ECE 363
Communication Networks

Medium Access Control Sublayer

Medium Access Control

- Type of links
  - Point-to-point links
    - e.g., PPP, switched Ethernet
  - Broadcast links (shared medium)
    - e.g., classic Ethernet, 802.11
    - Collisions occur when there is concurrent transmission
- Medium access
  - Static channel allocation: FDM/TDM/CDM
  - Dynamic channel allocation: ALOHA, CSMA, CSMA/CD

Static Channel Allocation

- Static allocation
  - Poor fit to systems with extremely bursty data traffic
  - Peak traffic to mean traffic ratios can be 1000:1
  - Most channels will be idle most of the time
- Dynamic allocation tries to resolve static allocation problems

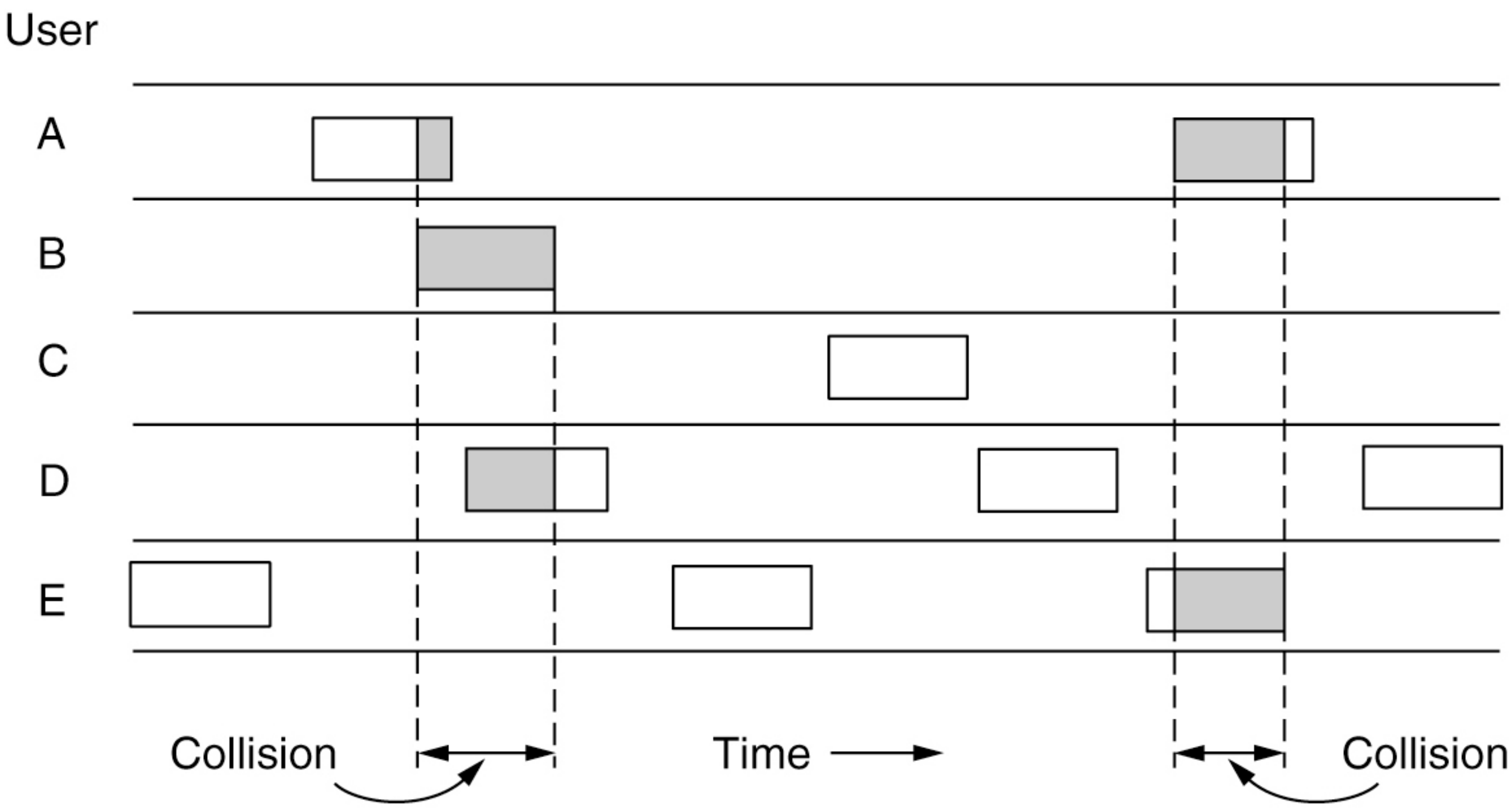
Assumptions for Dynamic Channel Allocation

- Independent traffic
- Single channel
- Observable collisions
- Continuous or slotted time
- Carrier sense or no carrier sense

ALOHA

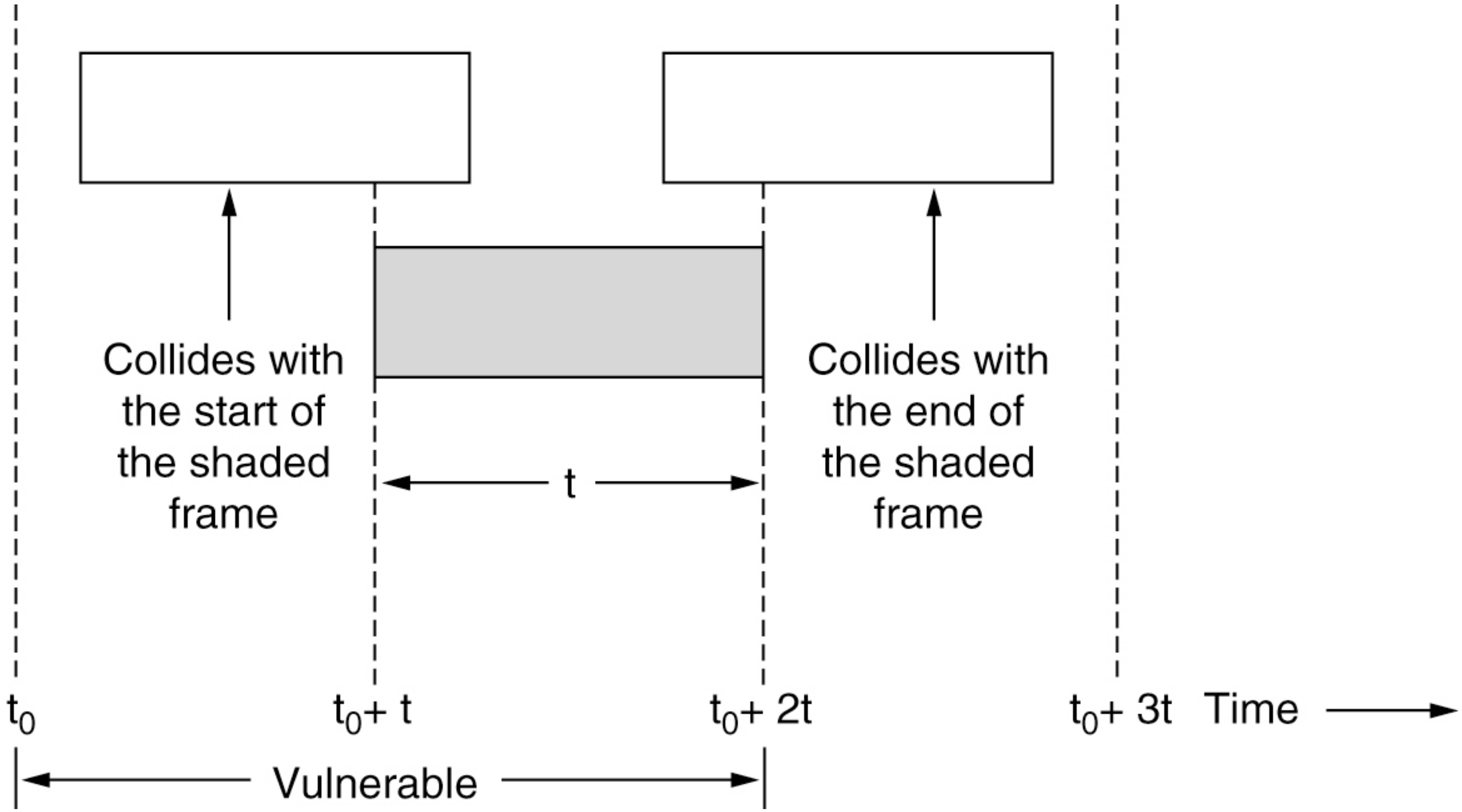
- Pure ALOHA
  - transmit, if collision, random backoff
- Slotted ALOHA
  - transmit in next slot, if collision, random backoff

