CSCI 460
Networks and Communications

Medium Access Control Sublayer

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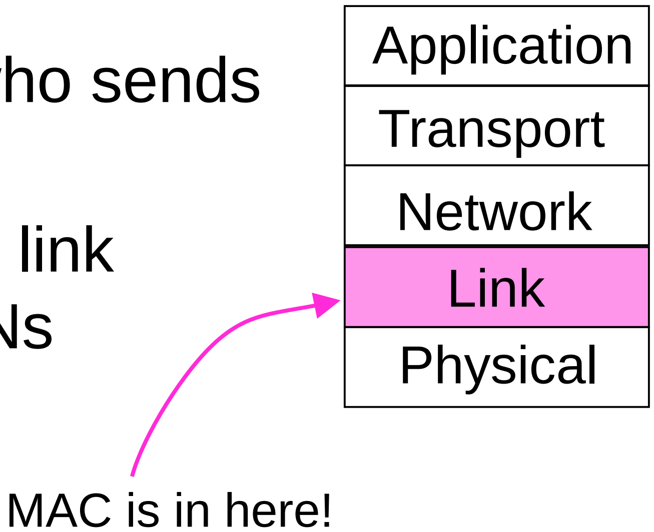
Outline

- Channel Allocation Problem
- Multiple Access Protocols
  - Pure and Slotted ALOHA
  - Carrier Sense Multiple Access (CSMA)
  - CSMA with Collision Detection (CSMA/CD)
  - Binary Exponential Backoff Algorithm
  - CSMA with Collision Avoidance (CSMA/CA)
- Ethernet and WiFi
- Repeaters, Hubs, Bridges, and Switches

The MAC Sublayer

Responsible for deciding who sends next on a multi-access link

- An important part of the link layer, especially for LANs



Channel Allocation Problem

For fixed channel and traffic from N users

- Divide up bandwidth using FDM, TDM, CDMA, etc.
- This is a static allocation, e.g., FM radio

This static allocation performs poorly for bursty traffic

- Allocation to a user will sometimes go unused

Channel Allocation Problem

Dynamic allocation gives the channel to a user when they need it. Potentially N times as efficient for N users.

Schemes vary with assumptions:

Assumption	**Implication**
Independent traffic	Often not a good model, but permits analysis
Single channel	No external way to coordinate senders
Observable collisions	Needed for reliability; mechanisms vary
Continuous or slotted time	Slotting may improve performance
Carrier sense	Can improve performance if available

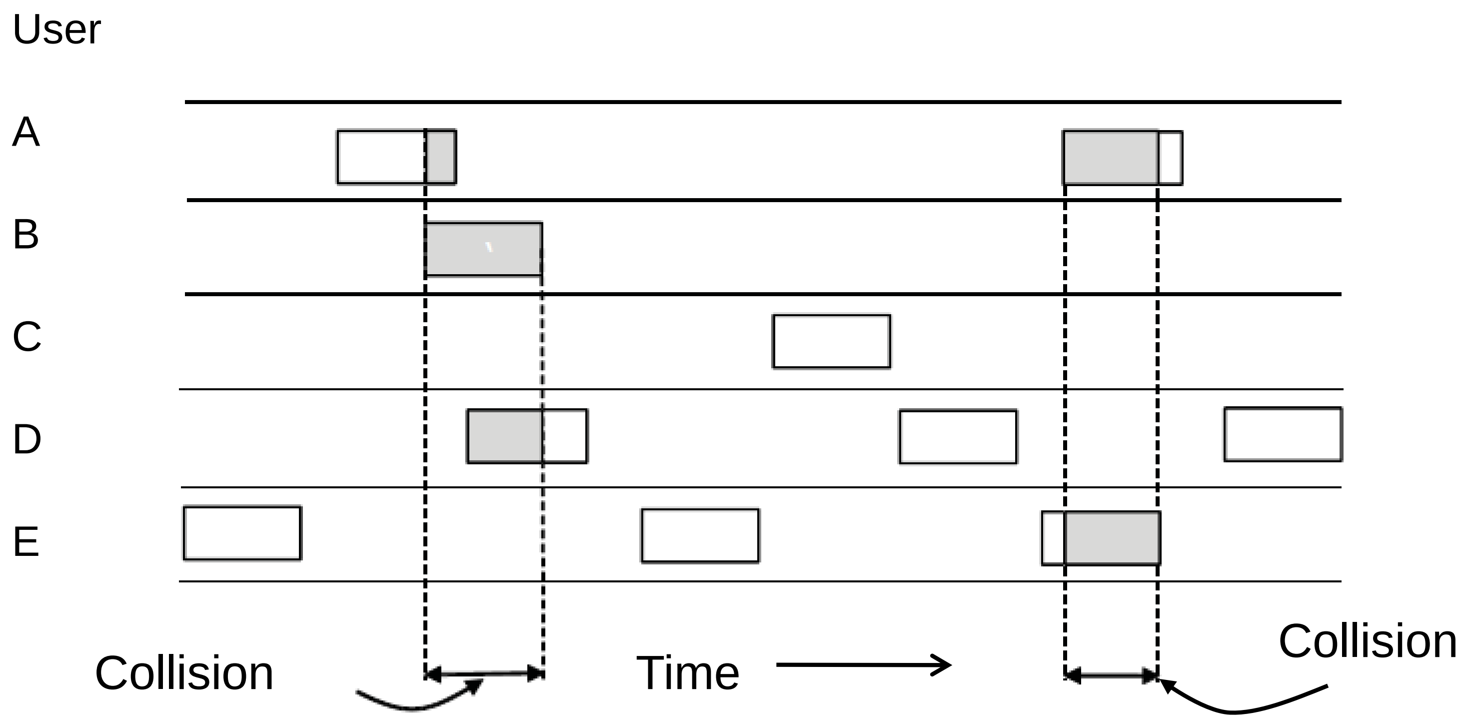
Multiple Access Protocols

- ALOHA »
- CSMA (Carrier Sense Multiple Access) »
- Collision-free protocols »
- Limited-contention protocols »
- Wireless LAN protocols »

ALOHA

In pure ALOHA, users transmit frames whenever they have data; users retry after a random time for collisions

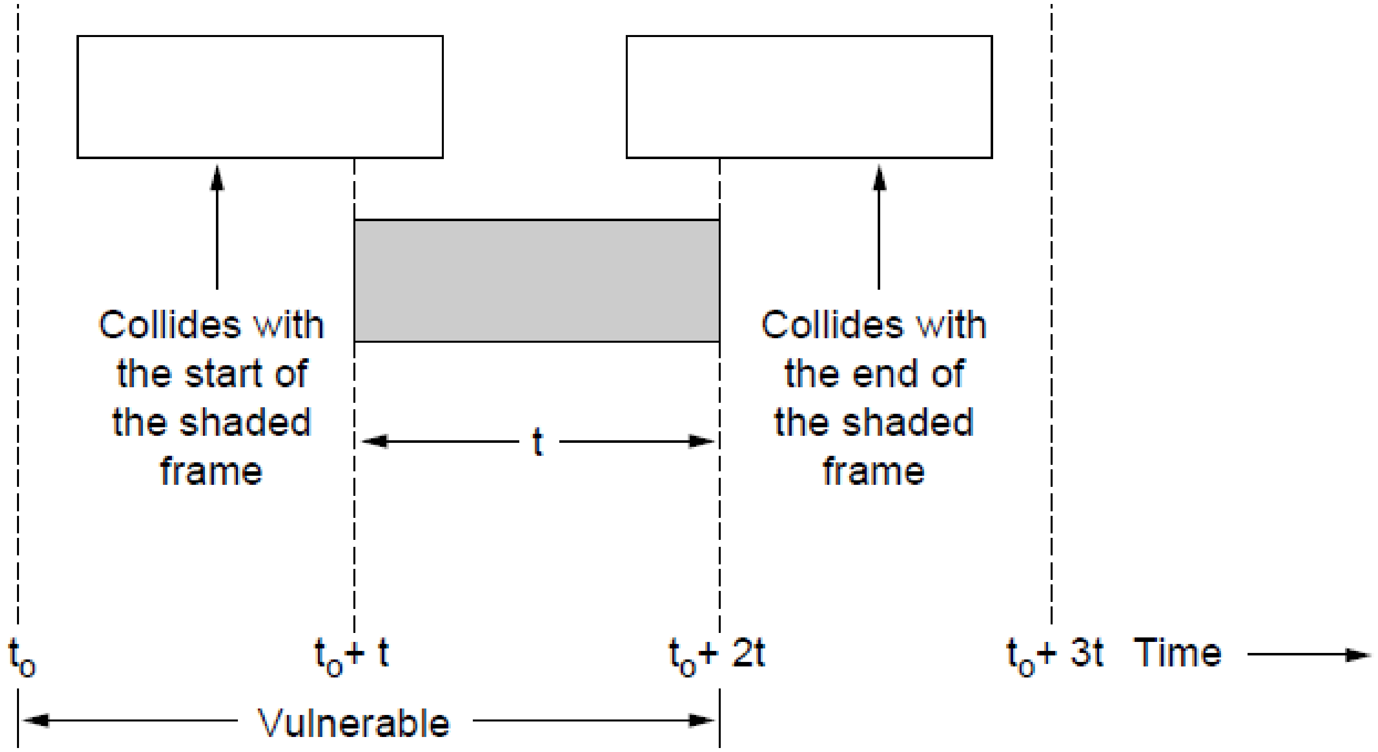
- Efficient and low-delay under low load



