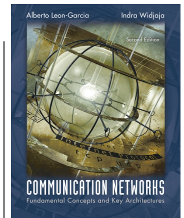
Chapter 6
Medium Access Control Protocols and Local Area Networks



Part I: Medium Access Control

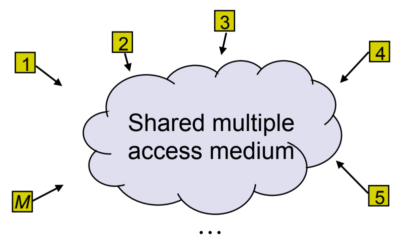
Part II: Local Area Networks

Chapter Overview

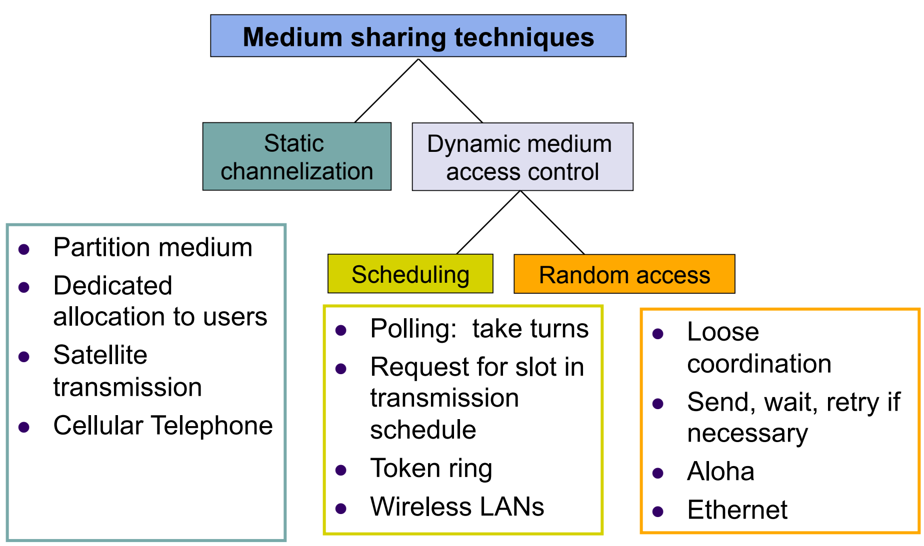
- **Broadcast Networks**
  - All information sent to all users
  - No routing
  - Shared media
  - Radio
    - Cellular telephony
    - Wireless LANs
  - Copper & Optical
    - Ethernet LANs
    - Cable Modem Access
- ***Medium Access Control***
  - How to coordinate access to shared medium
  - Data 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

Multiple Access Communications

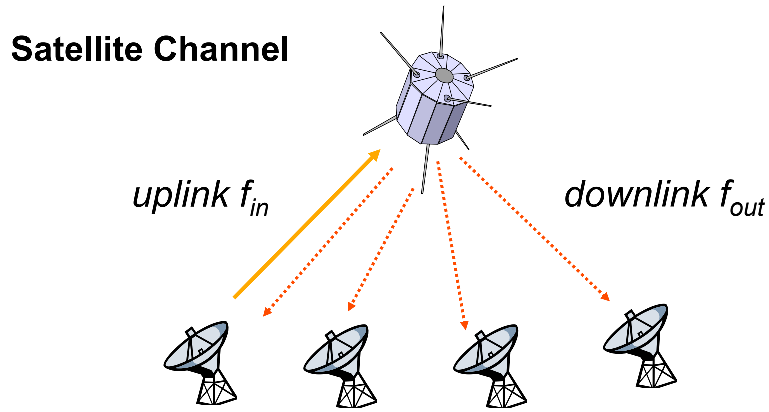
- Shared media basis for broadcast networks
  - Inexpensive: radio over air; copper or coaxial cable
  - M users communicate by broadcasting into medium
- Key issue: How to share the medium when there is a competition for it?



Approaches to Media Sharing

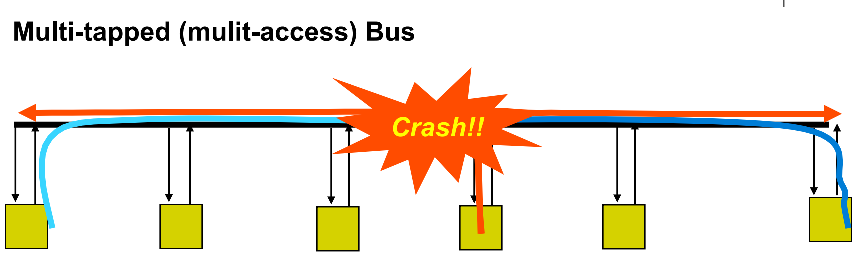


Channelization: Satellite



What we learned from the foundations of queueing theory?

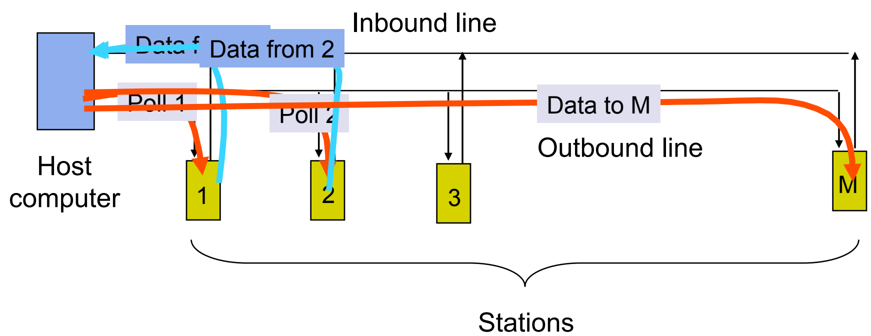
Random Access



Transmit when ready

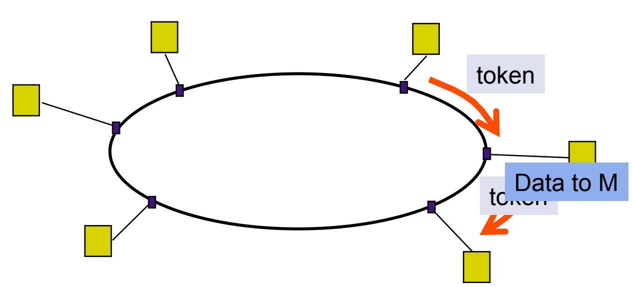
Transmissions can occur; need retransmission strategy

Scheduling: Polling



Scheduling: Token-Passing

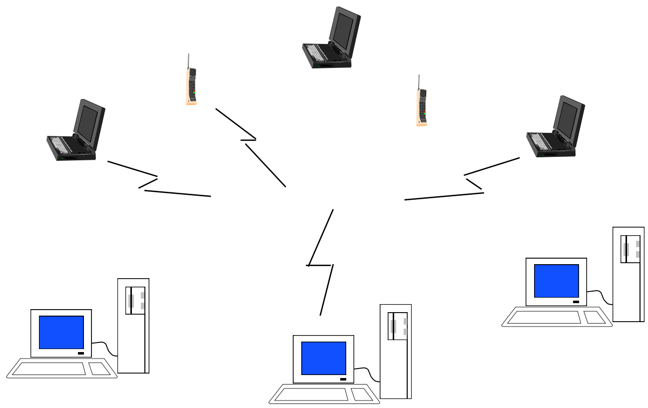
Ring networks



Station that holds token transmits into ring

Wireless LAN

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



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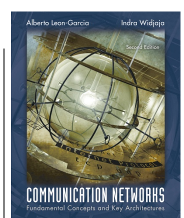


Random Access

Dynamic Channel Allocation

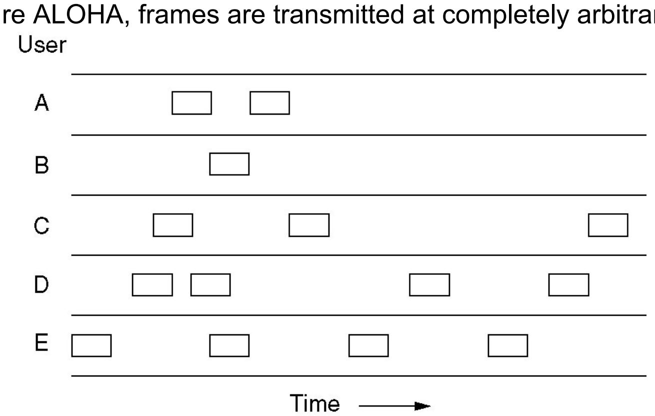
Assumptions

- Station Model: *N* independent stations generating frames at a constant rate, one-by-one transmission
- Single Channel: only one for all stations equivalently
- Collision: if two frames are transmitted simultaneously, the resulting signal is garbled
- (a) Continuous Time: transmission begins at any instant.
  (b) Slotted Time: transmission begins at the start of a slot.
- (a) Carrier Sense: stations can sense the channel busy or idle.
  (b) No Carrier Sense: just go ahead transmission

LANs generally have carrier sense, how about wireless networks?