ALOHA



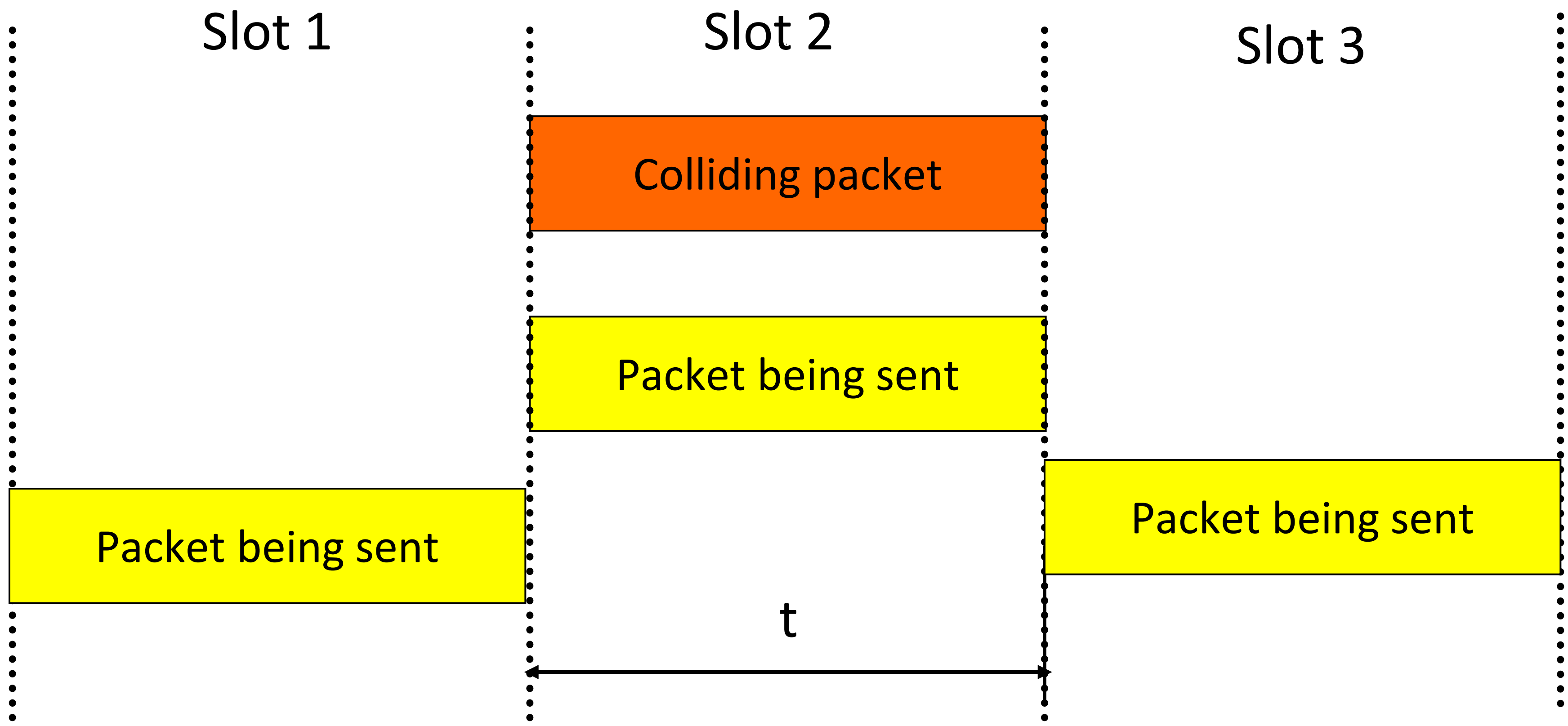
In pure ALOHA, frames are transmitted at arbitrary times

ALOHA

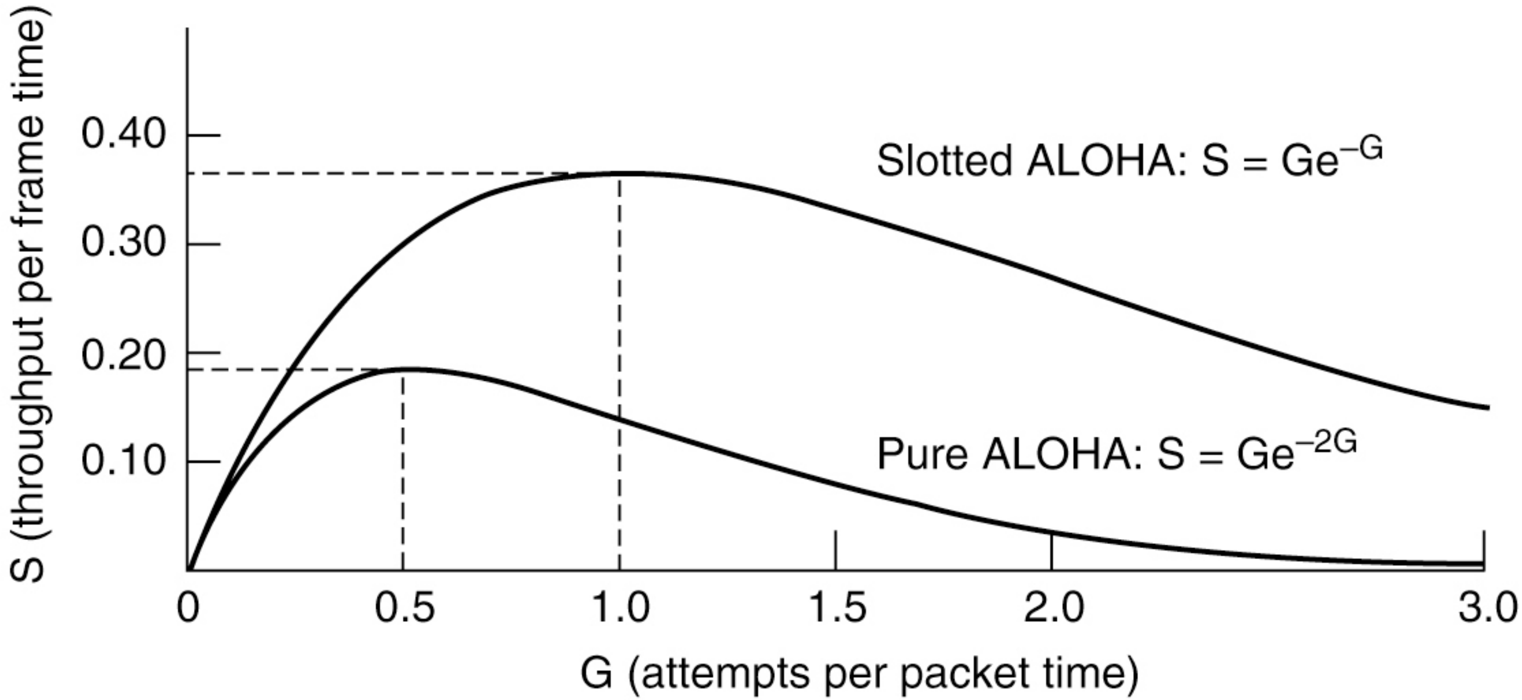


Vulnerable period for the shaded frame

Slotted ALOHA



ALOHA



Throughput versus offered traffic for ALOHA systems

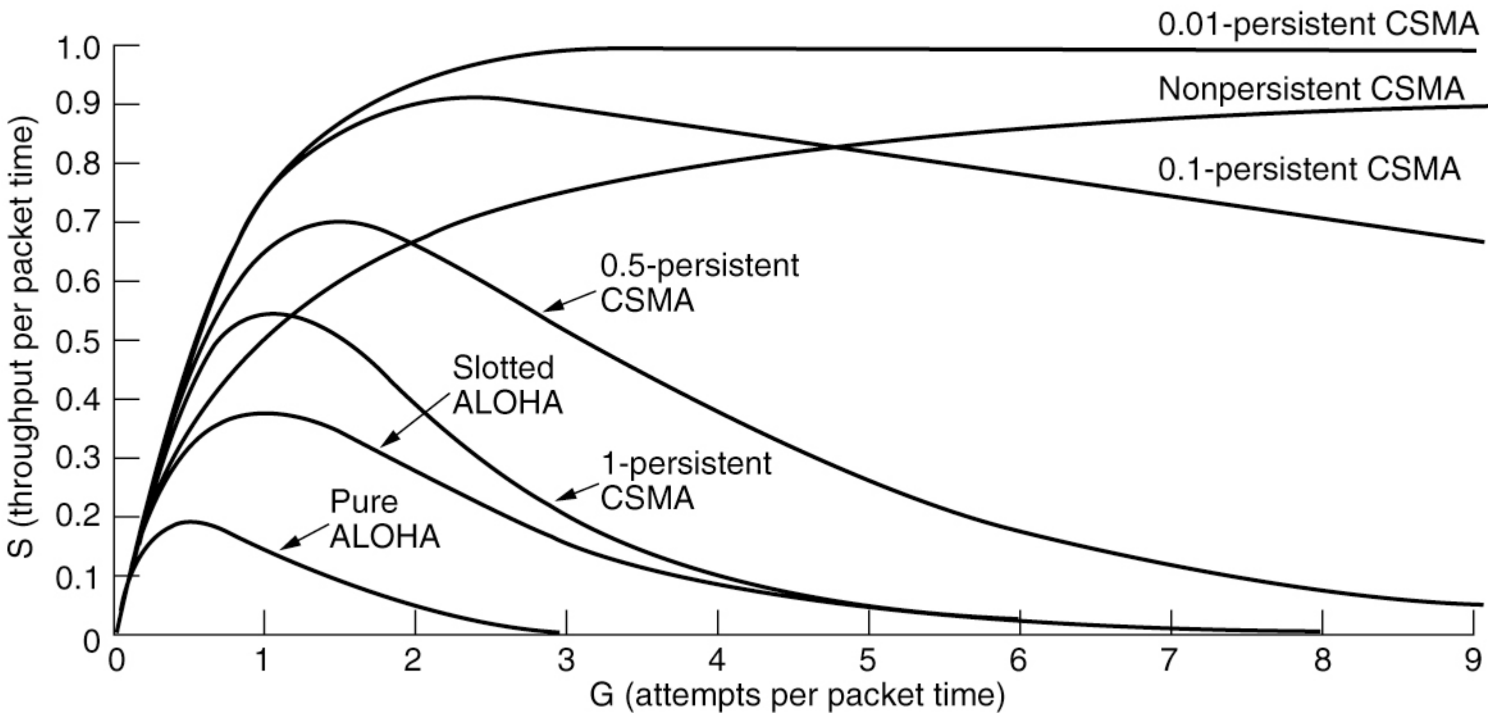
Carrier Sensing Multiple Access (CSMA)

