# The Medium Access Control Sublayer

Chapter 4

# Channel Allocation Problem

- Static channel allocation
- Assumptions for dynamic

# Disadvantages of static allocation

- Waste of capacity
- Increasing delay

  Delay = 1/(ServiceRate – ArrivalRate)

# 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

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# Multiple Access Protocols

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

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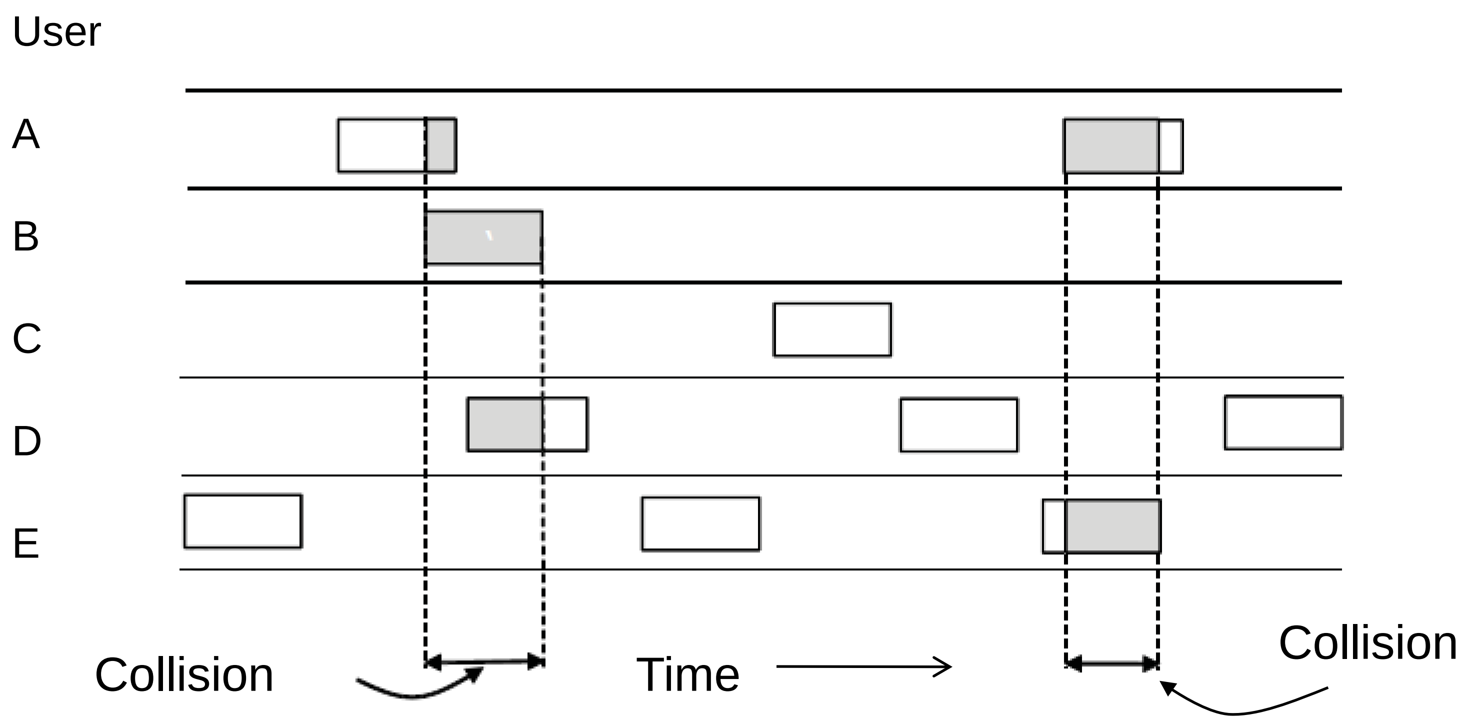
# ALOHA (1)