ALOHA

Collisions happen when other users transmit during a vulnerable period that is twice the frame time

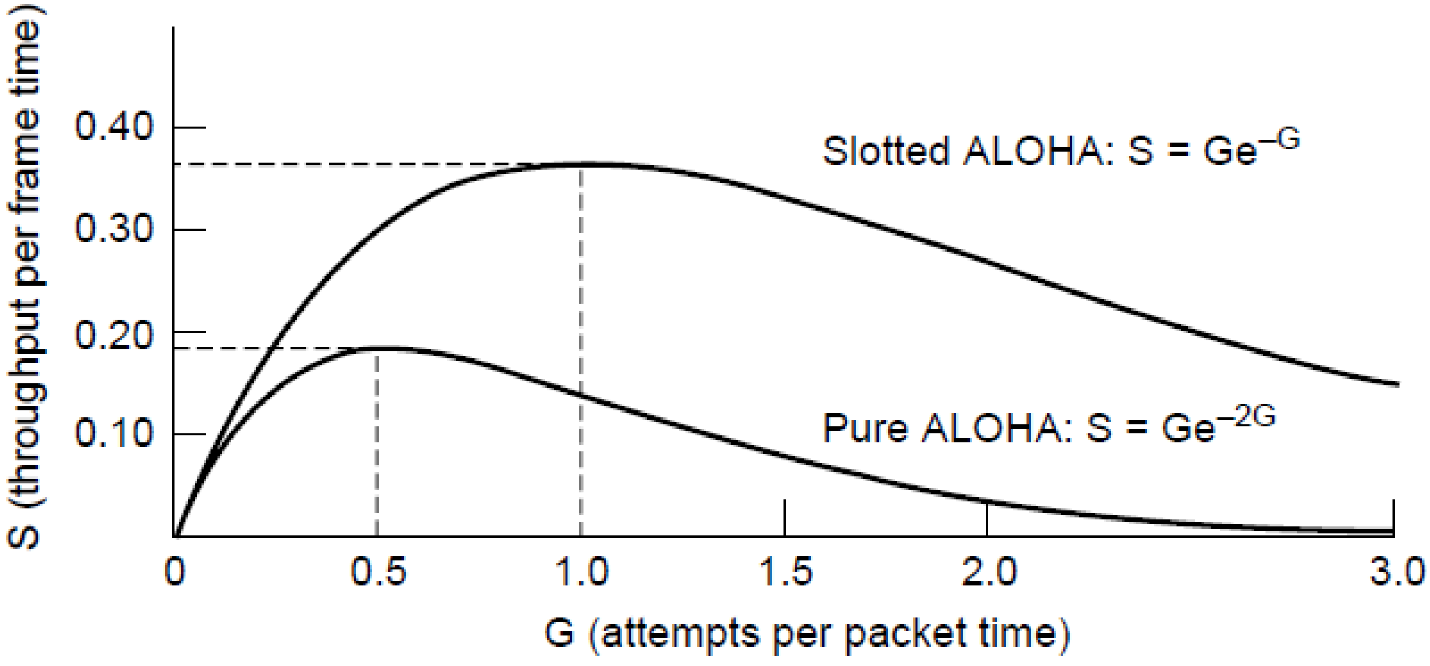
- Synchronizing senders to slots can reduce collisions



ALOHA

Slotted ALOHA is twice as efficient as pure ALOHA

- Low load wastes slots, high loads causes collisions
- Efficiency up to 1/e (37%) for random traffic models



CSMA

CSMA improves on ALOHA by sensing the channel!

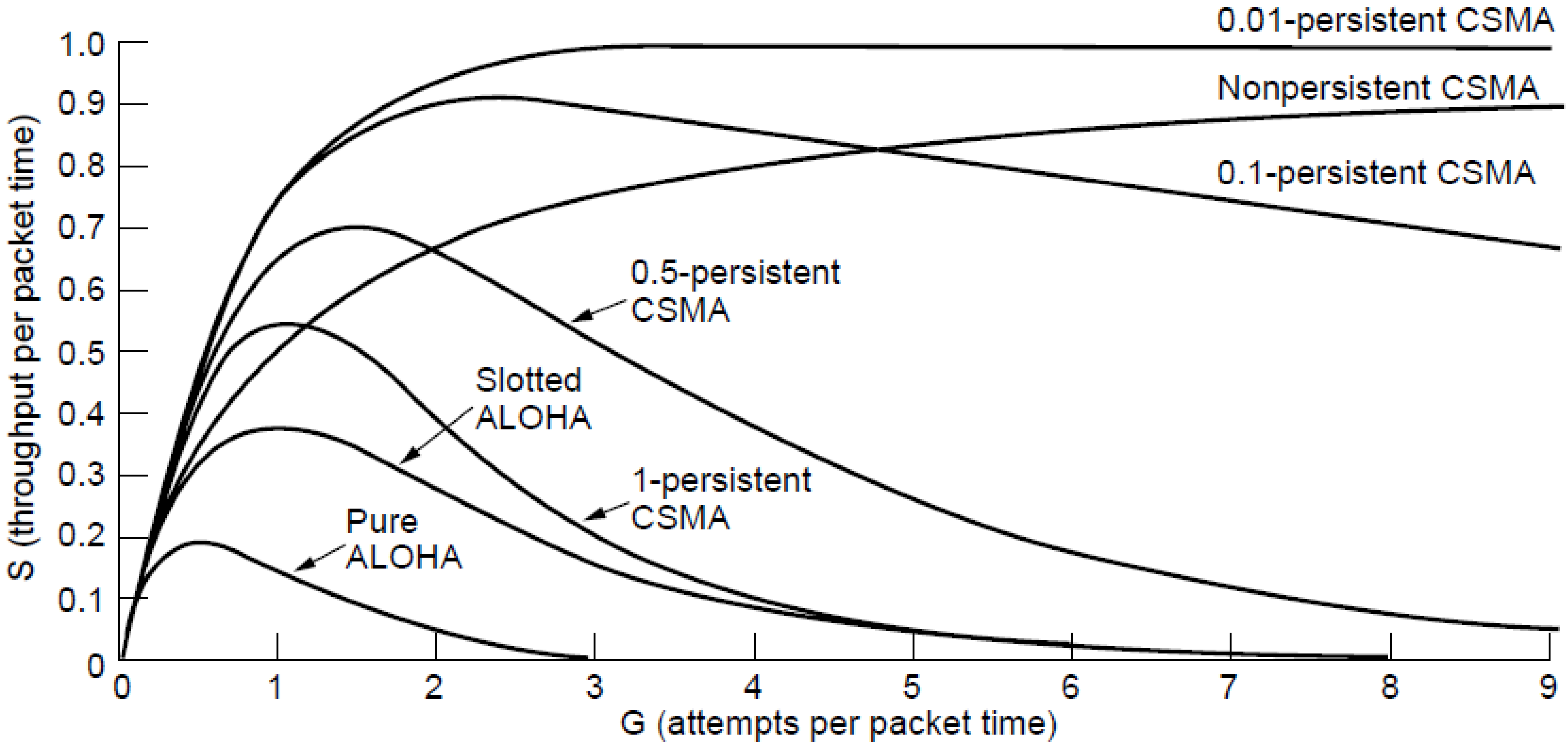
- User doesn’t send if it senses someone else

Variations on what to do if the channel is busy:

- 1-persistent (greedy) sends as soon as idle
- Nonpersistent waits a random time then tries again
- p-persistent sends with probability p when idle
  - Works on slotted time.
  - Repeats the algorithm in the next slot if it choses not to transmit in the current idle slot.
  - Waits for random time if idle slot is not found

