - “Intelligent hub”: fault isolation, net configuration, statistics

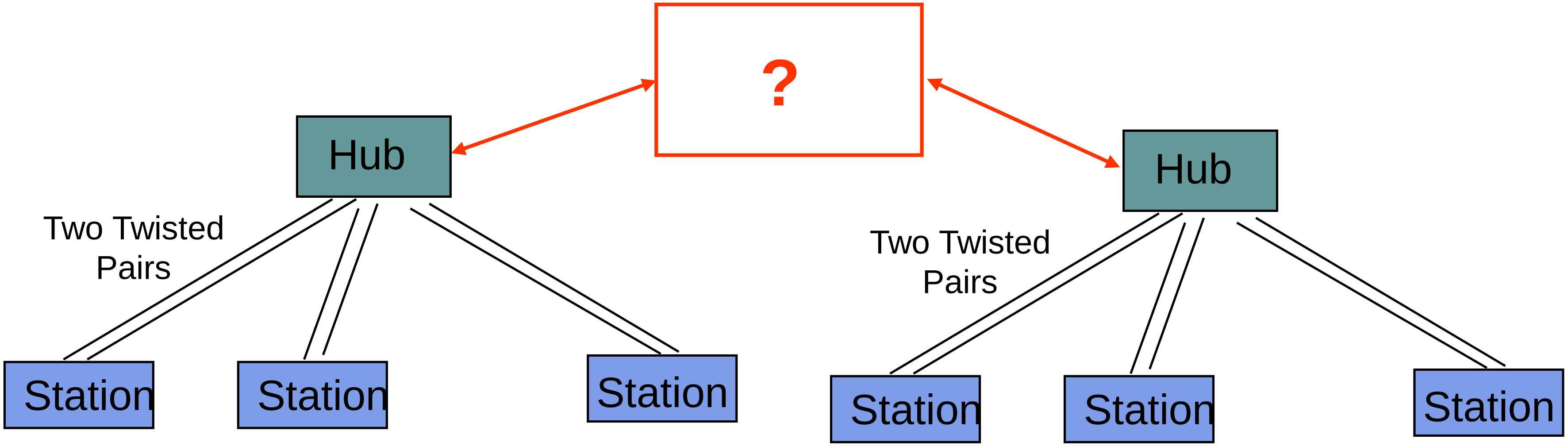
User community grows, need to interconnect hubs



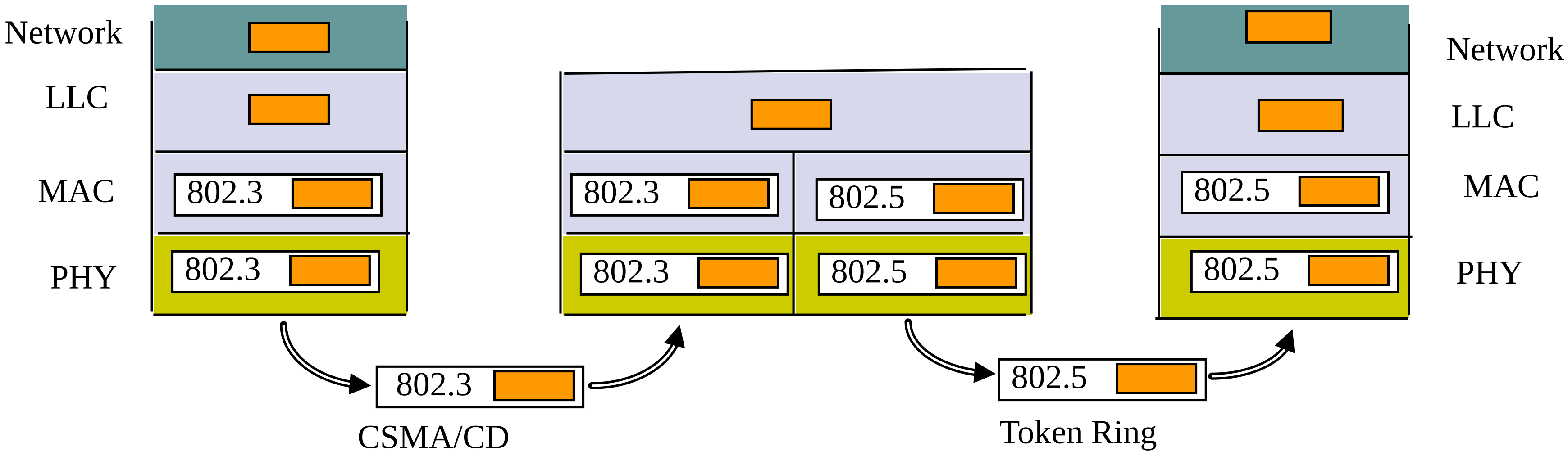
Hubs, Bridges & Routers

- Interconnecting Hubs
  - Repeater: Signal regeneration
    - All traffic appears in both LANs
  - Bridge: MAC address filtering (layer 2)
    - Local traffic stays in its own LAN
  - Routers: Internet routing (layer 3)
    - Based on IP addresses