Pure ALOHA

In pure ALOHA, frames are transmitted at completely arbitrary times.



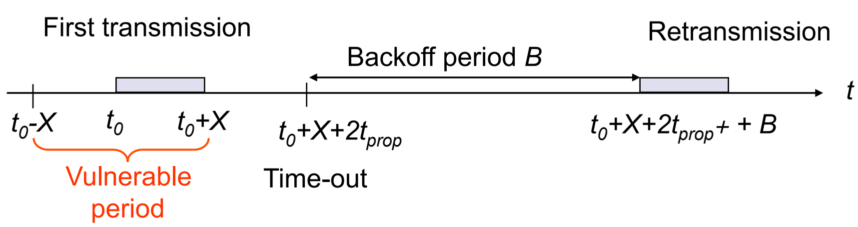
How a station knows its frame was destroyed due to collision?

Feedback property of broadcasting.

What is the efficiency of an ALOHA channel?

ALOHA

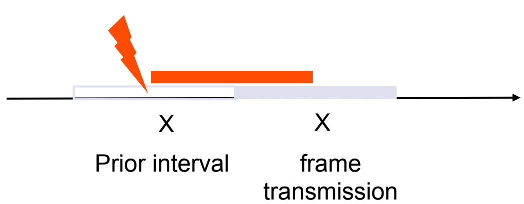
- Wireless link to provide data transfer between main campus & remote campuses of University of Hawaii
- Simplest solution: just do it
  - A station transmits whenever it has data to transmit
  - If more than one frames are transmitted, they interfere with each other (collide) and are lost
  - If ACK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



ALOHA Model

- Definitions and assumptions
  - *X* frame transmission time (assume constant)
  - *S*: throughput (average # successful frame transmissions per *X* seconds)
  - *G*: load (average # 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

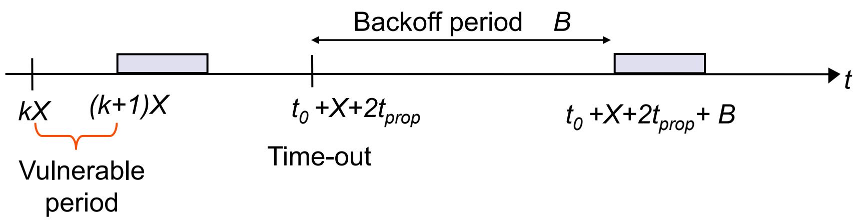
- *What is probability of no arrivals in vulnerable period?*
- Abramson assumption: Effect of backoff algorithm is that frame arrivals are equally likely to occur at any time interval
- *G* is avg. # arrivals per *X* seconds
- Divide *X* into *n* intervals of duration $\Delta = X/n$
- *p* = probability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

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

$$P_{success} = P[0 \text{ arrivals in 2X seconds}] =$$
$$= P[0 \text{ arrivals in 2n intervals}]$$
$$= (1-\text{p})^{2\text{n}} = \left(1-\frac{G}{n}\right)^{2n} \rightarrow e^{-2G} \quad \text{as n} \rightarrow \infty$$

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



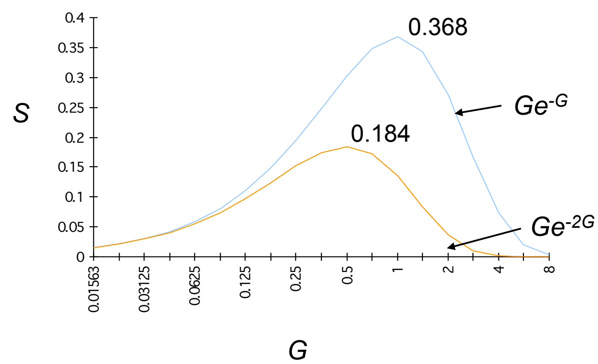
What is required to turn a pure ALOHA to a slotted ALOHA?

What benefit received by slotted ALOHA?

What is the price for the benefit? And how much?

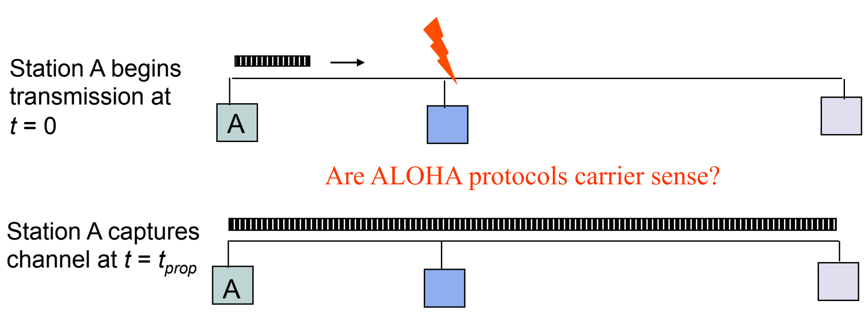
Throughput of Slotted ALOHA

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



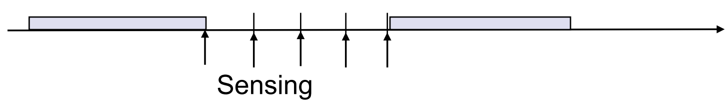
Carrier Sensing Multiple Access (CSMA)

- 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

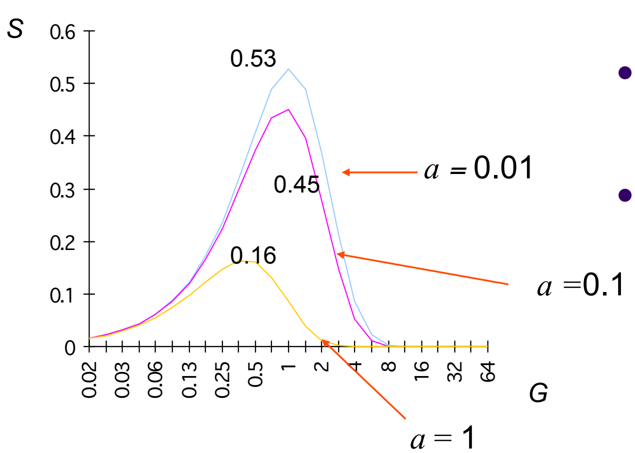


CSMA Options

- 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)
    - If busy, 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

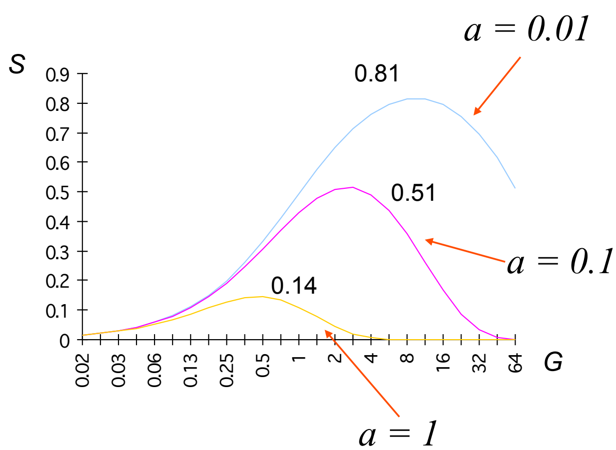


1-Persistent CSMA Throughput



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

Non-Persistent CSMA Throughput



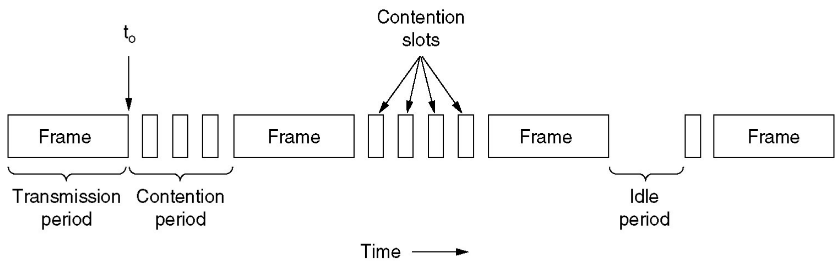
- Higher maximum throughput than 1-persistent for small a
- Worse than Aloha for $a > 1$

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 abort transmission, reschedule random backoff times, and try again at scheduled times - quickly terminating a damaged frame saves T& BW
- 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 Diagram

- CSMA/CD: **Widely used on LANs in the MAC sublayer**

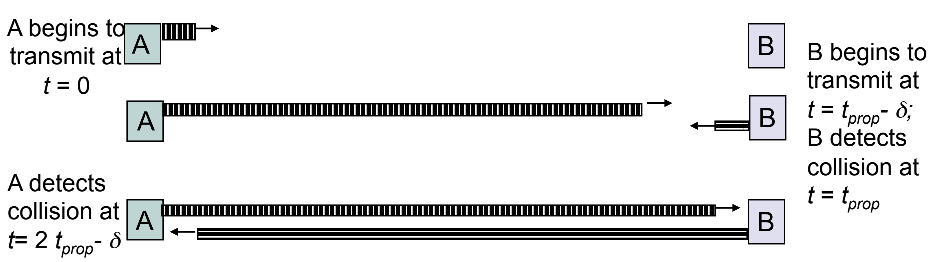


CSMA/CD can be in one of three states: contention, transmission, or idle.