- Persistent and nonpersistent CSMA
  - 1-persistent CSMA
  - Nonpersistent CSMA
  - *p*-persistent CSMA
- CSMA with collision detection (CSMA/CD)
  - Basis of the classic Ethernet LAN

CSMA Options

- Transmitter behavior when a busy channel is sensed
  - 1-persistent CSMA (most greedy)
    - Start transmission as soon as the channel becomes idle
    - Low delay and low efficiency
  - Nonpersistent CSMA (least greedy)
    - Wait a backoff period, then sense the channel again
    - High delay and high efficiency
  - *p*-persistent CSMA (adjustable greediness)
    - Initially, wait until the next slot
    - Afterwards, wait a random time and sense the channel again
    - When the channel is idle, transmit with probability p and defer to the next slot with probability q=1-p; continue while the channel is idle
    - Delay and efficiency can be balanced

Persistent and Nonpersistent CSMA



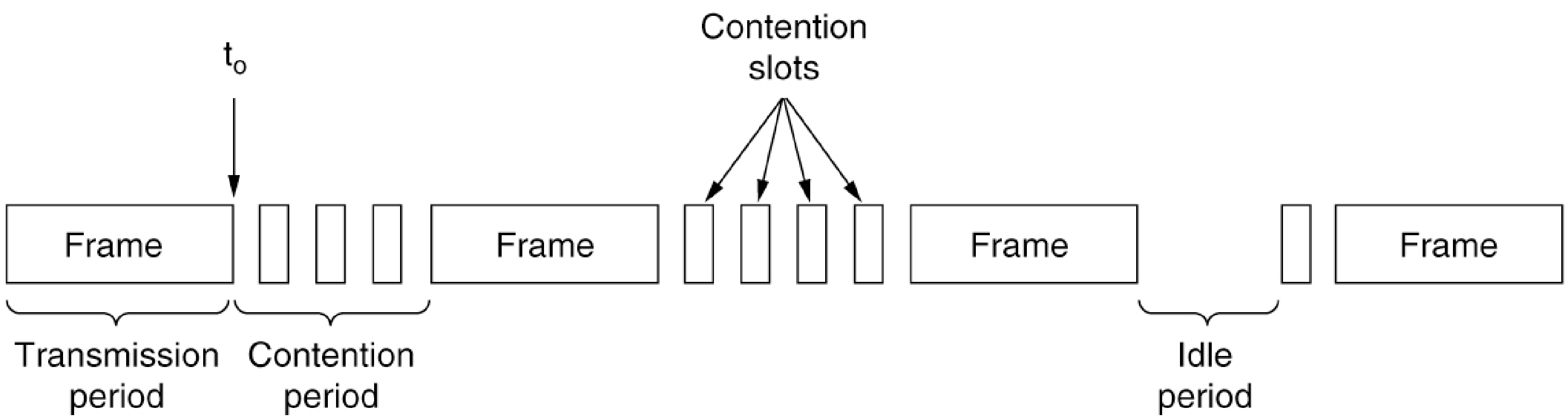
Nonpersistent CSMA: if busy, backoff

p-persistent CSMA: if busy, wait; if idle, transmit with probability *p*

CSMA with Collision Detection

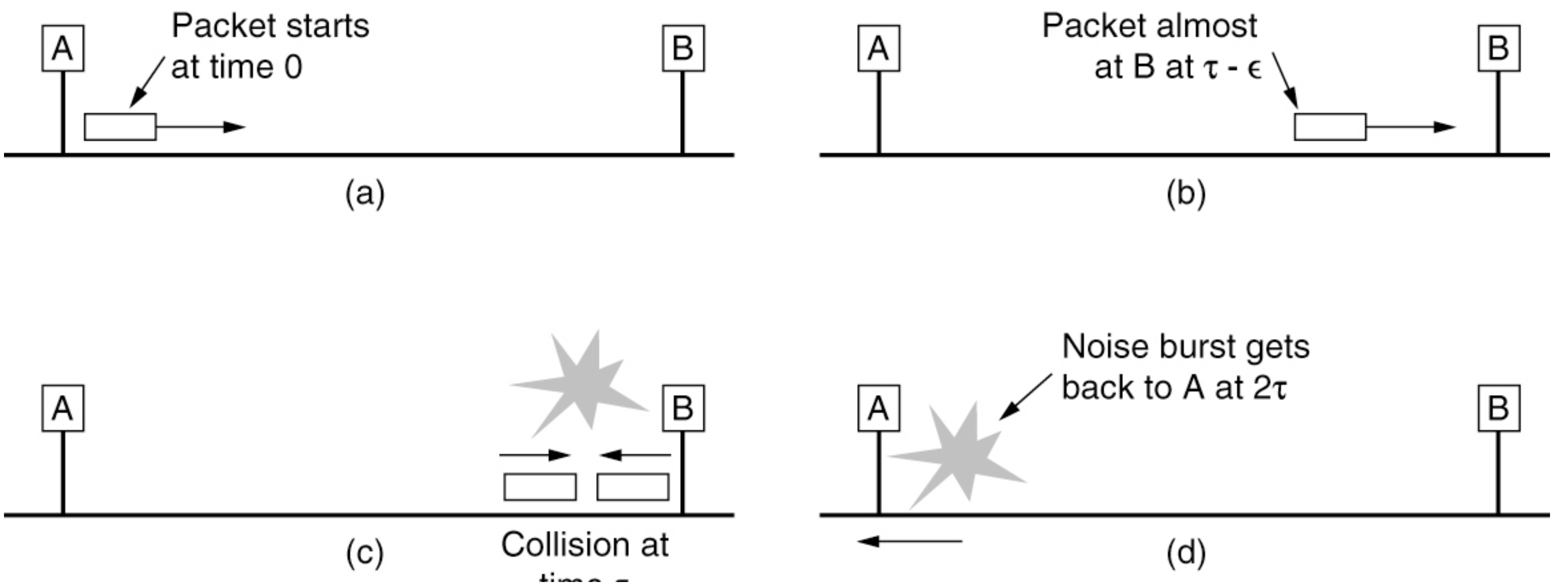
- As soon as stations detect a collision, they stop transmitting and backoff
  - Saves time and bandwidth
- CSMA/CD can be in one of three states
  - Contention
  - Transmission
  - Idle
- Frame time should be much longer than the propagation time

CSMA with Collision Detection



CSMA/CD can be in transmission, contention, or idle state

CSMA with Collision Detection

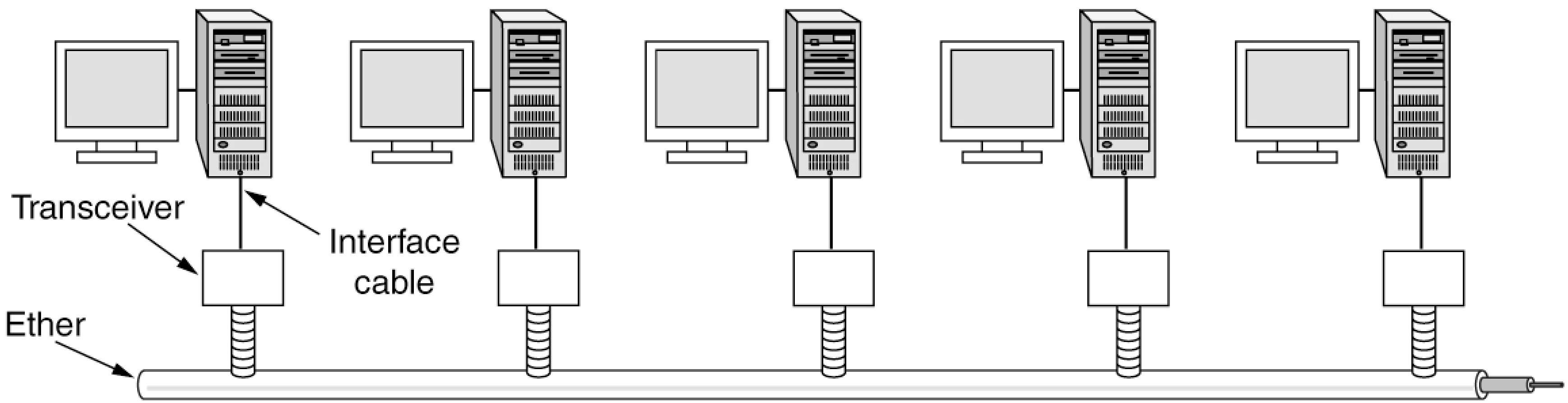


Collision detection can take as long as 2*t*.