CSMA– Persistence

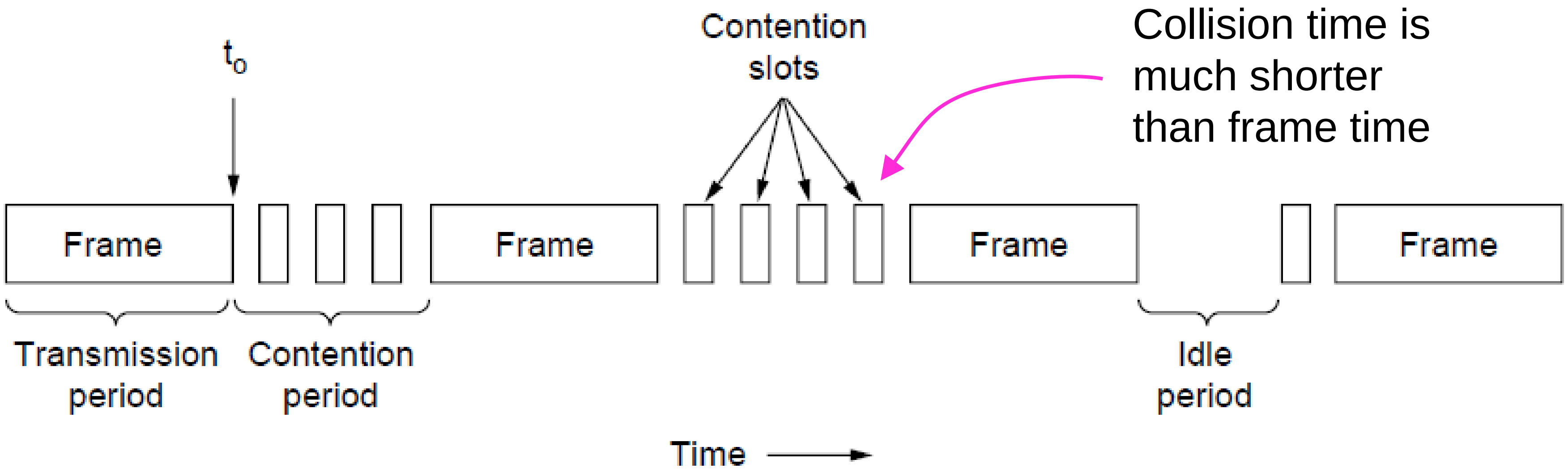
CSMA outperforms ALOHA, and being less persistent is better under high load



CSMA – Collision Detection

CSMA/CD improvement is to detect/abort collisions

- Reduced contention times improve performance



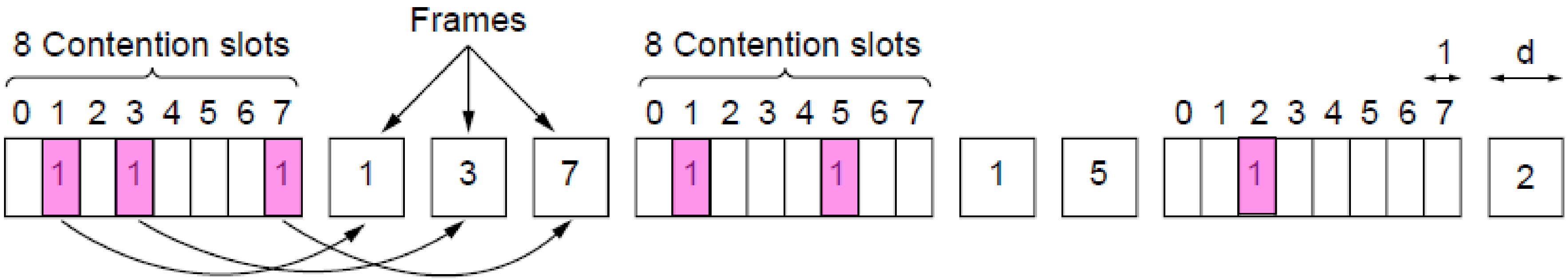
Collision-Free – Bitmap

Collision-free protocols avoid collisions entirely

- Senders must know when it is their turn to send

The basic bit-map protocol:

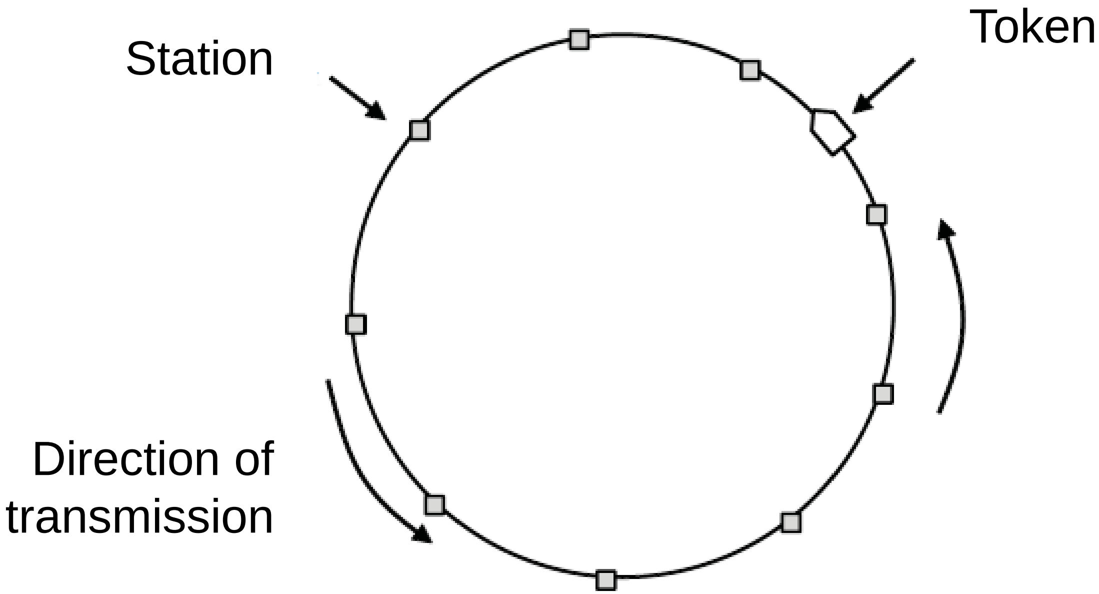
- Sender set a bit in contention slot if they have data
- Senders send in turn; everyone knows who has data



Collision-Free – Token Ring

Token sent round ring defines the sending order

- Station with token may send a frame before passing
- Idea can be used without ring too, e.g., token bus



Wireless LAN Protocols

Wireless has complications compared to wired.

Nodes may have different coverage regions

- Leads to hidden and exposed terminals

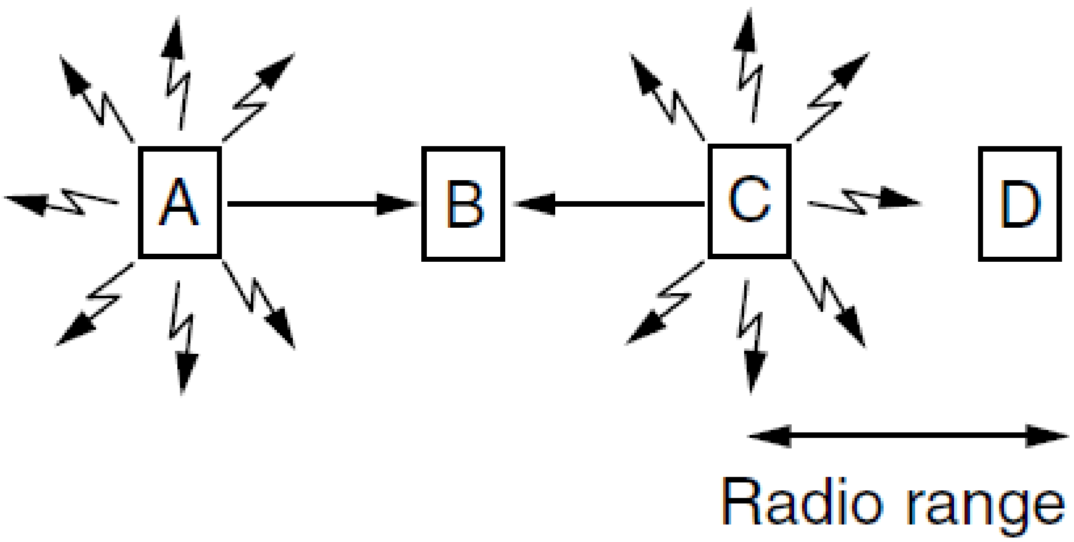
Nodes can’t detect collisions, i.e., sense while sending

