

# The Medium Access Control Sublayer

## Chapter 4

# Channel Allocation Problem

- Static channel allocation
- Assumptions for dynamic

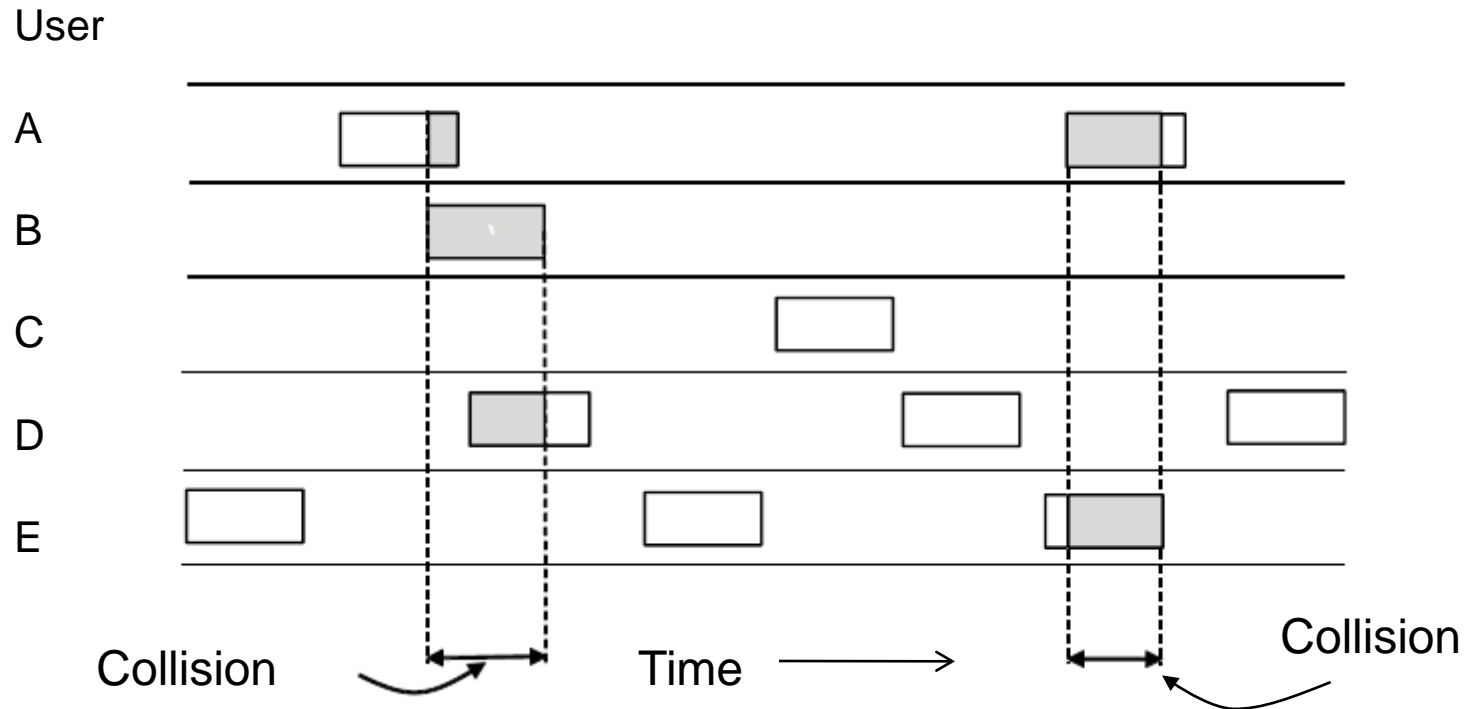
# Assumptions for Dynamic Channel Allocation

1. Independent traffic
2. Single channel
3. Observable Collisions
4. Continuous or slotted time
5. Carrier sense or no carrier sense

# Multiple Access Protocols

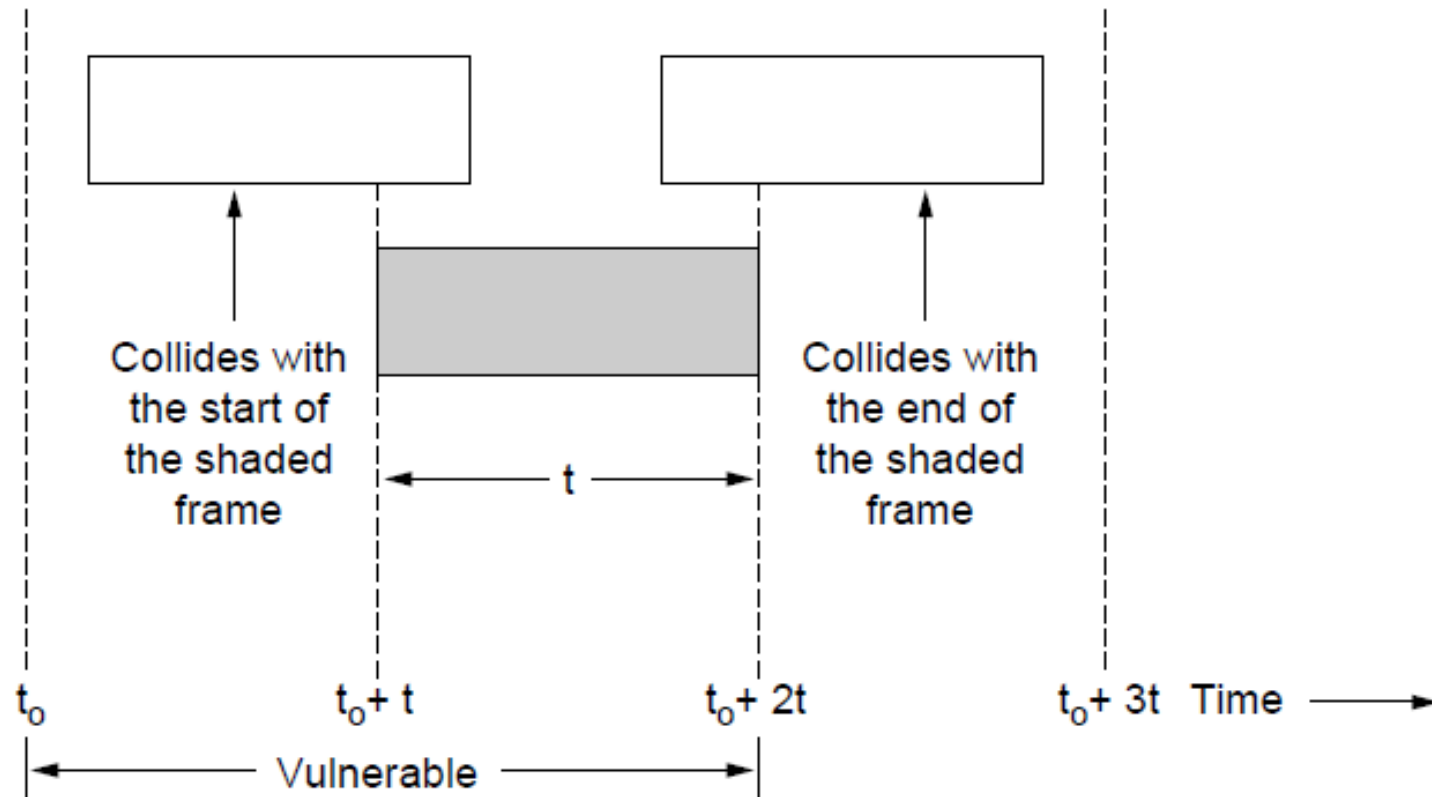
- ALOHA
- Carrier Sense Multiple Access
- Collision-free protocols
- Limited-contention protocols
- Wireless LAN protocols

# ALOHA (1)



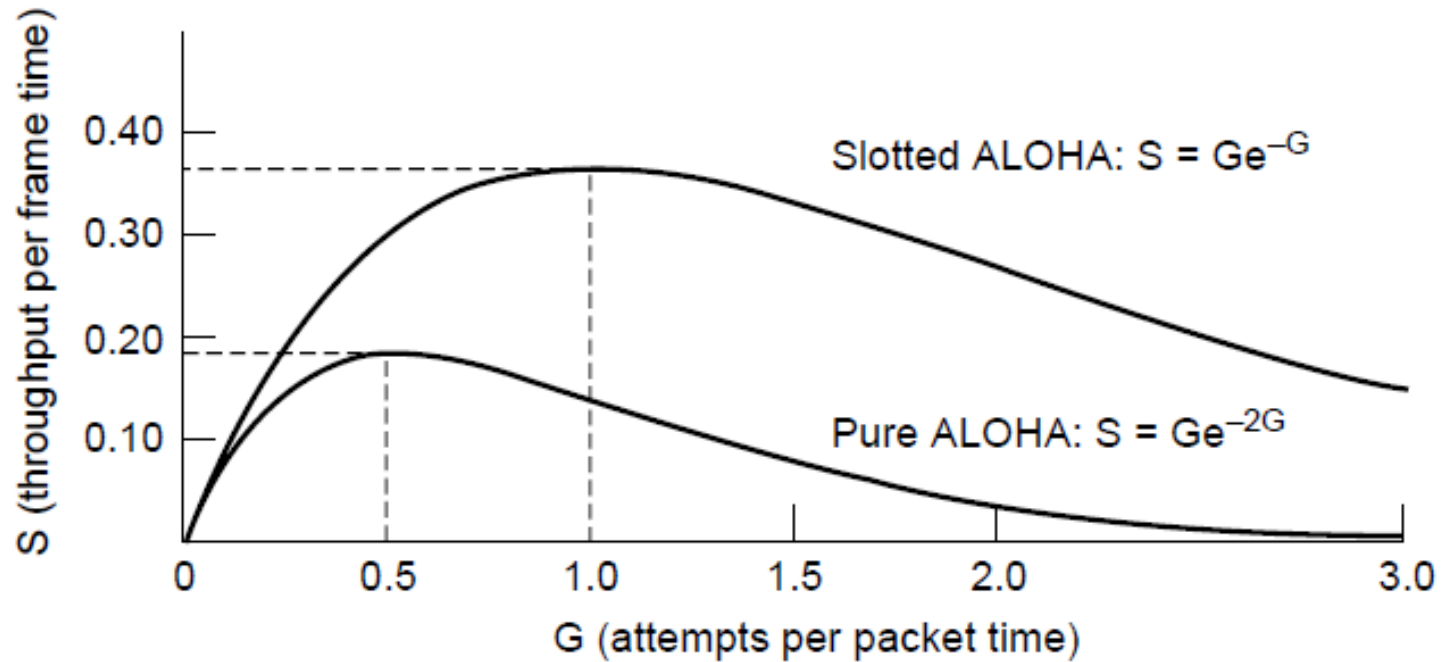
In pure ALOHA, frames are transmitted  
at completely arbitrary times

# ALOHA (2)



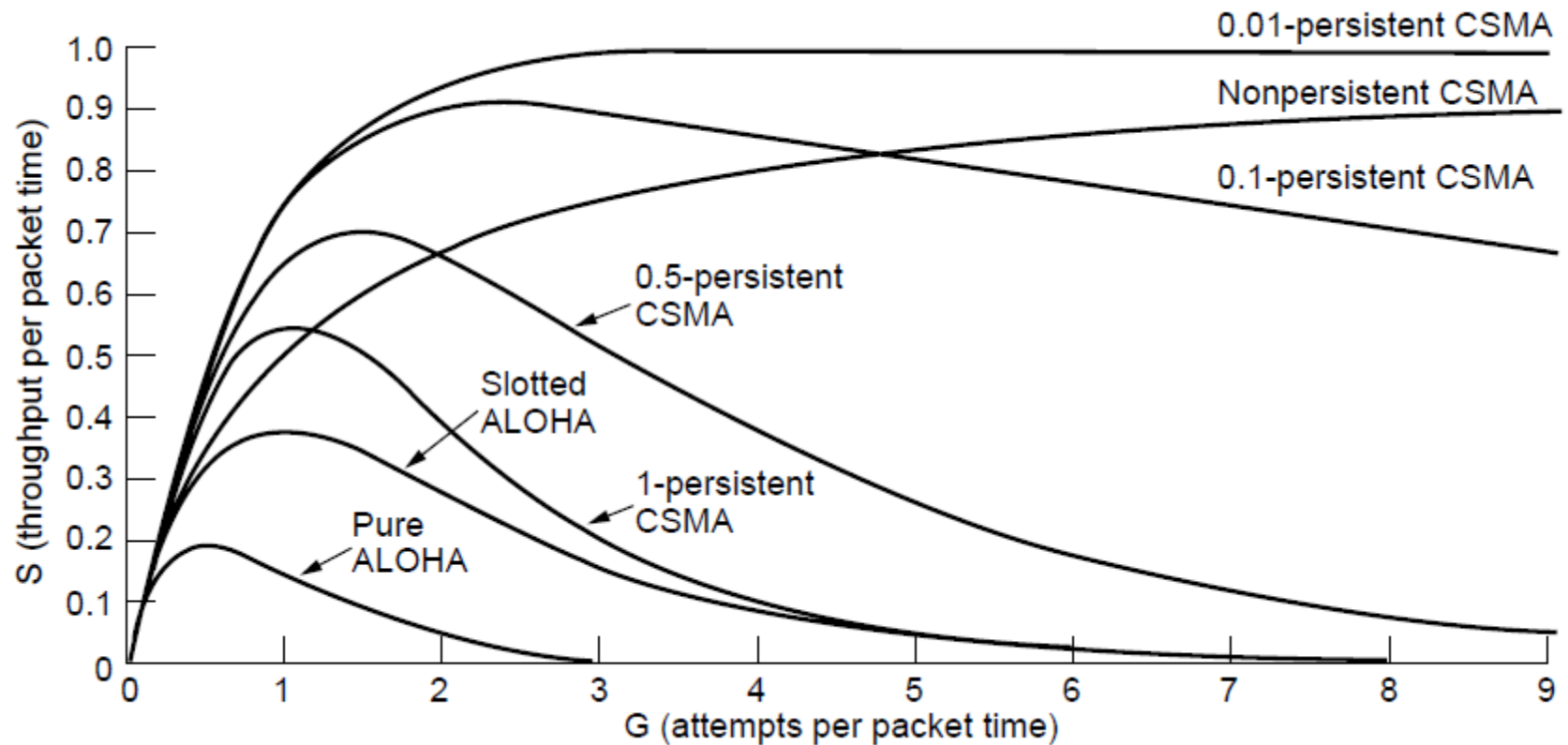
Vulnerable period for the shaded frame.

# ALOHA (3)



Throughput versus offered traffic for ALOHA systems.

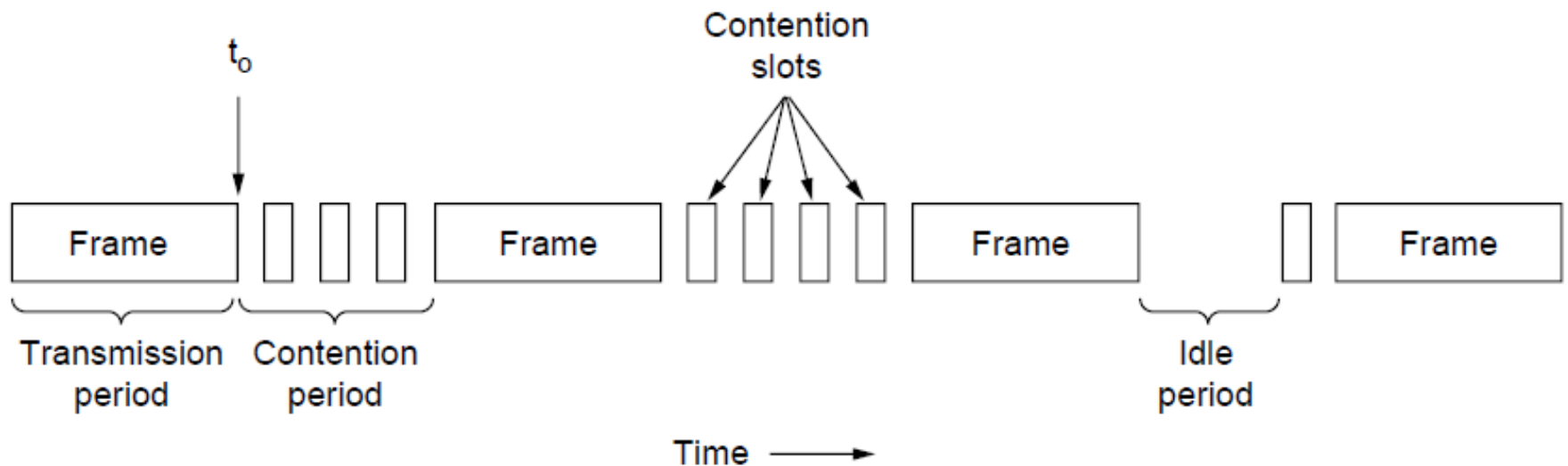
# Persistent and Nonpersistent CSMA



Comparison of the channel utilization versus load for various random access protocols.