Ethernet

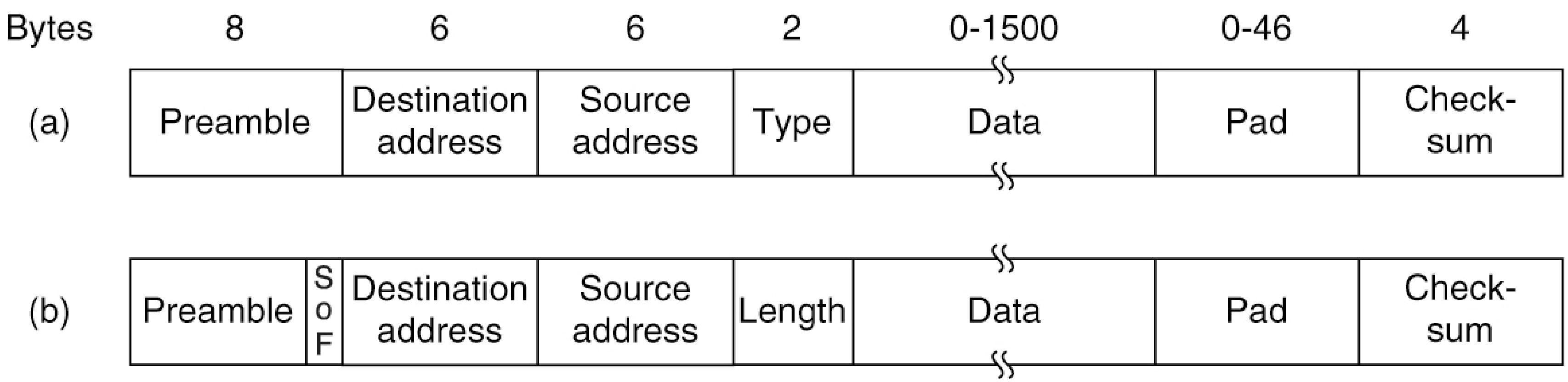
- Classic Ethernet physical layer
- Classic Ethernet MAC sublayer protocol
  - CSMA/CD with binary exponential backoff
- Switched Ethernet
- Fast Ethernet and beyond

Classic Ethernet Physical Layer



Classic Ethernet

Classic Ethernet Frame Format



Frame formats (a) Ethernet (DIX) (b) IEEE 802.3

Classic Ethernet Frame Format

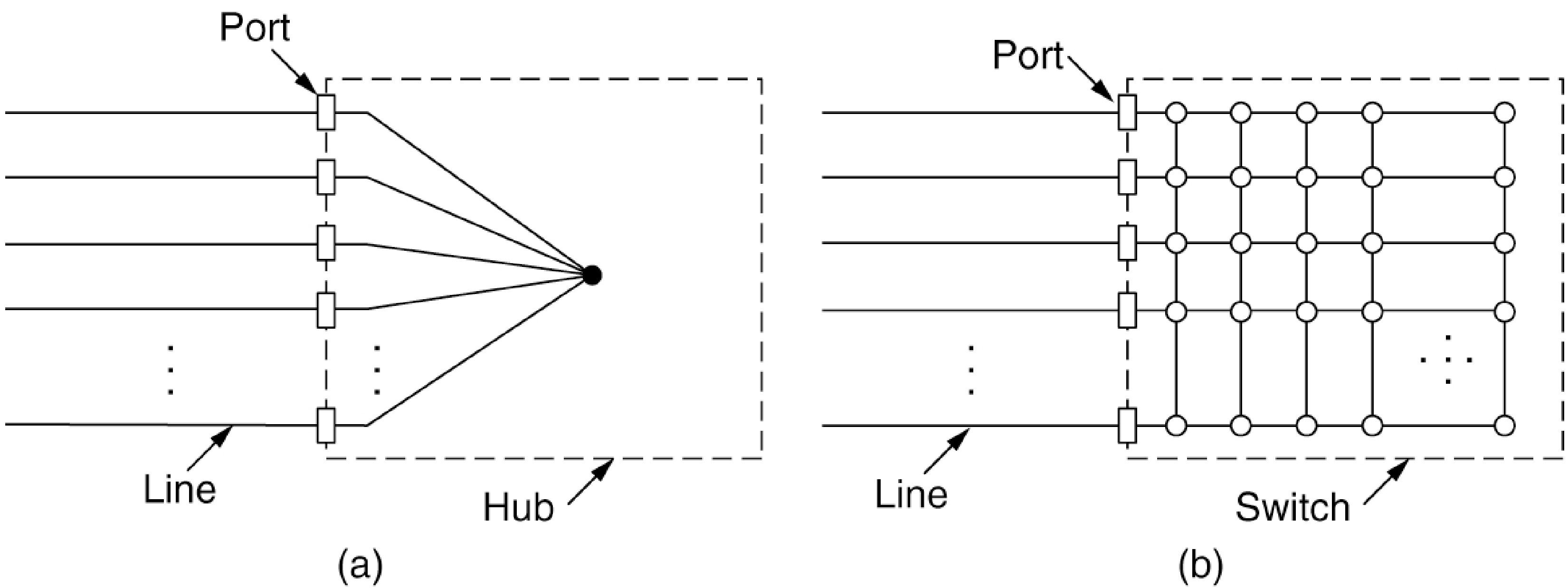
- Destination/source addresses (6 bytes each)
- Type/Length
  - Values less than or equal to 0x600 are type
    - e.g. 0x800 (IP)
  - Values below 0x600 are length
- Data: 0 to 1500 bytes
- Pad: 0 to 46 bytes
  - minimal frame length
- CRC: 4 bytes (32 bits)
- CSMA/CD with binary exponential backoff

Ethernet CSMA/CD Algorithm

- Sense channel
  - if idle: start frame transmission
  - if busy: wait until channel idle, then transmit
- If entire frame transmitted without collision - done!
- If another transmission is detected while sending
  - abort, send jamming signal
- After aborting, enter binary (exponential) backoff
  - after the *i*th collision, choose a backoff slot at random from

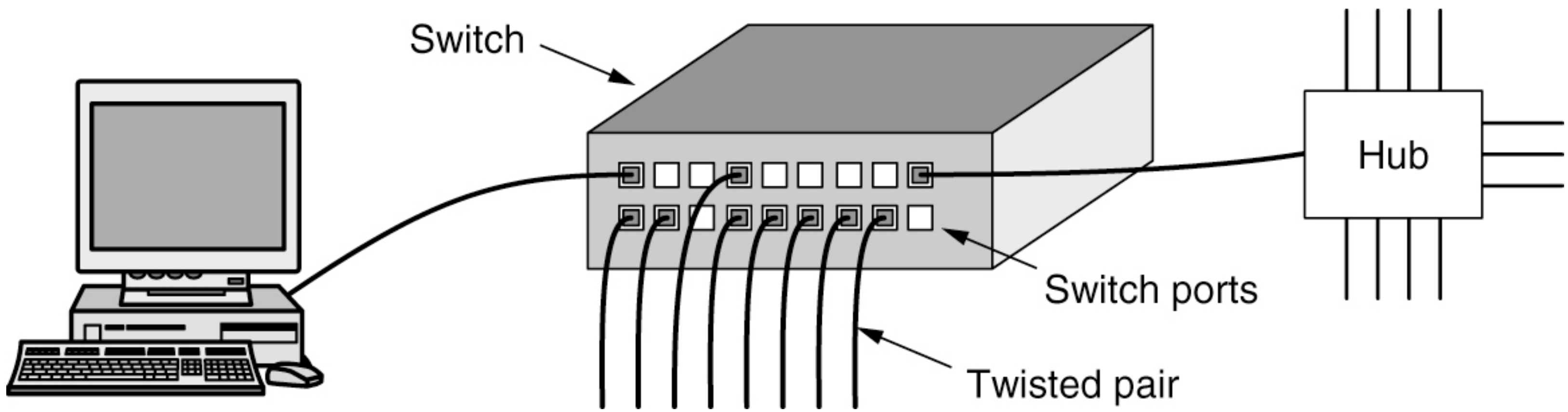
    $\{0,1,2, \ldots, 2^i-1\}$
  - After 10 collisions fix the range to {0, 1, …, 1023}
  - After 16 collisions report failure