Can collision occurs with CSMA/CD? If so, when occurs and not occurs?

When a station can seize the channel for transmission (how long is the contention)?

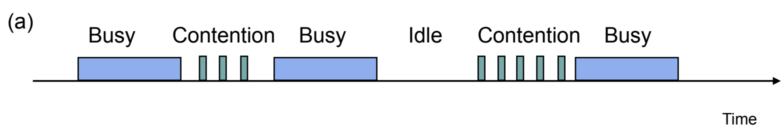
CSMA/CD reaction time



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:

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

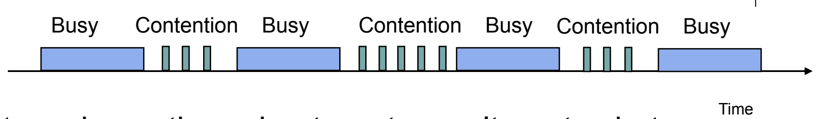
- By taking derivative of $P_{success}$ we find max occurs at p=1/n

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

- 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
  - How long for a station to find out that a transmission is just over, and then to start contention again?

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

- where:

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

  $a = t_{prop}/X$

  ν meters/sec. speed of light in medium

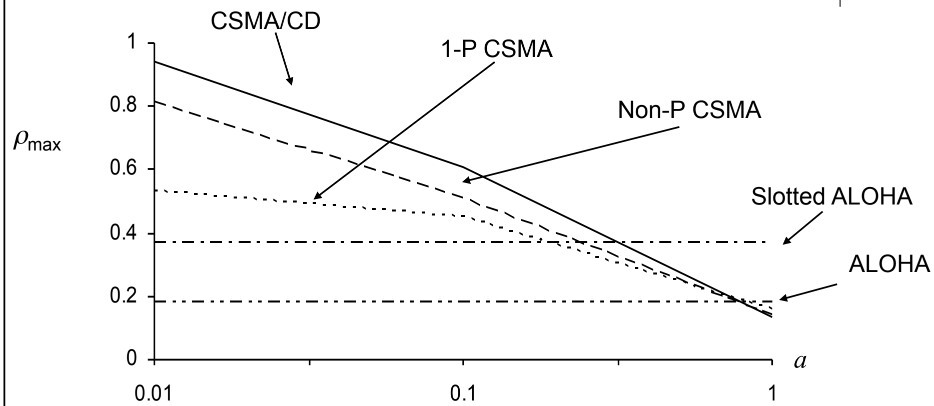
  d meters is diameter of system

  2*e*+1 = 6.44

CSMA-CD Application: Ethernet

- First Ethernet LAN standard used CSMA-CD
  - 1-persistent Carrier Sensing
  - R = 10 Mbps
  - 2 * t_{prop} = 51.2 microseconds
    - 512 bits = 64 byte slot
    - accommodates 2.5 km + 4 repeaters
  - Truncated Binary Exponential Backoff
    - After *n*th collision, select backoff from {0, 1,…, 2^k – 1}, where k=min(n, 10)

Throughput for Random Access MACs



- For small a: CSMA-CD has best *maximum throughput*
- For larger a: Aloha & slotted Aloha better *maximum throughput*, since not dependent on a (reaction time)

Carrier Sensing and Priority Transmission

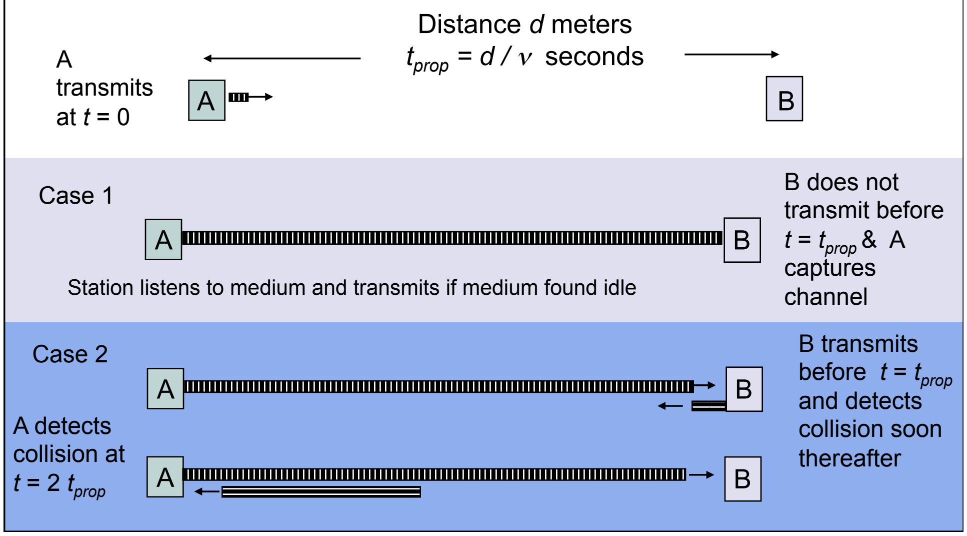
- Certain applications require faster response than others, e.g. ACK messages
- Impose different inter-frame times
  - High priority traffic sense channel for time τ_1
  - Low priority traffic sense channel for time $\tau_2 > \tau_1$
  - High priority traffic, if present, seizes channel first
- This priority mechanism is used in IEEE 802.11 wireless LAN

Delay-Bandwidth Product

- *Delay-bandwidth* product key parameter
  - Coordination in sharing medium involves using bandwidth (explicitly or implicitly)
  - Difficulty of coordination commensurate with delay-bandwidth product
- Simple two-station example
  - Station with frame to send listens to medium and transmits if medium found idle (carrier sense)
  - Station monitors medium to detect collision
  - If collision occurs, station that begin transmitting earlier retransmits (propagation time is known)

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

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

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

Normalized Delay-Bandwidth Product

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

t_{prop}: Propagation delay

L/R: Time to transmit a frame

Typical MAC Efficiencies

Two-Station Example:

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

CSMA-CD (Ethernet) protocol:

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

Token-ring network

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

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

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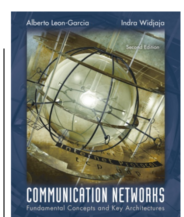


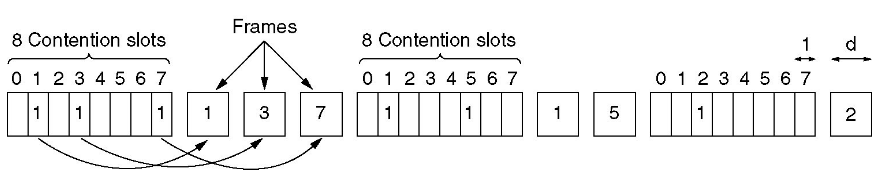
Scheduling

Scheduling for Medium Access Control

- Schedule frame transmissions to avoid collision in shared medium
  - ✓ More efficient channel utilization
  - ✓ Less variability in delays
  - ✓ Can provide fairness to stations
  - × Increased computational or procedural complexity
- Two main approaches
  - Reservation
  - Polling

A Bit-Map Protocol

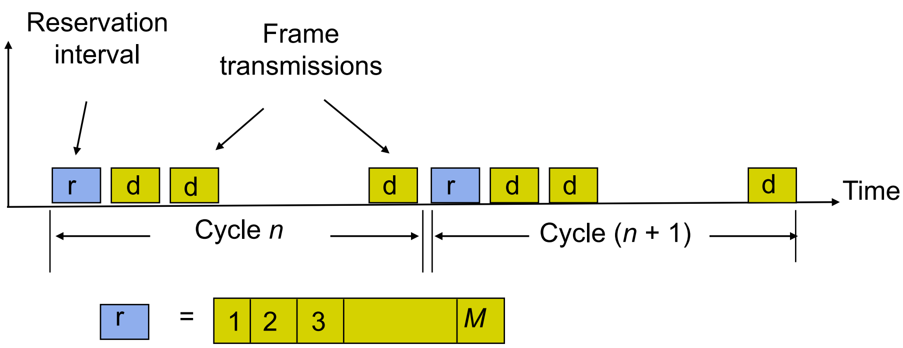
- Assumptions: **M** stations have unique addresses 0 to M -1
  - **Which station gets the channel after a successful transmission?**
- A bit-map protocol:
  - a contention period has exactly M slots and a station **j** announces it has a frame to send by inserting 1 into slot **j**



The basic bit-map protocol.