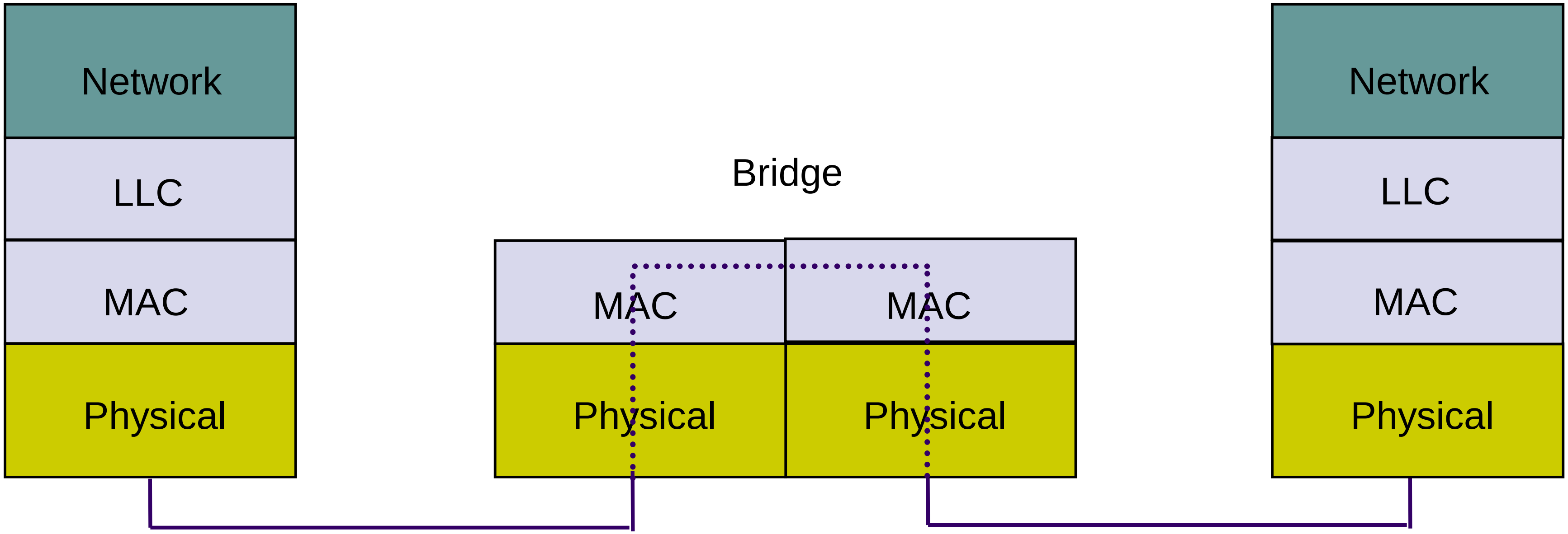


General Bridge Issues



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

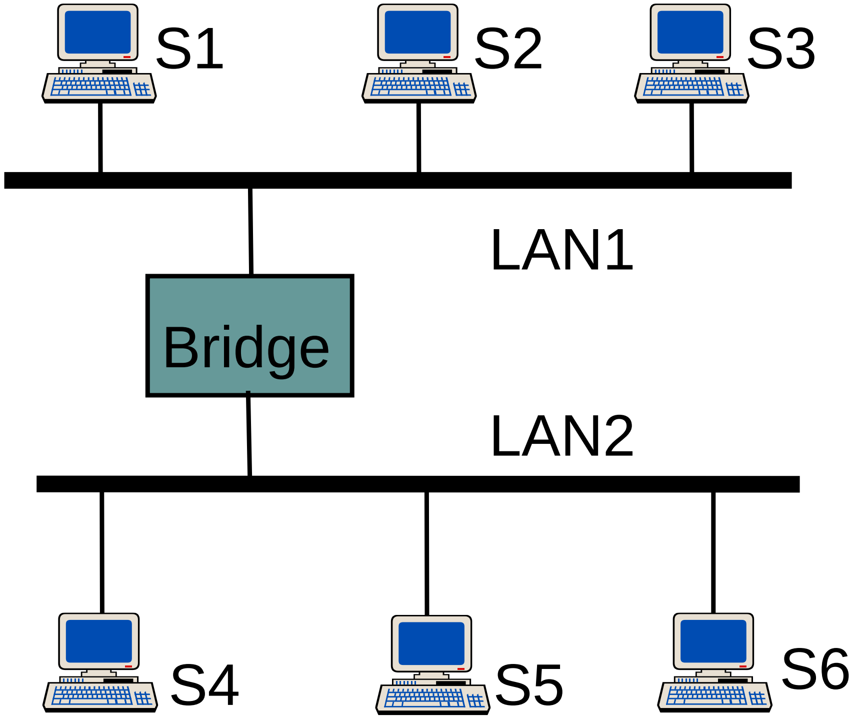
Bridges of Same Type

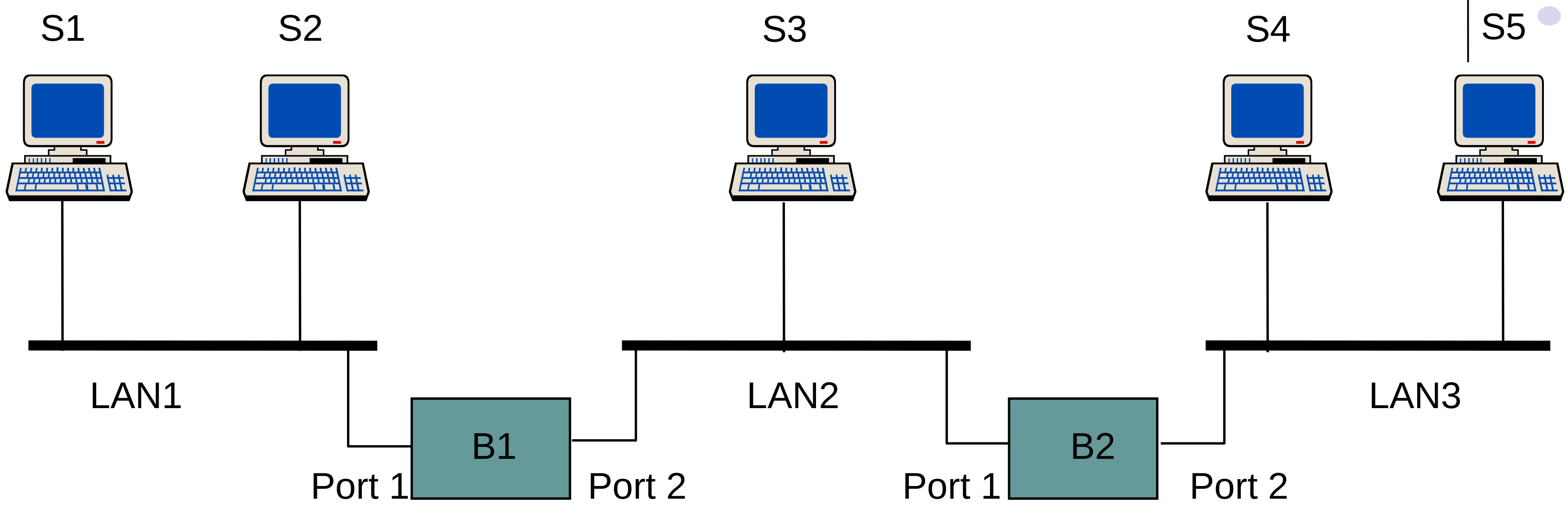


- Common case involves LANs of same type
- Bridging is done at MAC level

Transparent Bridges

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

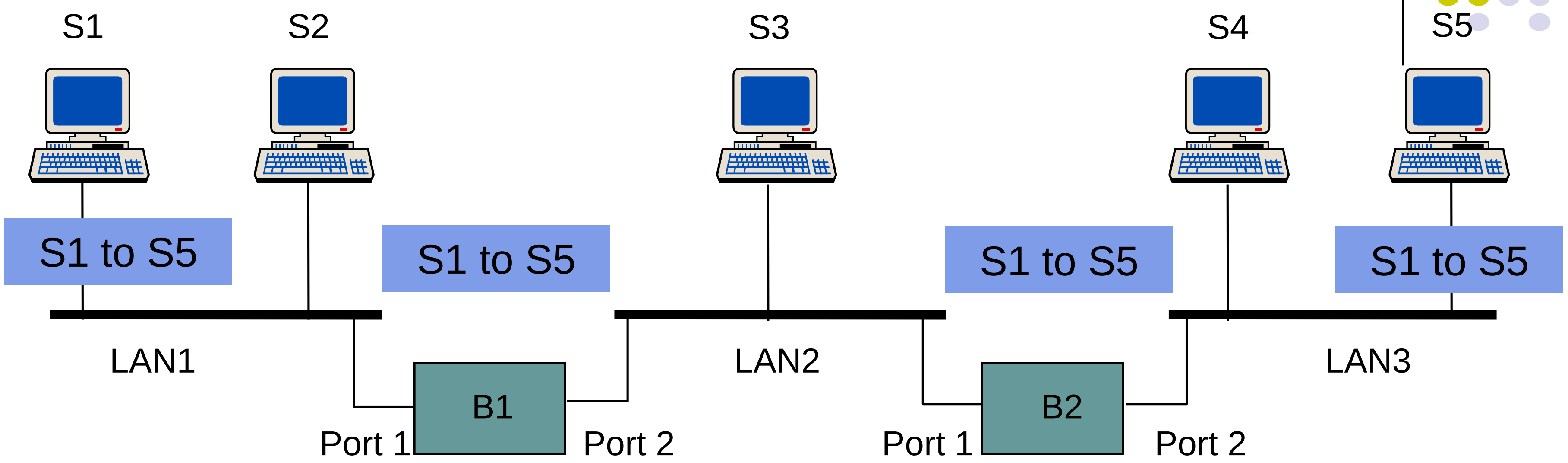