- Makes collisions expensive and to be avoided

Wireless LANs – Hidden terminals

Hidden terminals are senders that cannot sense each other but nonetheless collide at intended receiver

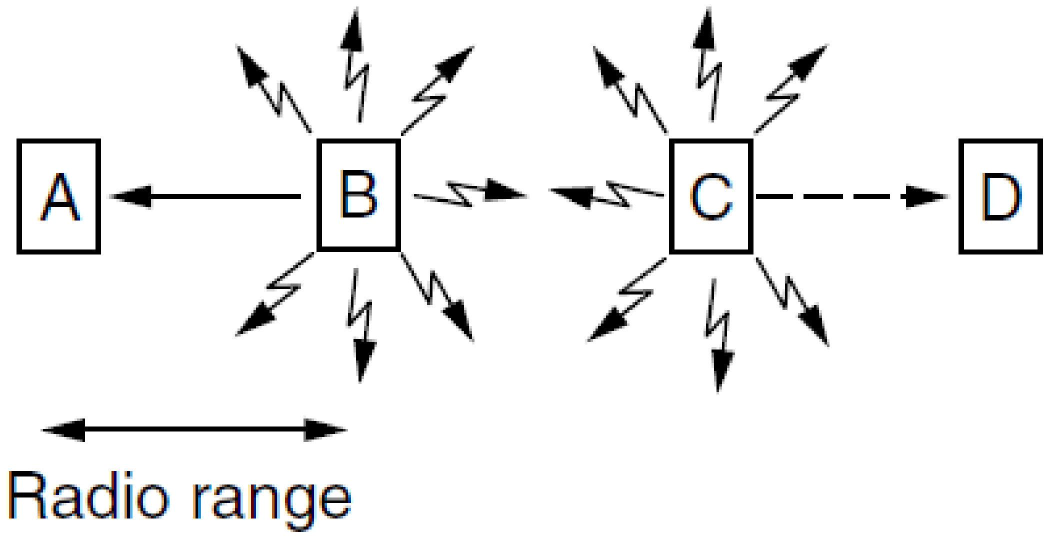
- Want to prevent; loss of efficiency
- A and C are hidden terminals when sending to B



Wireless LANs – Exposed terminals

Exposed terminals are senders who can sense each other but still transmit safely (to different receivers)

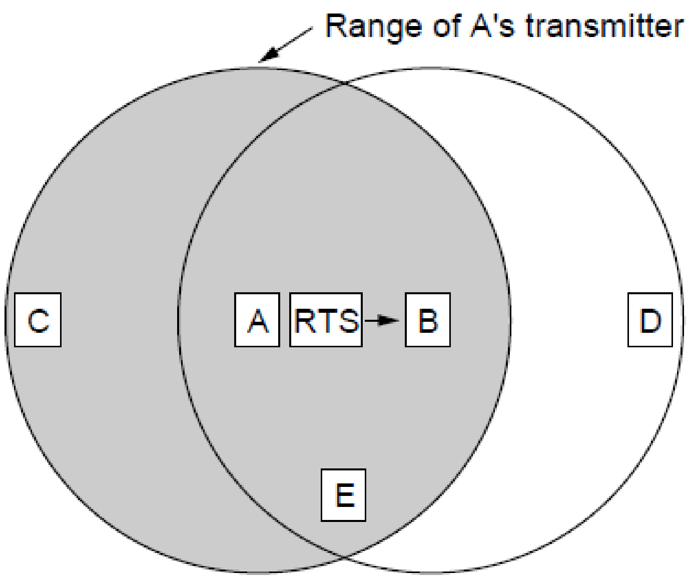
- Desirably concurrency; improves performance
- B → A and C → D are exposed terminals



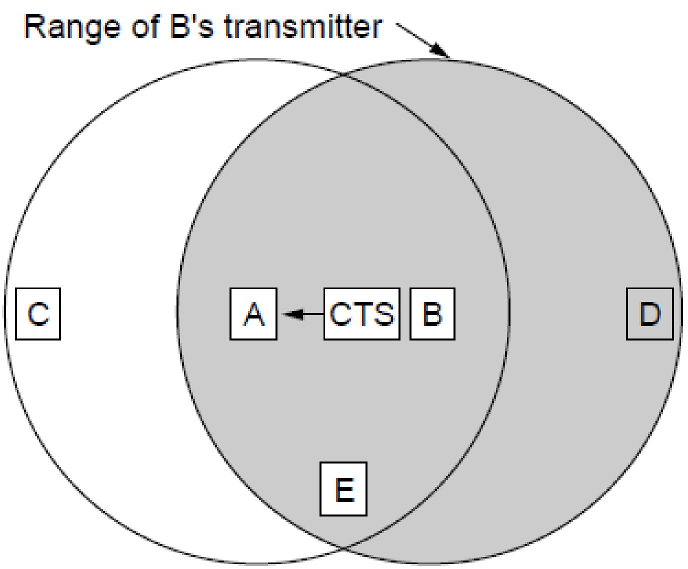
Wireless LANs – MACA

MACA protocol grants access for A to send to B:

- A sends RTS to B [left]; B replies with CTS [right]
- A can send with exposed but no hidden terminals



A sends RTS to B; C and E hear and defer for CTS



B replies with CTS; D and E hear and defer for data

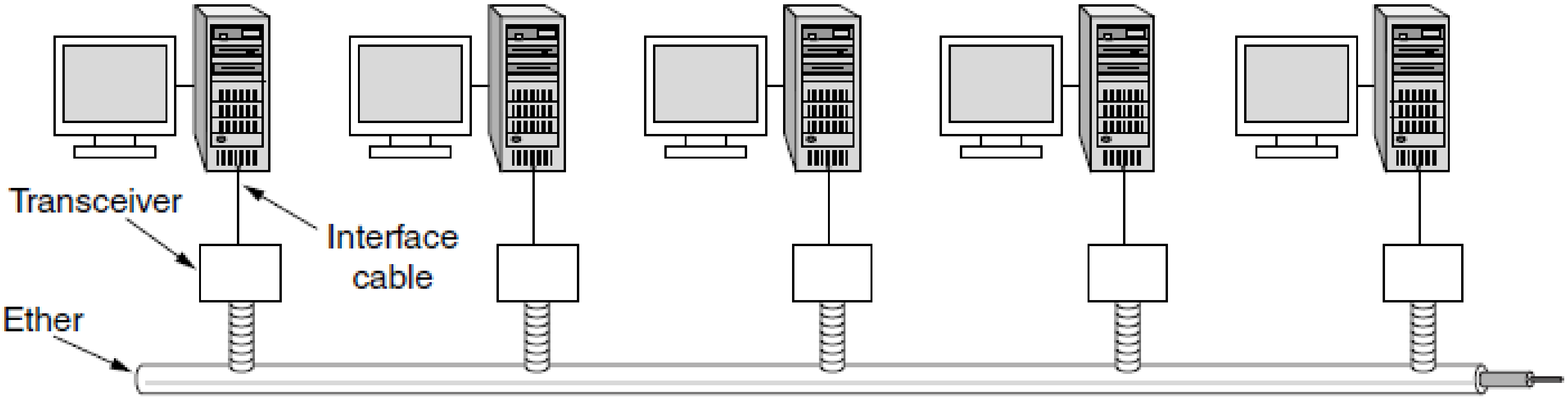
Ethernet

- Classic Ethernet »
- Switched/Fast Ethernet »
- Gigabit/10 Gigabit Ethernet »

Classic Ethernet – Physical Layer

One shared coaxial cable to which all hosts attached

- Up to 10 Mbps, with Manchester encoding
- Hosts ran the classic Ethernet protocol for access



Classic Ethernet – MAC

MAC protocol is 1-persistent CSMA/CD (earlier)