Switched Ethernet



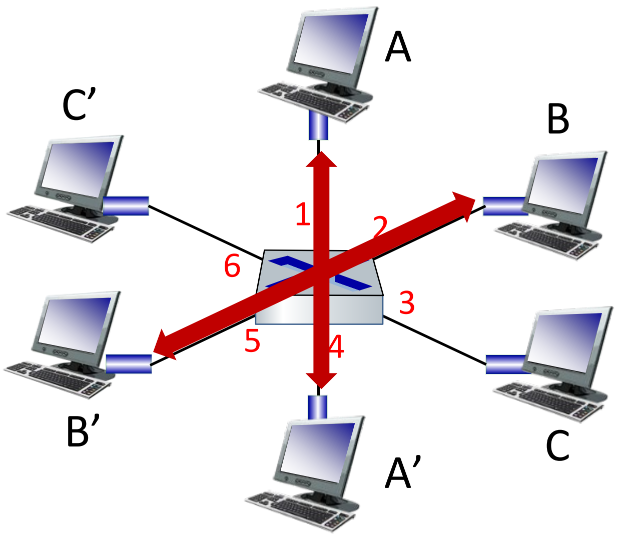
(a) Hub (b) Switch

Switched Ethernet



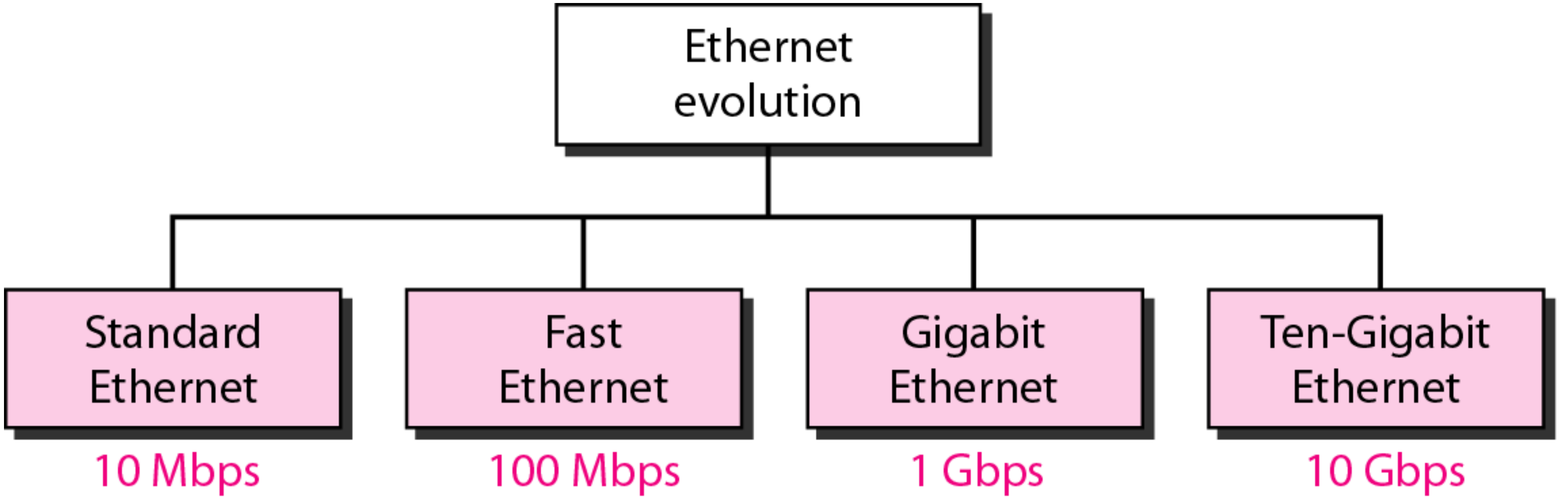
Switched Ethernet

- Stations have a dedicated, direct connection to switch
- Ethernet protocol is used on *each* incoming link, so each link is its own collision domain
- Allows for multiple simultaneous transmissions
  - A-to-A' and B-to-B' simultaneous transmissions without collisions



switch with six interfaces (1,2,3,4,5,6)

Ethernet Evolution Through Four Generations



Fast Ethernet

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 Ethernet

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

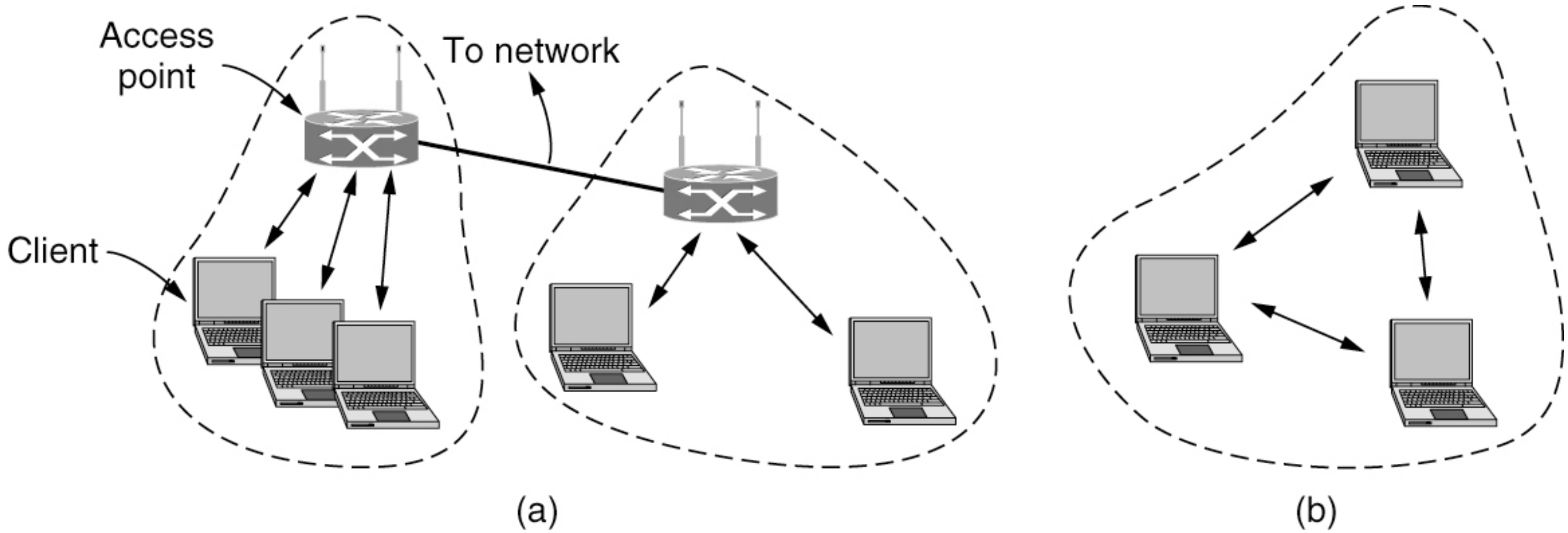
10-Gigabit Ethernet

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

Wireless LANs

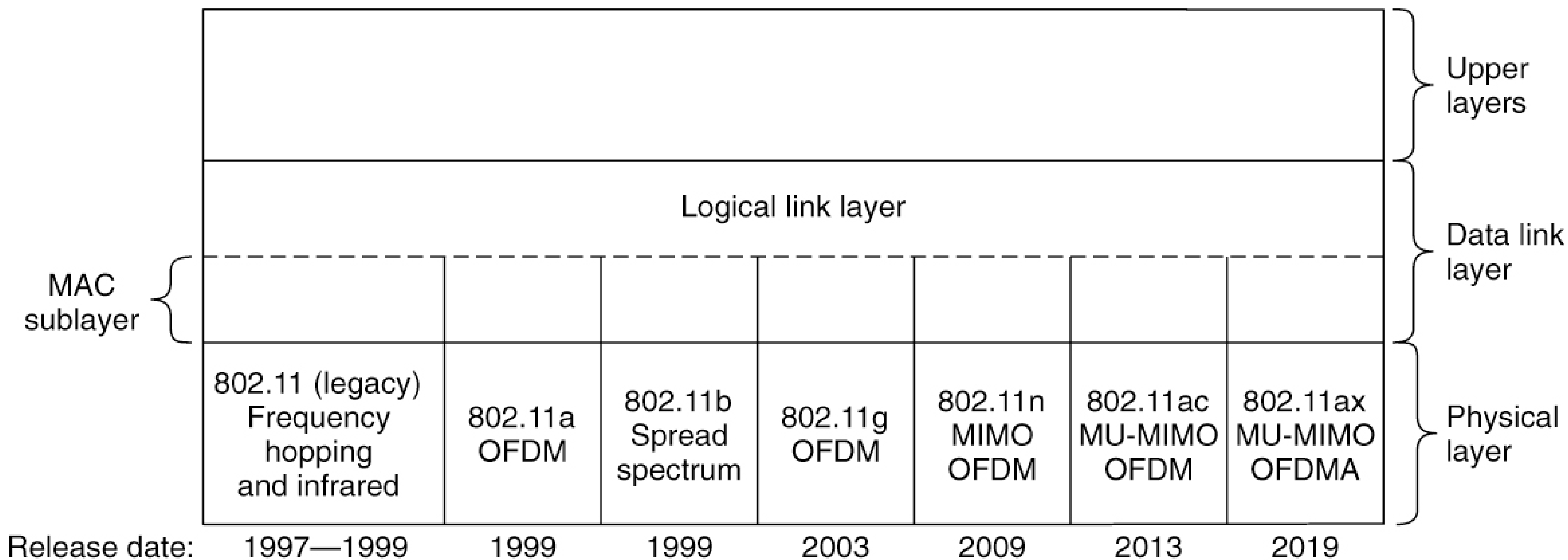
- Very popular!
  - 802.11a: 5 GHz, 54 Mbps, 30 ft
  - 802.11b: 2.4 GHz, 11 Mbps, 100 ft
  - 802.11g: 2.4 GHz, 54Mbps, 100 ft
  - 802.11n: 2.4 GHz, 540 Mbps
- Infrastructure mode
  - access point
- Ad-hoc mode