In pure ALOHA, frames are transmitted at completely arbitrary times

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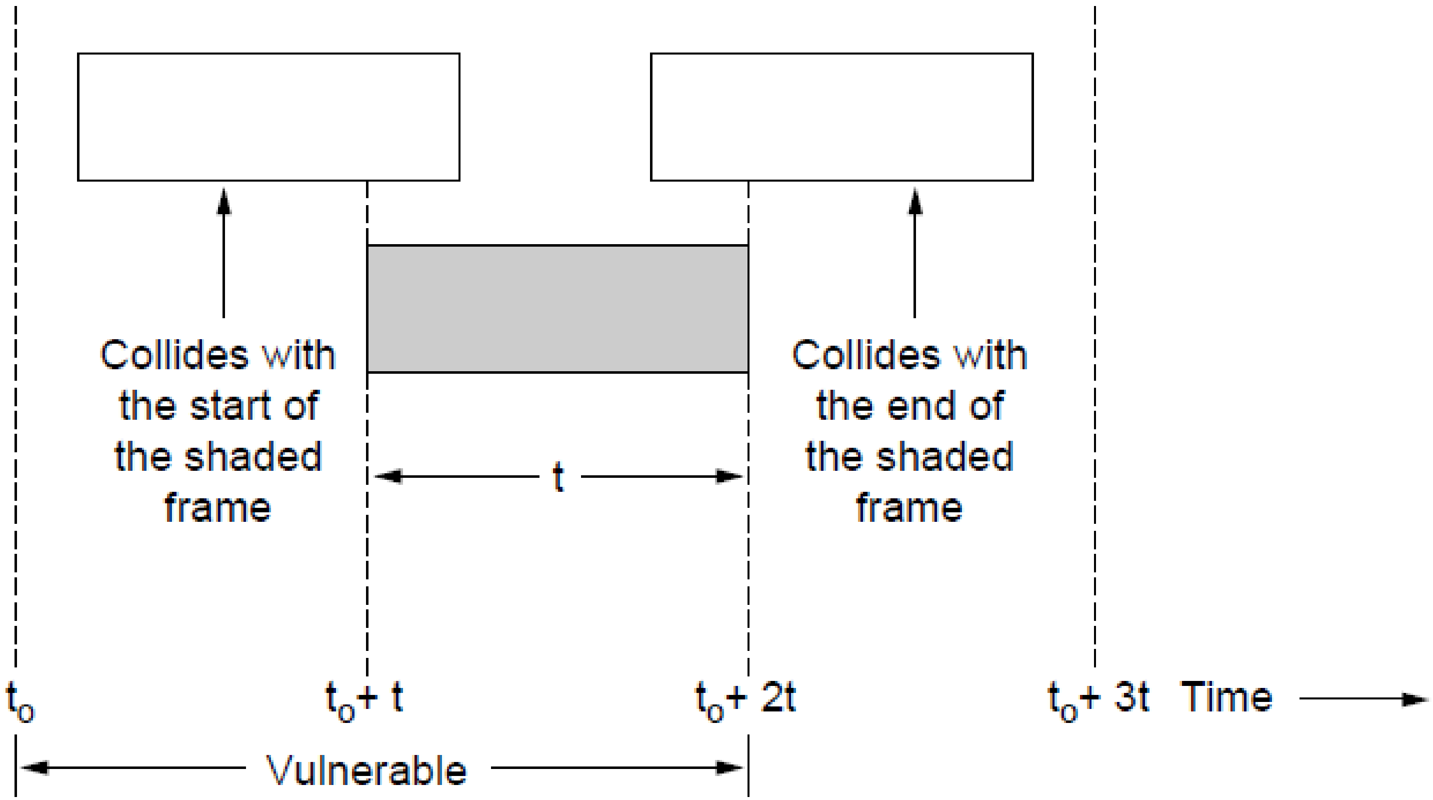
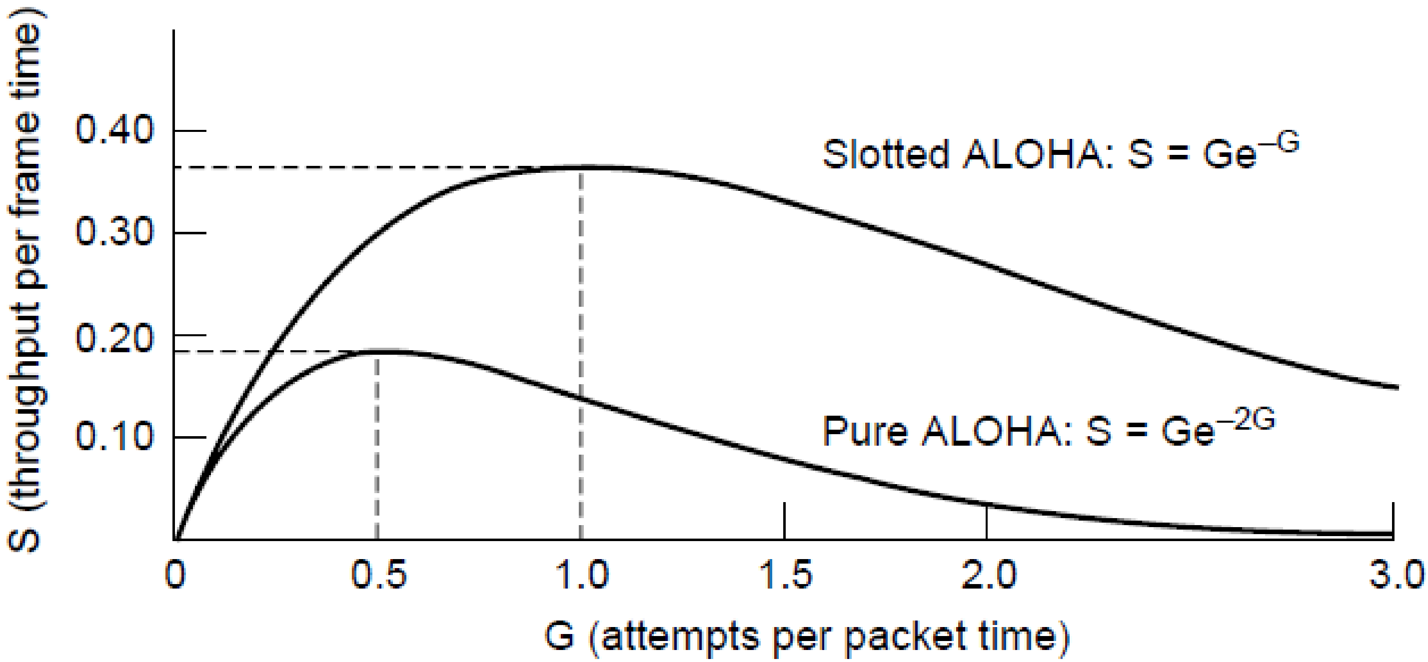
# ALOHA (2)




Vulnerable period for the shaded frame.

# ALOHA (3)




Throughput versus offered traffic for ALOHA systems.

# Carrier Sense Multiple Access (CSMA) Protocols

- Protocols in which stations listen for a carrier and act accordingly are called carrier sense protocols.
- 1-persistent CSMA
  - If the channel is busy sense till it becomes idle,  transmit and wait, if collusion wait a random perid of time then retry.
- Nonpersistent CSMA
  - If busy donot sense retry after a random