What is the length of a mini-slot?
Is it fair to stations with different addresses? Worst case?

Collision-free Res. Systems



- Transmissions organized into cycles
- Cycle: reservation interval + frame transmissions
- Reservation interval has a mini-slot for ***each*** station to request reservations for frame transmissions

Reservation System Options

- Centralized or distributed system
  - *Centralized systems*: A central controller listens to reservation information, decides order of transmission, issues grants
  - *Distributed systems*: Each station determines its slot for transmission from the reservation information
- Single or Multiple Frames
  - *Single frame reservation*: Only one frame transmission can be reserved within a reservation cycle
  - *Multiple frame reservation*: More than one frame transmission can be reserved within a frame
- Channelized or Random Access Reservations
  - *Channelized (typically TDMA) reservation*: Reservation messages from different stations are multiplexed without any risk of collision
  - *Random access reservation*: Each station transmits its reservation message randomly until the message goes through

Efficiency of Reservation Systems

- Assume mini-slot duration = vX (v < 1)
- A single frame reservation scheme
  - If propagation delay is negligible and there are *M* stations, a single frame transmission requires *(1+v)X* seconds
  - Link is fully loaded when all stations transmit, maximum efficiency is:

$$\rho_{\max} = \frac{MX}{M\mathrm{v}X + MX} = \frac{1}{1+\mathrm{v}}$$

- A *k* frame reservation scheme
  - If *k* frame transmissions can be reserved with a reservation message and if there are *M* stations, as many as *Mk* frames can be transmitted in *XM(k+v)* seconds
  - Maximum efficiency is:

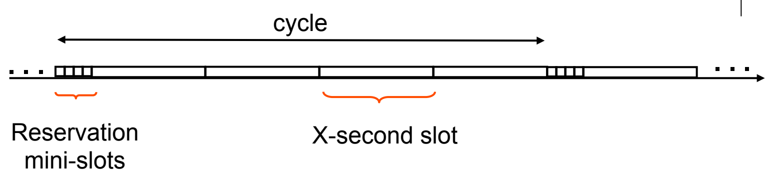
$$\rho_{\max} = \frac{MkX}{M\mathrm{v}X + MkX} = \frac{1}{1+\frac{\mathrm{v}}{k}}$$

Efficiency of Reservation Systems

- *Large number of light traffic stations*
  - Dedicating a mini-slot to each station is inefficient,

    How inefficient - What if the propagation delay is not negligible?

Application of Slotted Aloha



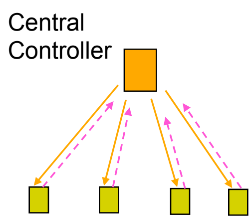
- Reservation protocol allows a large number of stations with infrequent traffic to reserve slots to transmit their frames in future cycles
- Each cycle has mini-slots allocated for making reservations
- Stations use slotted Aloha during mini-slots to request slots

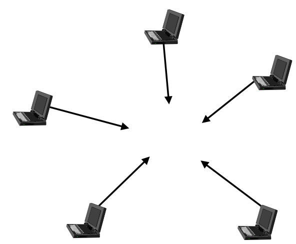
Example: GPRS

- General Packet Radio Service
  - Packet data service in GSM cellular radio
  - GPRS devices, e.g. cellphones or laptops, send packet data over radio and then to Internet
  - Slotted Aloha MAC used for reservations
  - Single & multi-slot reservations supported

Polling Systems

- *Centralized systems*: A central controller accepts requests from stations and issues grants to transmit
- *Distributed systems*: Stations implement a decentralized algorithm to determine transmission order





Polling System Options

- Service Limits: How much is a station allowed to transmit per poll?
  - *Exhaustive*: until station's data buffer is empty (including new frame arrivals)
  - *Gated*: all data in buffer when poll arrives
  - *Frame-Limited*: one frame per poll
  - *Time-Limited*: up to some maximum time
- Priority mechanisms
  - More bandwidth & lower delay for stations that appear multiple times in the polling list
  - Issue polls for stations with message of priority k or higher

Comparison of MAC approaches

- Channelization
  - Feasible if traffic is steady
- Aloha & Slotted Aloha
  - Simple & quick transfer at very low load
  - Accommodates large number of low-traffic bursty users
  - Highly variable delay at moderate loads
  - Efficiency does not depend on a
- CSMA-CD
  - Quick transfer and high efficiency for low delay-bandwidth product
  - Can accommodate large number of bursty users
  - Variable and unpredictable delay

Comparison of MAC approaches

- Reservation
  - On-demand transmission of bursty or steady streams
  - Accommodates large number of low-traffic users with slotted Aloha reservations
  - Can incorporate QoS
  - Handles large delay-bandwidth product via delayed grants
- Polling
  - Generalization of time-division multiplexing
  - Provides fairness through regular access opportunities
  - Can provide bounds on access delay
  - Performance deteriorates with large delay-bandwidth product

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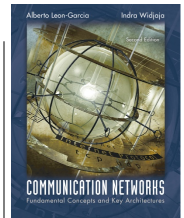


Part II: Local Area Networks
Overview of LANs
Ethernet
Token Ring and FDDI
802.11 Wireless LAN
LAN Bridges

What is a LAN?

Local area means:

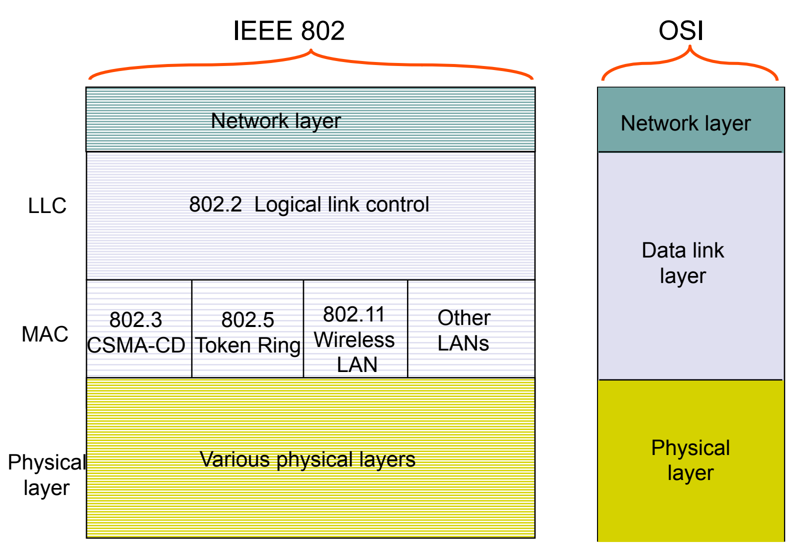
- Private ownership
  - freedom from regulatory constraints of WANs
- Short distance (~1km) between computers
  - low cost
  - very high-speed, relatively error-free communication
  - complex error control unnecessary
- Machines are constantly moved
  - Keeping track of location of computers a chore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

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

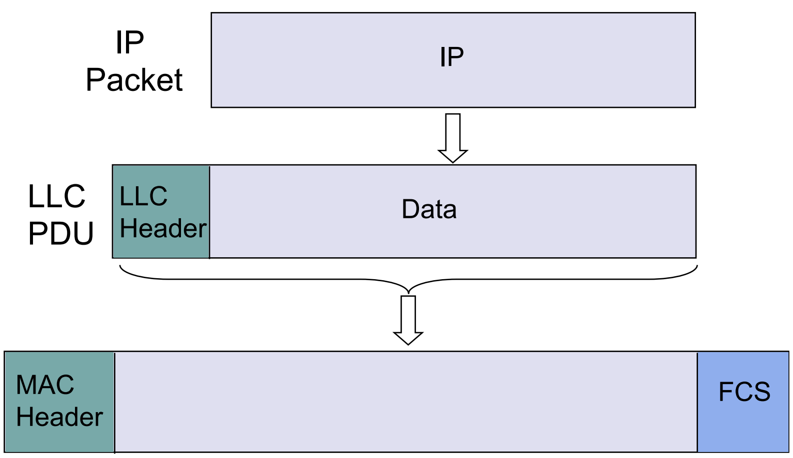


Logical Link Control Services

- 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).