802.11 Architecture



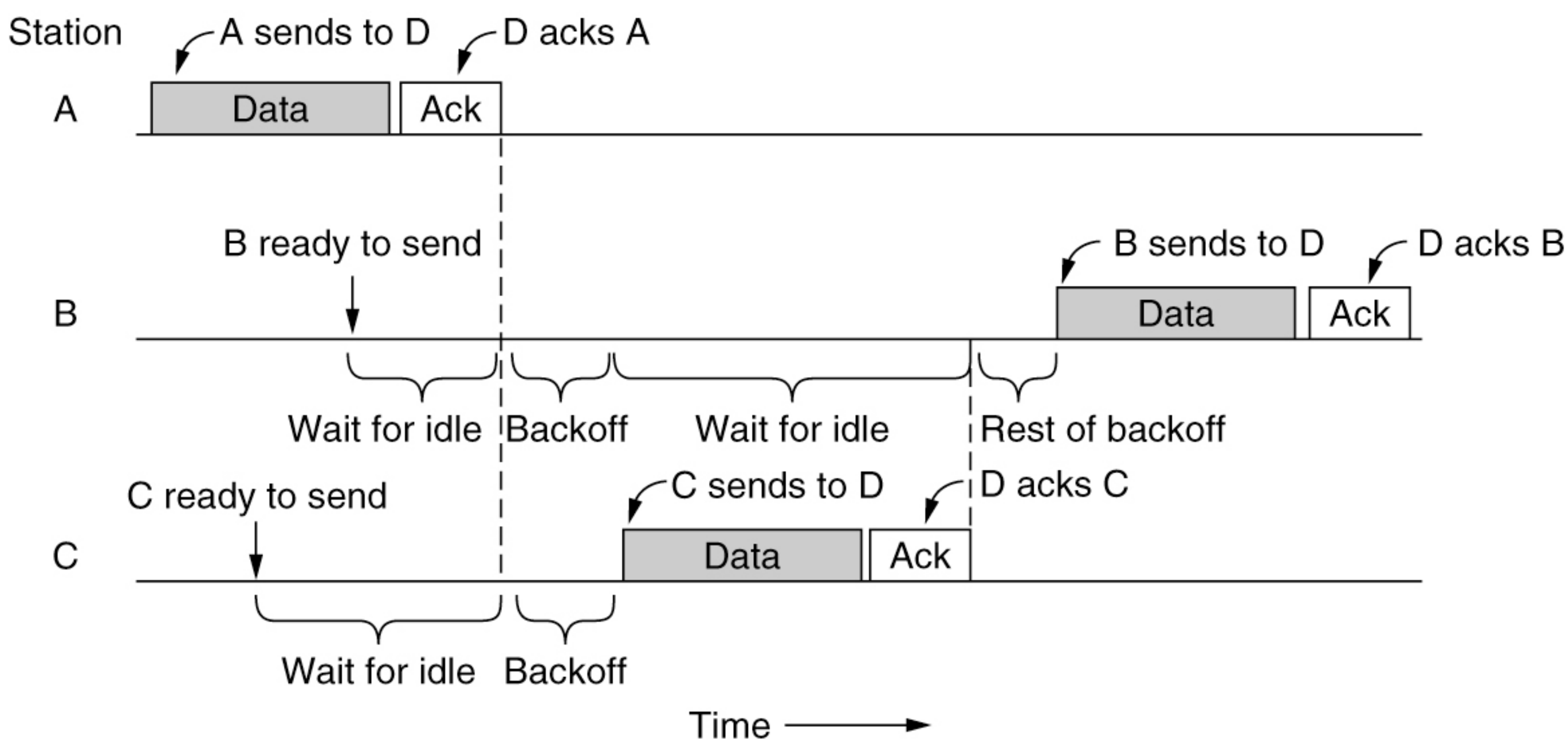
(a) Infrastructure mode (b) Ad-hoc mode

The 802.11 Protocol Stack



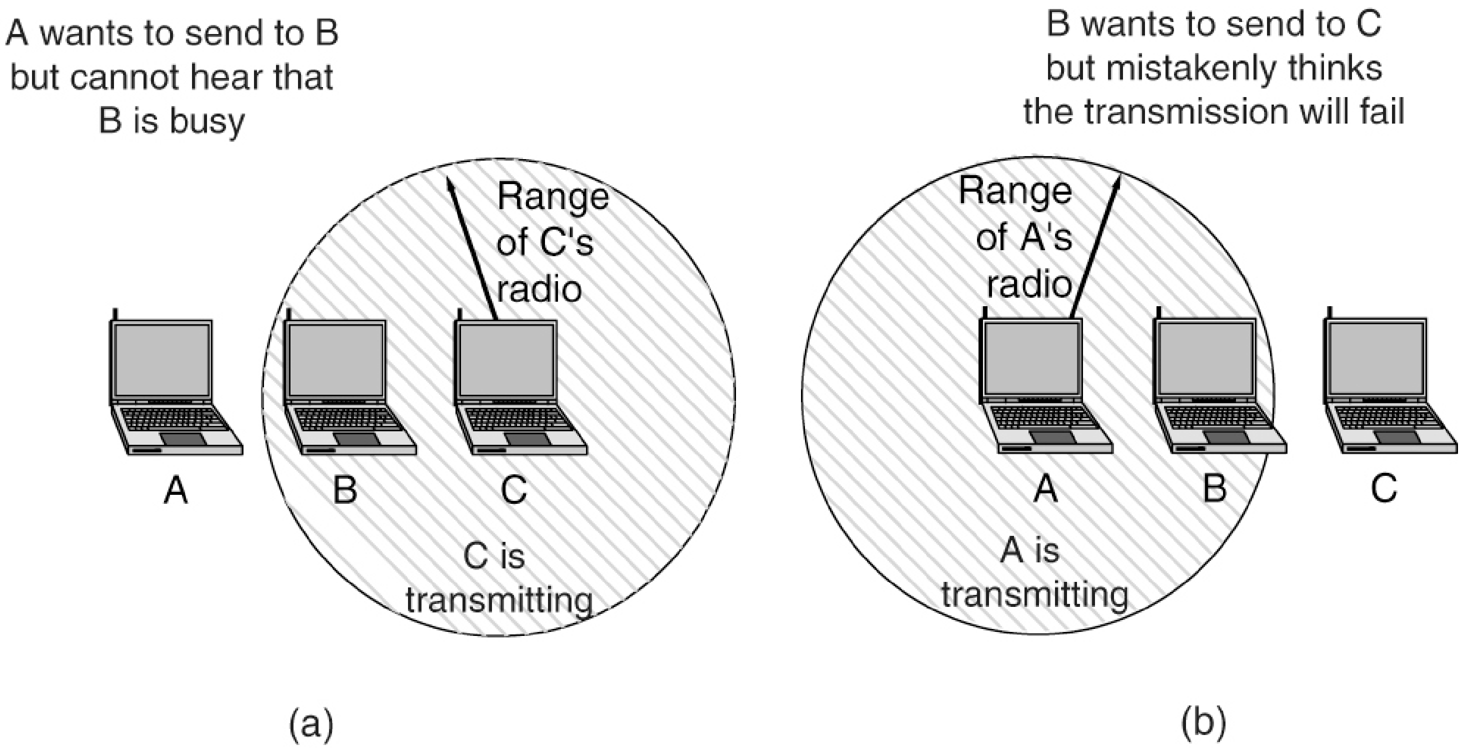
Part of the 802.11 protocol stack

802.11 MAC Sublayer Protocol



Sending a frame with CSMA/CA

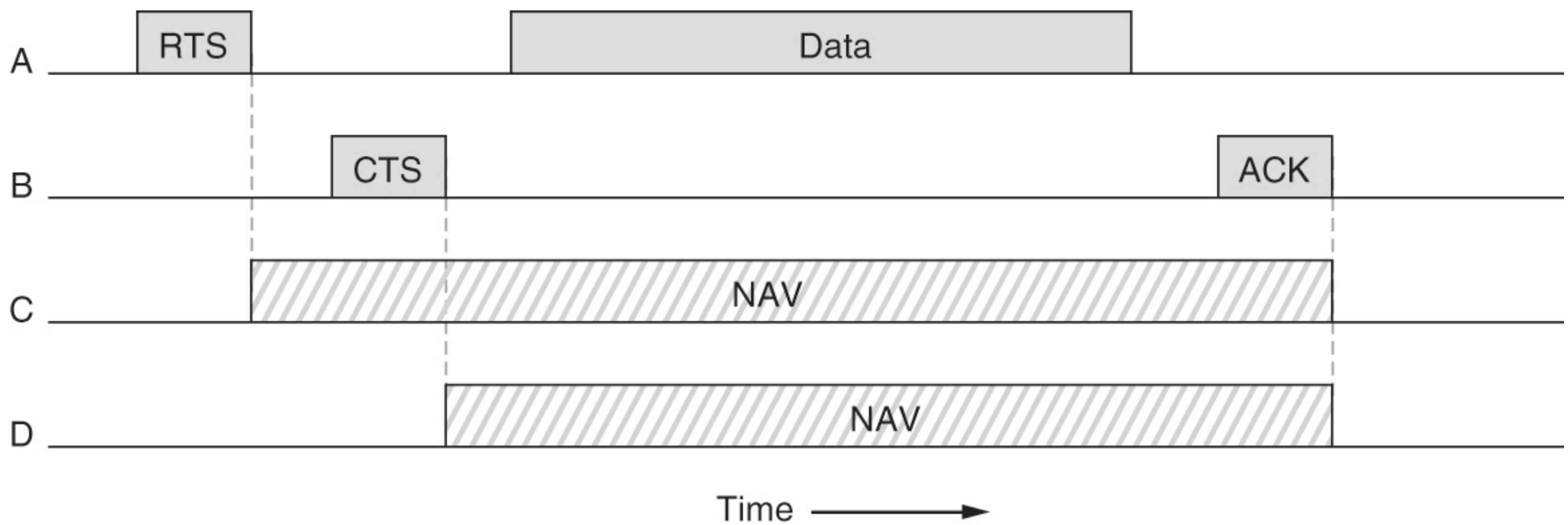
802.11 MAC Sublayer Protocol



(a) The hidden terminal problem.