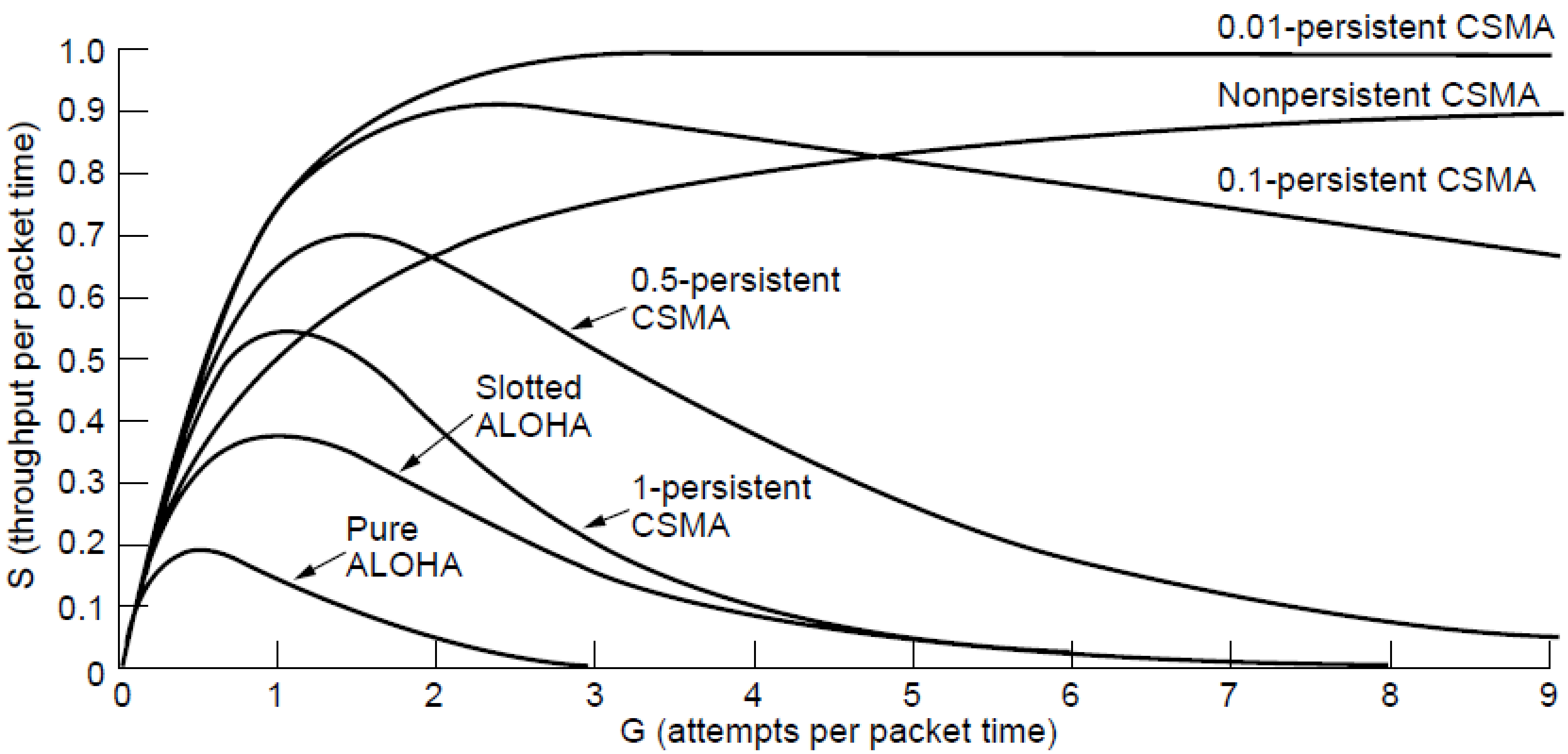
# Carrier Sense Multiple Access (CSMA) Protocols

- p-persistent CSMA
  - Works for slotted channels. If it is idle, transmit with prob p in that slot, with prob (1-p) defer. If decided to transmit in the next slot , in the next slot transmits or defers.

    If the slot is busy, wait for the next slot and retry the above algorithm.

    It continues till the frame transmitted.

# Persistent and Nonpersistent CSMA




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

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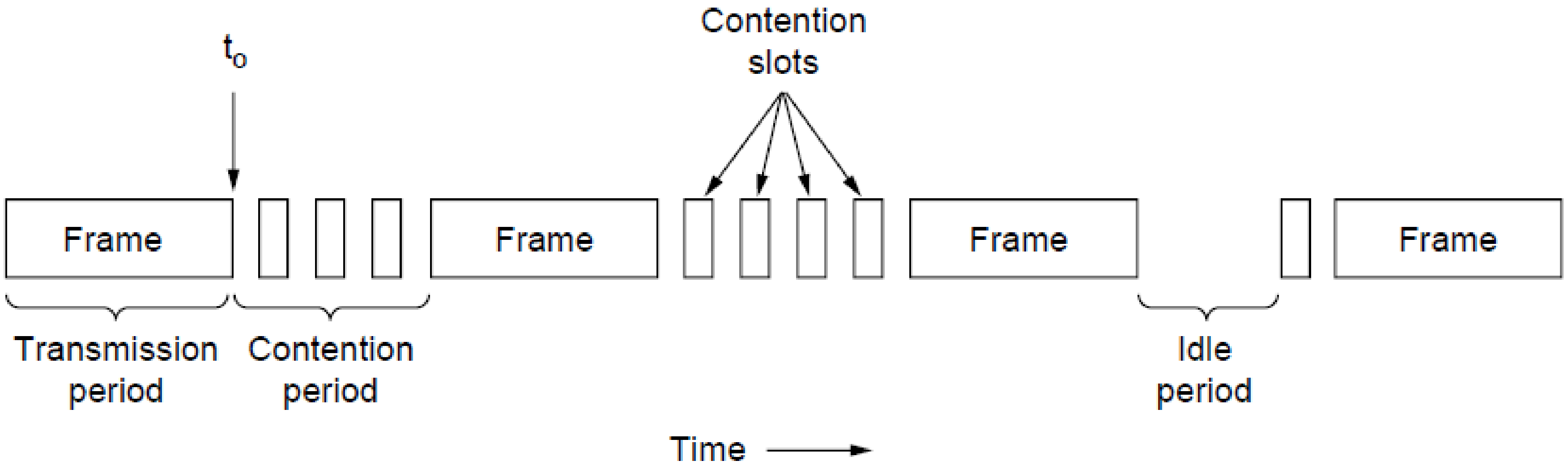
# CSMA with Collision Detection (CSMA/CD)




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

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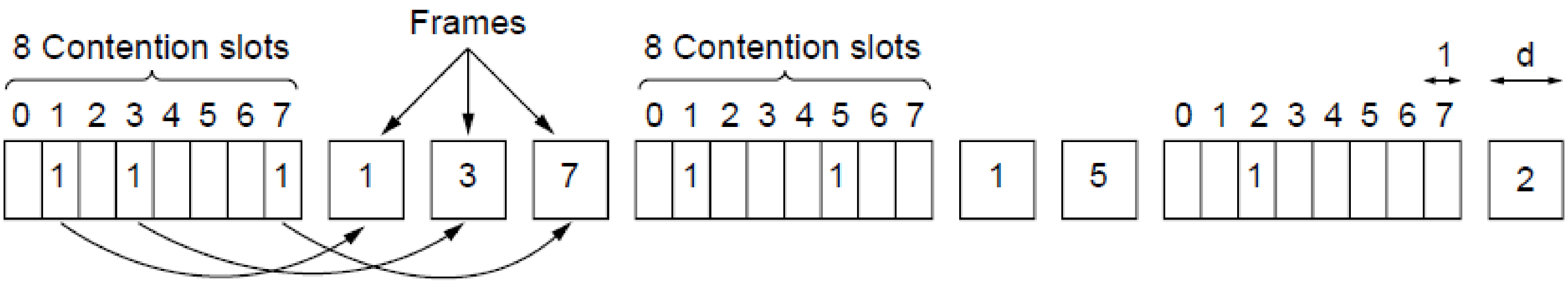
# CSMA/CD

- CSMA/CD is the basis for Ethernet-LAN.
- Question: How long one should wait to detect a collision?