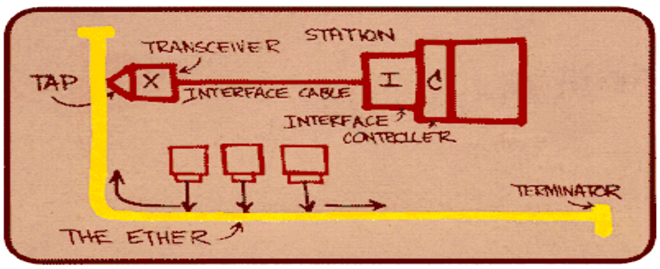
Encapsulation of MAC frames



Ethernet - 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

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 segment generated by collision
  - quantum for retransmission scheduling
  - At least round-trip propagation
- Truncated binary exponential backoff
  - for nth retransmission: $0 < r < 2^k$, where k=min(n,10)
  - Give up after 16 retransmissions

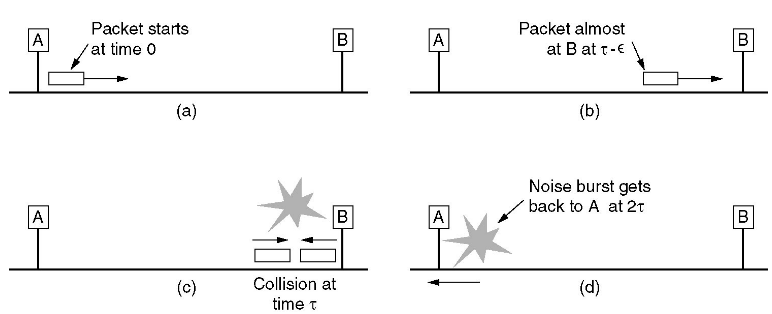
IEEE 802.3 Original Parameters

- Transmission Rate: 10 Mbps
- Min Frame: 512 bits = 64 bytes
- Slot time: 512 bits/10 Mbps = 51.2 μsec
- Max Length: 2500 meters + 4 repeaters

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

Ethernet Minimal Frame Size

- Why there is a minimum length (64B) for a frame?
  - All frames must take more than 2τ to send so that the transmission is still taking place when the noise burst gets back to the sender.

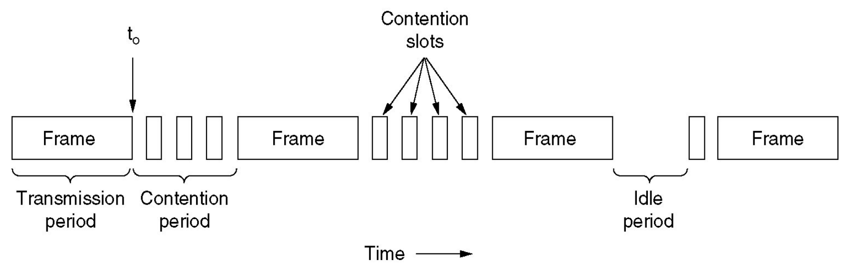


Collision detection can take as long as 2τ (50 **μsec**).

Binary Exponential Backoff

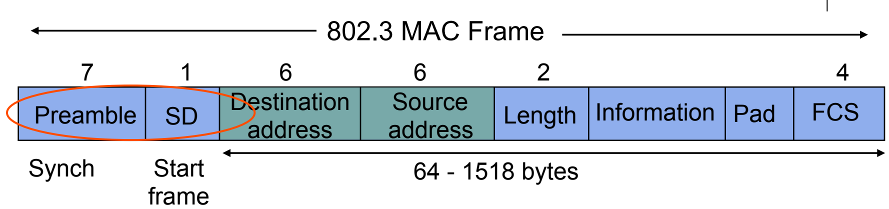
- CSMA/CD
  - If there is a collision, a station waits a random amount of time to try again, how randomization is done?
  - Binary exponential backoff: after *k* collisions, a random number between 0 to 2^*k* – 1 is chosen, that number of slots is skipped

What is a time slot used in Ethernet?



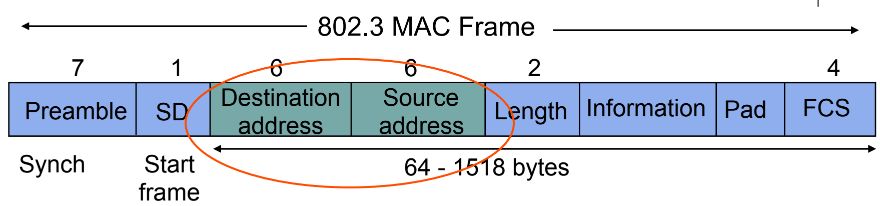
CSMA/CD can be in one of three states: contention, transmission, idle.

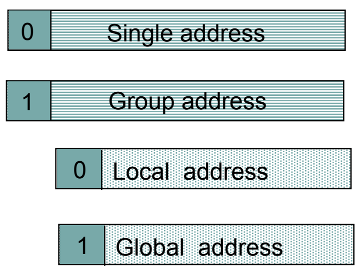
IEEE 802.3 MAC Frame



- 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 10101011
- Receivers look for change in 10 pattern

IEEE 802.3 MAC Frame

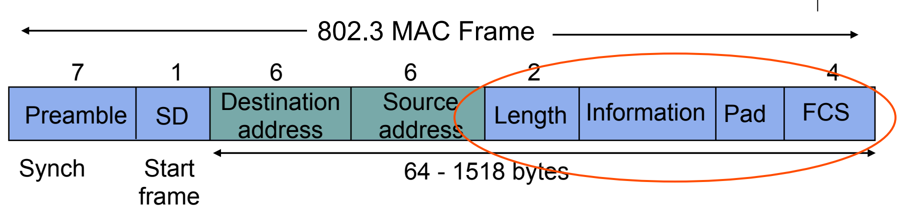




- Destination address
  - single address
  - group address
  - broadcast = 111...111

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

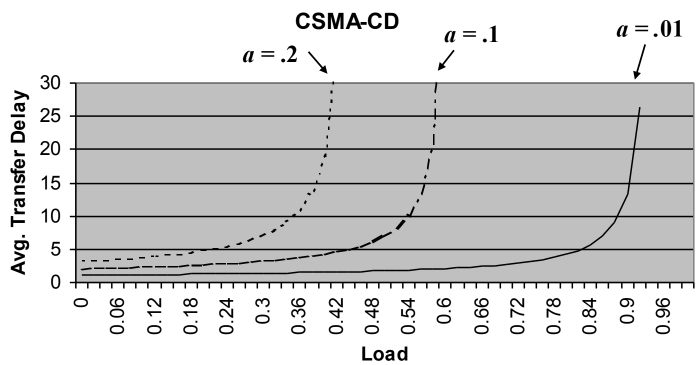
IEEE 802.3 MAC Frame



- 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 if failed CRC

Why no error control (ARQ) in 802.3?

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, and operated primarily in a switched mode
- Extensive deployment in backbone of enterprise data networks and in server farms

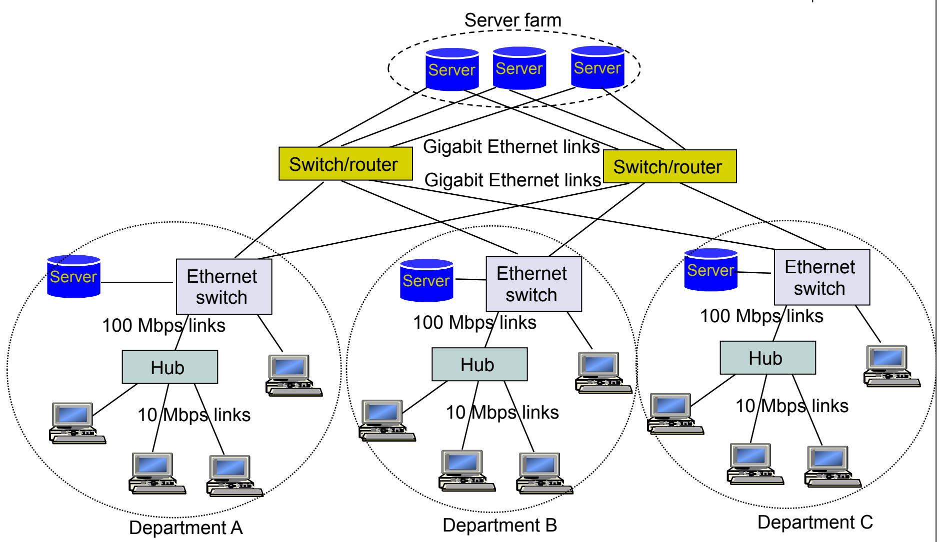
10 Gigabit Ethernet

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**

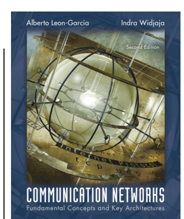
- Frame structure preserved
- CSMA-CD protocol officially abandoned
- LAN PHY for local network applications
- WAN PHY for wide area interconnection using SONET OC-192c
- Extensive deployment in metro networks anticipated