Address	Port

Address	Port

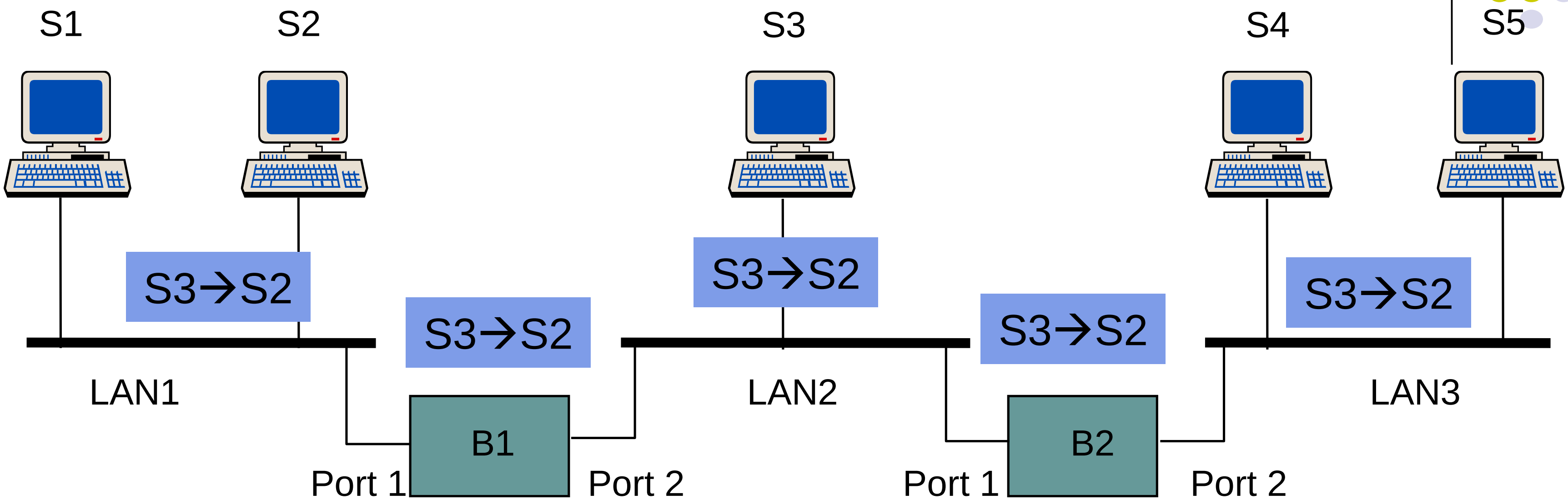
S1→S5



Address	Port
S1	1

Address	Port
S1	1

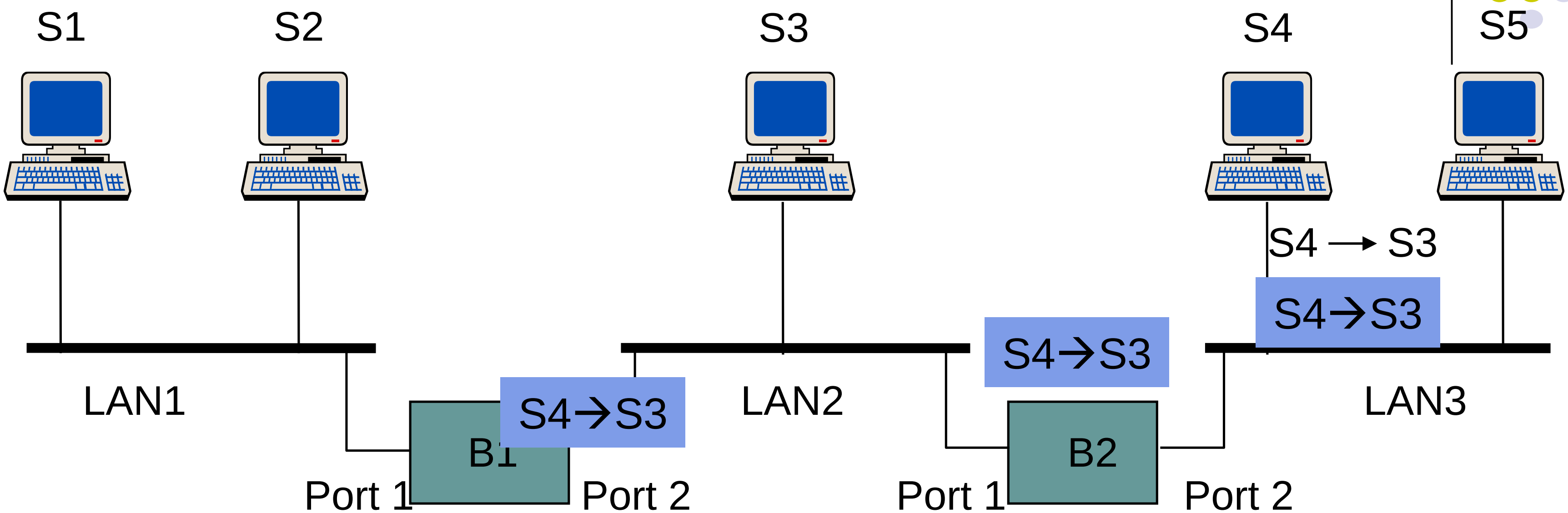
S3→S2



Address	Port
S1	1
S3	2

Address	Port
S1	1
S3	1

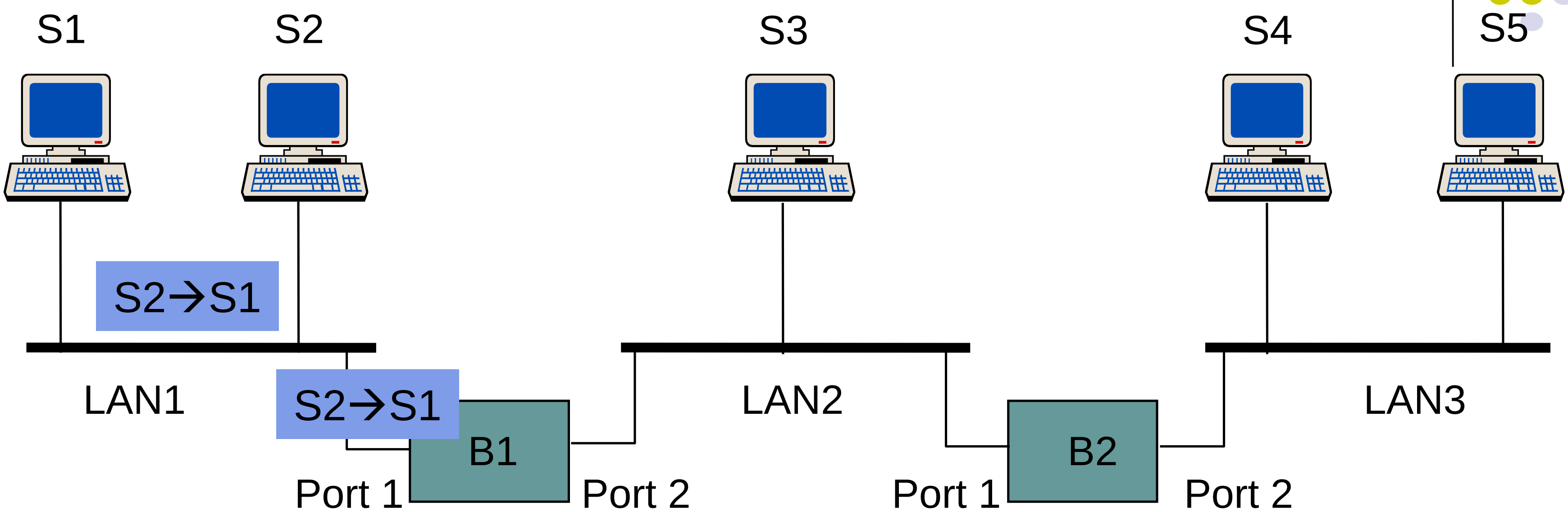
S4→S3



Address	Port
S1	1
S3	2
S4	2

Address	Port
S1	1
S3	1
S4	2

S2→S1



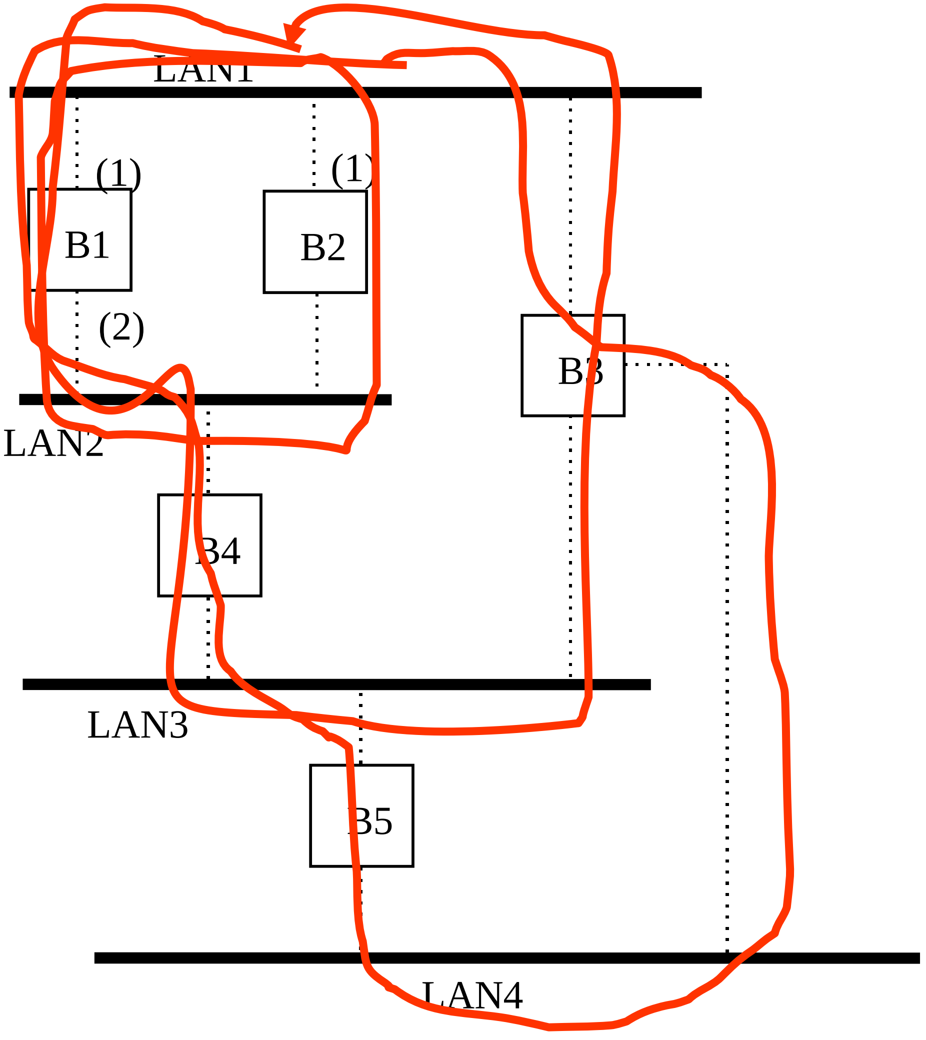
Address	Port
S1	1
S3	2
S4	2
S2	1

Address	Port
S1	1
S3	1