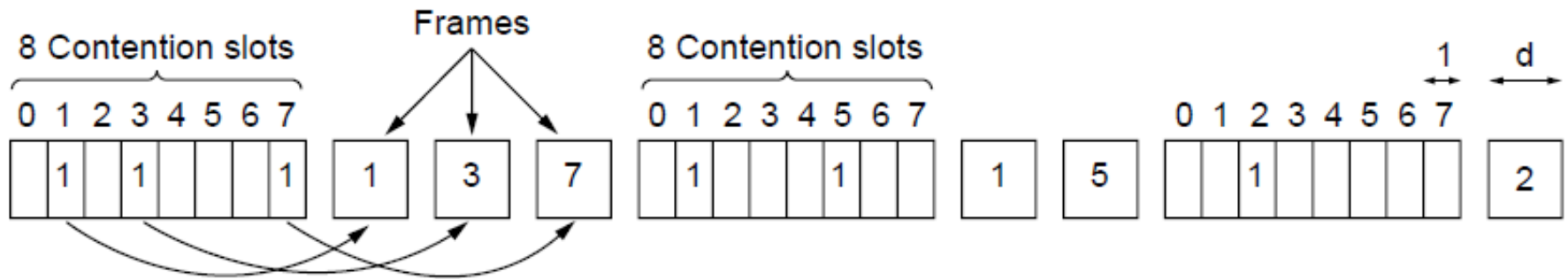


# CSMA with Collision Detection



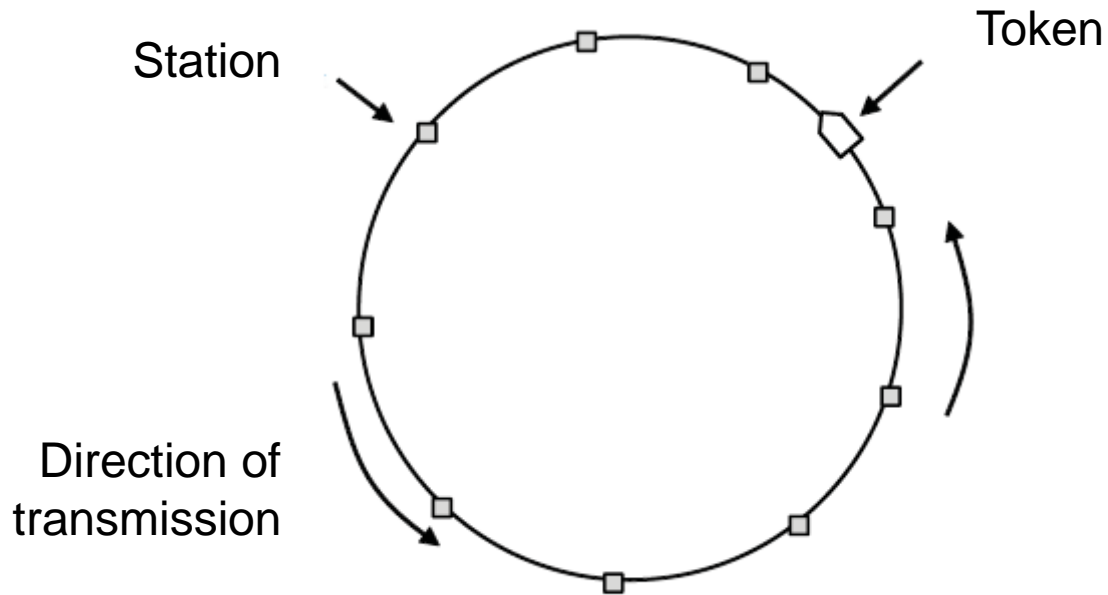
CSMA/CD can be in one of three states: contention, transmission, or idle.

# Collision-Free Protocols (1)



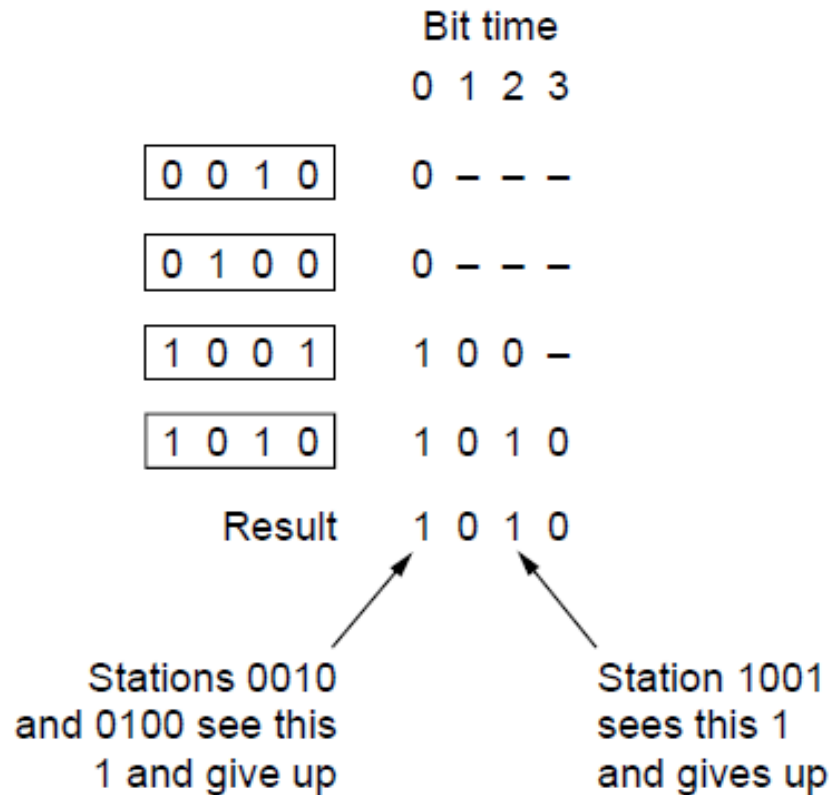
The basic bit-map protocol.

# Collision-Free Protocols (2)



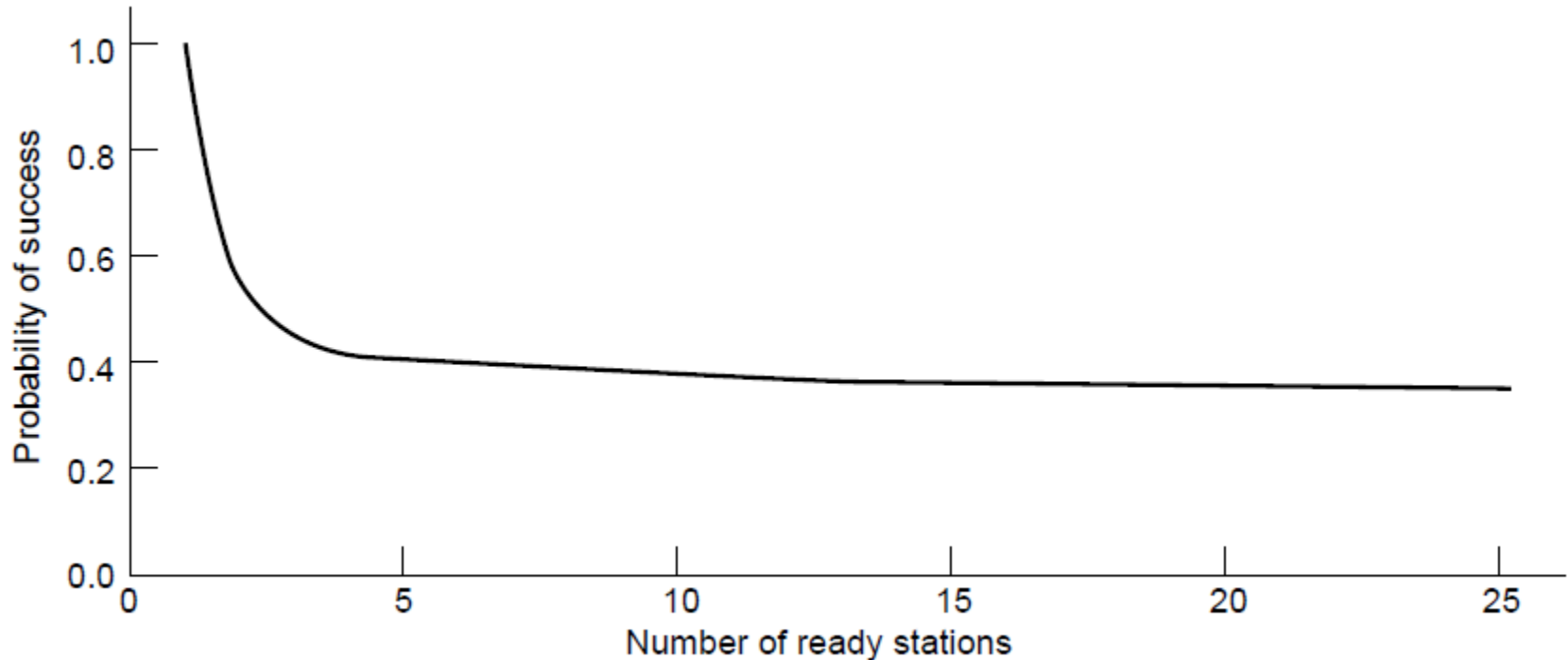
Token ring.

# Binary Countdown



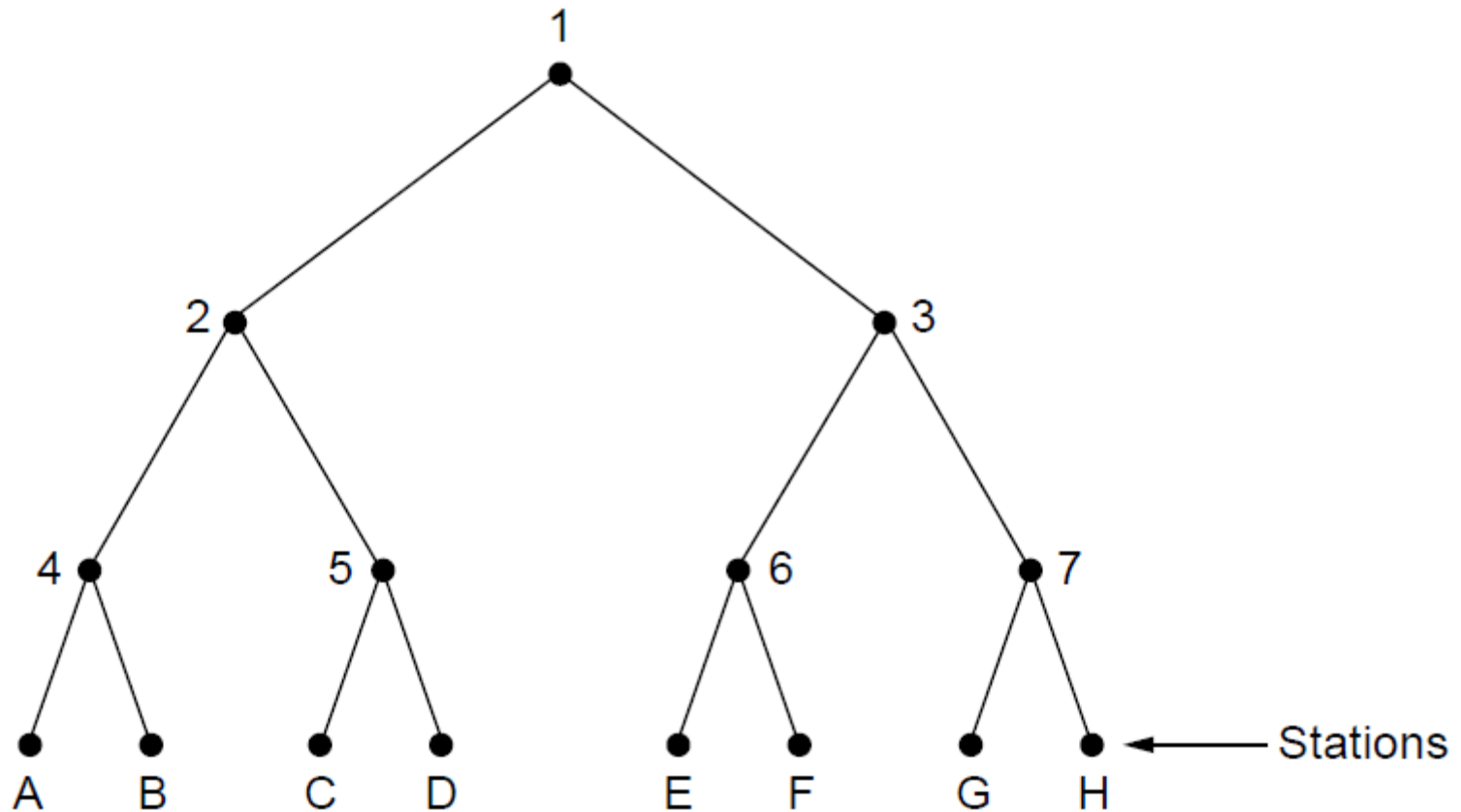
The binary countdown protocol. A dash indicates silence.

# Limited-Contention Protocols



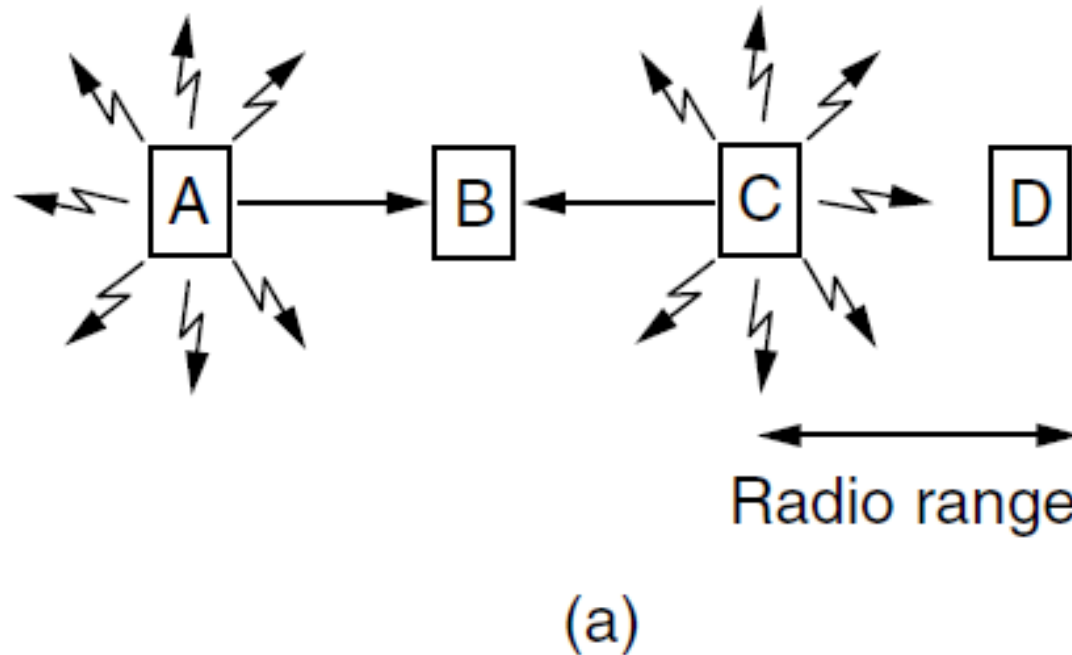
Acquisition probability for a symmetric contention channel.

# The Adaptive Tree Walk Protocol



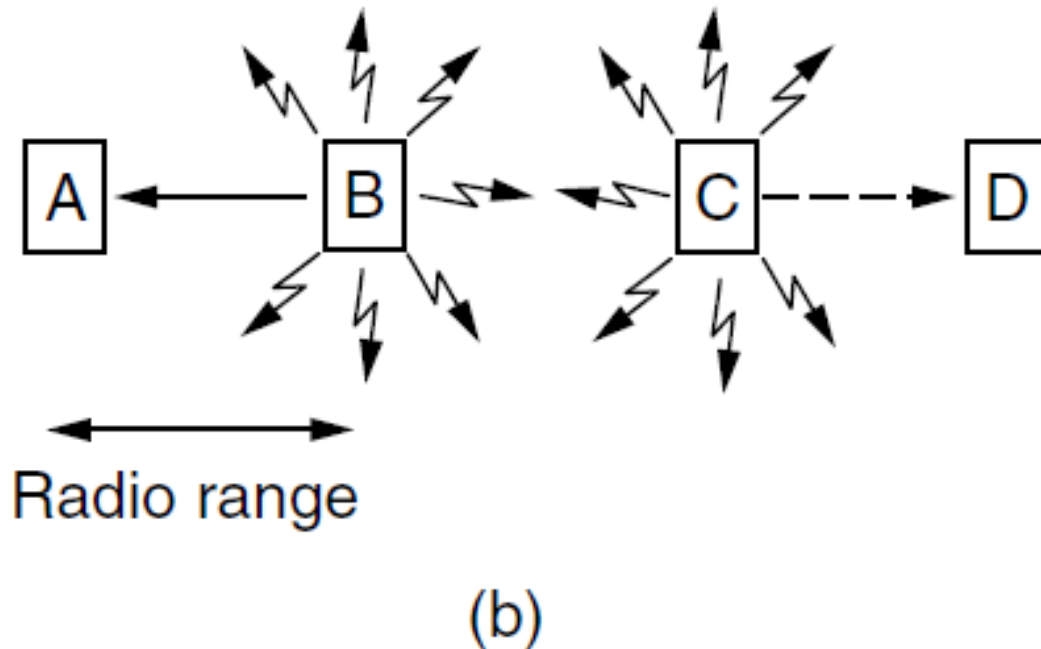
The tree for eight stations

# Wireless LAN Protocols (1)



A wireless LAN. (a) A and C are hidden terminals when transmitting to B.