Typical Ethernet Deployment



Chapter 6

Medium Access Control Protocols and Local Area Networks

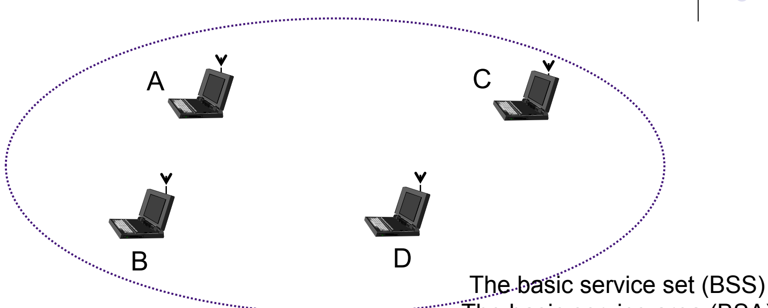


802.11 Wireless LAN

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
  - × Susceptible to noise and interference: reliability!
  - × Signal strength varies in space & time: coverage!
  - × Signal can be captured by snoopers: security!

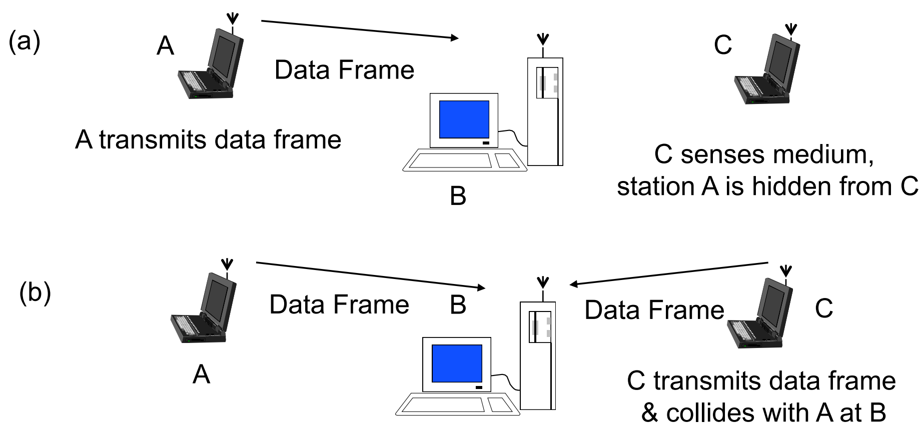
Ad Hoc Communications



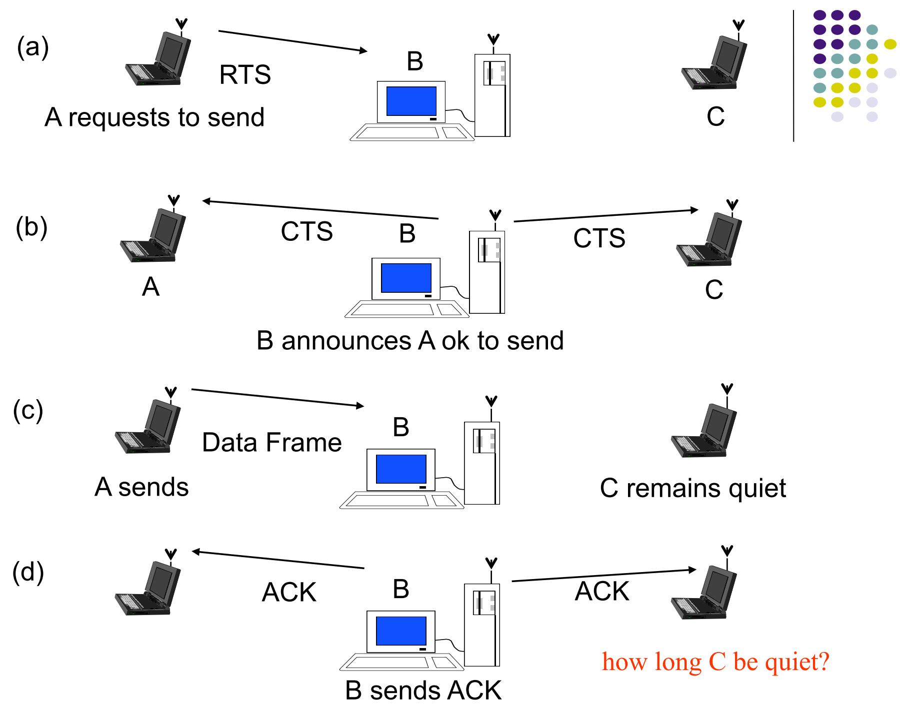
- Temporary association of group of stations
  - Within range of each other
  - Need to exchange information
  - E.g. Presentation in meeting, or distributed computer game, or both

Hidden Terminal Problem

Why not use CSMA-CD as wireless Ethernet?

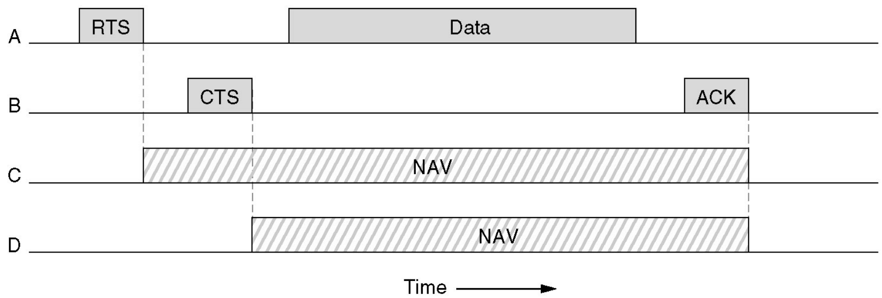


- New MAC: CSMA with *Collision Avoidance (MACA)*



Example

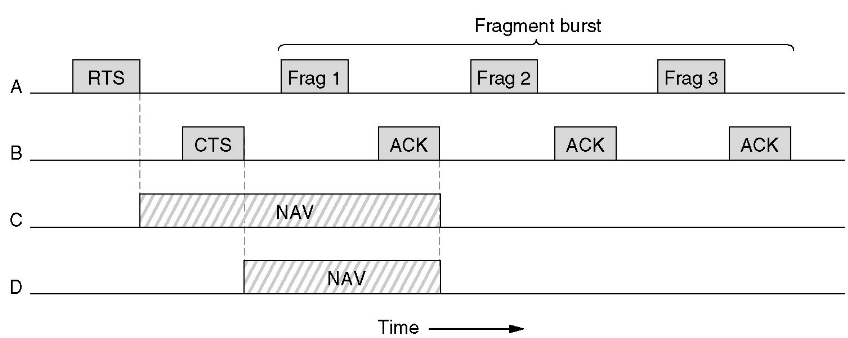
A wants to send data to B. C is within A's range and D is within B's range but not within A's range.



The use of virtual channel sensing using CSMA/CA (MACA).

How C and D knows how long to set NAV (network allocation vector)?

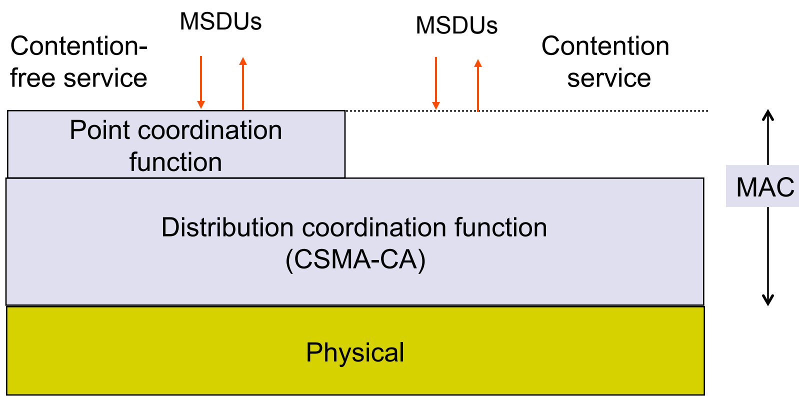
- **If a frame is too long, very little of chance getting through undamaged and will probably have to be retransmitted**
  - **802.11 allows frames to be fragmented to smaller pieces, each individually sequenced and acked with Stop&Wait**
    - **A fragment burst after a RTS/CTS**



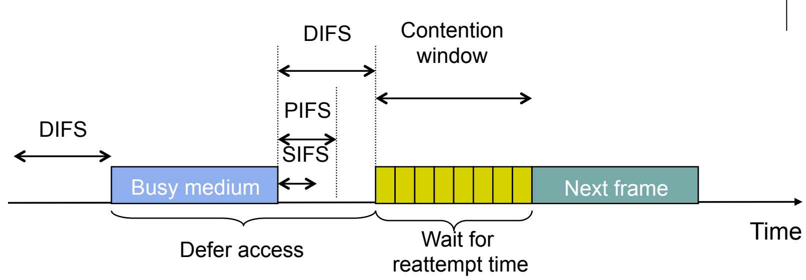
How to guarantee the burst transfer will complete?