S4	2

Adaptive Learning

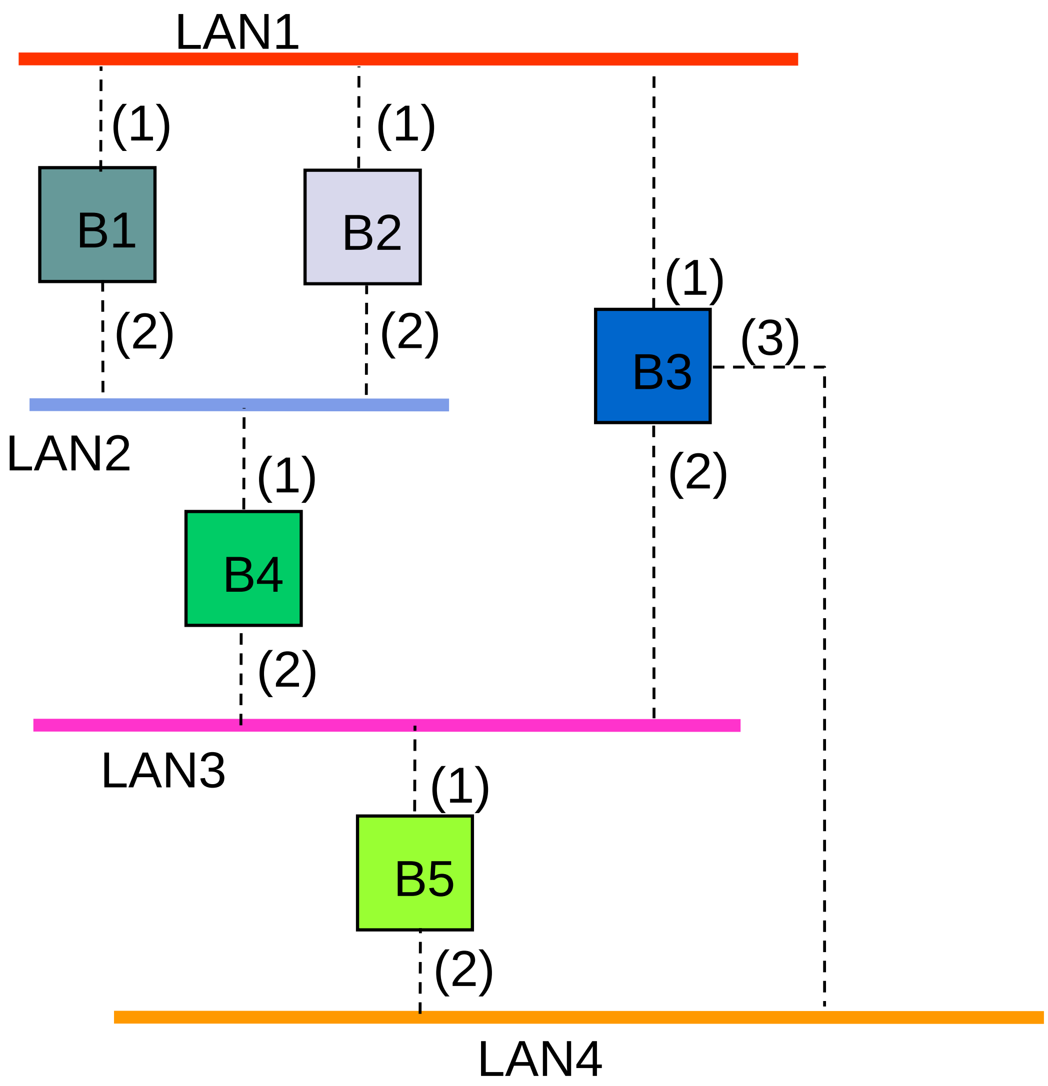
- In a static network, tables eventually store all addresses & learning stops
- In practice, stations are added & moved all the time
  - Introduce timer (minutes) to age each entry & force it to be relearned periodically
  - If frame arrives on port that differs from frame address & port in table, update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