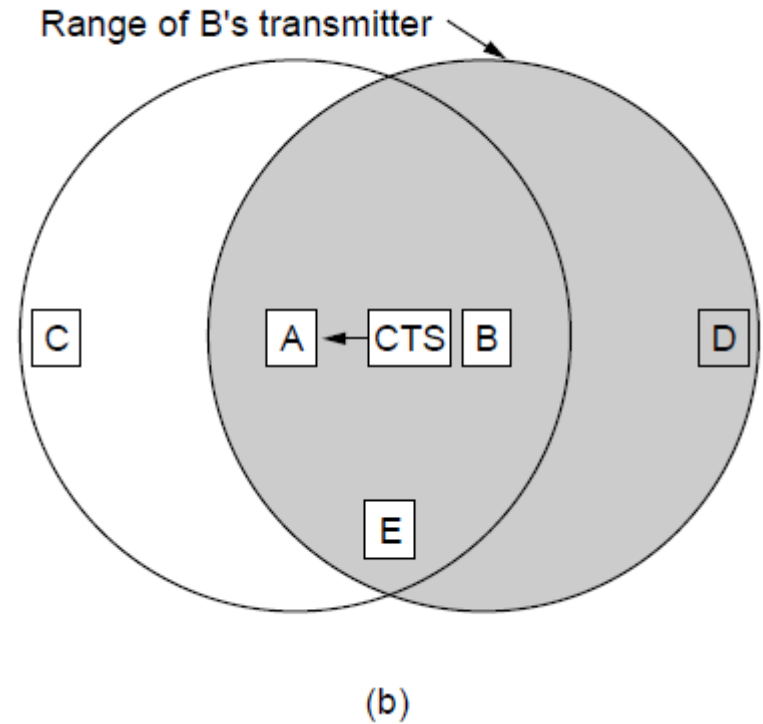
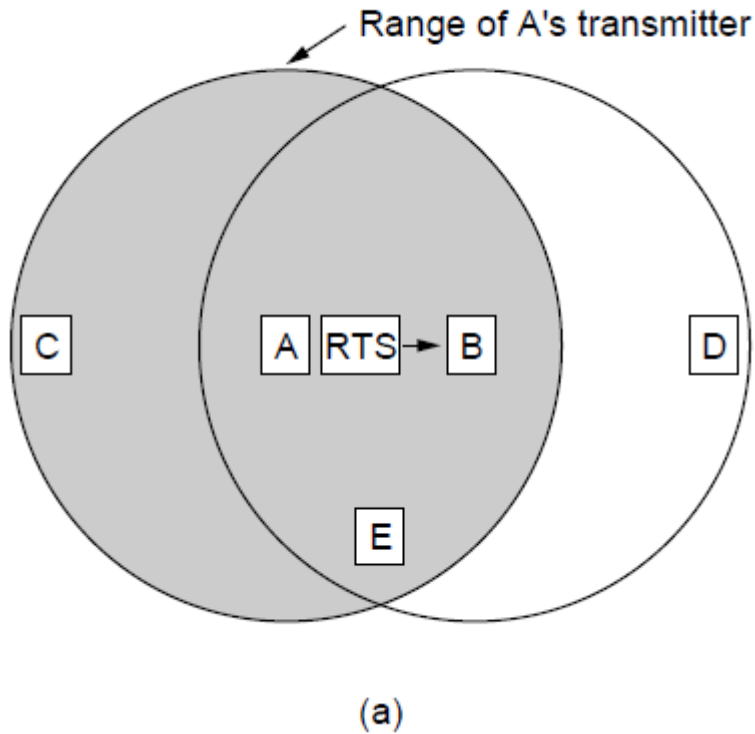
## Wireless LAN Protocols (2)



A wireless LAN. (b) B and C are exposed terminals when transmitting to A and D.



# Wireless LAN Protocols (3)

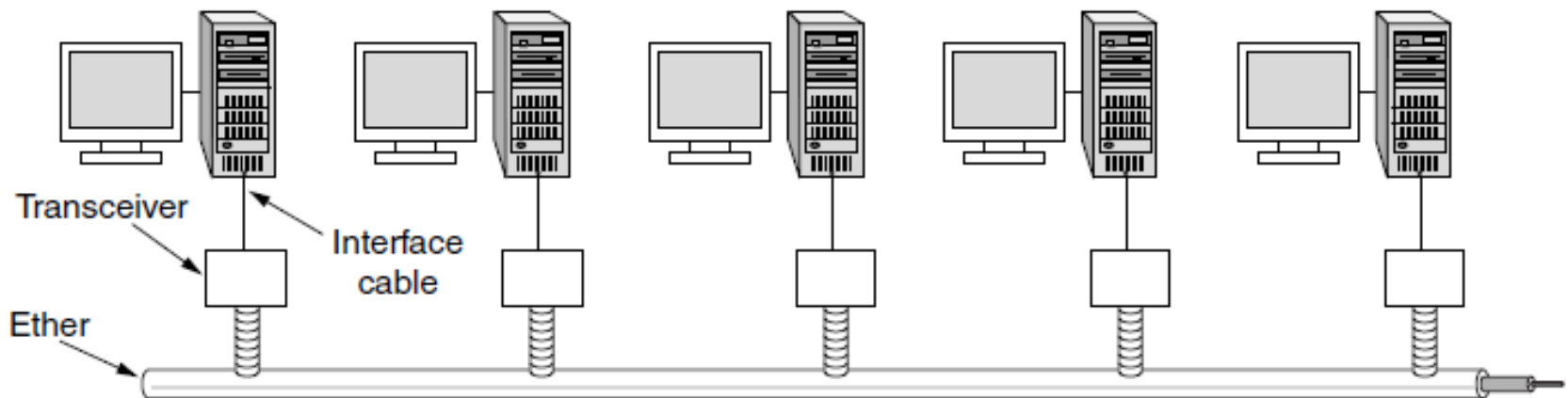


The MACA protocol. (a) *A sending an RTS to B.* (b) *B responding with a CTS to A.*

# Ethernet

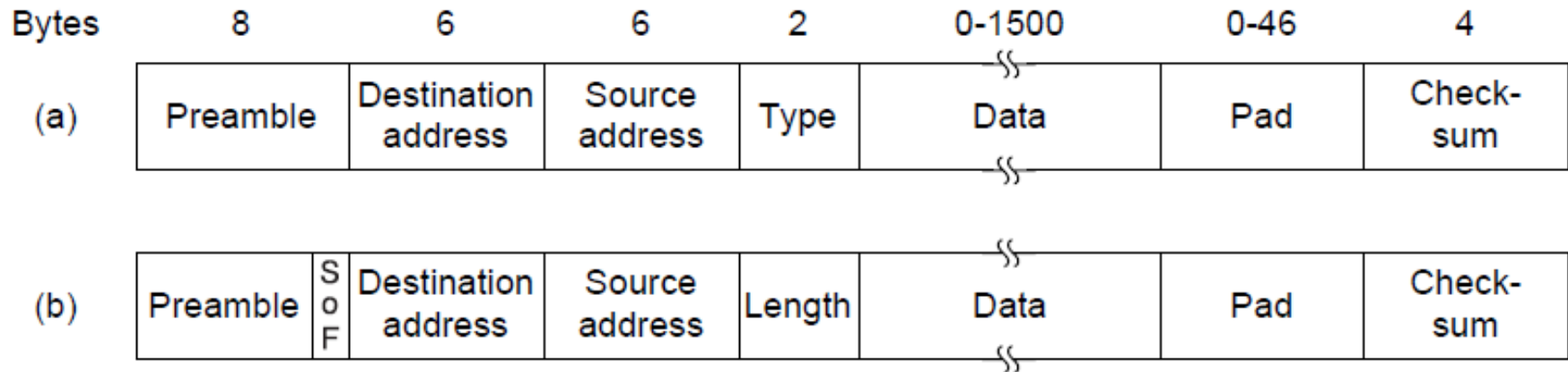
- Physical layer
- MAC sublayer protocol
- Ethernet performance
- Switched Ethernet
- Fast Ethernet
- Gigabit Ethernet
- 10 Gigabit Ethernet
- IEEE 802.2: Logical Link Control
- Retrospective on Ethernet

# Classic Ethernet Physical Layer



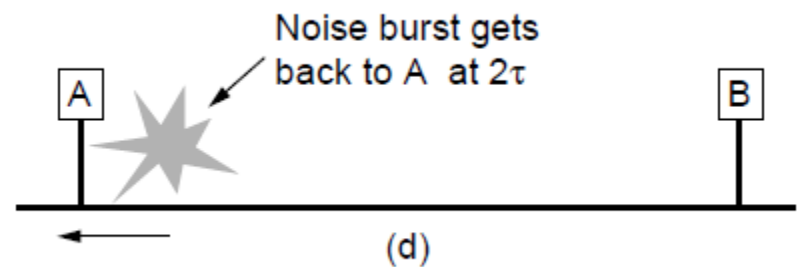
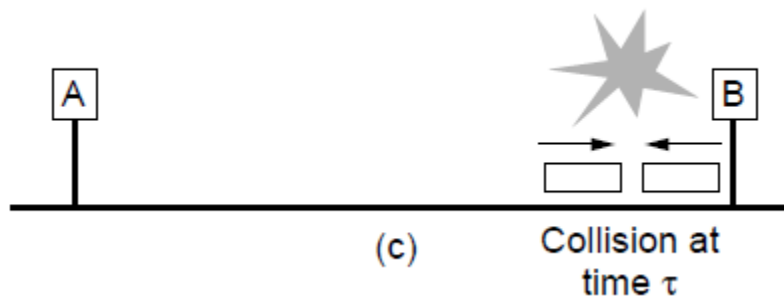
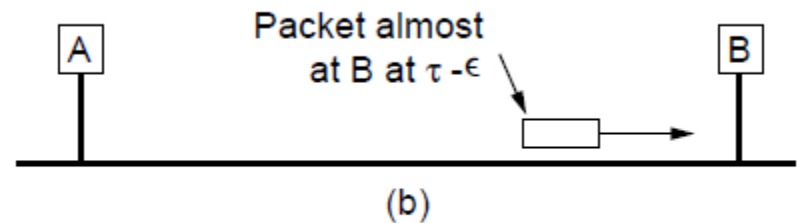
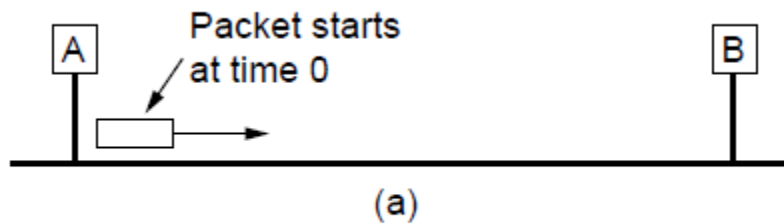
Architecture of classic Ethernet

# MAC Sublayer Protocol (1)



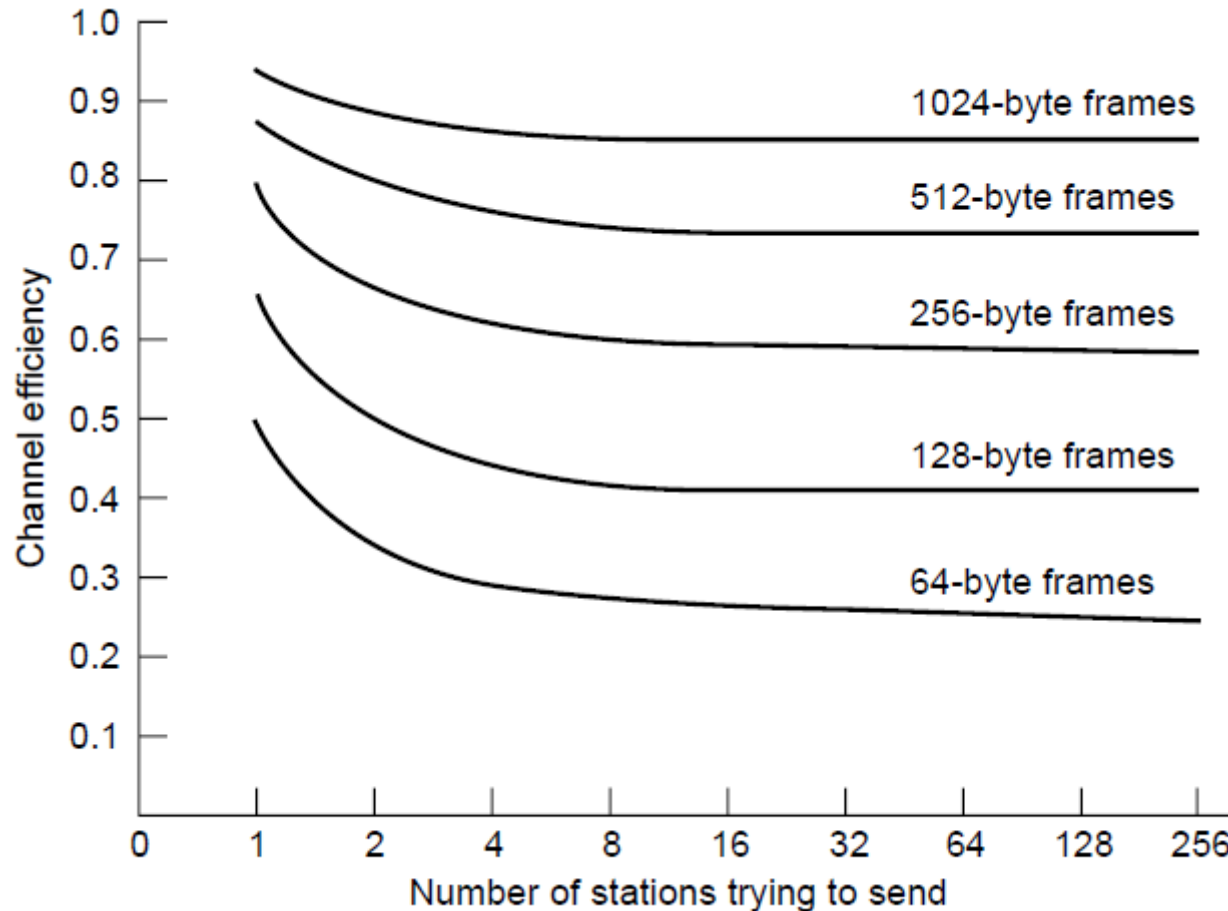
Frame formats. (a) Ethernet (DIX). (b) IEEE 802.3.

# MAC Sublayer Protocol (2)



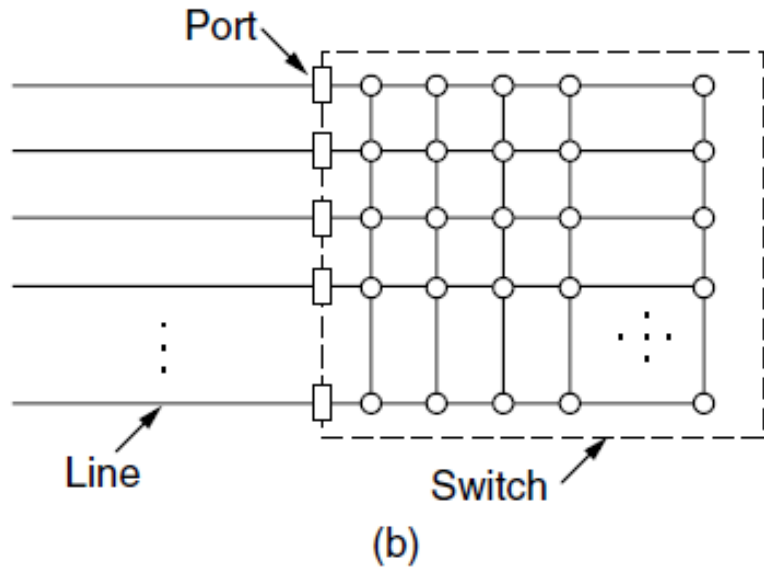
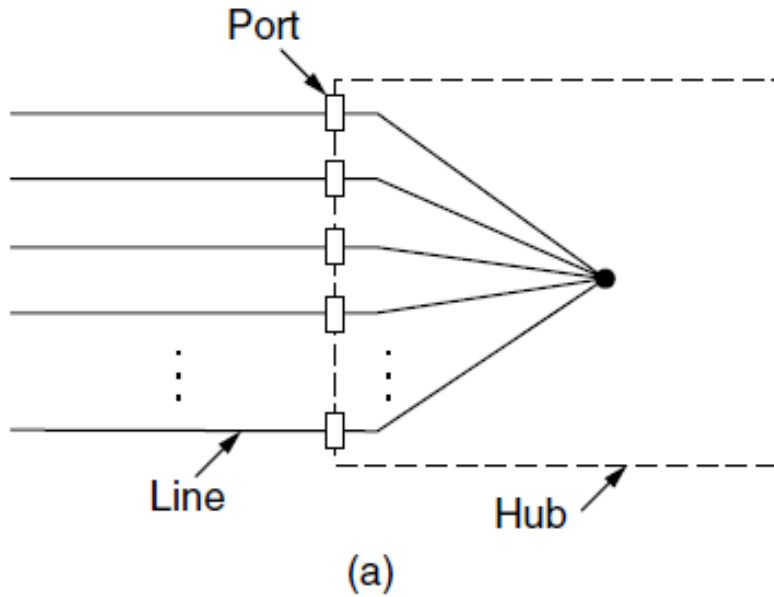
Collision detection can take as long as  $2\tau$ .

# Ethernet Performance



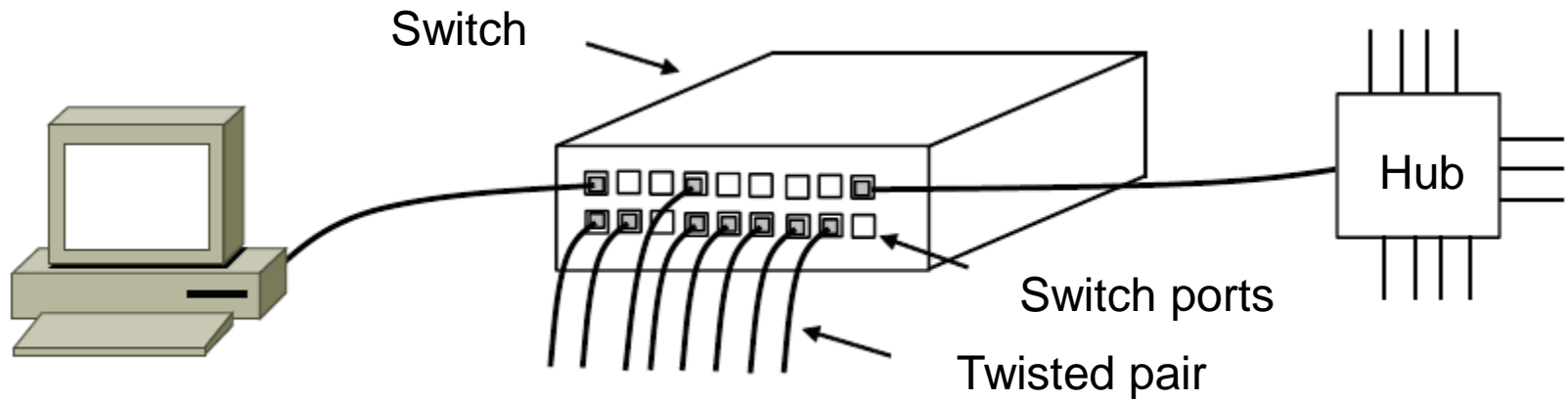
Efficiency of Ethernet at 10 Mbps with 512-bit slot times.