IEEE 802.11 MAC Services

- Contention Service: Best effort
- Contention-Free Service: time-bounded transfer (controlled by AP)
- MAC can alternate between Contention Periods (CPs) & Contention-Free Periods (CFPs)

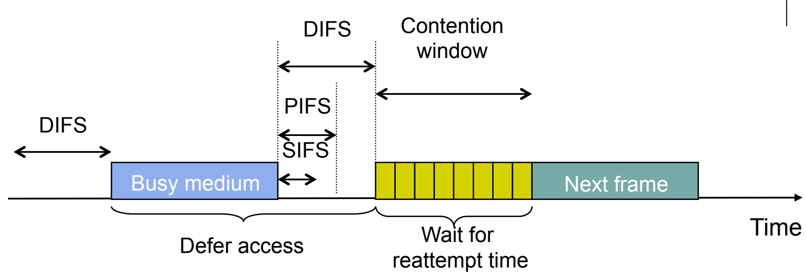


Distributed Coordination Function (DCF)



- DCF provides basic access service
  - Asynchronous best-effort data transfer
  - All stations contend for access to medium
- CSMA-CA
  - Ready stations wait for completion of transmission
  - All stations must wait *Interframe Space (IFS)*

Priorities through Interframe Spacing

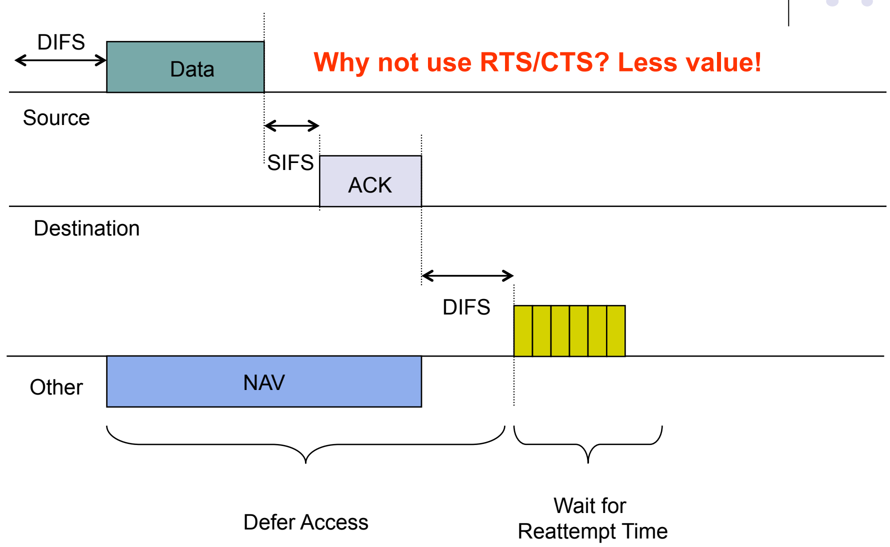


- High-Priority frames wait Short IFS (SIFS)
  - Typically to complete exchange in progress
  - ACKs, CTS, data frames of *segmented MSDU*, etc.
- PCF IFS (PIFS) to initiate Contention-Free Periods
- DCF IFS (DIFS) to transmit data & MPDUs
- EIFS for receiver to recover a bad frame

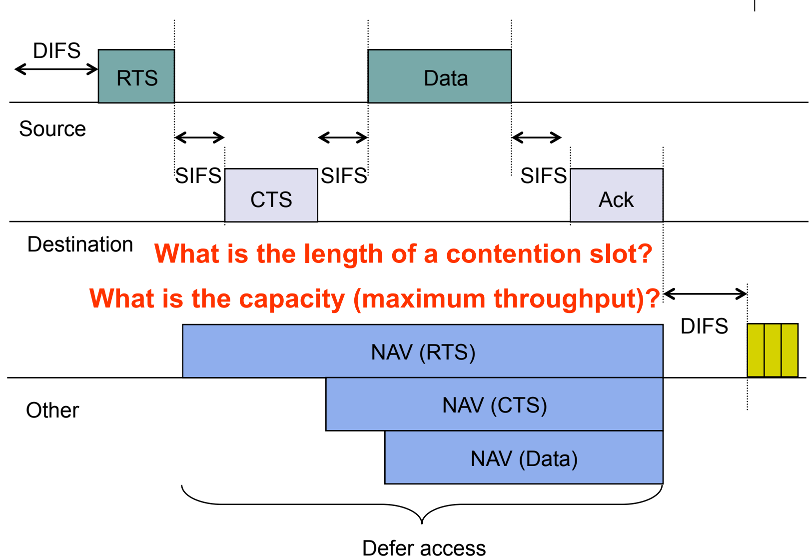
Contention & Backoff Behavior

- If channel is still idle after DIFS period, ready station can transmit an *initial* MPDU
- If channel becomes busy before DIFS, then station must schedule *backoff* time for reattempt
  - Backoff period is integer # of *idle contention time slots*
  - Waiting station monitors medium & decrements backoff timer each time an idle contention slot transpires
  - Station can contend when backoff timer expires
- A station that completes a frame transmission is not allowed to transmit immediately
  - Must first perform a backoff procedure

Transmission of MPDU without RTS/CTS



Transmission of MPDU with RTS/CTS



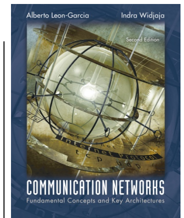
Collisions, Losses & Errors

- Collision Avoidance
  - When station senses channel busy, it waits until channel becomes idle for DIFS period & then begins random backoff time (in units of idle slots)
  - Station transmits frame when backoff timer expires
  - If collision occurs (how to know it?), recompute backoff over interval that is twice as long
- Receiving stations of error-free frames send ACK
  - Sending station interprets non-arrival of ACK as loss
  - Executes backoff and then retransmits
  - Receiving stations use sequence numbers to identify duplicate frames

Point Coordination Function

- PCF provides connection-oriented, contention-free service through *polling*
- *Point coordinator (PC)* in AP performs PCF
- Polling table up to implementor
- CFP repetition interval
  - Determines frequency with which CFP occurs
  - Initiated by *beacon frame* transmitted by PC in AP
  - Contains CFP and CP
  - During CFP stations may only transmit to respond to a poll from PC or to send ACK

Chapter 6
Medium Access Control Protocols and Local Area Networks



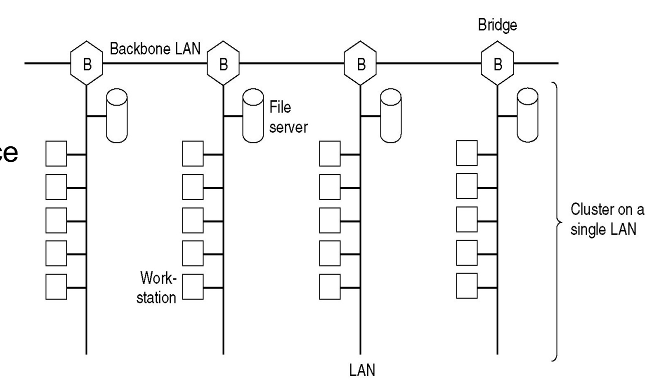
LAN Bridges

Data Link Layer Switching

Data Link Layer Switching

Multiple LANs connected by a backbone to handle a total load higher than the capacity of a single LAN.