Avoiding Loops

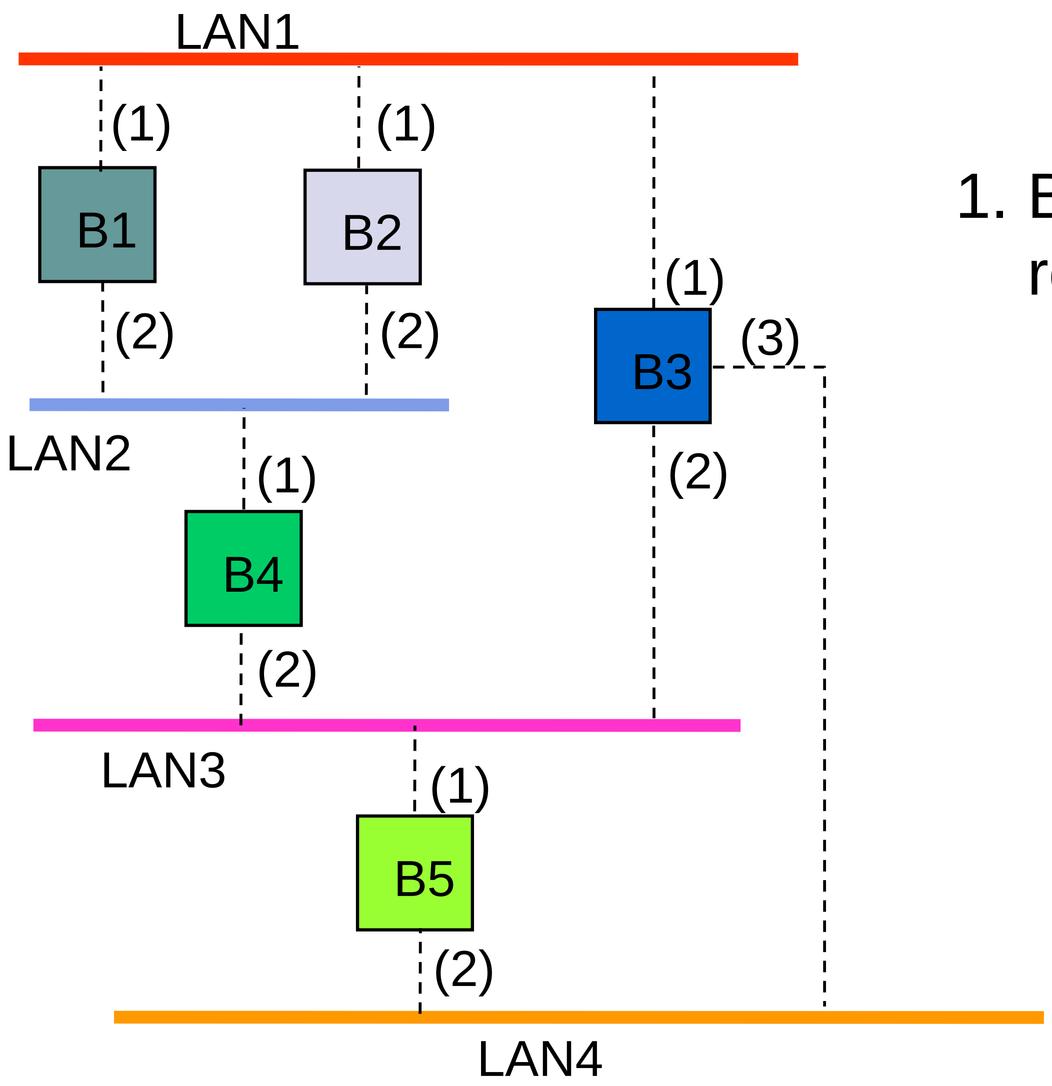


Spanning Tree Algorithm

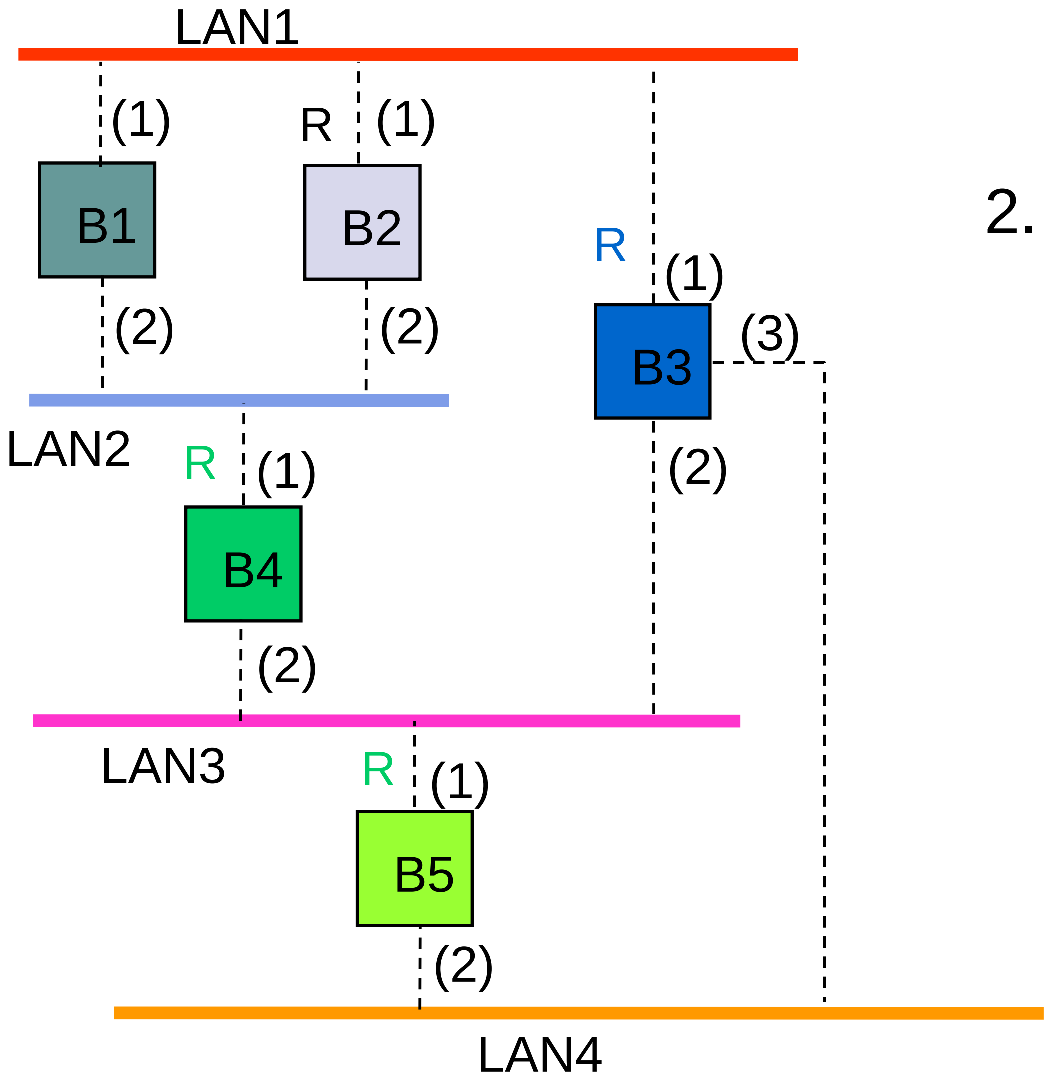
1. Select a *root bridge* among all the bridges
   - root bridge = the lowest bridge ID
2. Determine the *root port* for each bridge except the root bridge
   - root port = port with the least-cost path to the root bridge
3. Select a *designated bridge* for each LAN