# Collision-Free Protocols (1)




The basic bit-map protocol.

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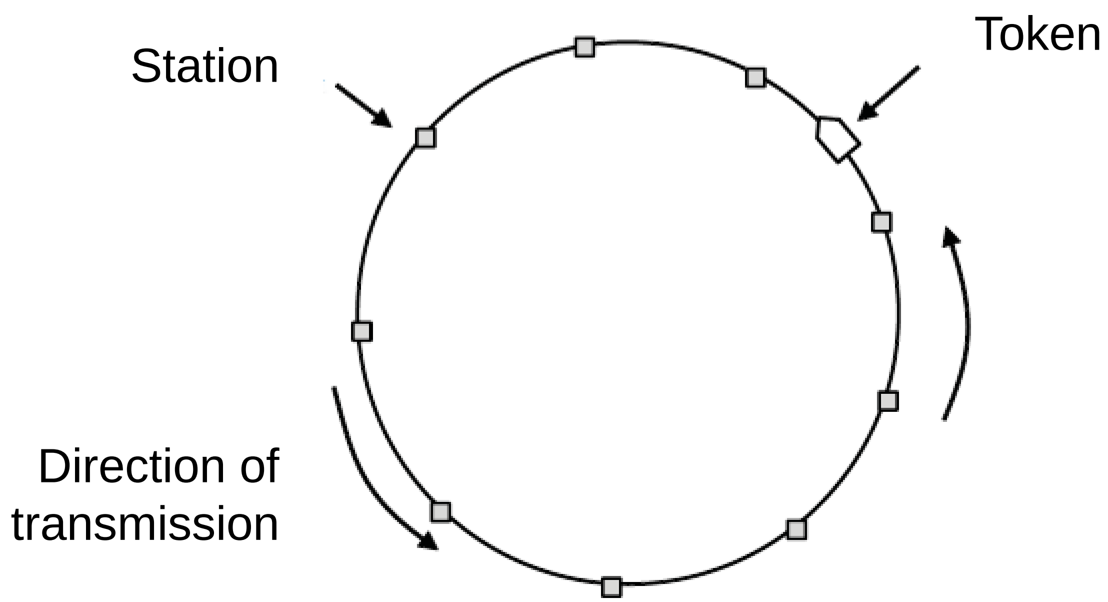
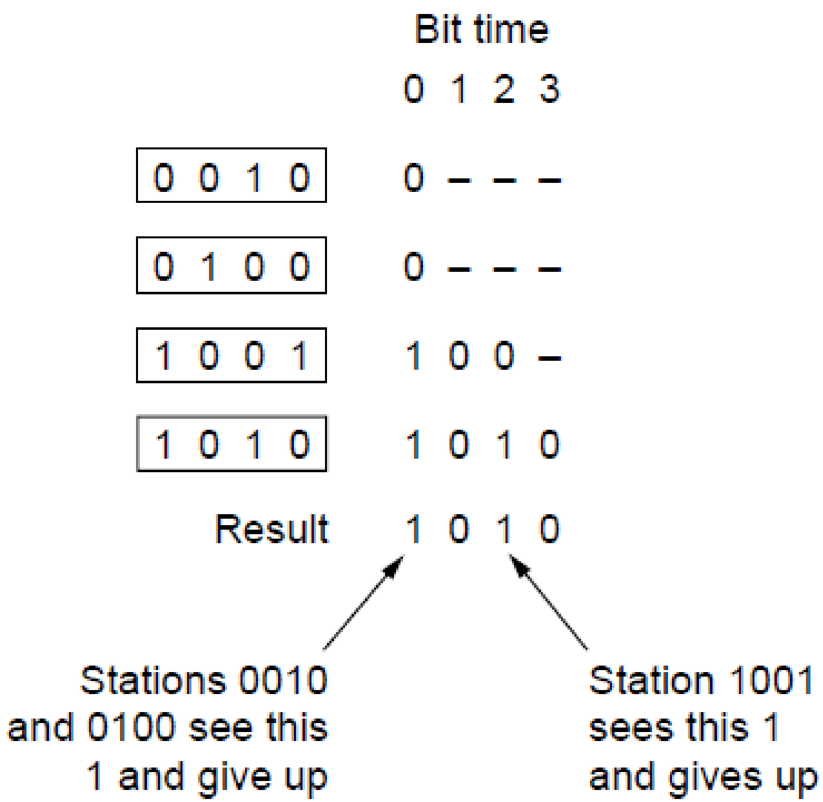
# Collision-Free Protocols (2)