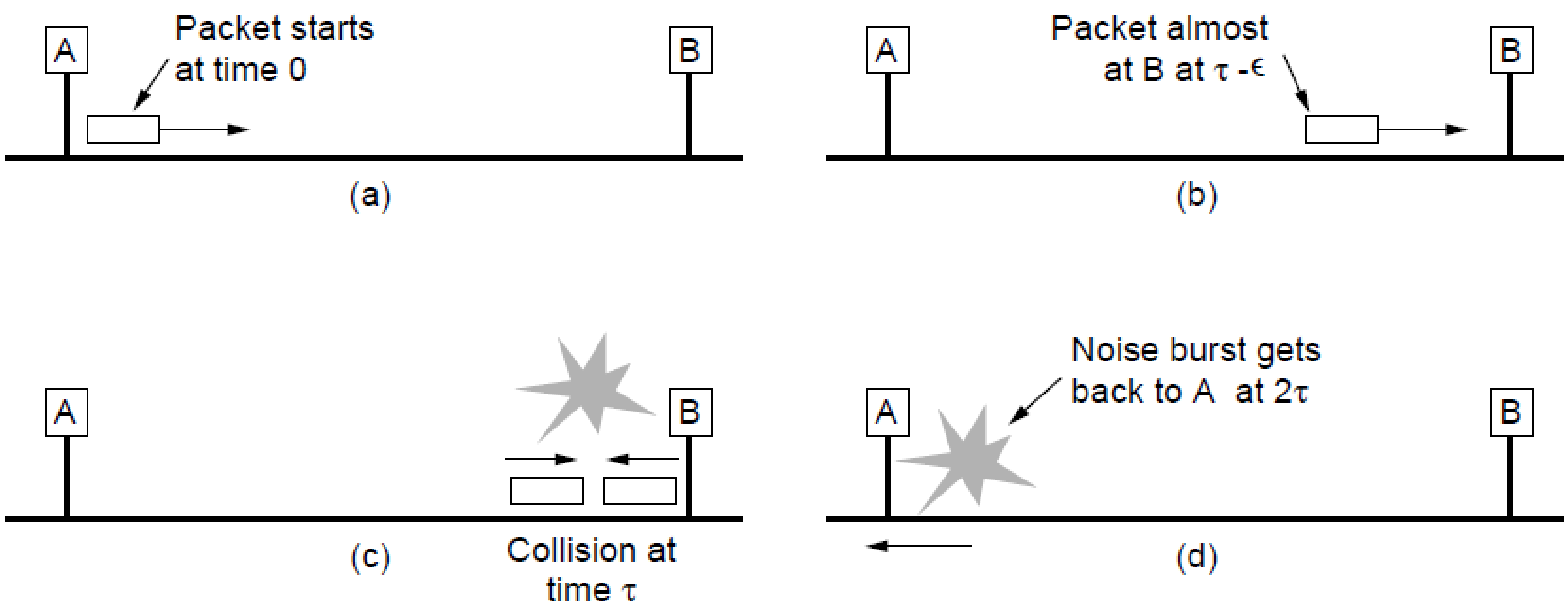
- Random delay (backoff) after collision is computed with BEB (Binary Exponential Backoff)
- Frame format is still used with modern Ethernet.

Bytes	8		6	6	2	0-1500	0-46	4
Ethernet (DIX)	Preamble		Destination address	Source address	Type	Data	Pad	Check-sum
IEEE 802.3	Preamble	SoF	Destination address	Source address	Length	Data	Pad	Check-sum

Classic Ethernet – MAC

Collisions can occur and take as long as 2τ to detect

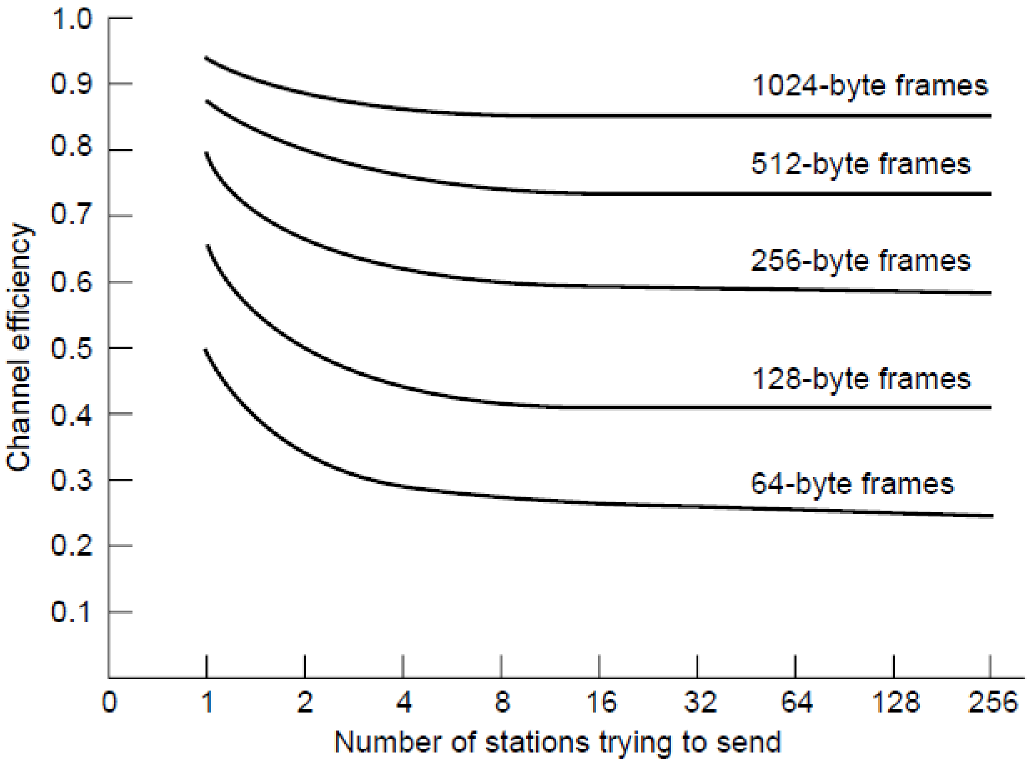
- τ is the time it takes to propagate over the Ethernet
- Leads to minimum packet size for reliable detection



Classic Ethernet – Performance

Efficient for large frames, even with many senders

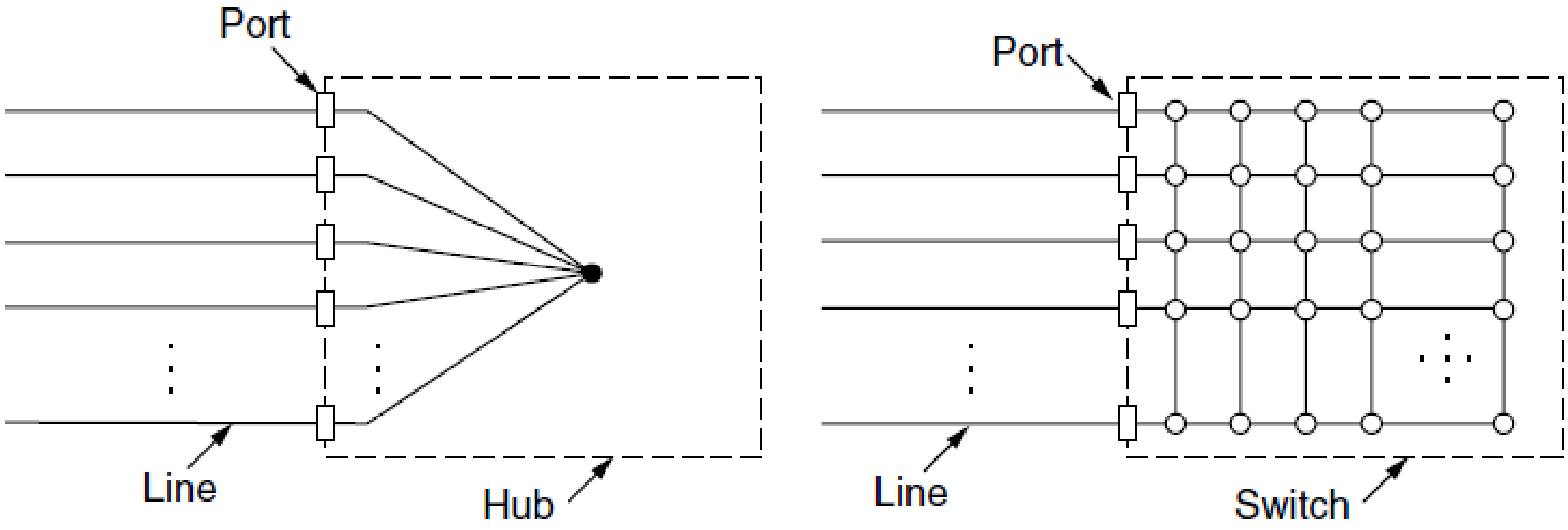
- Degrades for small frames (and long LANs)