   - designated bridge = bridge has least-cost path from the LAN to the root bridge
   - *designated port* connects the LAN and the designated bridge
4. All root ports and all designated ports are placed into a “forwarding” state. These are the only ports that are allowed to forward frames. The other ports are placed into a “blocking” state



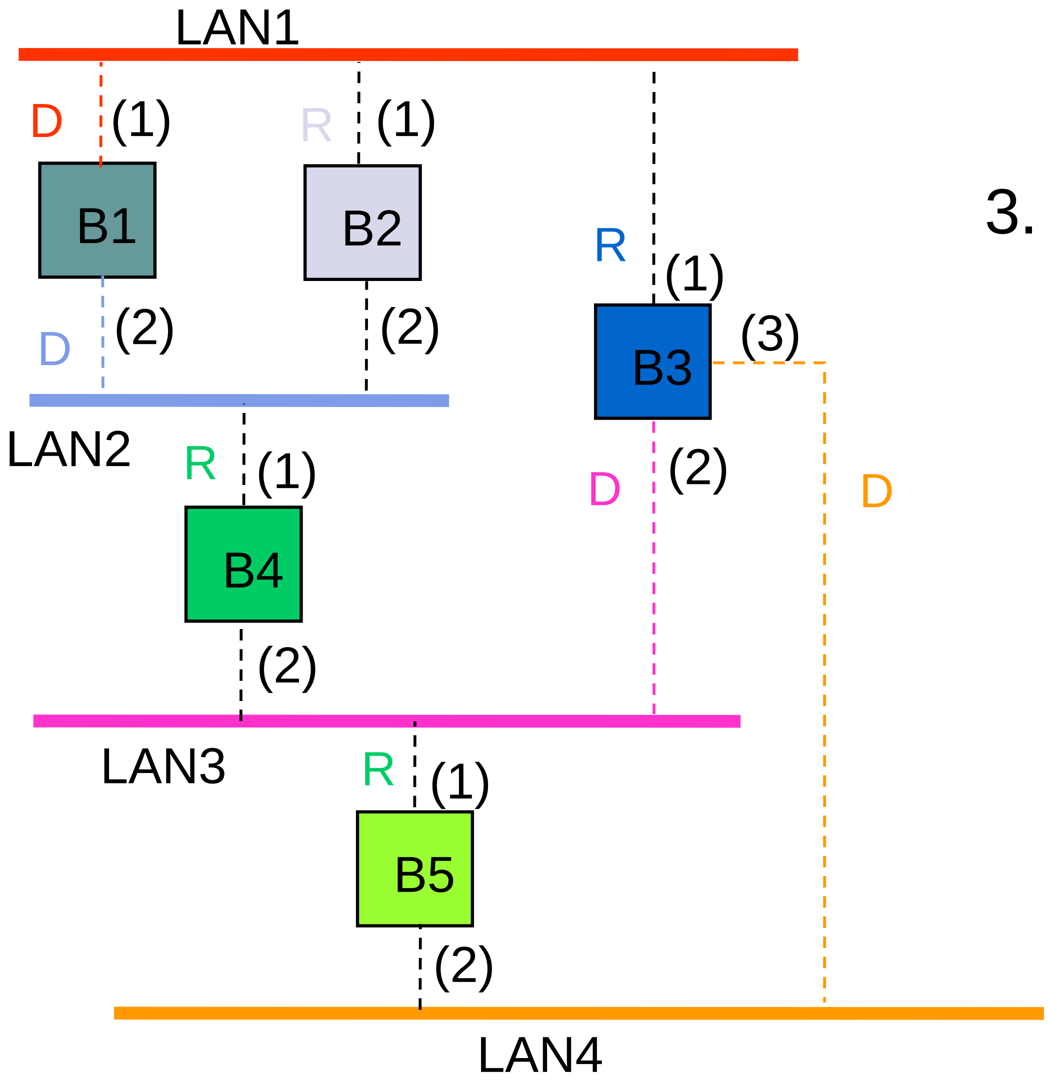
LAN1
(1)
(1)
B1
B2
(1)
(2)
(2)
(3)
B3
LAN2
(1)
(2)
B4
(2)
LAN3
(1)
B5
(2)
LAN4