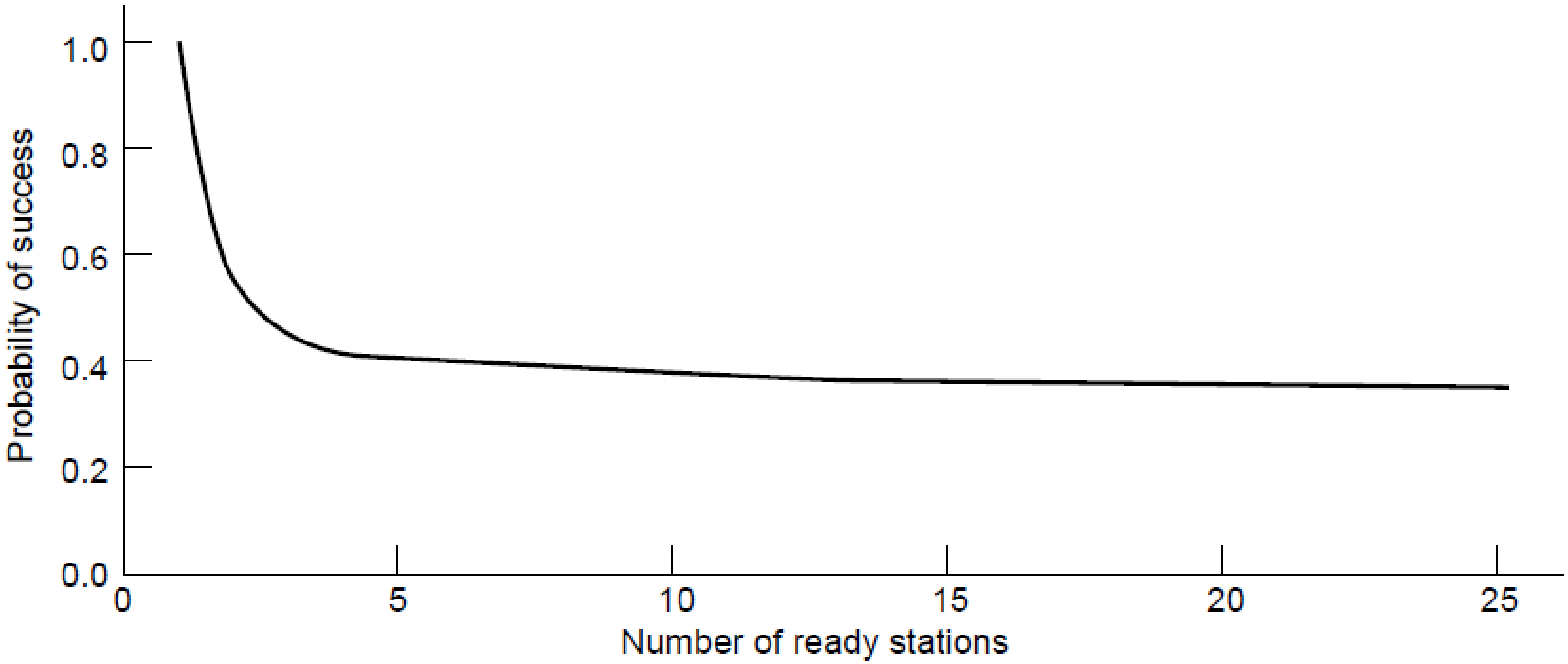

Token ring.

# Binary Countdown (SKIPPED)



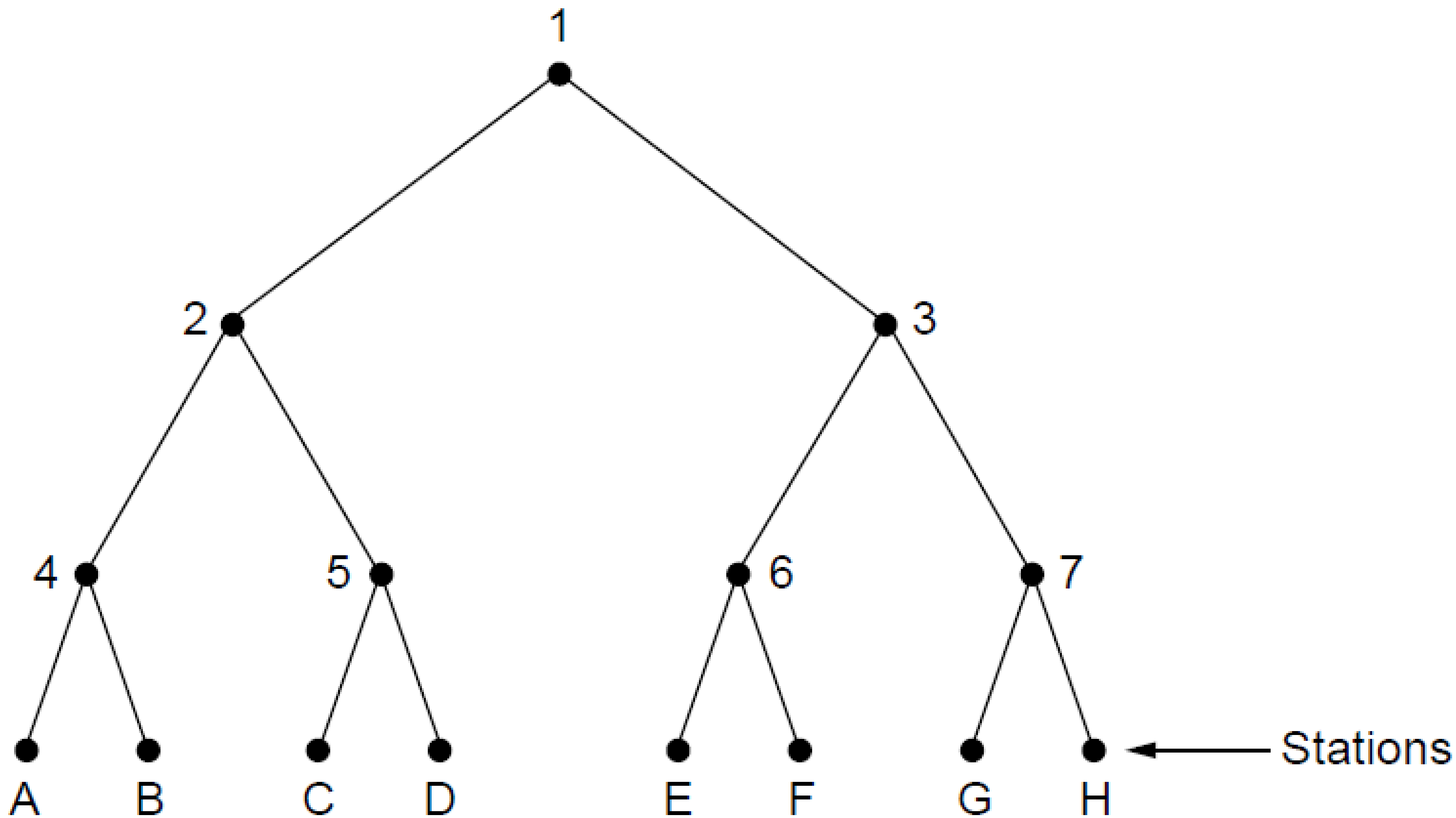

The binary countdown protocol. A dash indicates silence.