# Switched Ethernet (1)



(a) Hub. (b) Switch.

# Switched Ethernet (2)



An Ethernet switch.

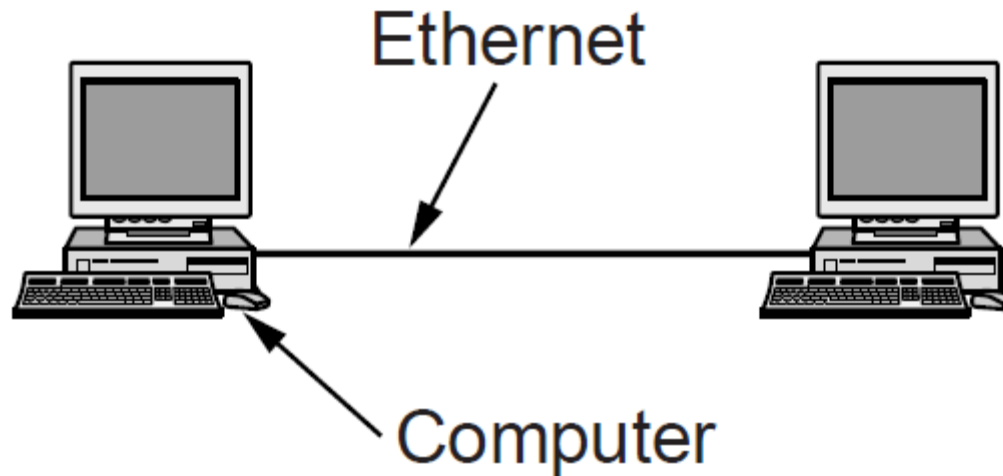


# Fast Ethernet

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

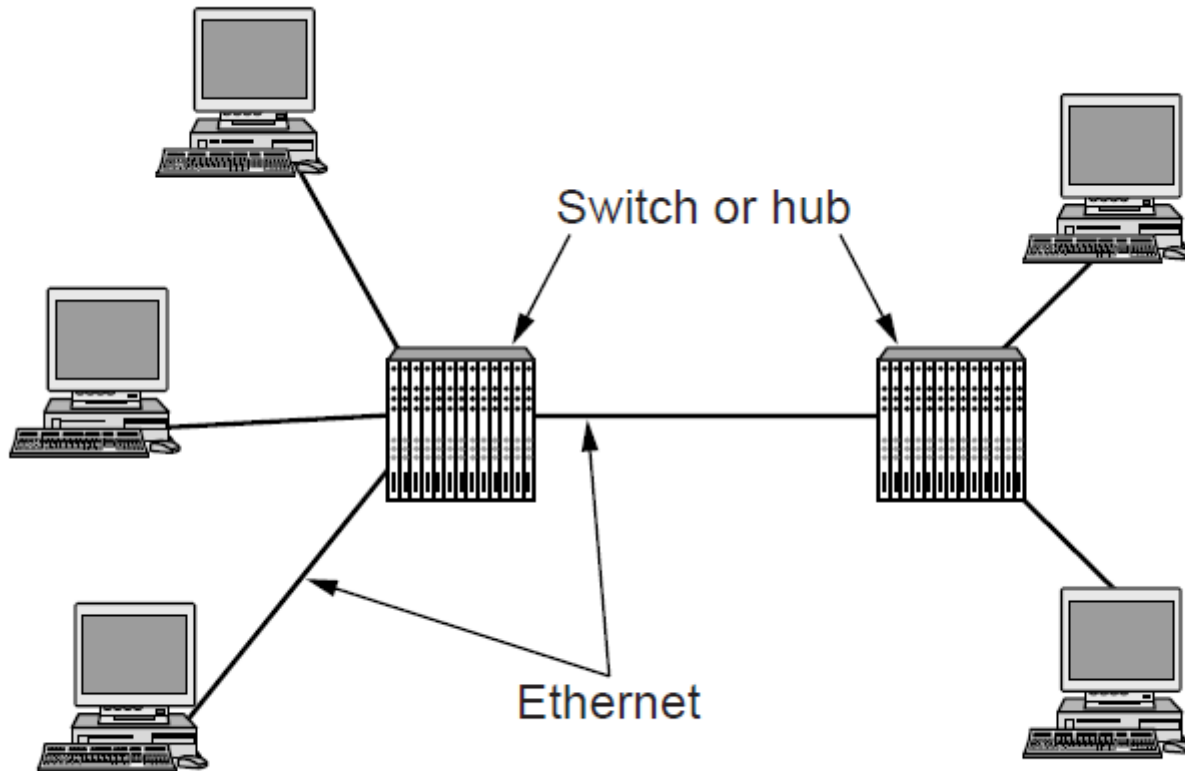
The original fast Ethernet cabling.

# Gigabit Ethernet (1)



A two-station Ethernet

# Gigabit Ethernet (2)



A two-station Ethernet

# Gigabit Ethernet (3)

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 $\mu$ ) or multimode (50, 62.5 $\mu$ )
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

Gigabit Ethernet cabling.

# 10 Gigabit Ethernet

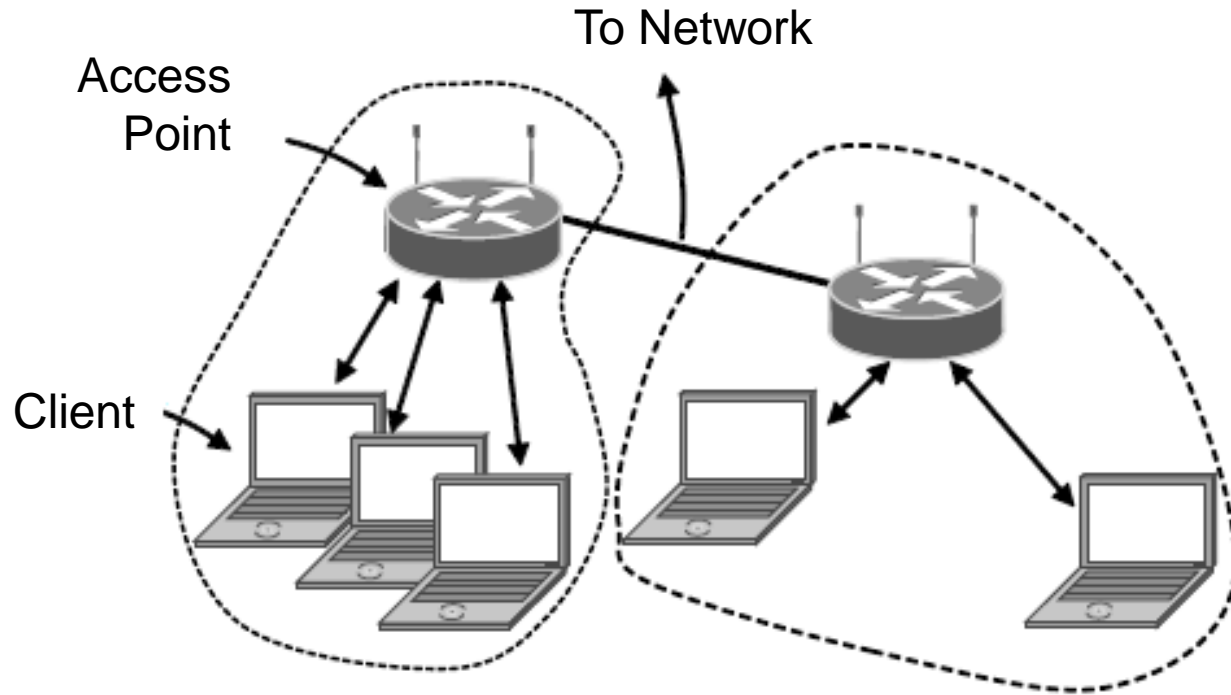
Name	Cable	Max. segment	Advantages
10GBase-SR	Fiber optics	Up to 300 m	Multimode fiber (0.85μ)
10GBase-LR	Fiber optics	10 km	Single-mode fiber (1.3μ)
10GBase-ER	Fiber optics	40 km	Single-mode fiber (1.5μ)
10GBase-CX4	4 Pairs of twinax	15 m	Twinaxial copper
10GBase-T	4 Pairs of UTP	100 m	Category 6a UTP

## Gigabit Ethernet cabling

# Wireless Lans

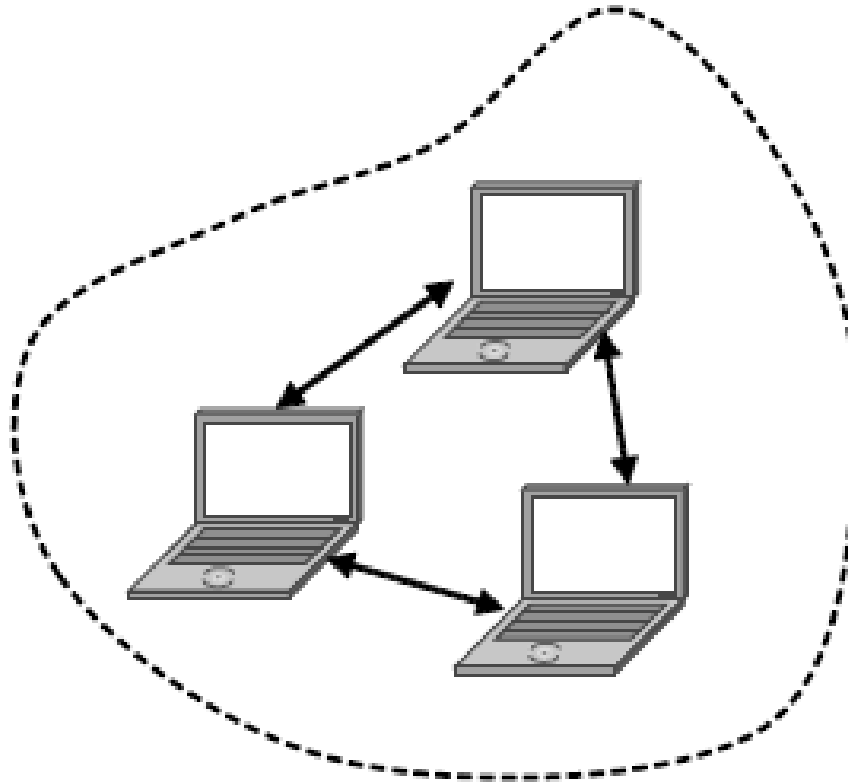
- 802.11 architecture and protocol stack
- 802.11 physical layer
- 802.11 MAC sublayer protocol
- 802.11 frame structure
- Services

# 802.11 Architecture and Protocol Stack (1)



802.11 architecture – infrastructure mode

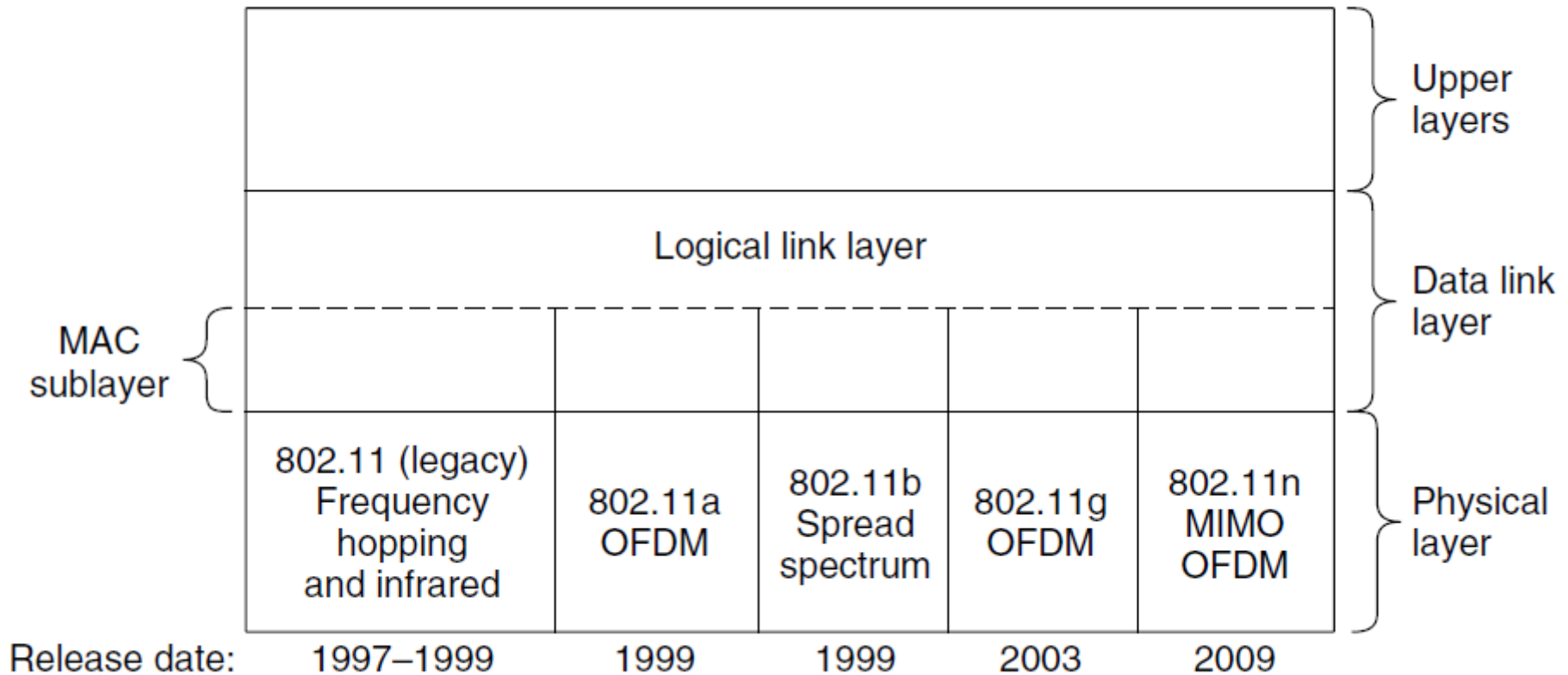
# 802.11 Architecture and Protocol Stack (2)



802.11 architecture – ad-hoc mode

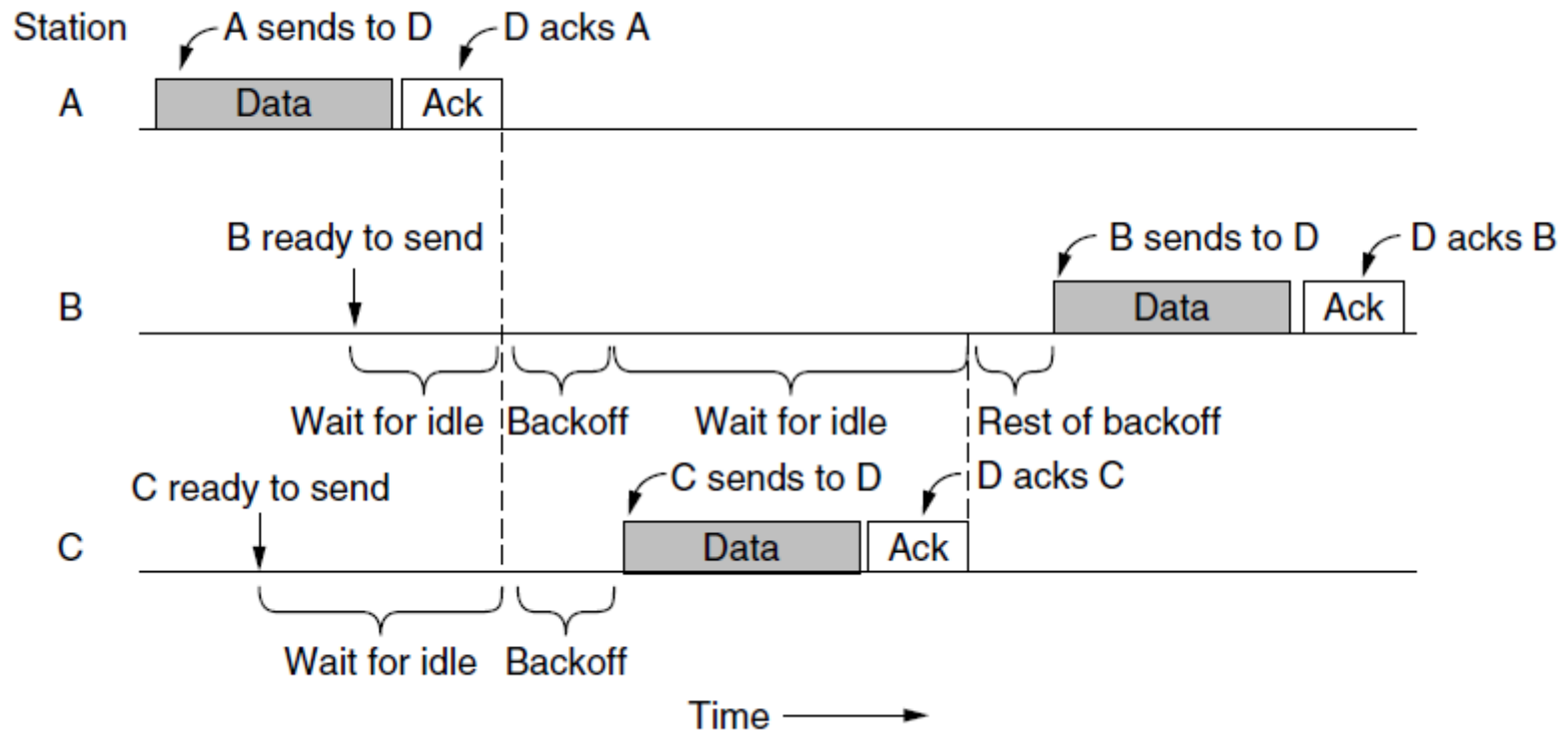


# 802.11 Architecture and Protocol Stack (3)



Part of the 802.11 protocol stack.