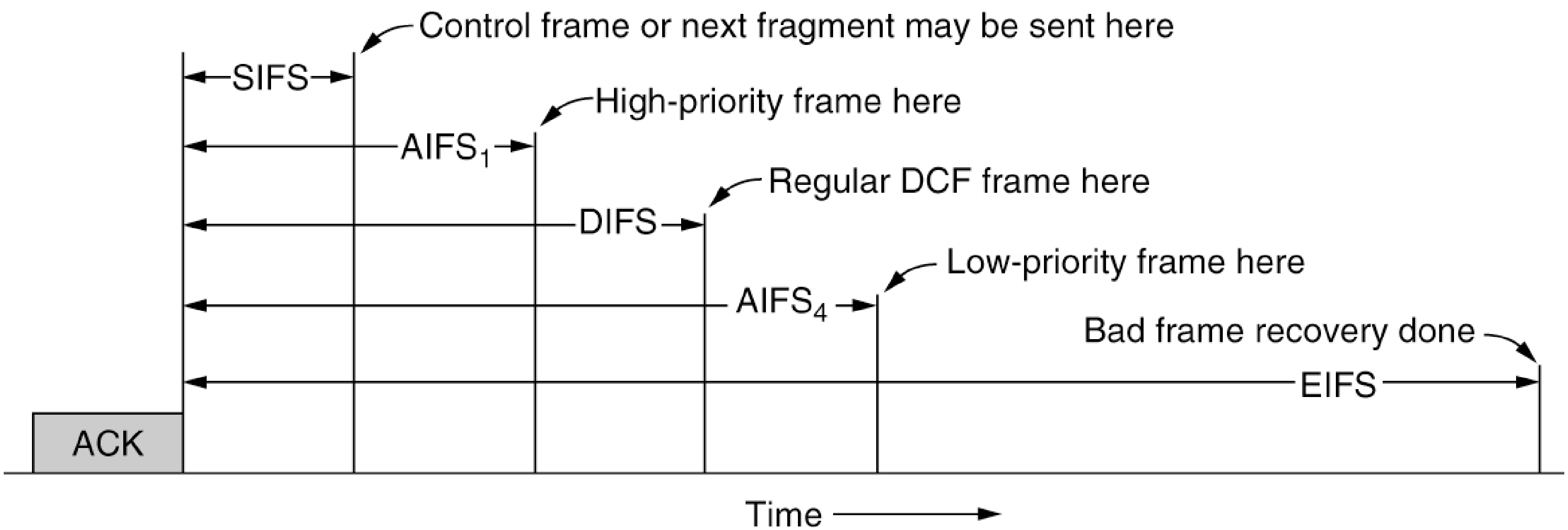
(b) The exposed terminal problem.

802.11 MAC Sublayer Protocol



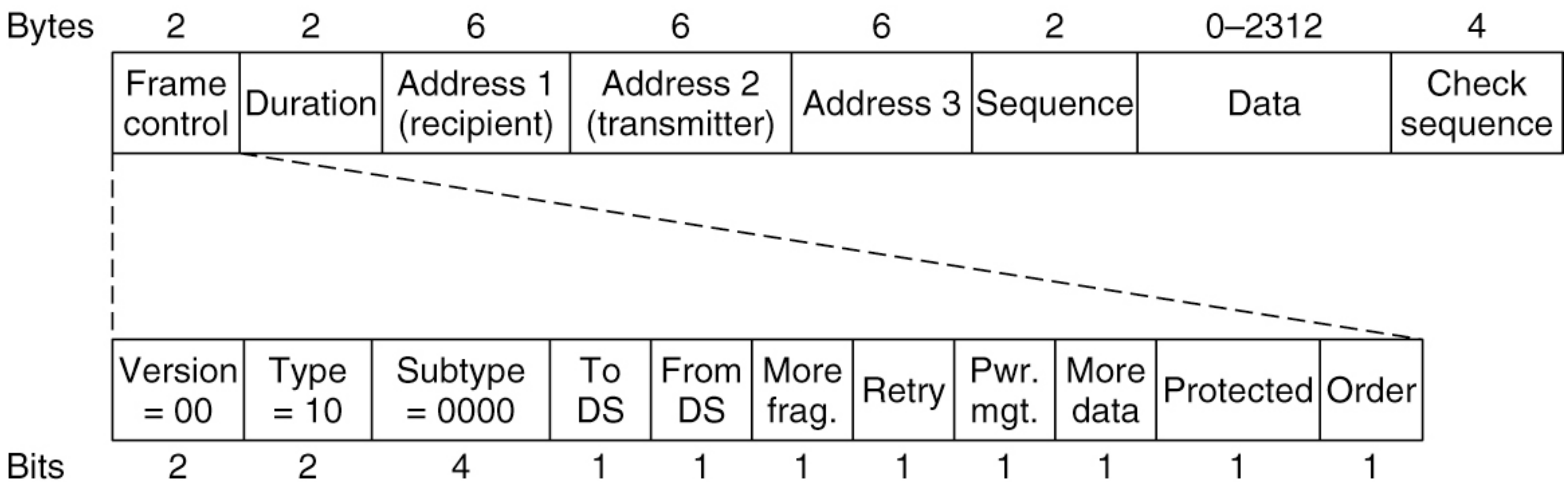
Virtual channel sensing using CSMA/CA

802.11 MAC Sublayer Protocol



Interframe spacing in 802.11

The 802.11 Frame Structure

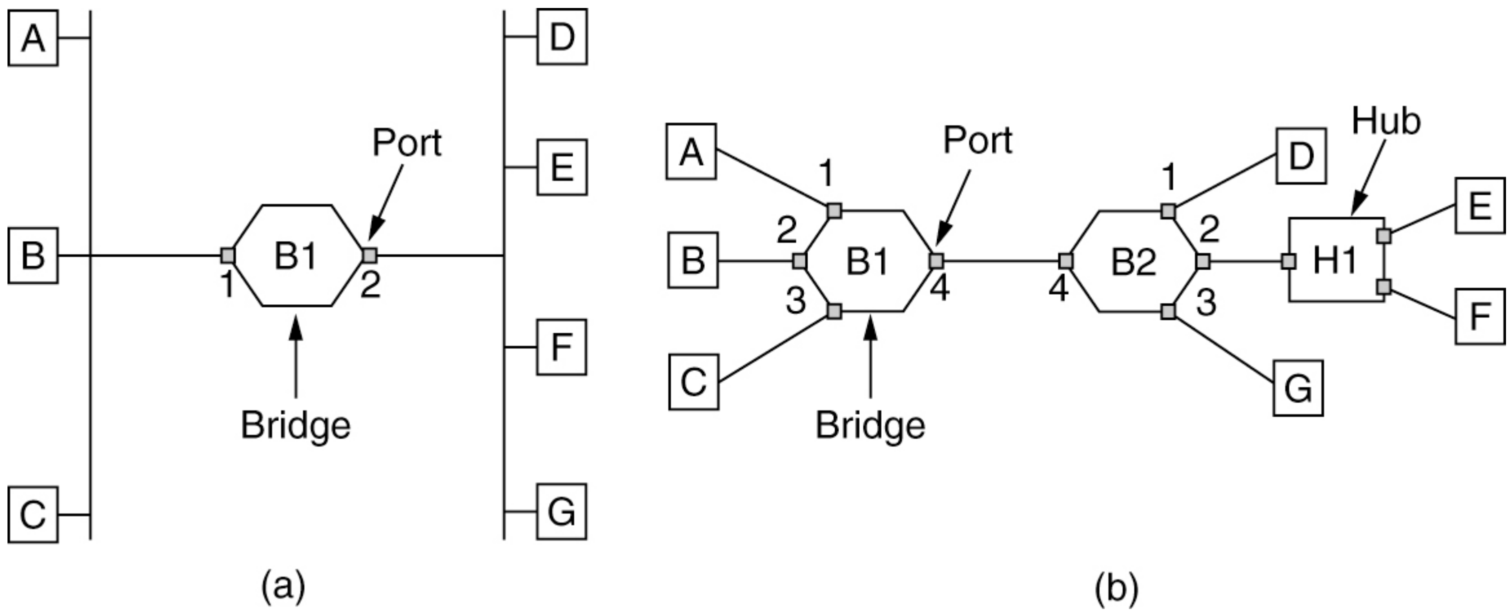


802.11 data frame format

Data Link Layer Switching

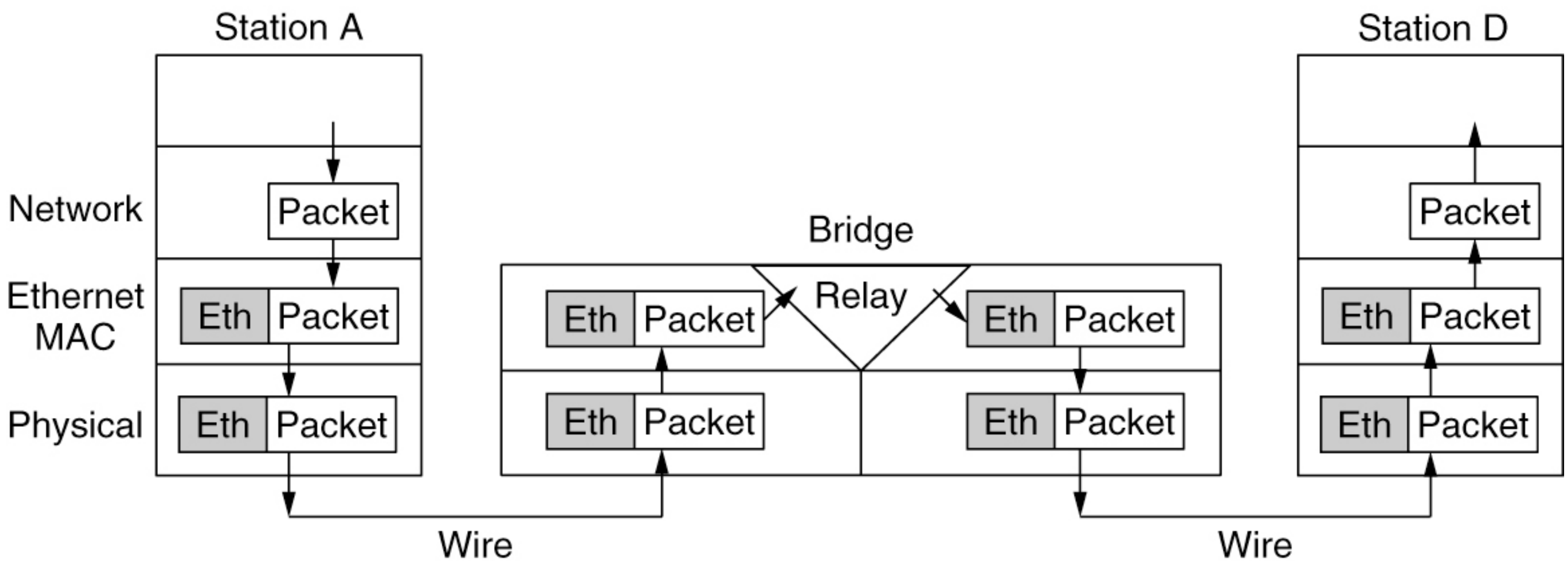
- Uses of bridges
- Learning bridges
- Spanning tree bridges
- Repeaters, hubs, bridges, switches, routers, and gateways