# Limited-Contention Protocols (SKIPPED)



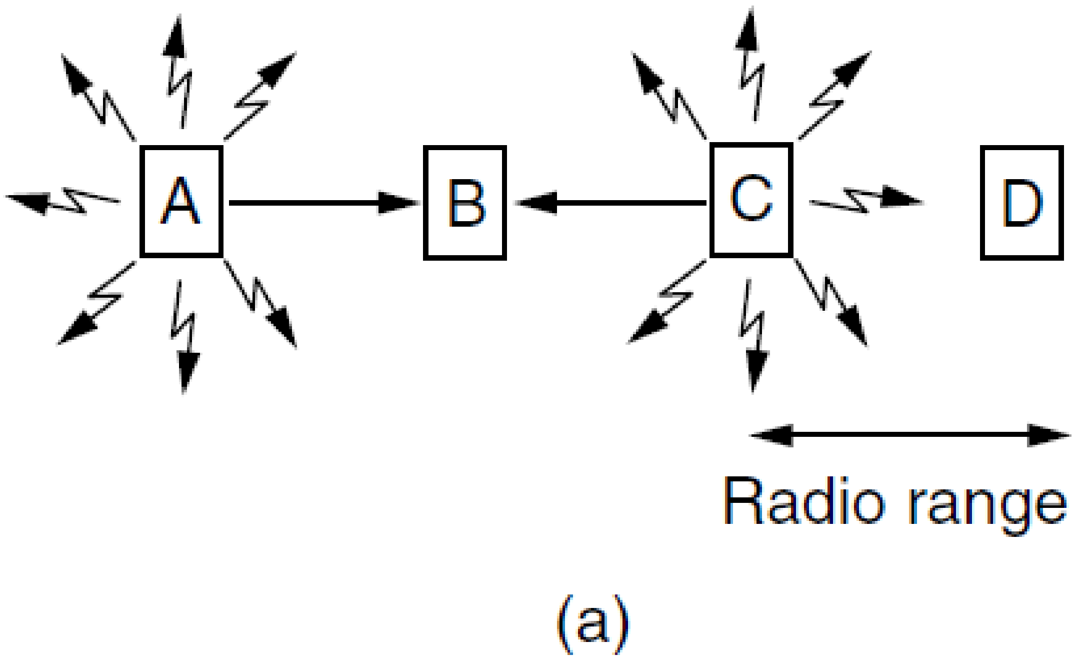

Acquisition probability for a symmetric contention channel.

# The Adaptive Tree Walk Protocol (SKIPPED)



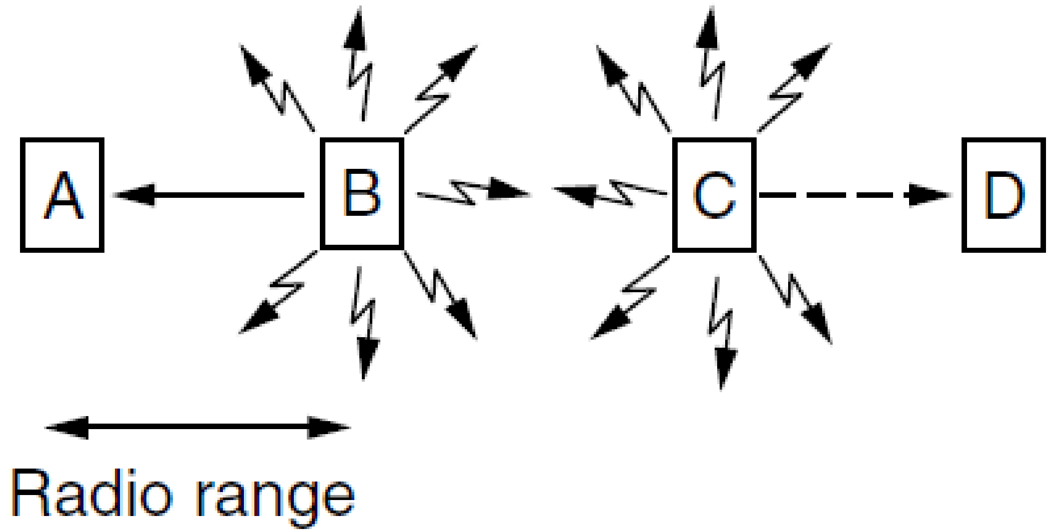

The tree for eight stations

# Wireless LAN Protocols (1)




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

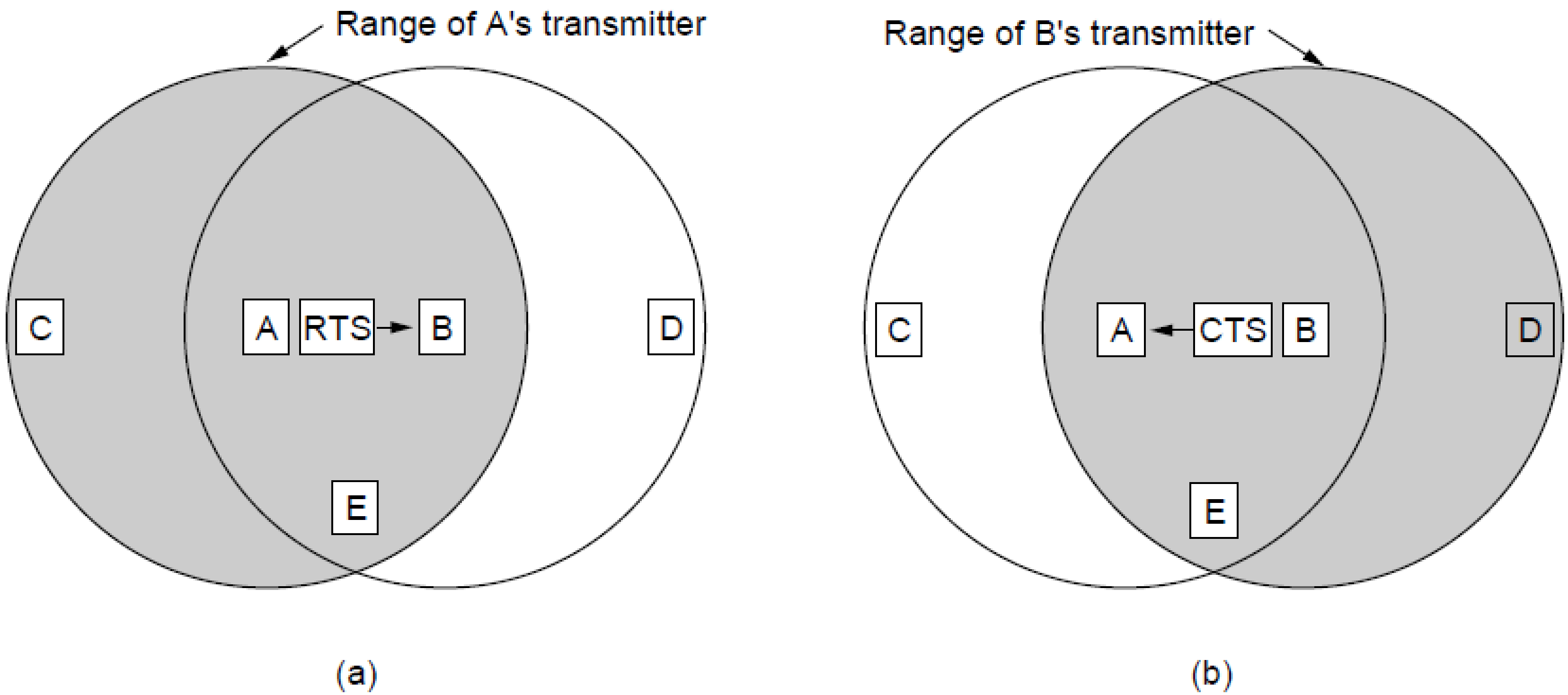
# Wireless LAN Protocols (2)