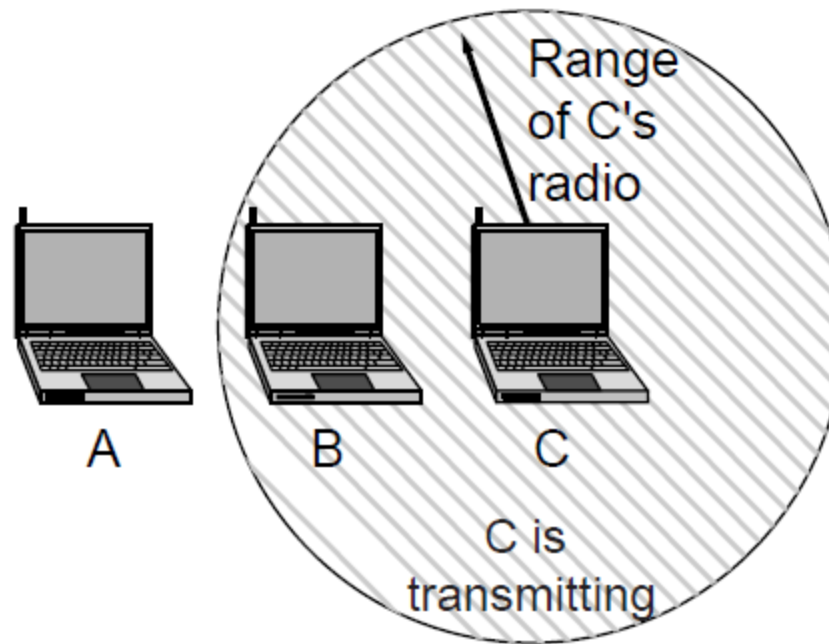
# The 802.11 MAC Sublayer Protocol (1)



Sending a frame with CSMA/CA.

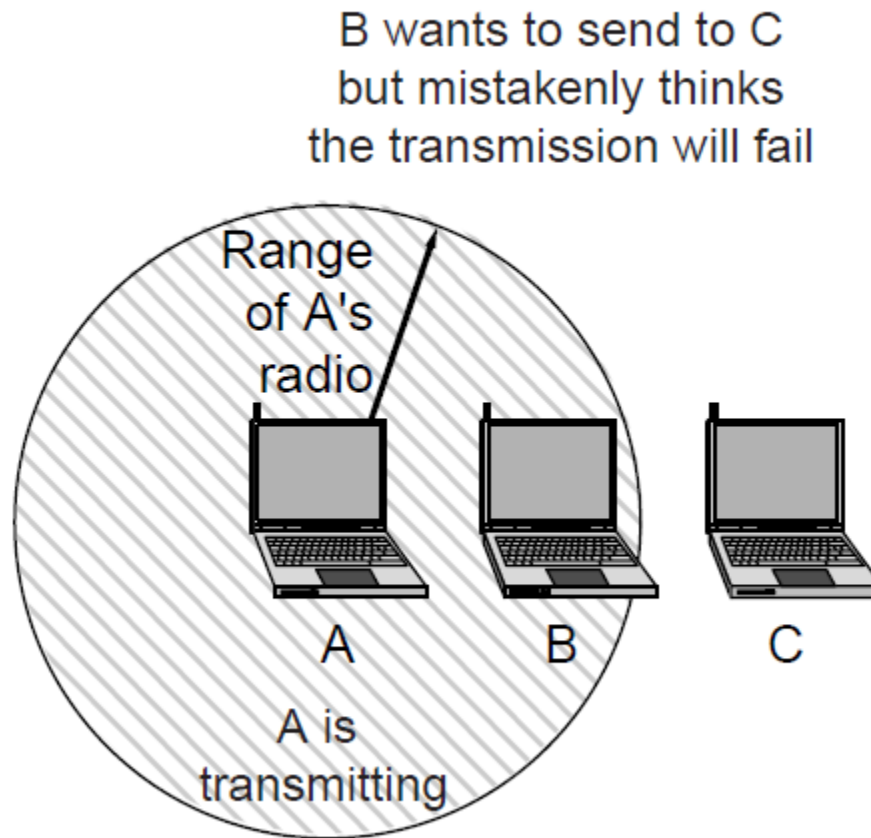
# The 802.11 MAC Sublayer Protocol (2)

A wants to send to B  
but cannot hear that  
B is busy



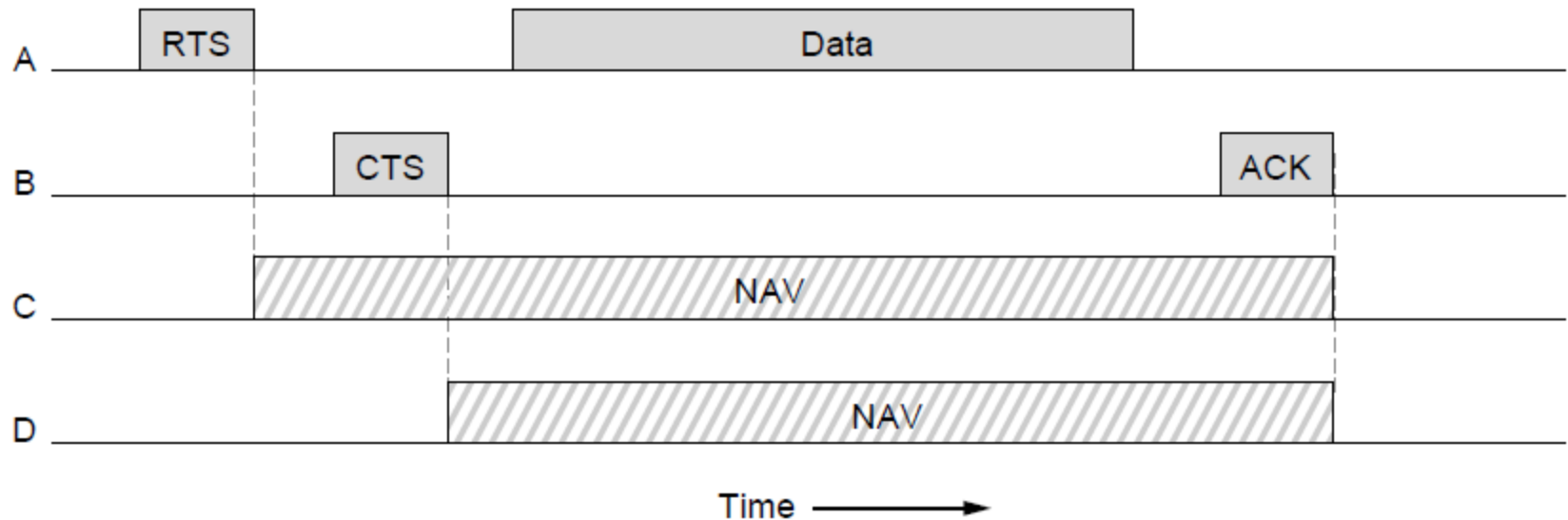
The hidden terminal problem.

# The 802.11 MAC Sublayer Protocol (3)



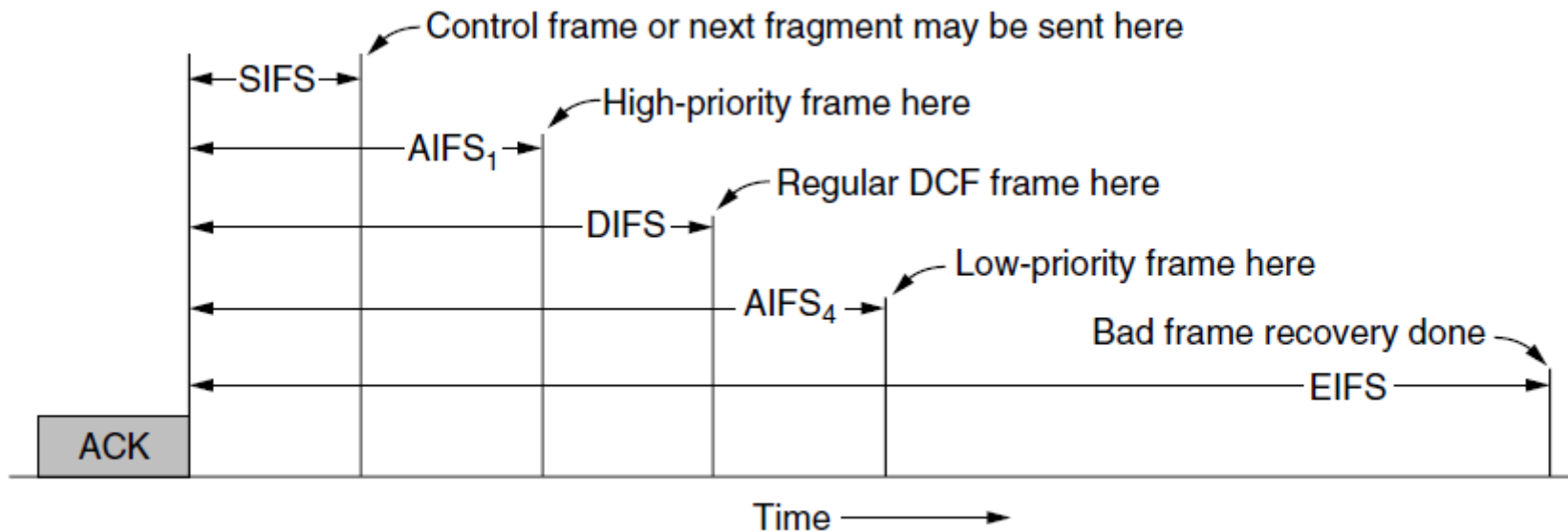
The exposed terminal problem.

# The 802.11 MAC Sublayer Protocol (4)



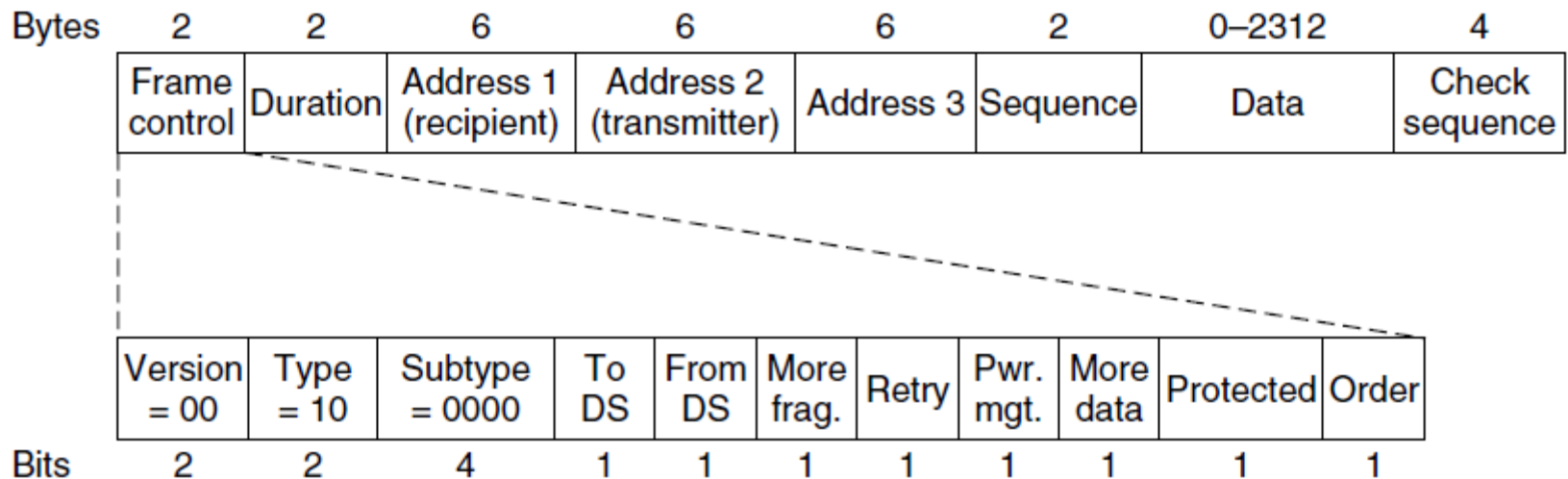
The use of virtual channel sensing using CSMA/CA.

# The 802.11 MAC Sublayer Protocol (5)



Interframe spacing in 802.11

# 802.11 Frame Structure



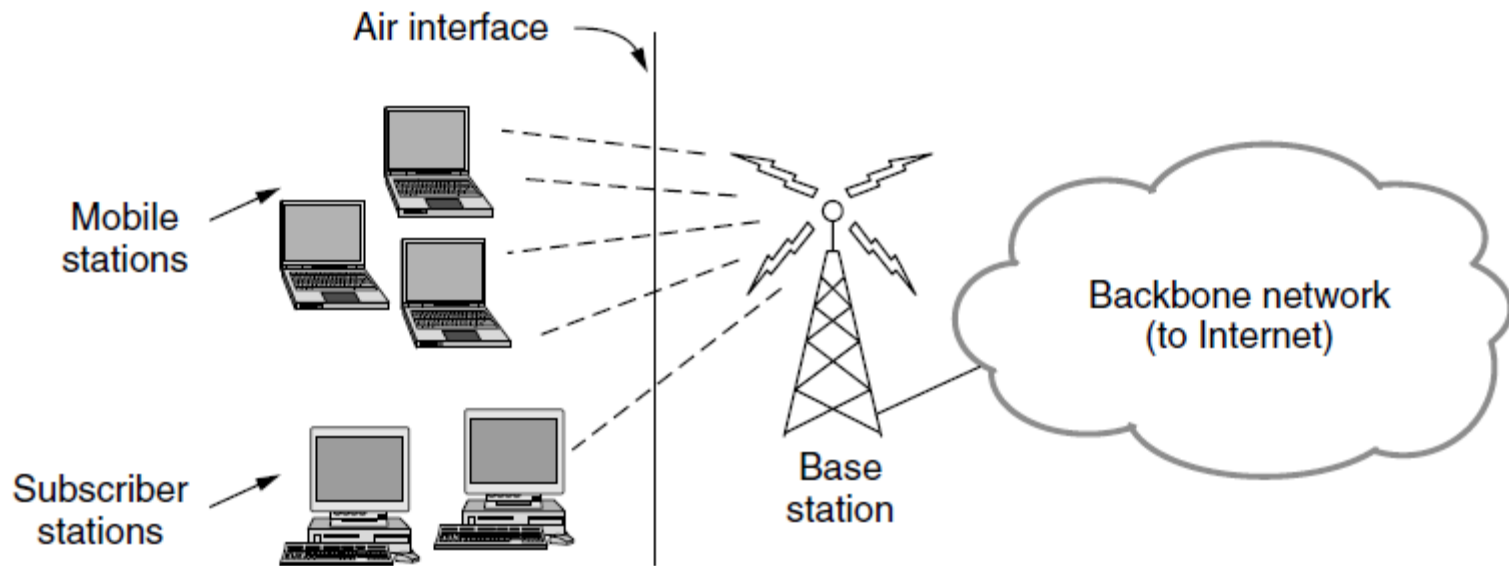
Format of the 802.11 data frame

# Broadband Wireless

- Comparison of 802.16 with 802.11, 3G
- 802.16 architecture and protocol stack
- 802.16 physical layer
- 802.16 frame structure