10 Mbps Ethernet,
64 byte min. frame

Switched/Fast Ethernet

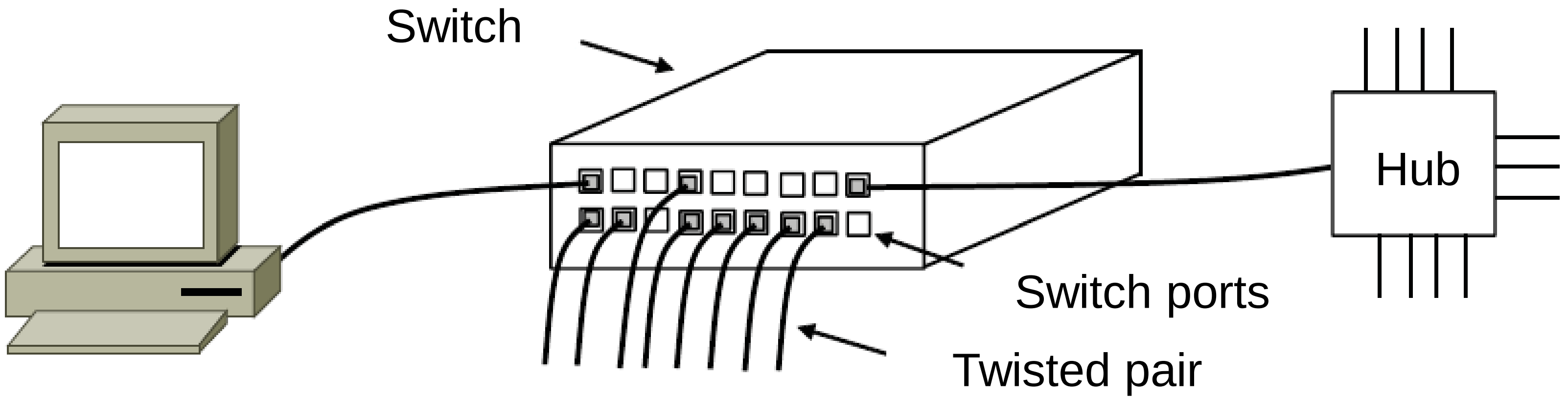
- Hubs wire all lines into a single CSMA/CD domain
- Switches isolate each port to a separate domain
  - Much greater throughput for multiple ports
  - No need for CSMA/CD with full-duplex lines



Switched/Fast Ethernet

Switches can be wired to computers, hubs and switches

- Hubs concentrate traffic from computers
- Switch does not concentrate frames but switches frames from source to destination.
- How to switch frames?



Switched/Fast Ethernet

Fast Ethernet extended Ethernet from 10 to 100 Mbps

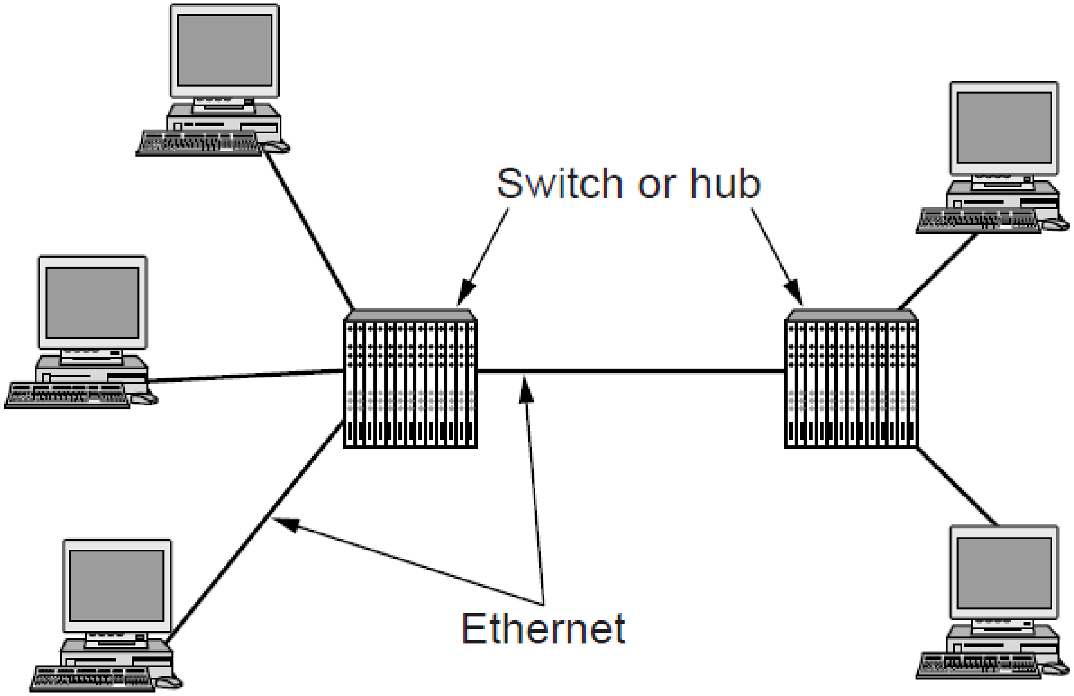
- Twisted pair (with Cat 5) dominated the market

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps (Cat 5 UTP)
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

Gigabit / 10 Gigabit Ethernet

Switched Gigabit Ethernet is now the garden variety

- With full-duplex lines between computers/switches



Gigabit / 10 Gigabit Ethernet

- Gigabit Ethernet is commonly run over twisted pair

Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

- 10 Gigabit Ethernet is being deployed where needed

Name	Cable	Max. segment	Advantages
10GBase-SR	Fiber optics	Up to 300 m	Multimode fiber (0.85μ)
10GBase-LR	Fiber optics	10 km	Single-mode fiber (1.3μ)
10GBase-ER	Fiber optics	40 km	Single-mode fiber (1.5μ)
10GBase-CX4	4 Pairs of twinax	15 m	Twinaxial copper
10GBase-T	4 Pairs of UTP	100 m	Category 6a UTP

- 40/100 Gigabit Ethernet is under development

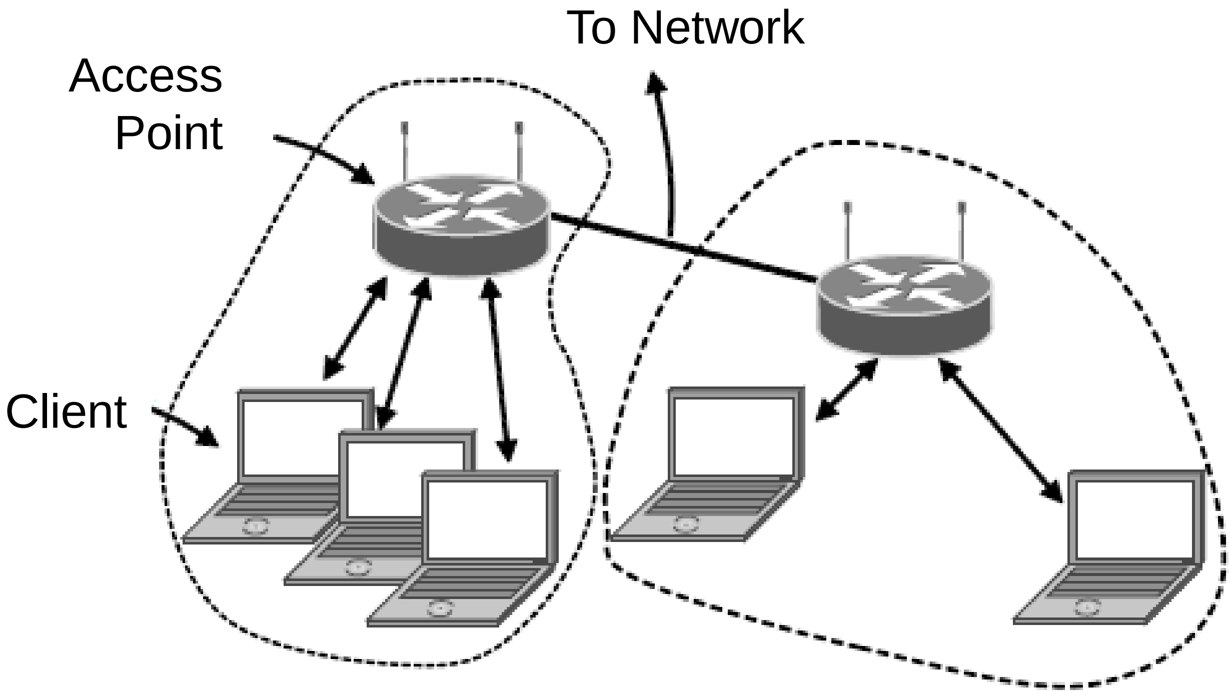
Wireless LANs

- 802.11 architecture/protocol stack »
- 802.11 physical layer »
- 802.11 MAC »
- 802.11 frames »