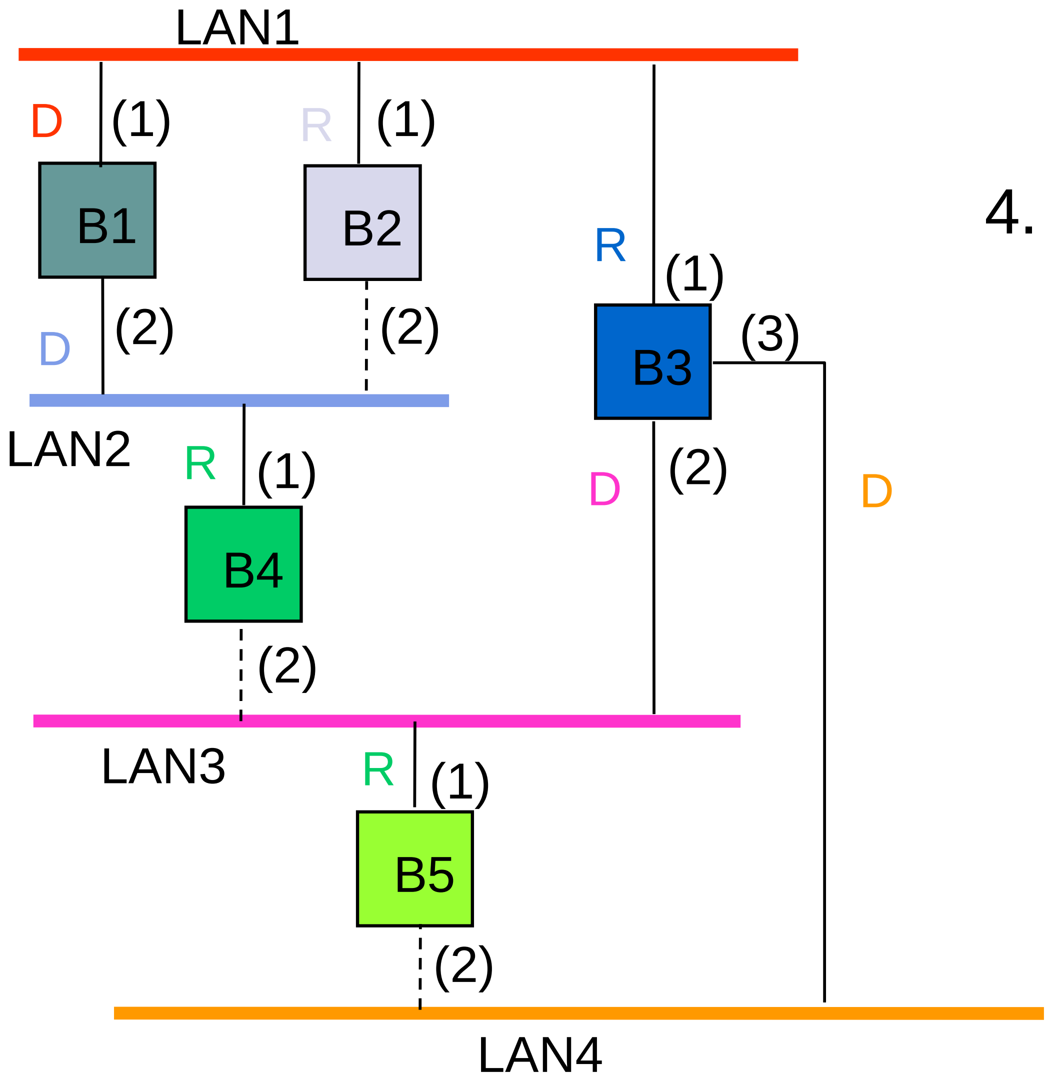
1. Bridge 1 selected as root bridge



2. Root port selected for every bridge except root port



3. Select designated bridge for each LAN

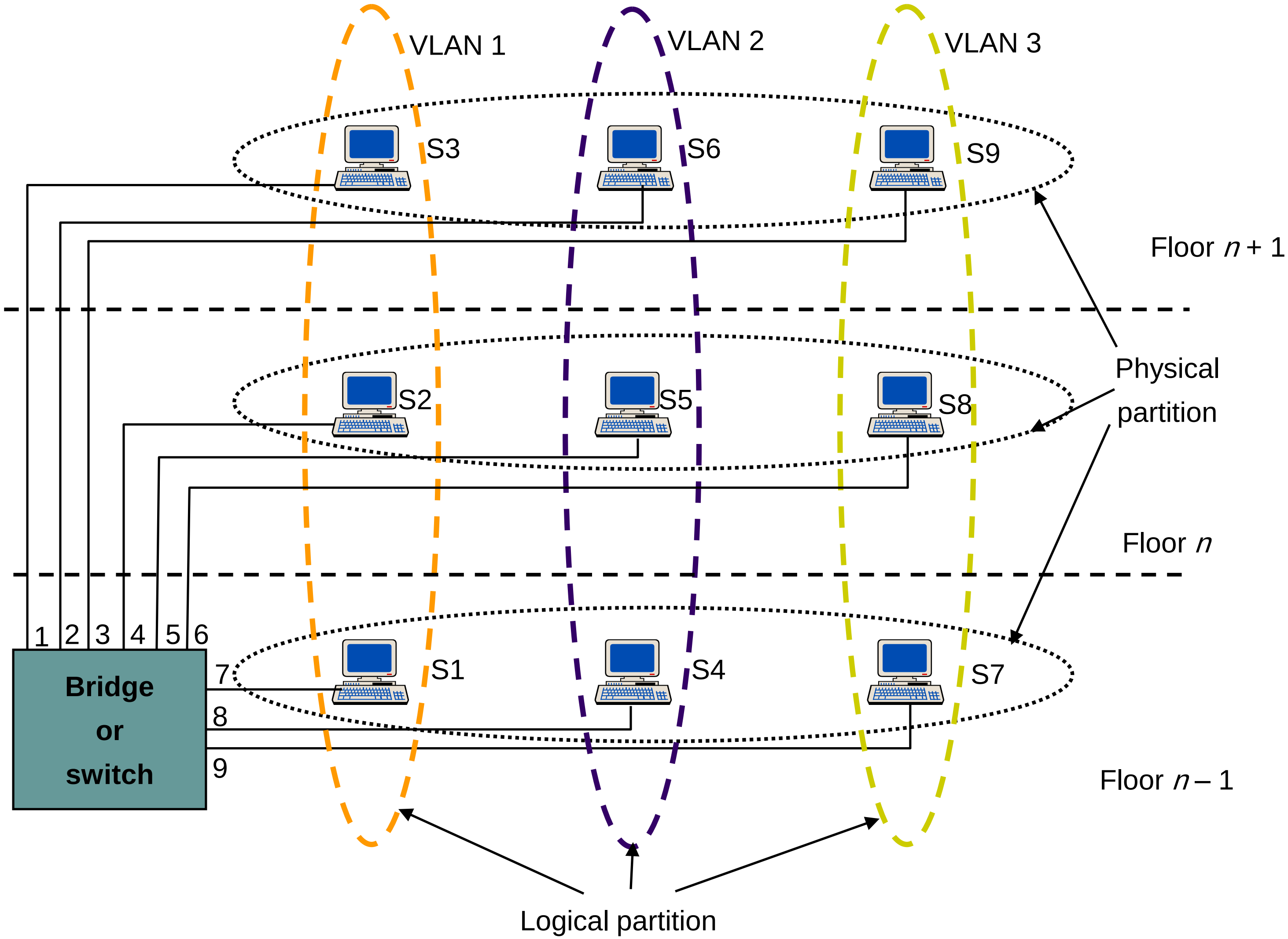


4. All root ports & designated ports put in forwarding state

VLAN

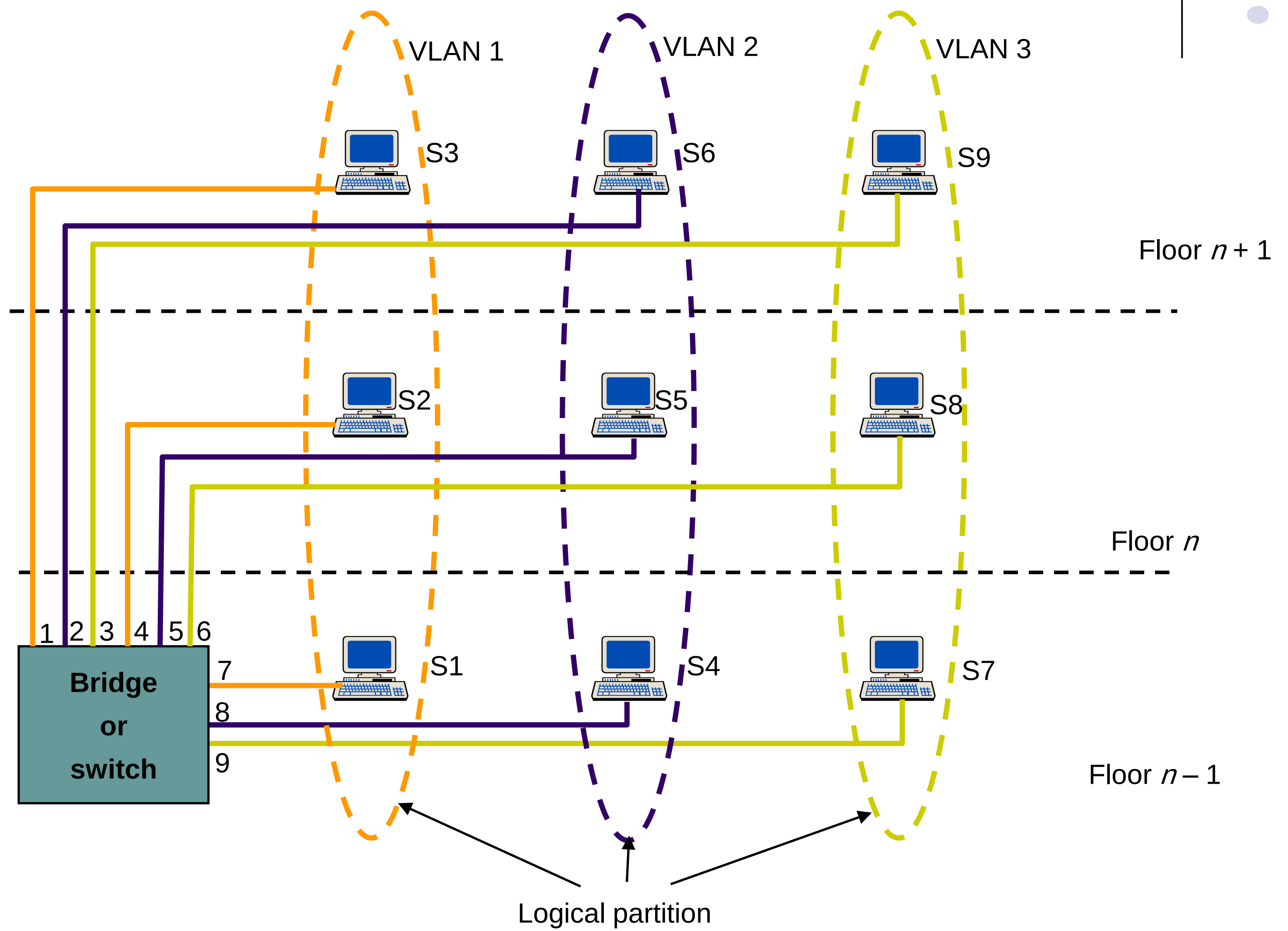
- Group of devices on one or more LANs that are configured so that they can communicate as if they were attached to the same wire, when in fact they are located on a number of different LAN segments
- Benefits of VLAN
  - Increased performance
  - Improved manageability
  - Network tuning and simplification of software configurations
  - Physical topology independence
  - Increased security options

Virtual LAN



VLAN 1
VLAN 2
VLAN 3
S3
S6
S9
S2
S5
S8
S1
S4
S7
Floor n + 1
Floor n
Floor n – 1
Physical
partition
Logical partition
Bridge
or
switch
1
2
3
4
5
6
7
8
9

Per-Port VLANs



Bridge only forwards frames to outgoing ports associated with same VLAN

Tagged VLANs

- More flexible than Port-based VLANs
- Insert VLAN tag after source MAC address in each frame
  - VLAN protocol ID + tag
- VLAN-aware bridge forwards frames to outgoing ports according to VLAN ID
- VLAN ID can be associated with a port statically through configuration or dynamically through bridge learning
- IEEE 802.1q
- Visit http://en.wikipedia.org/wiki/VLAN for more details

READING

- Read the sections covered in class