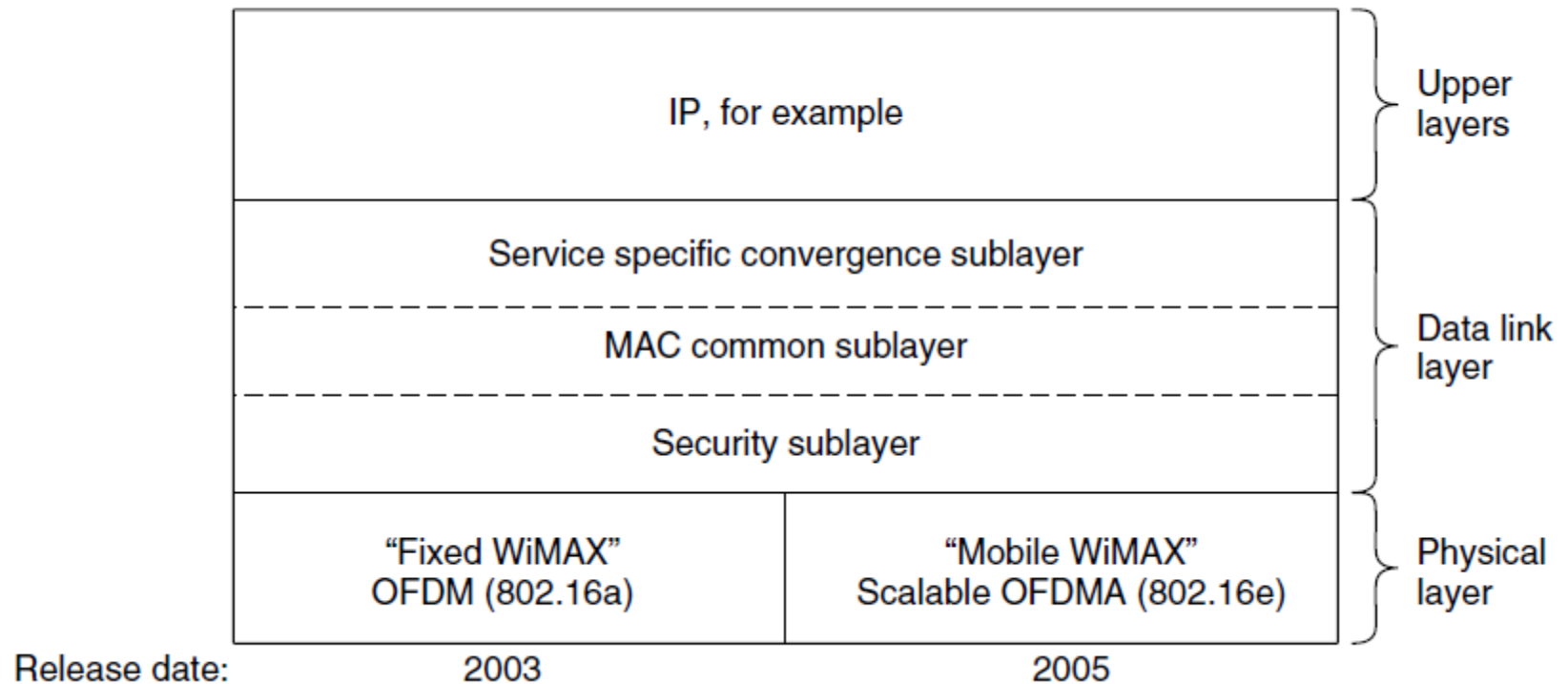


# Comparison of 802.16 with 802.11 and 3G



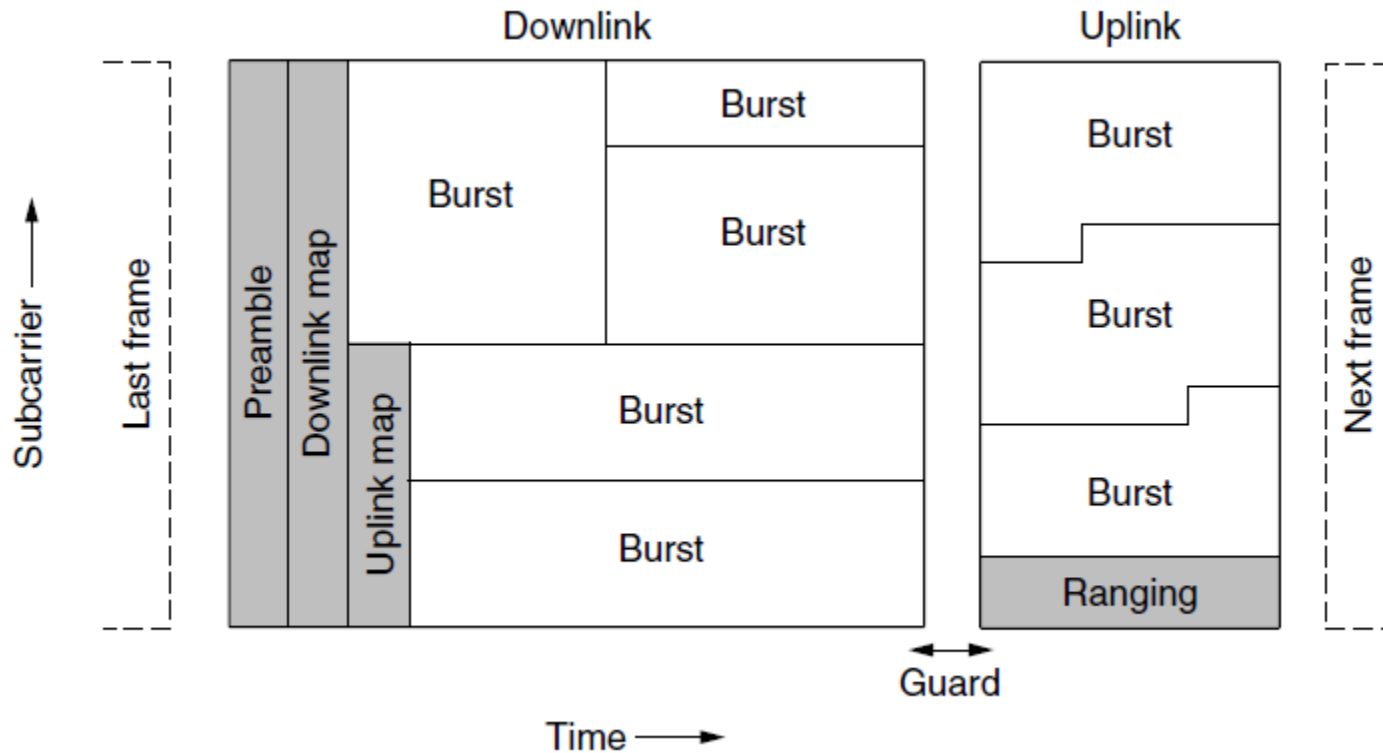
The 802.16 architecture

# 802.16 Architecture and Protocol Stack



The 802.16 protocol stack

# 802.16 Physical Layer



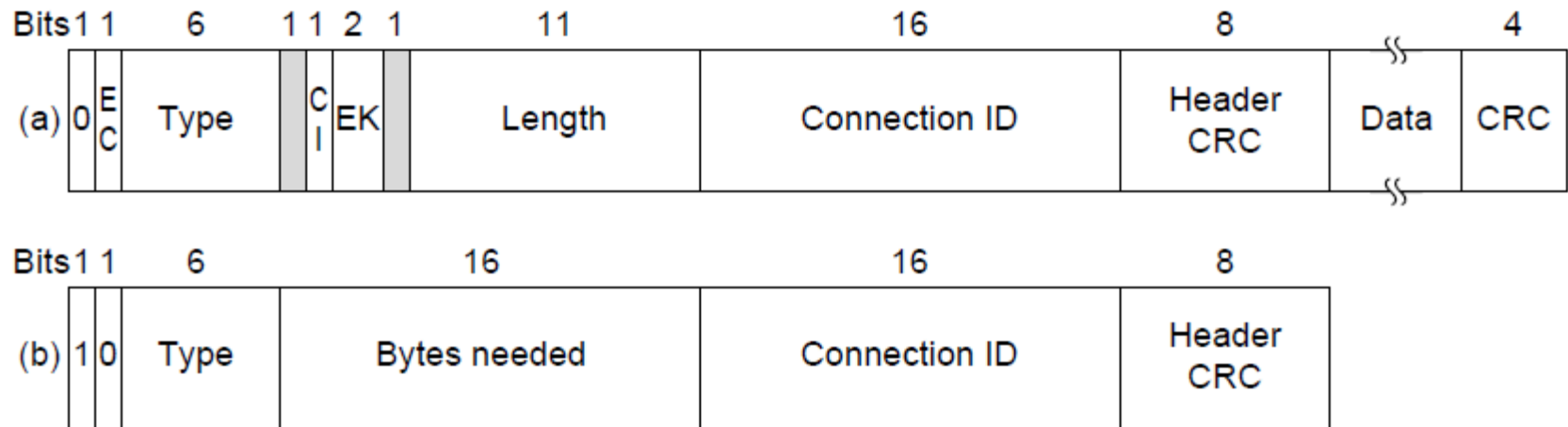
Frames structure for OFDMA with time division duplexing.

# 802.16 MAC Sublayer Protocol

## Classes of service

1. Constant bit rate service.
2. Real-time variable bit rate service.
3. Non-real-time variable bit rate service.
4. Best-effort service.

# 802.16 Frame Structure

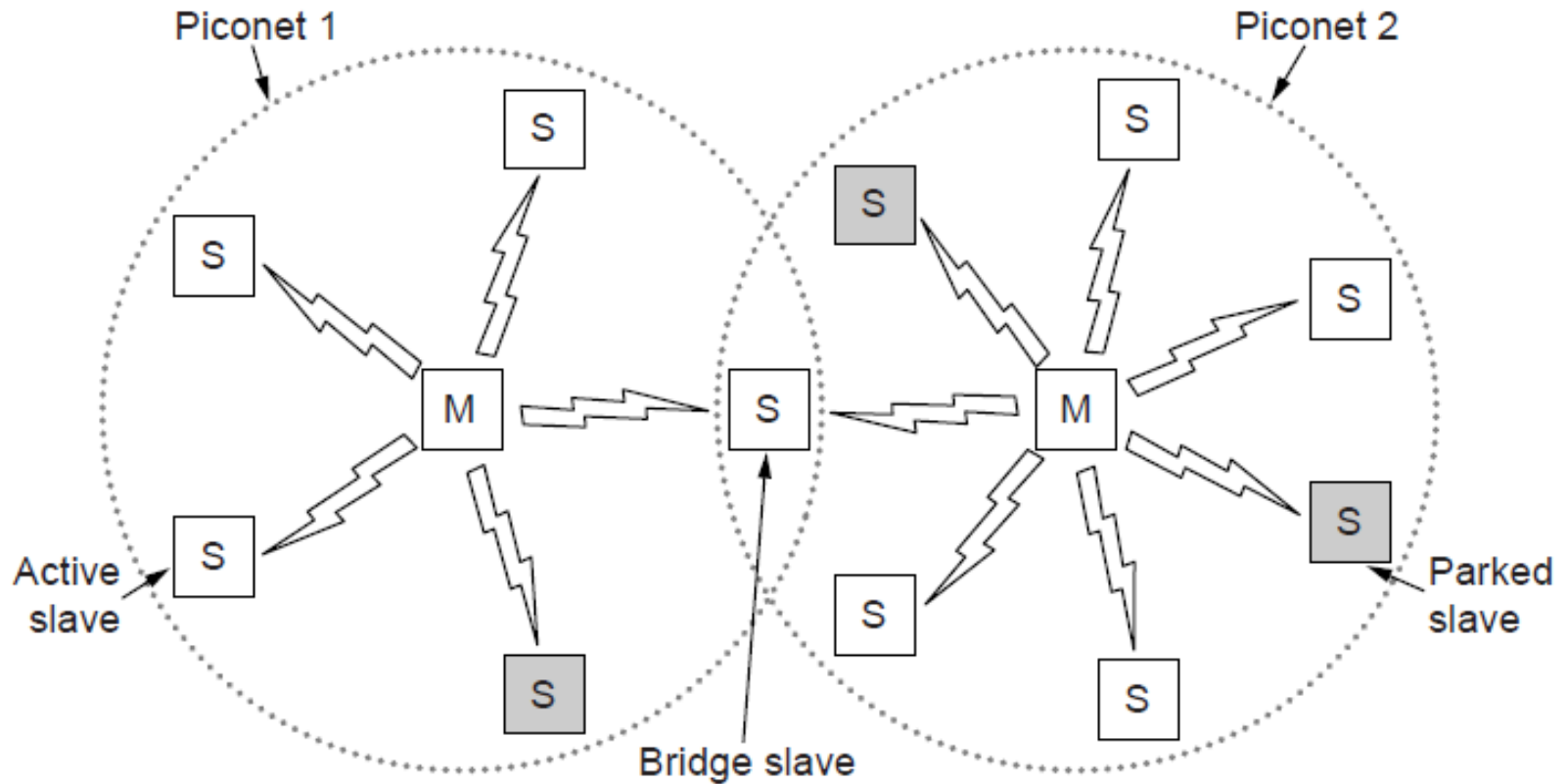


(a) A generic frame. (b) A bandwidth request frame.

# Bluetooth

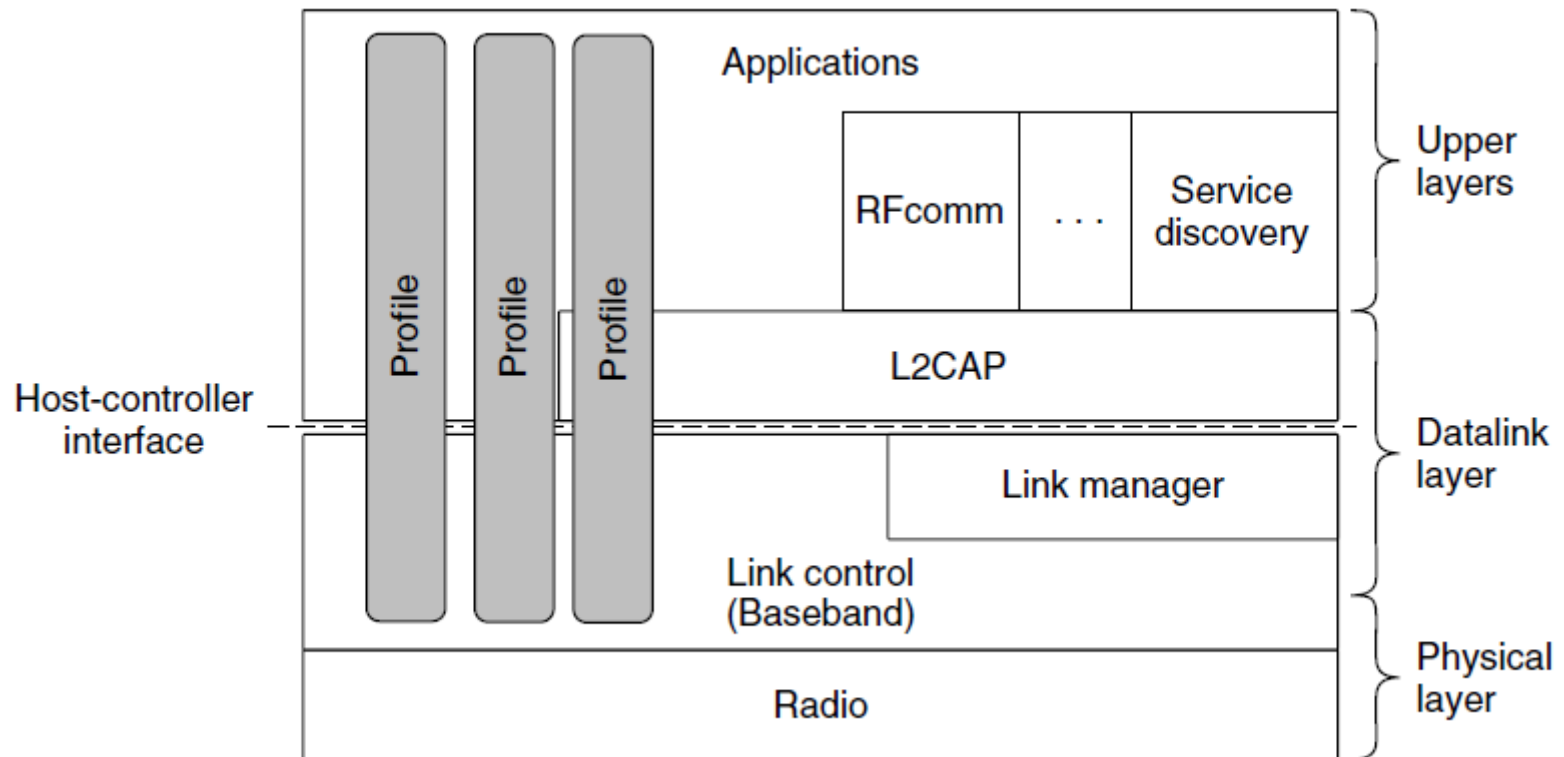
- Architecture
- Applications
- Protocol stack
- Radio layer
- Link layers
- Frame structure

# Bluetooth Architecture



Two piconets can be connected to form a scatternet

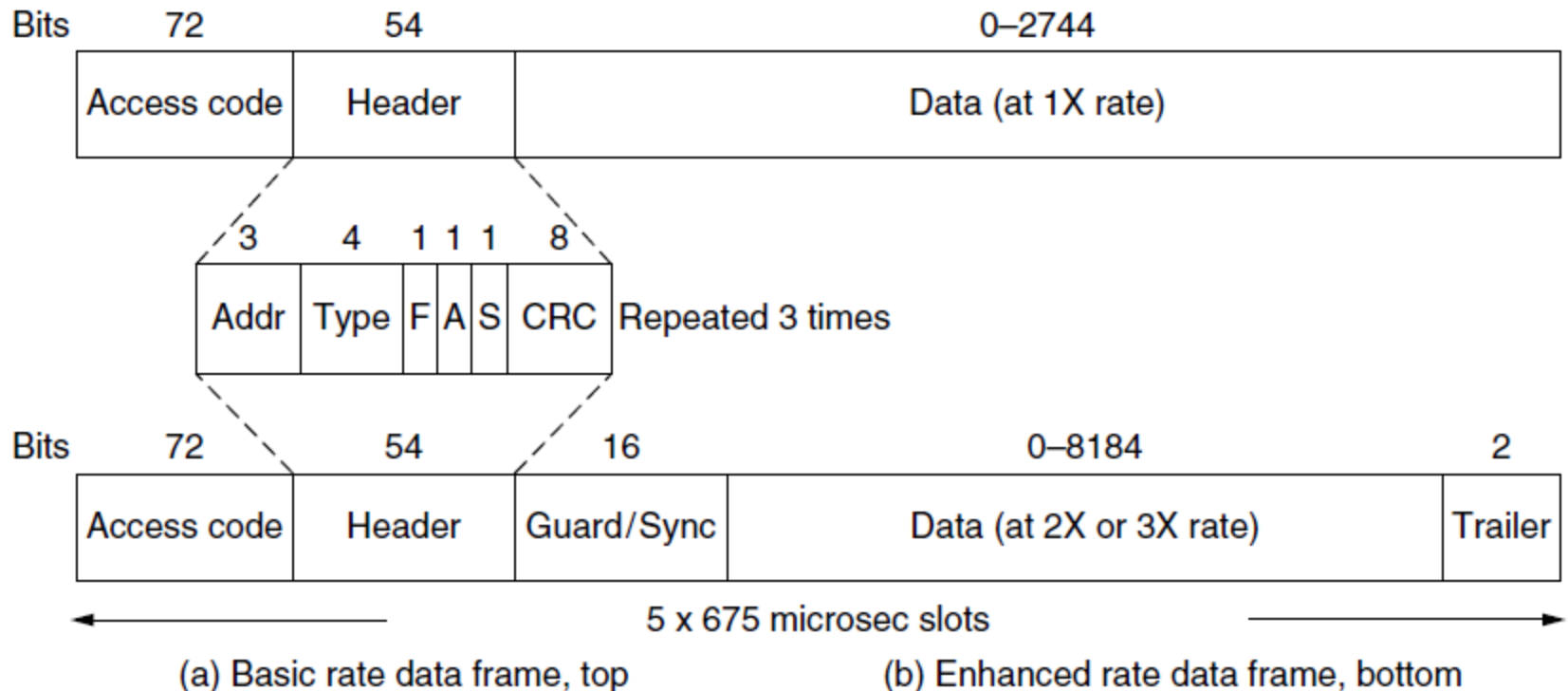
# Bluetooth Protocol Stack



The Bluetooth protocol architecture.