- organizations
- geography
- Load sharing
- Longer distance
- Security

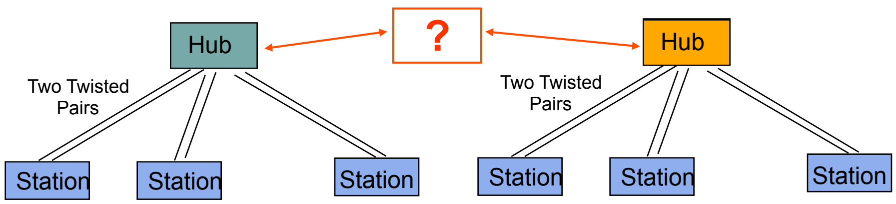


Hubs, Bridges & Routers

- 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

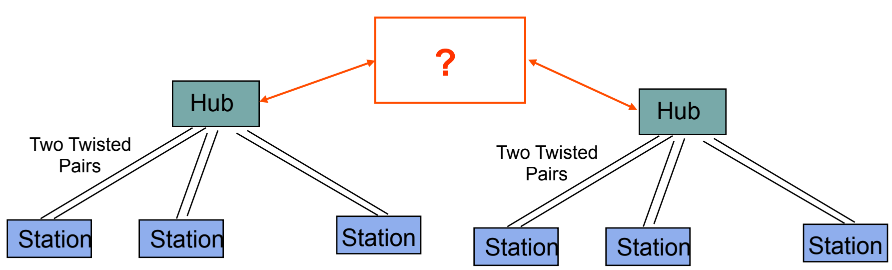
Hubs are for different types of LANs



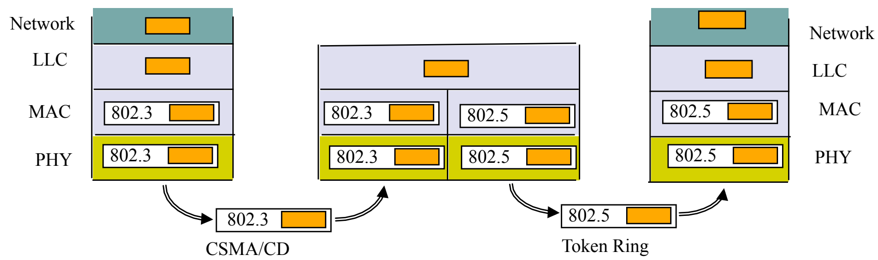
Hubs, Bridges & Routers

- 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

Higher Scalability

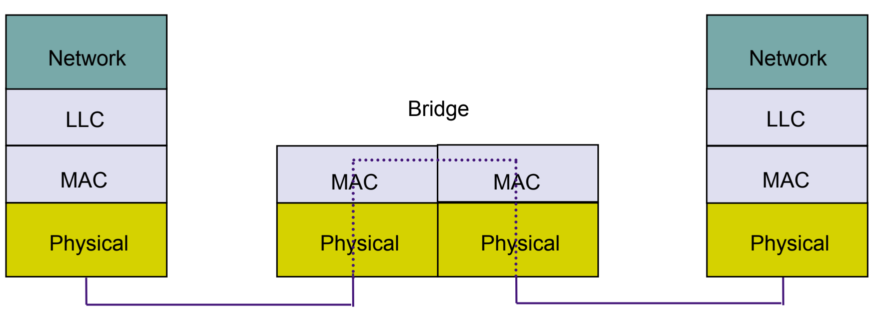


General Bridge Issues



- 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; security
  - Difference in maximum frame length

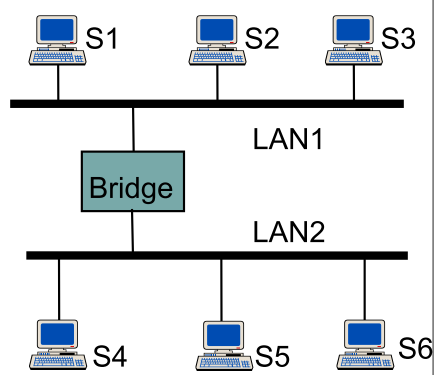
Bridges of Same Type



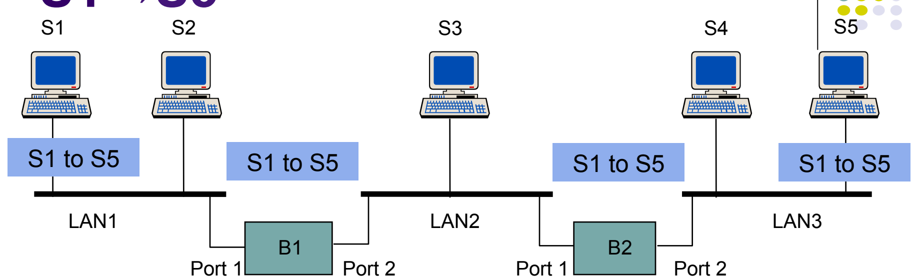
- Common case involves LANs of same type
- Bridging is done at MAC level

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



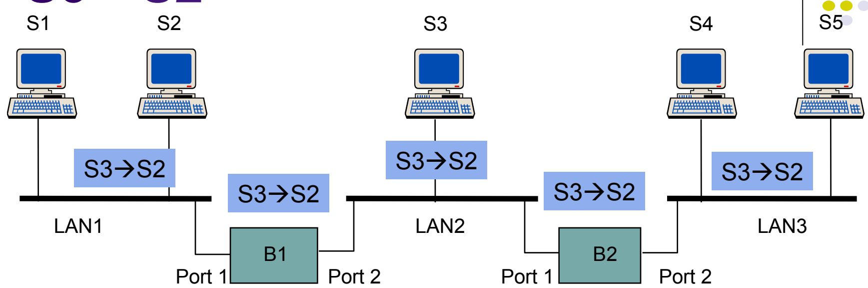
S1→S5



Address	Port
S1	1

Address	Port
S1	1

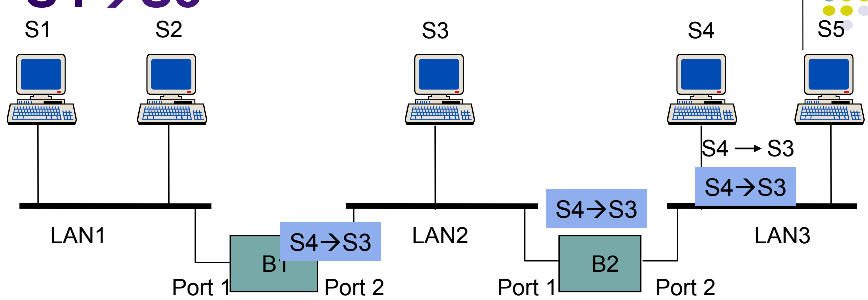
S3→S2



Address	Port
S1	1
S3	2

Address	Port
S1	1
S3	1

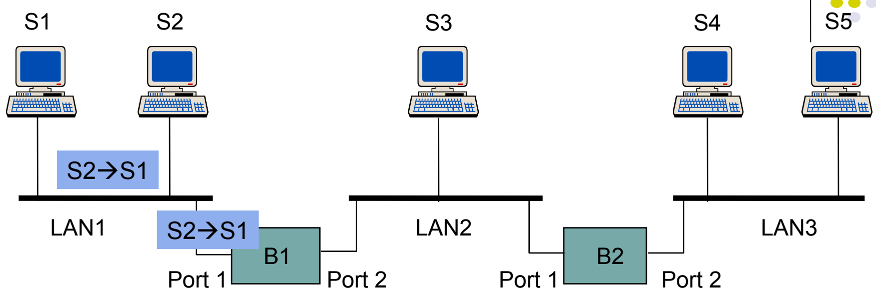
S4→S3



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

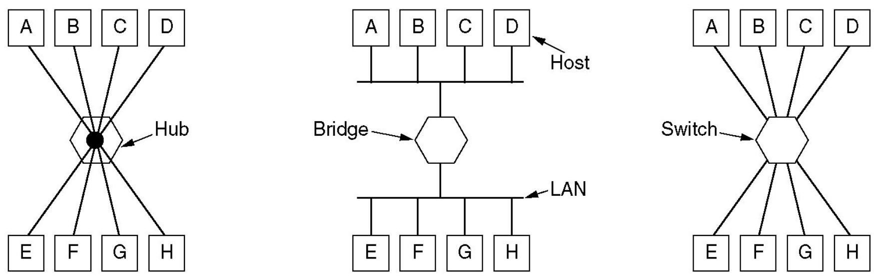
Address	Port
S1	1
S3	1
S4	2

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

What to do if "Loop" bridges? What is a spanning tree?

Repeaters, Hubs, Bridges, Switches, Routers and Gateways



(a) A hub. (b) A bridge. (c) a switch.

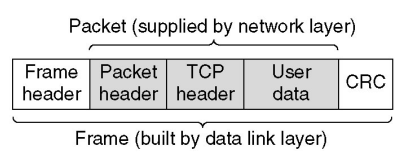
Cut-through switches vs. store-and-forward switches

How about collision domain?

Repeaters, Hubs, Bridges, Switches, Routers and Gateways

Application layer	Application gateway
Transport layer	Transport gateway
Network layer	Router
Data link layer	Bridge, switch
Physical layer	Repeater, hub

(a)



(b)

(a) Which device is in which layer.
(b) Frames, packets, and headers.