802.11 Architecture/Protocol Stack

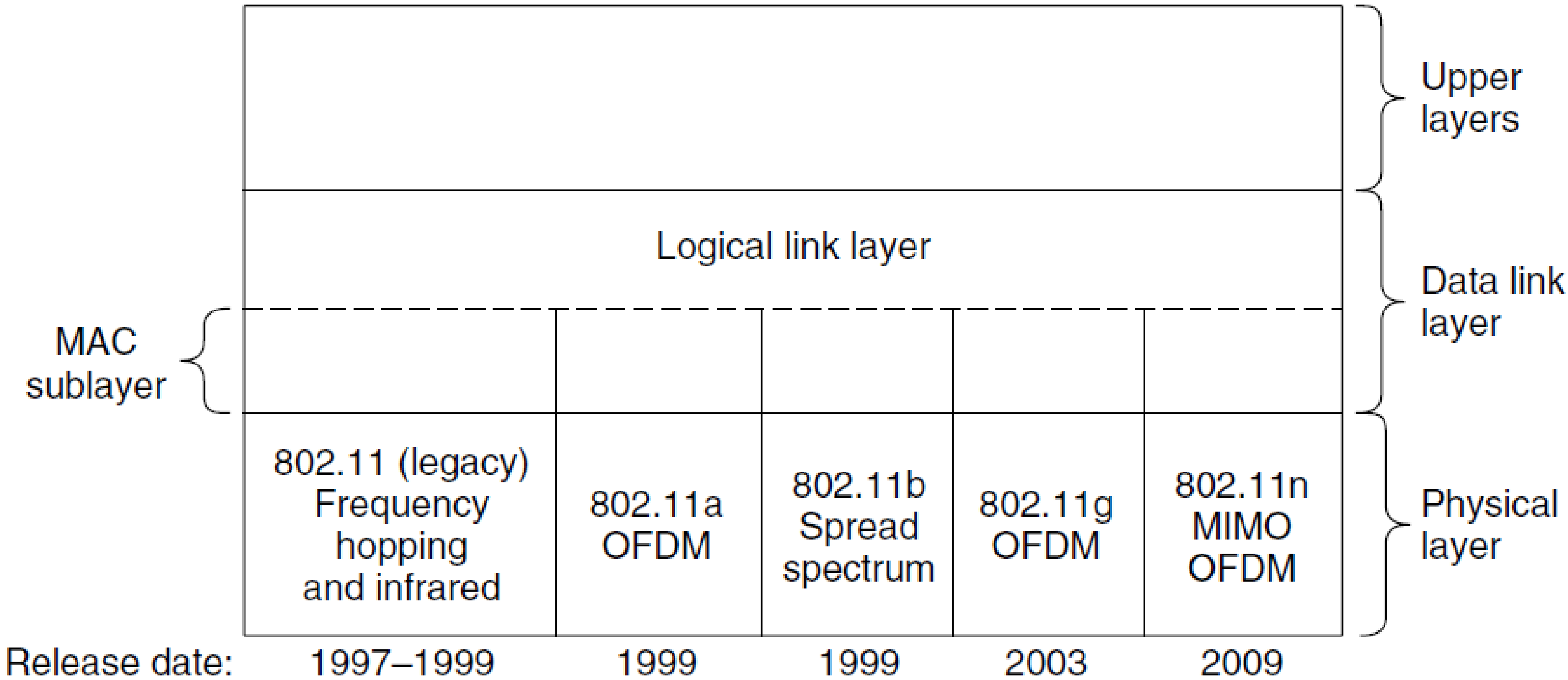
Wireless clients associate to a wired AP (Access Point)

- Called infrastructure mode; there is also ad-hoc mode with no AP, but that is rare.



802.11 Architecture/Protocol Stack

MAC is used across different physical layers



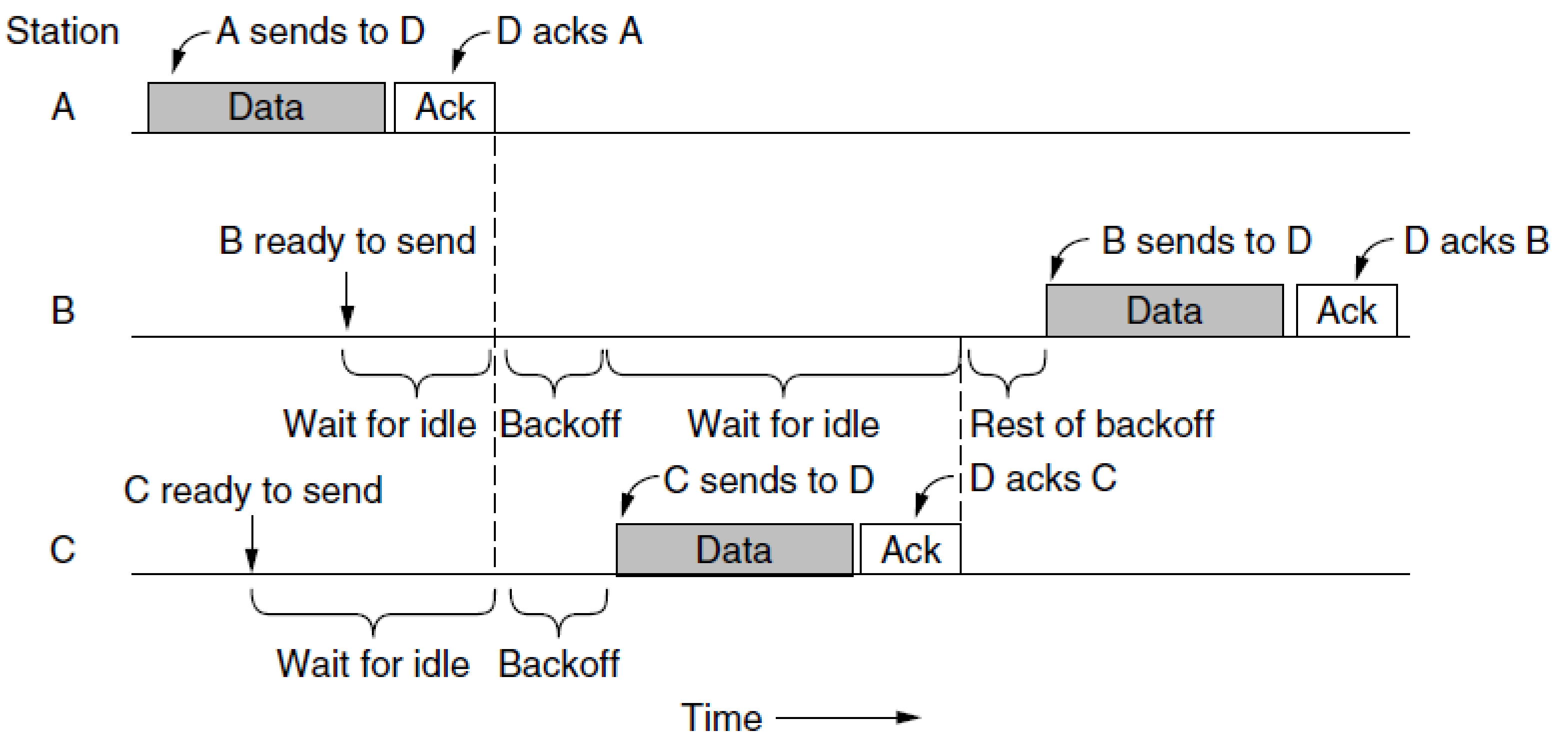
802.11 physical layer

- NICs are compatible with multiple physical layers
  - E.g., 802.11 a/b/g

Name	Technique	Max. Bit Rate
802.11b	Spread spectrum, 2.4 GHz	11 Mbps
802.11g	OFDM, 2.4 GHz	54 Mbps
802.11a	OFDM, 5 GHz	54 Mbps
802.11n	OFDM with MIMO, 2.4/5 GHz	600 Mbps