(b)

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

# Wireless LAN Protocols (3)




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

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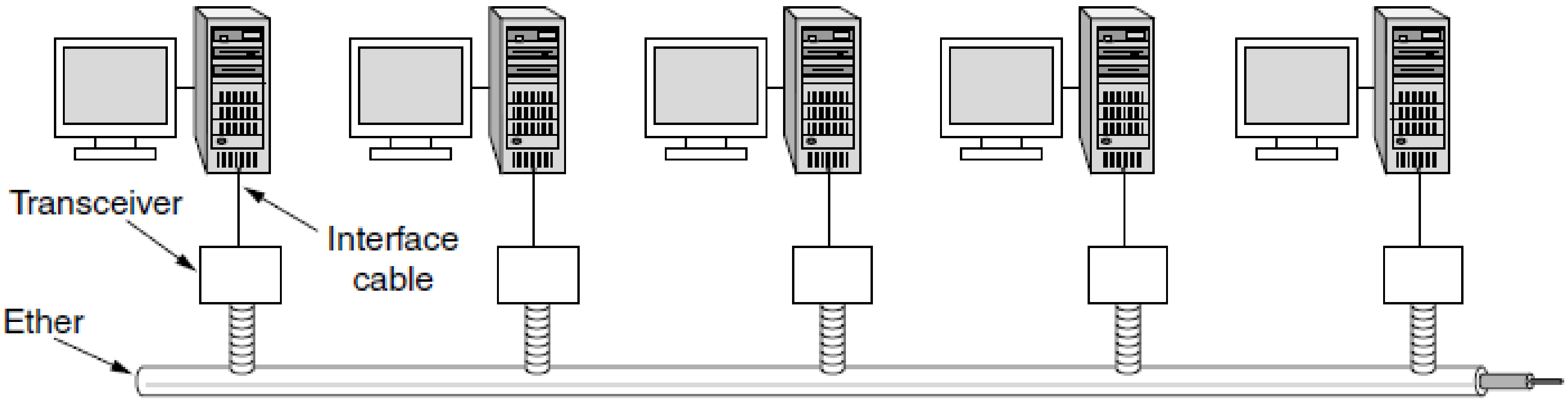
# Ethernet (IEEE 802.3)

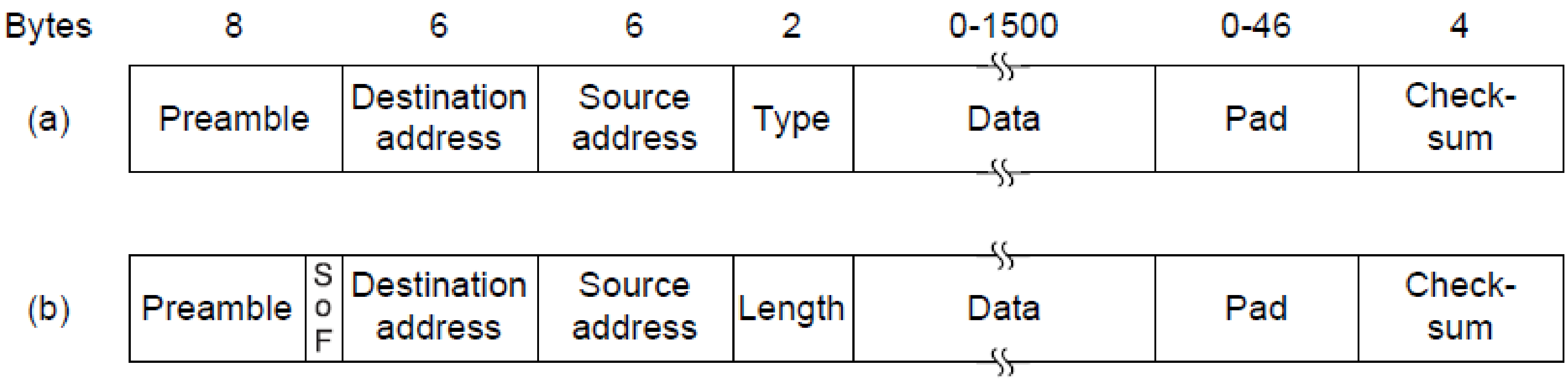
- Physical layer
- MAC sublayer protocol
- Ethernet performance
- Switched Ethernet
- Fast Ethernet
- Gigabit Ethernet
- 10 Gigabit Ethernet
- IEEE 802.2: Logical Link Control
- Retrospective on Ethernet