Learning Bridges



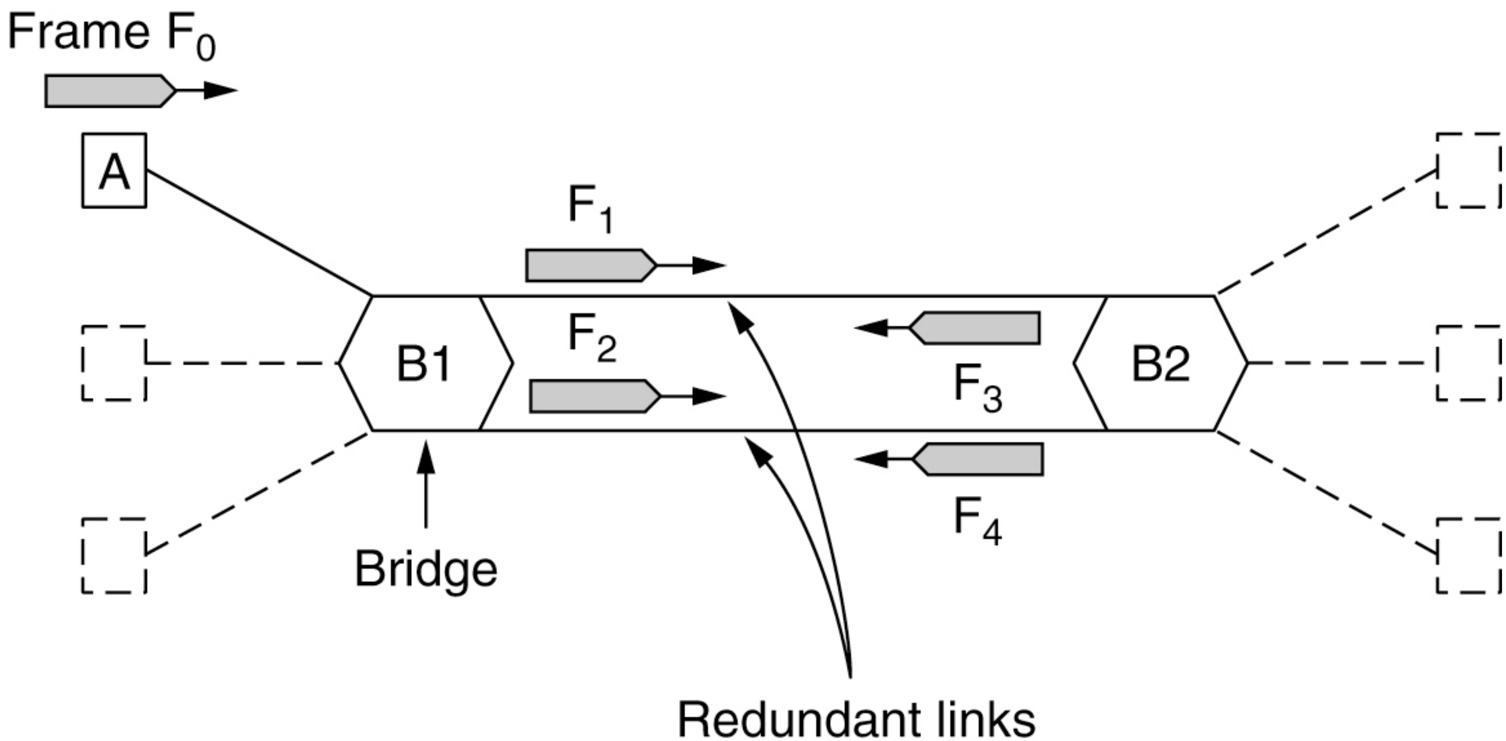
(a) Bridge connecting two multidrop LANs. (b) Bridges (and a hub) connecting seven point-to-point stations.

Learning Bridges



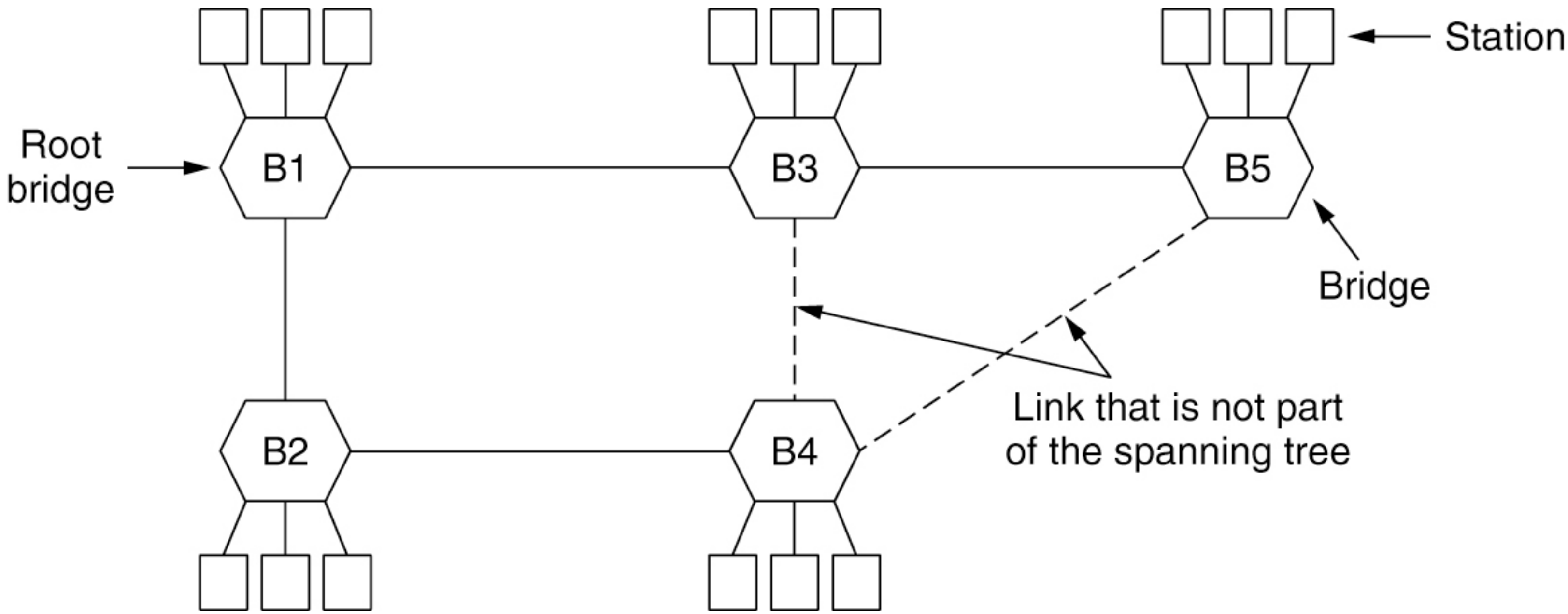
Protocol processing at a bridge

Spanning-Tree Bridges



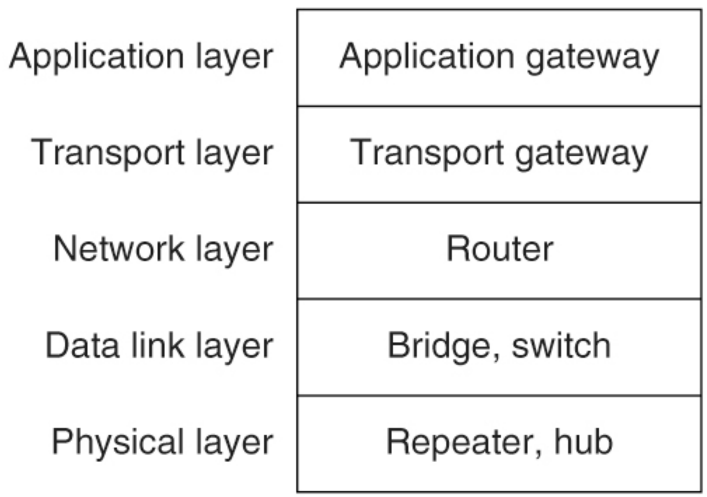
Bridges with two parallel links

Spanning-Tree Bridges

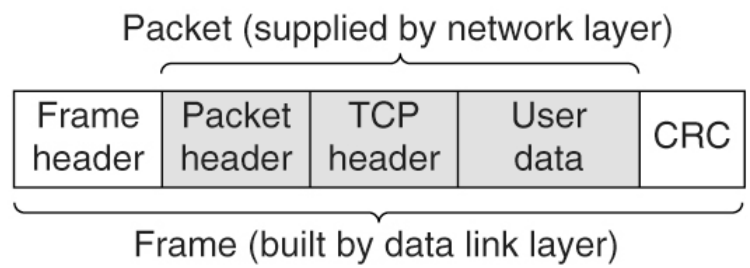


A spanning tree connecting five bridges. The dashed lines are links that are not part of the spanning tree.

Repeaters, Hubs, Bridges, Switches, Routers, and Gateways



(a)



(b)

(a) Which device is in which layer.

(b) Frames, packets, and headers.