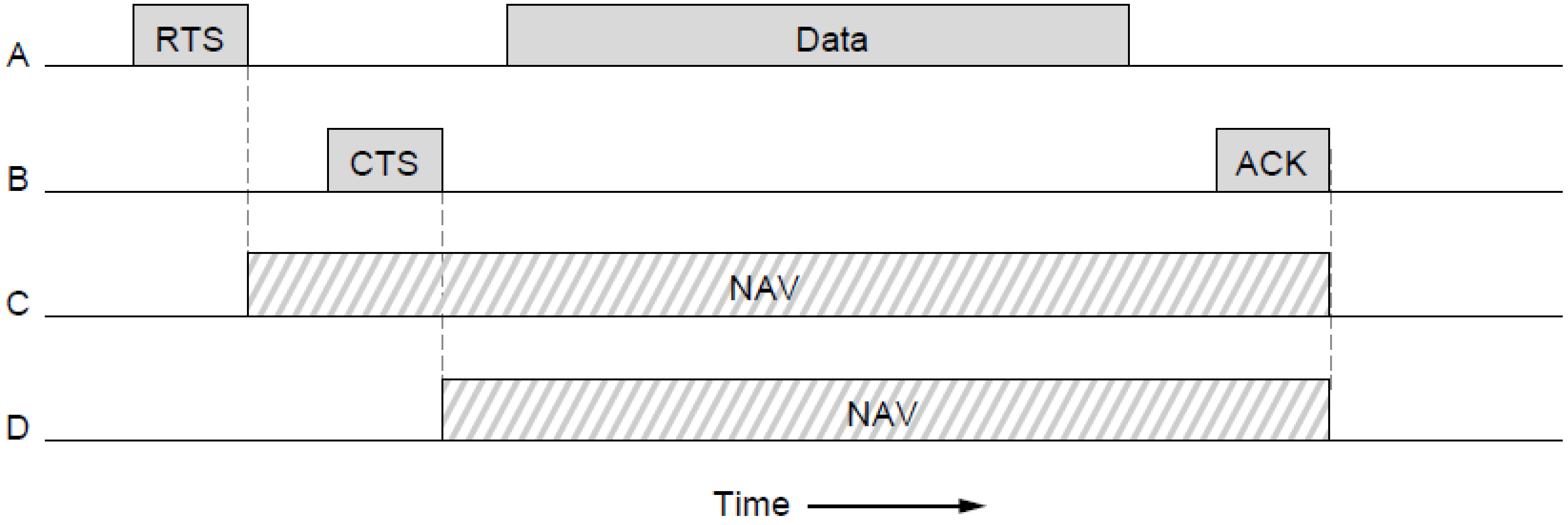
802.11 MAC

- CSMA/CA inserts backoff slots to avoid collisions
- MAC uses ACKs/retransmissions for wireless errors



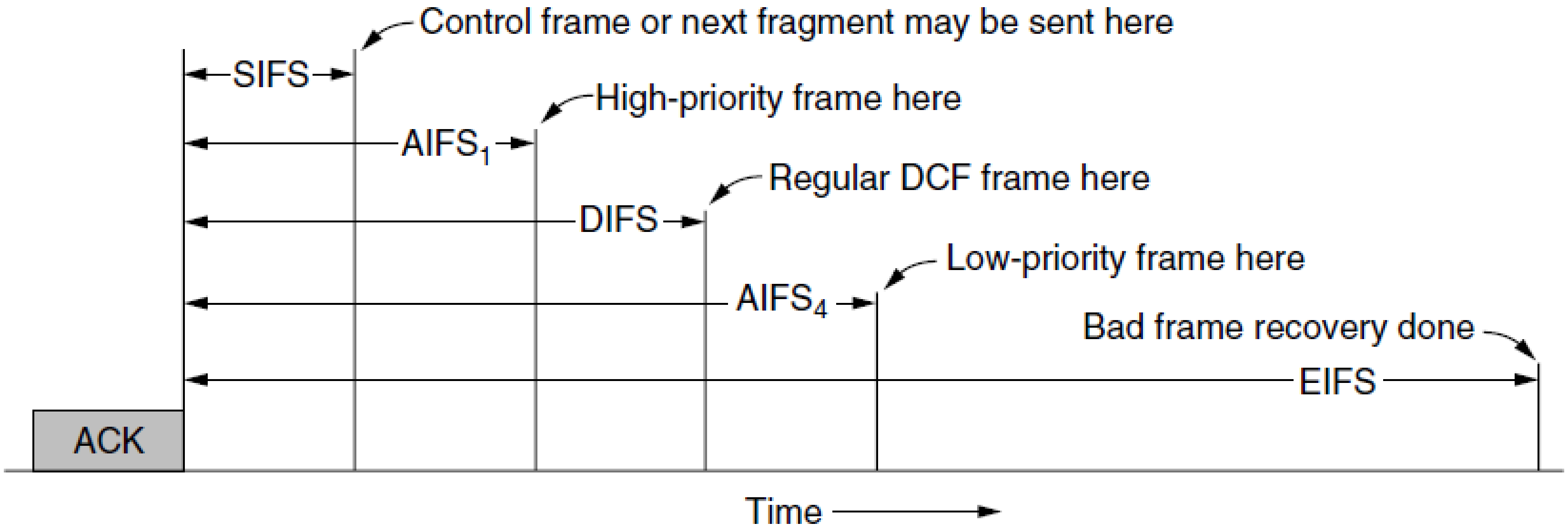
802.11 MAC

Virtual channel sensing with the NAV and optional RTS/CTS (often not used) avoids hidden terminals



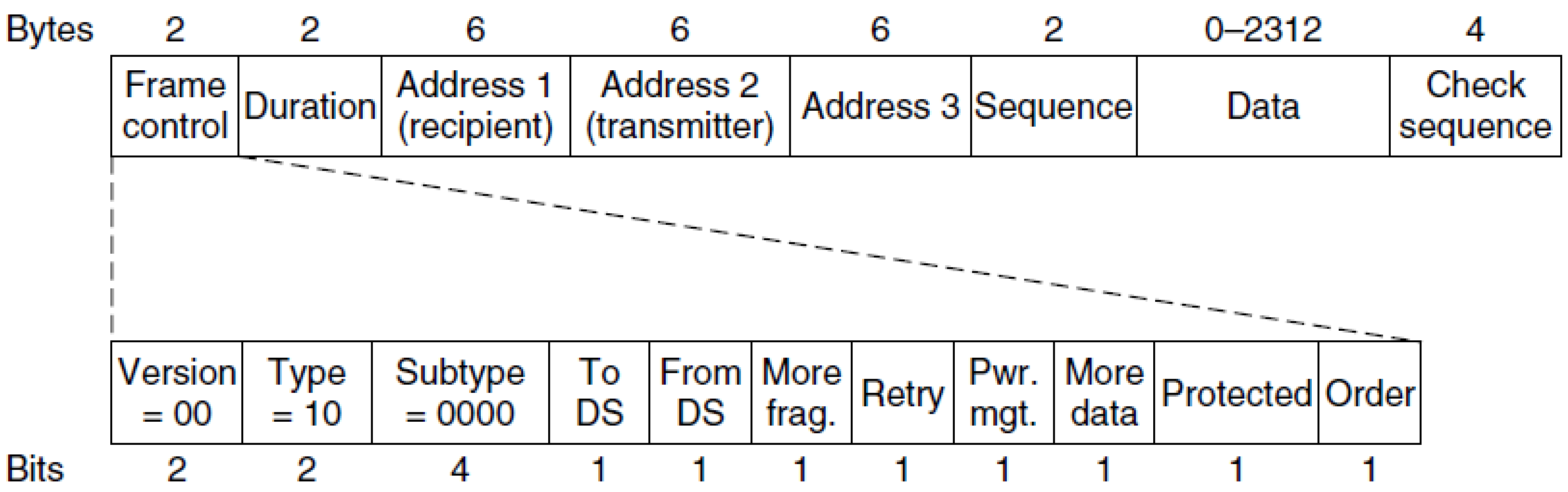
802.11 MAC

- Different backoff slot times add quality of service
  - Short intervals give preferred access, e.g., control, VoIP
- MAC has other mechanisms too, e.g., power save



802.11 Frames

- Frames vary depending on their type (Frame control)
- Data frames have 3 addresses to pass via APs



Summary

- Channel Allocation Problem
- Multiple Access Protocols
  - Pure and Slotted ALOHA
  - Carrier Sense Multiple Access (CSMA)
  - CSMA with Collision Detection (CSMA/CD)
  - Binary Exponential Backoff Algorithm
  - CSMA with Collision Avoidance (CSMA/CA)
- Ethernet and WiFi
- Repeaters, Hubs, Bridges, and Switches

Next: Network Layer

- Store and Forward Packet Switching
- Datagrams
- Routers
- Routing Algorithms
  - Shortest Path Routing
  - Distance Vector Routing
  - Link State Routing
- Internet Protocol (IP)
  - IP Packet
  - IP Address
  - Routing Information Protocol (RIP)
  - Open Shortest Path First Protocol (OSPF)
  - Address Resolution Protocol (ARP)
  - Dynamic Host Configuration Protocol (DHCP)
  - Network Address Translation (NAT)
  - Internet Control Message Protocol (ICMP)