# Bluetooth Frame Structure

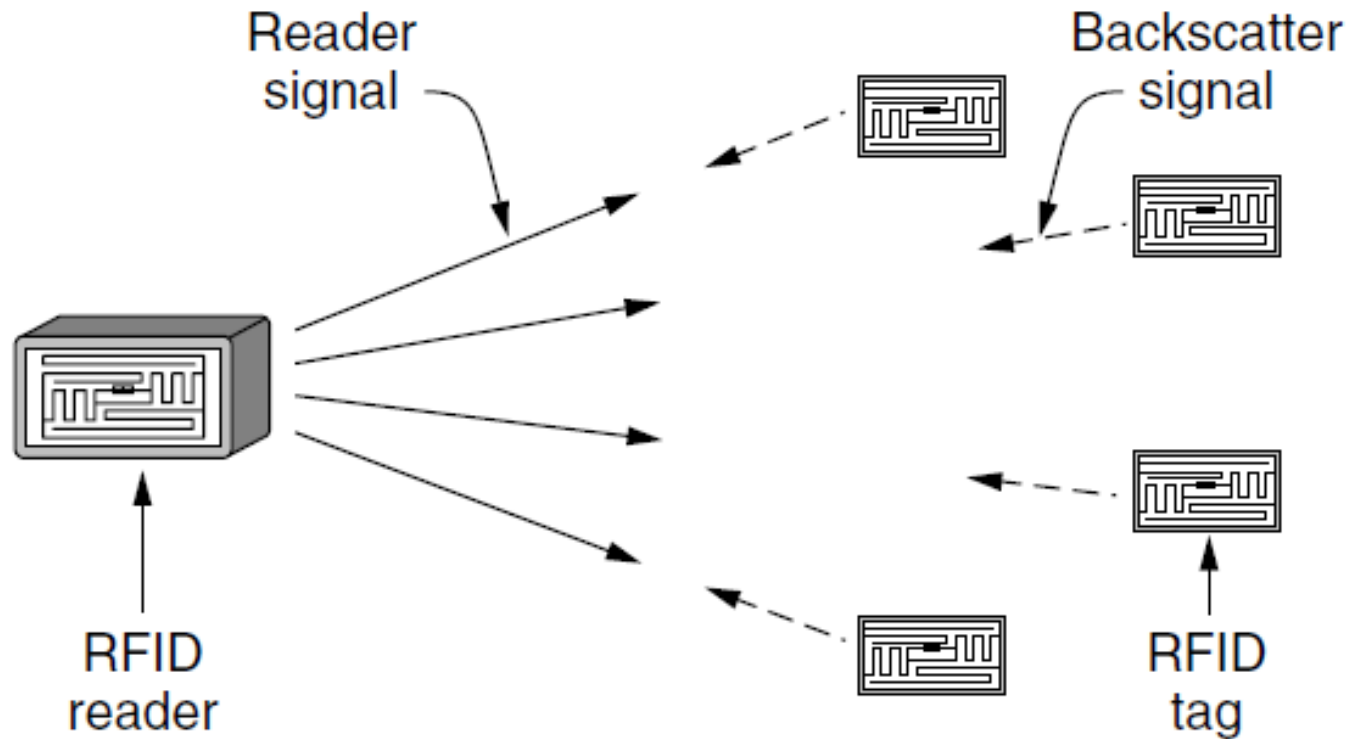


Typical Bluetooth data frame at (a) basic, and (b) enhanced, data rates.

# RFID

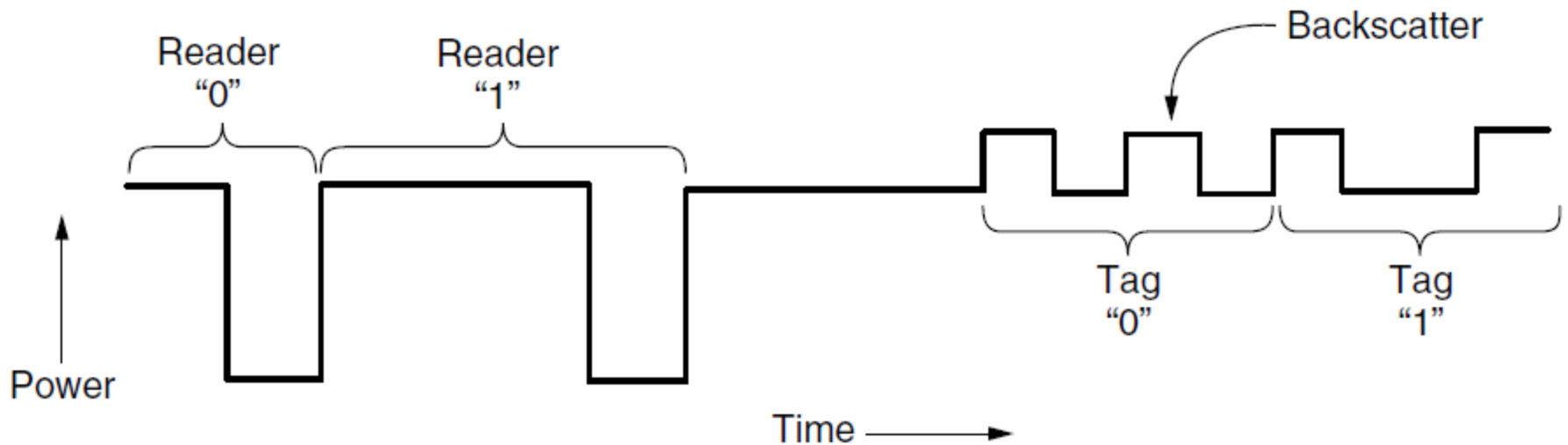
- EPC Gen 2 architecture
- EPC Gen 2 physical layer
- EPC Gen 2 tag identification layer
- Tag identification message formats

# EPC Gen 2 Architecture



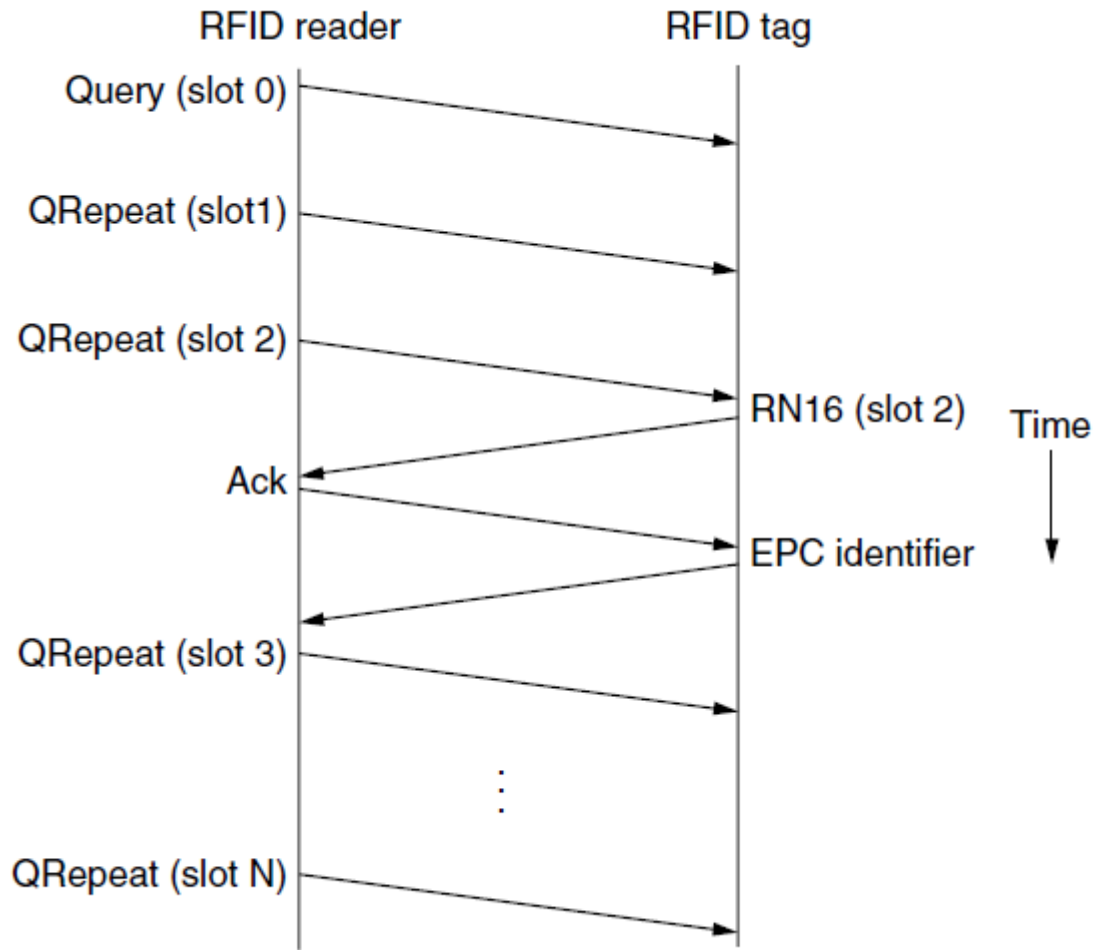
RFID architecture.

# EPC Gen 2 Physical Layer



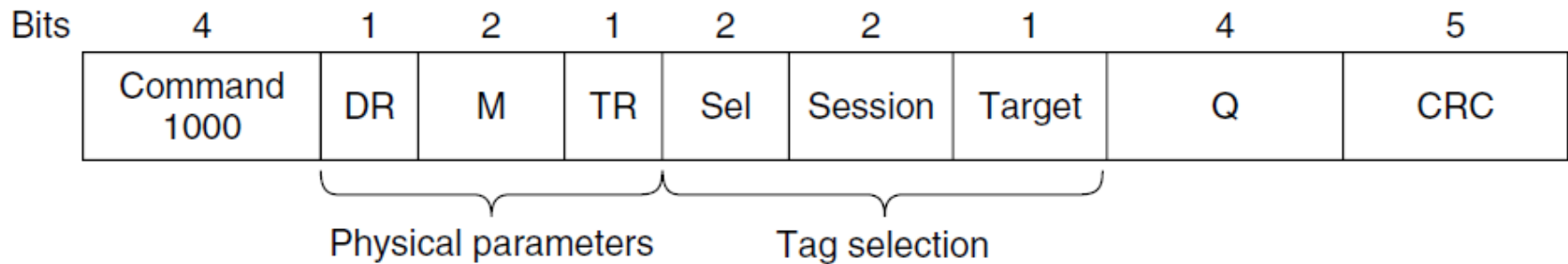
Reader and tag backscatter signals.

# EPC Gen 2 Tag Identification Layer



Example message exchange to identify a tag.

# Tag Identification Message Formats

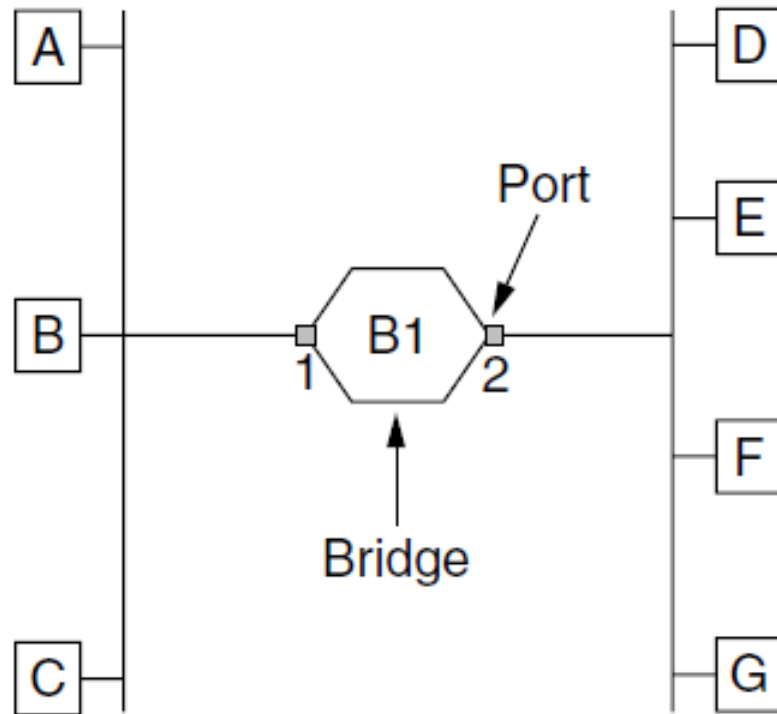


Format of the Query message.

# Data Link Layer Switching

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

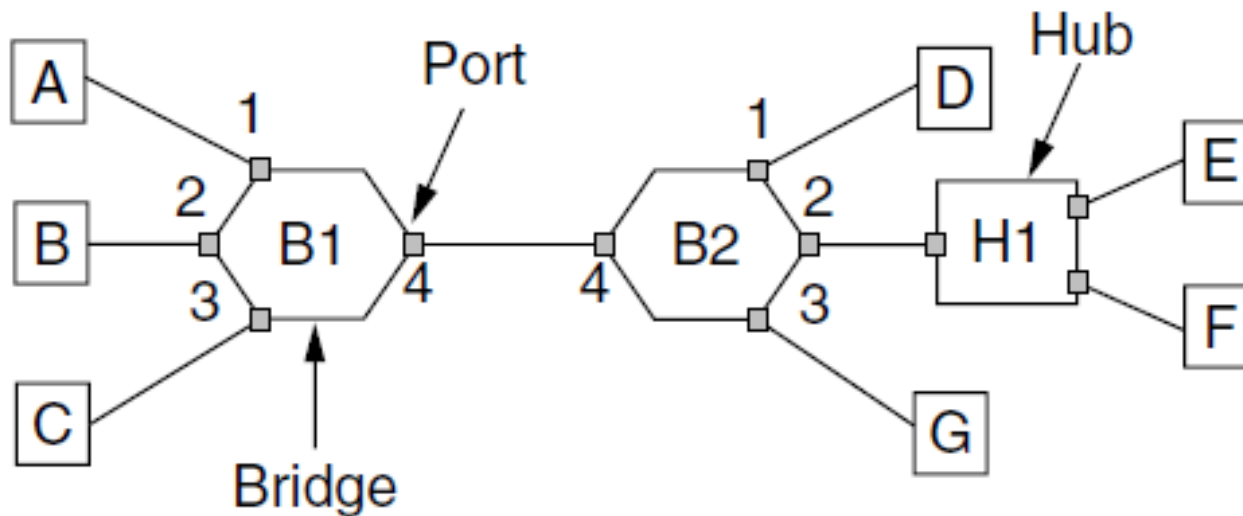
# Learning Bridges (1)



Bridge connecting two multidrop LANs

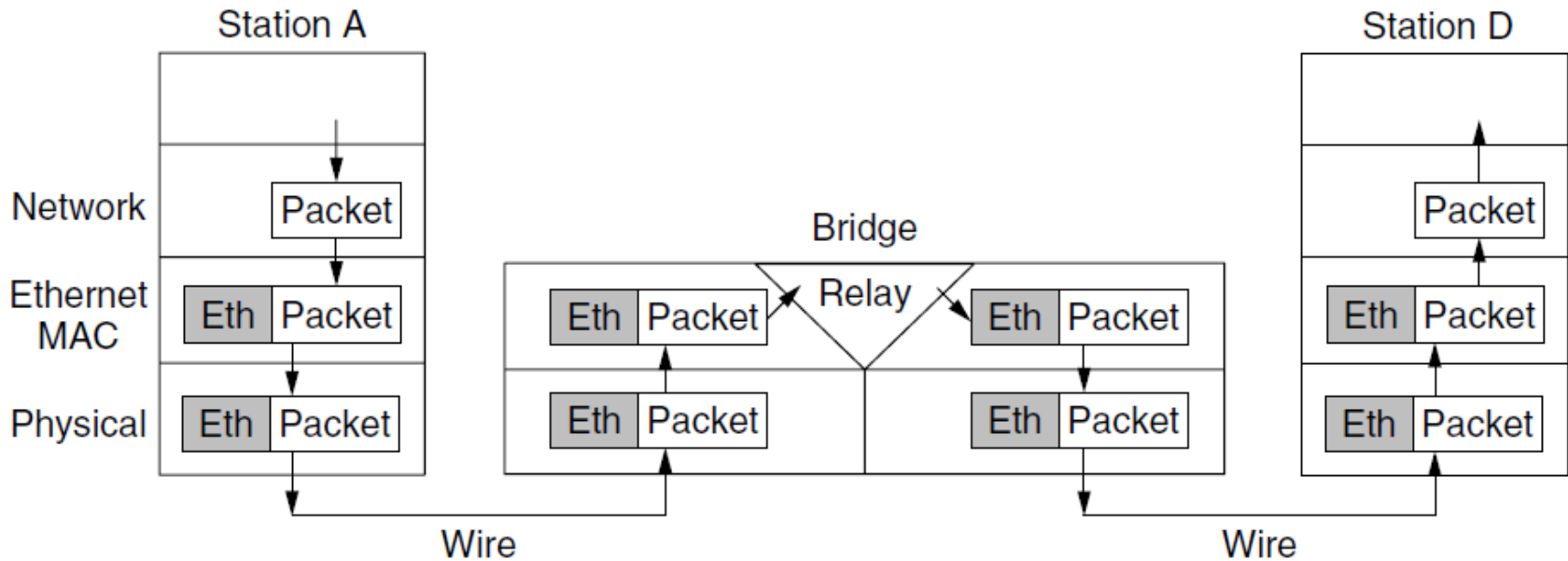


# Learning Bridges (2)



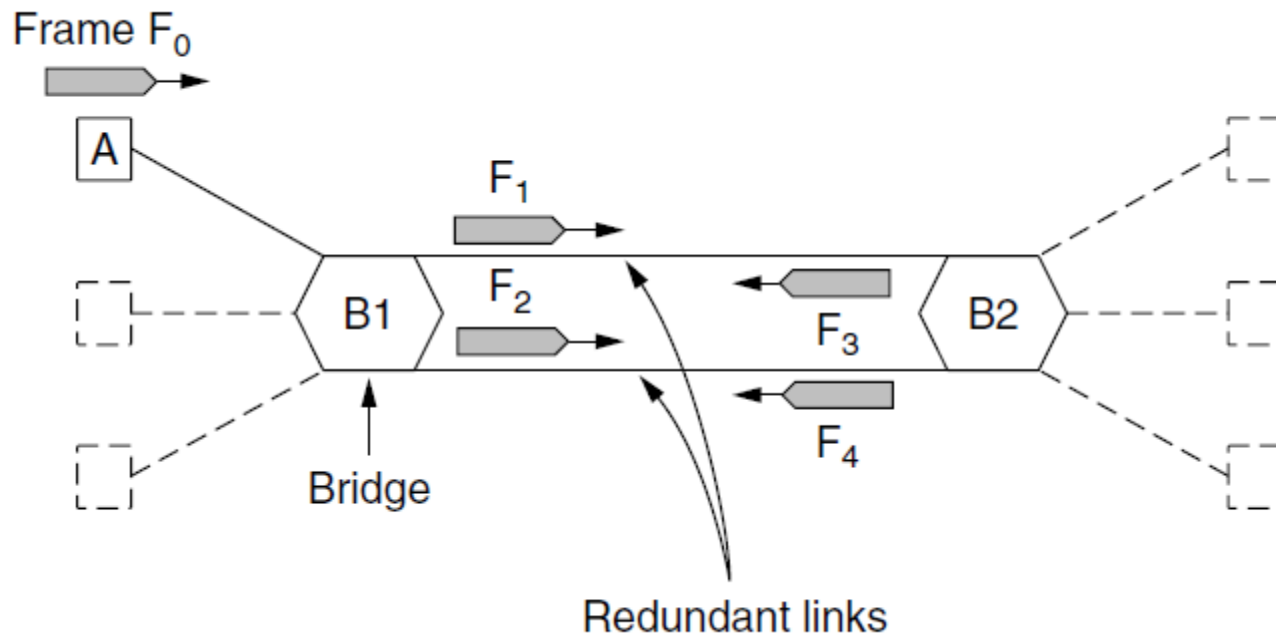
Bridges (and a hub) connecting seven point-to-point stations.

# Learning Bridges (3)



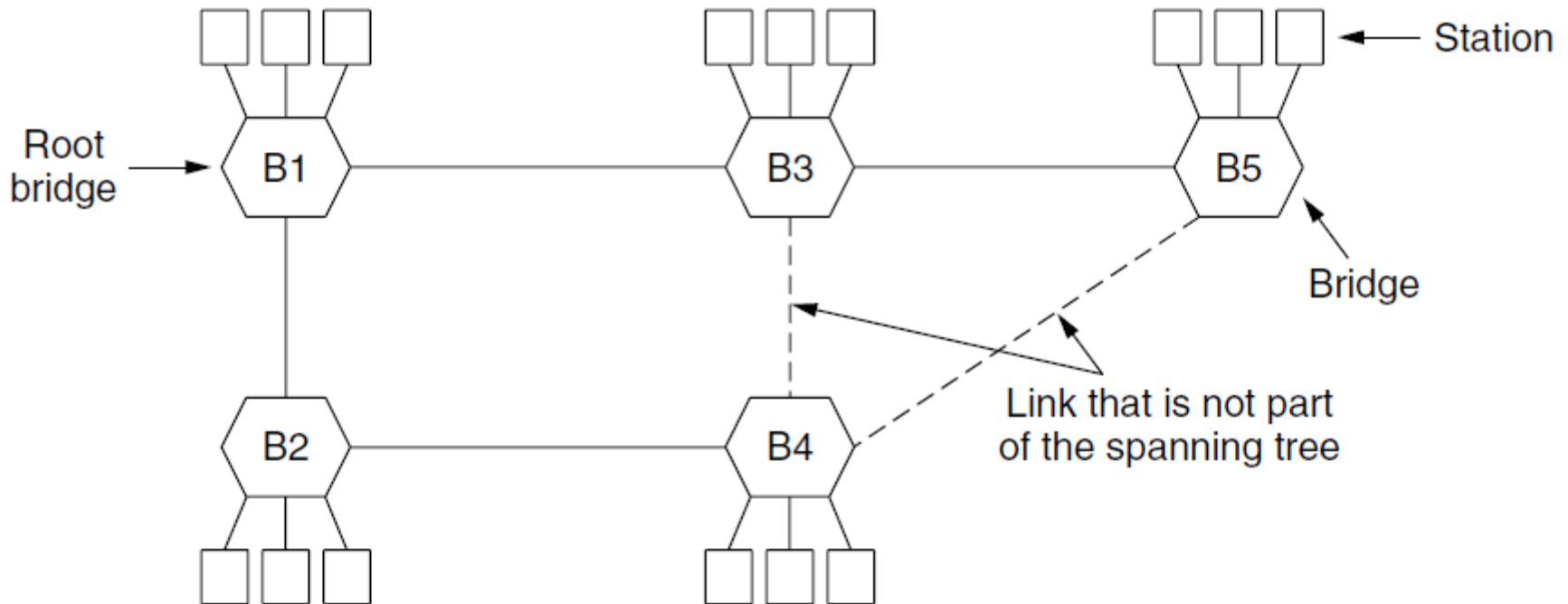
Protocol processing at a bridge.

# Spanning Tree Bridges (1)



Bridges with two parallel links

# Spanning Tree Bridges (2)



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

# Poem by Radia Perlman (1985)

## Algorithm for Spanning Tree (1)

*I think that I shall never see  
A graph more lovely than a tree.  
A tree whose crucial property  
Is loop-free connectivity.  
A tree which must be sure to span.  
So packets can reach every LAN.*

. . .

# Poem by Radia Perlman (1985)

## Algorithm for Spanning Tree (2)

. . .

*First the Root must be selected*

*By ID it is elected.*

*Least cost paths from Root are traced*

*In the tree these paths are placed.*

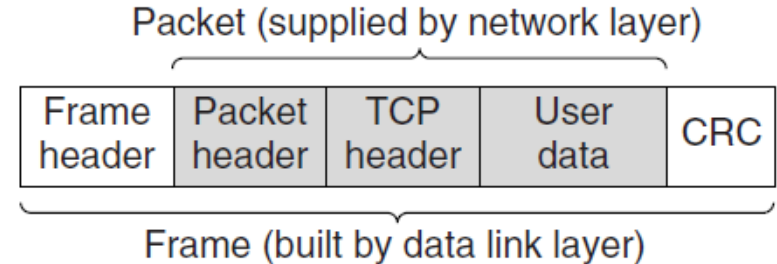
*A mesh is made by folks like me*

*Then bridges find a spanning tree.*

# 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)

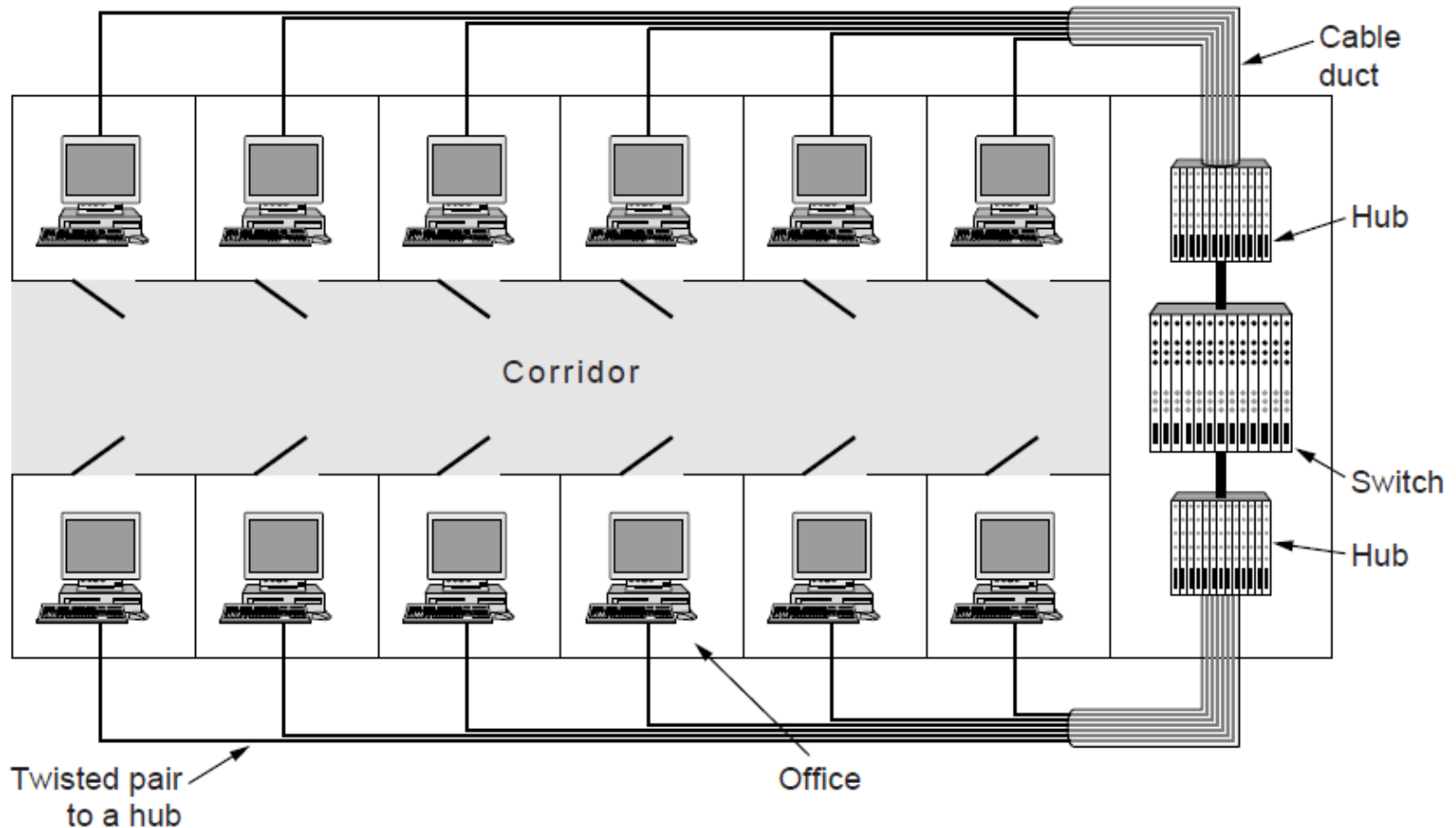


(b)

(a) Which device is in which layer.

(b) Frames, packets, and headers.

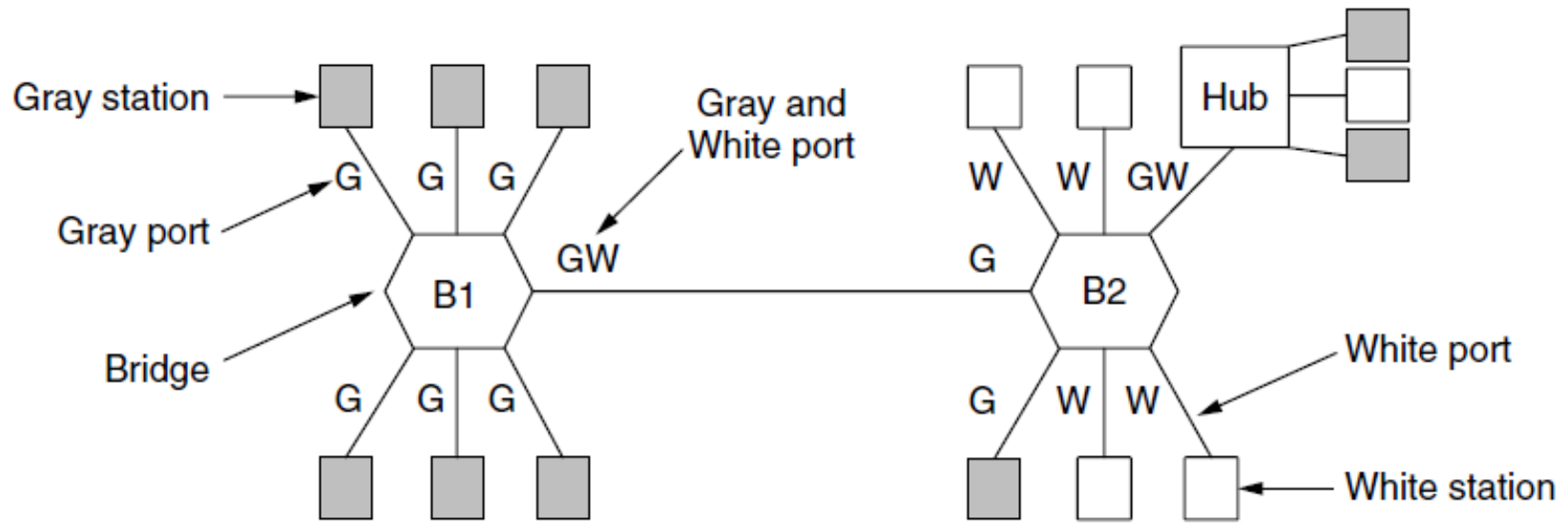
# Virtual LANs (1)



A building with centralized wiring using hubs and a switch.

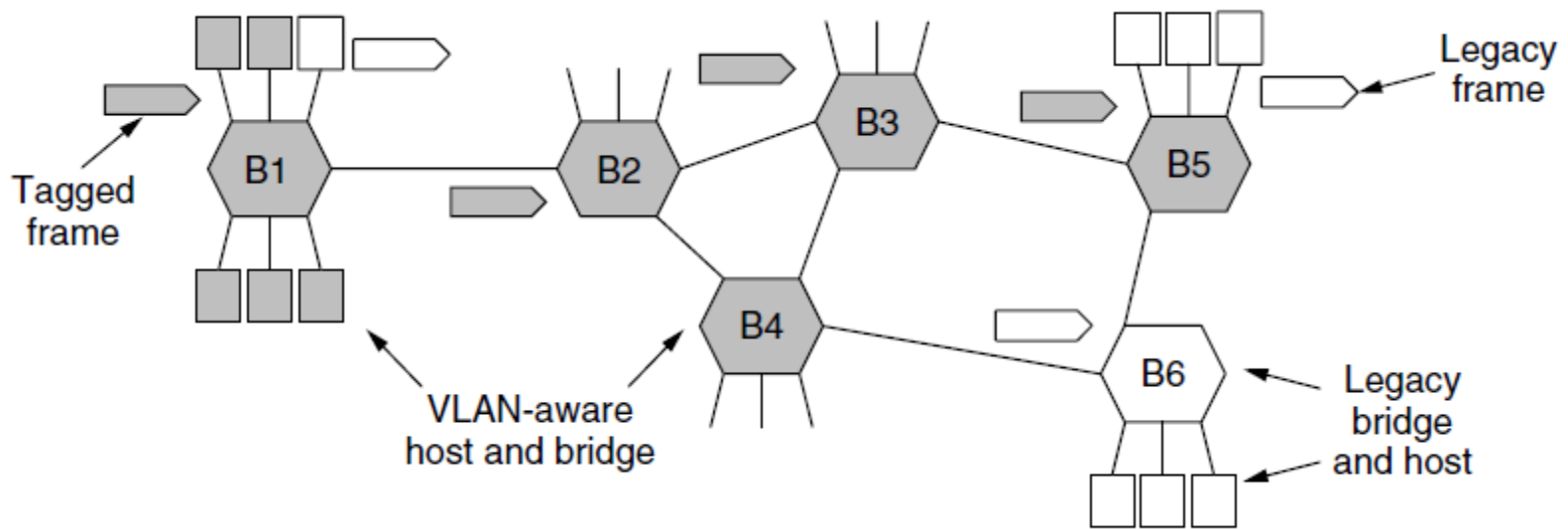


# Virtual LANs (2)



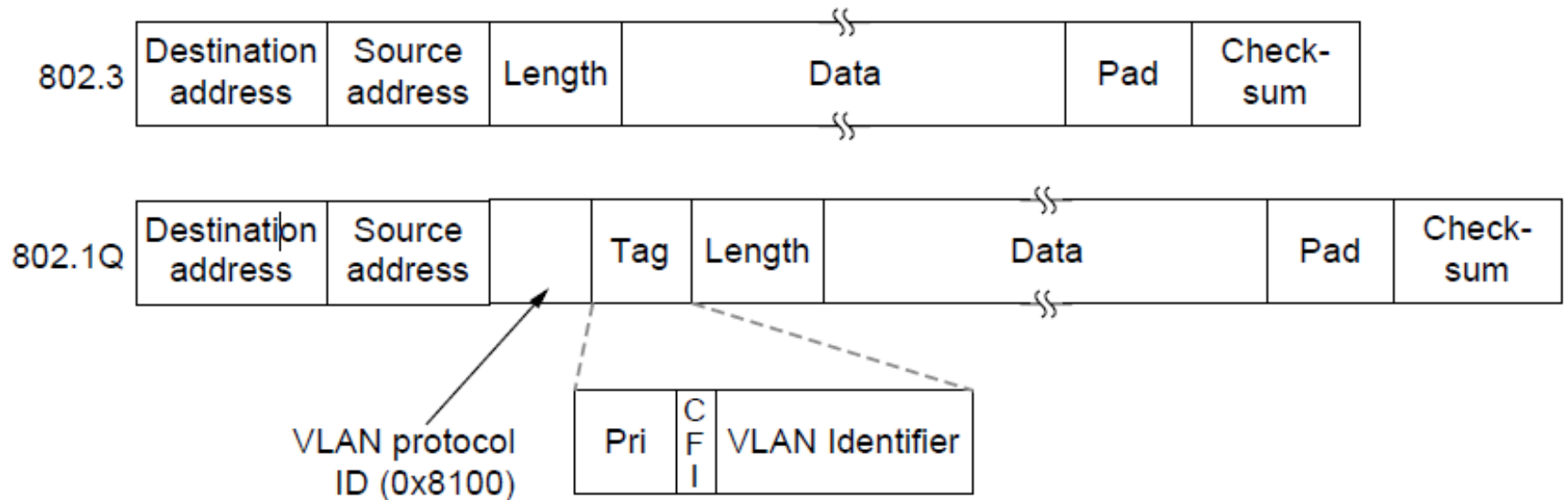
Two VLANs, gray and white, on a bridged LAN.

# The IEEE 802.1Q Standard (1)



Bridged LAN that is only partly VLAN-aware. The shaded symbols are VLAN aware. The empty ones are not.

# The IEEE 802.1Q Standard (2)



The 802.3 (legacy) and 802.1Q Ethernet frame formats.

End

Chapter 4