# Classic Ethernet Physical Layer




Architecture of classic Ethernet

# MAC Sublayer Protocol (1)




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

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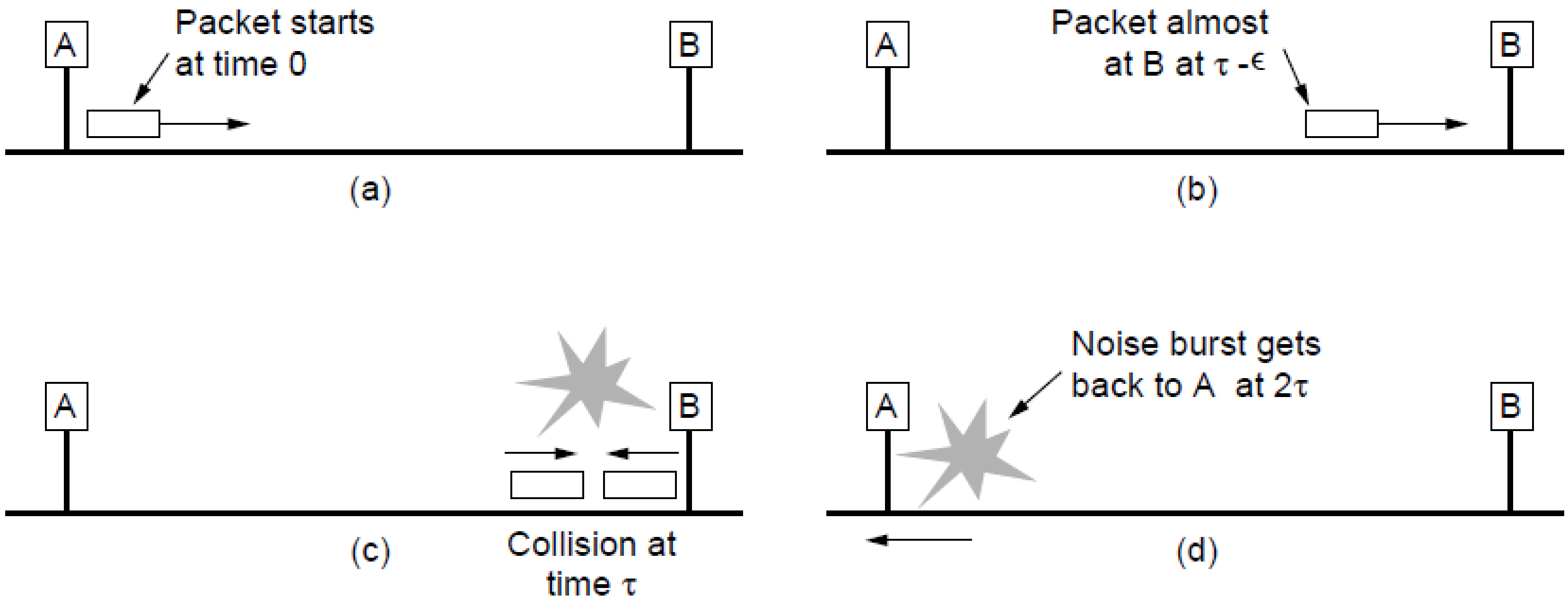
# MAC Sublayer Protocol (2)




Collision detection can take as long as 2τ.

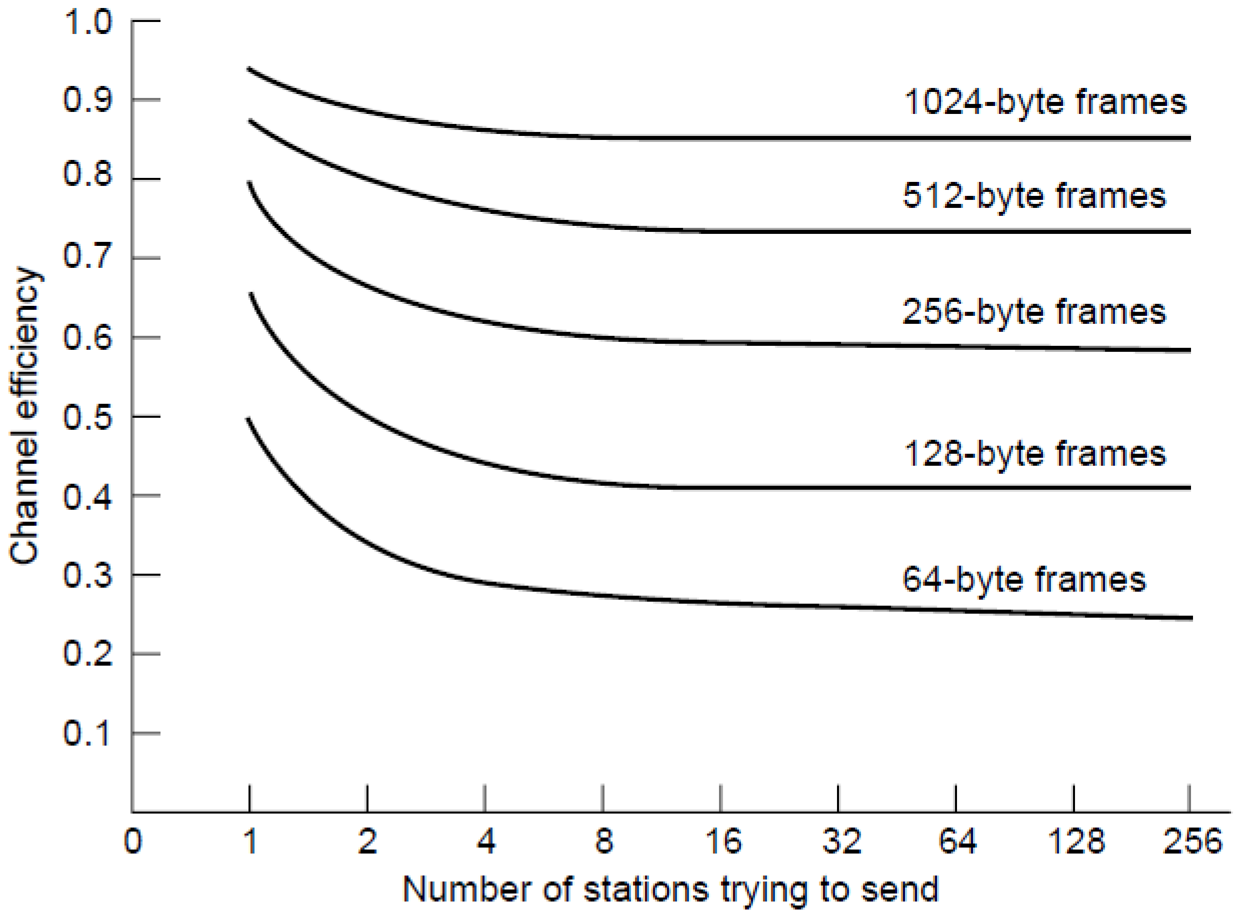
# Minimum Frame Size

- 10-Mbps Ethernet LAN with max length 2500 m (4 repeaters)
- Round trip time: 50 $\mu$sec
- In this duration 500 bits can be transmitted
- Hence min. frame size: 64Bytes

# CSMA/CD with Binary Exponential Backoff

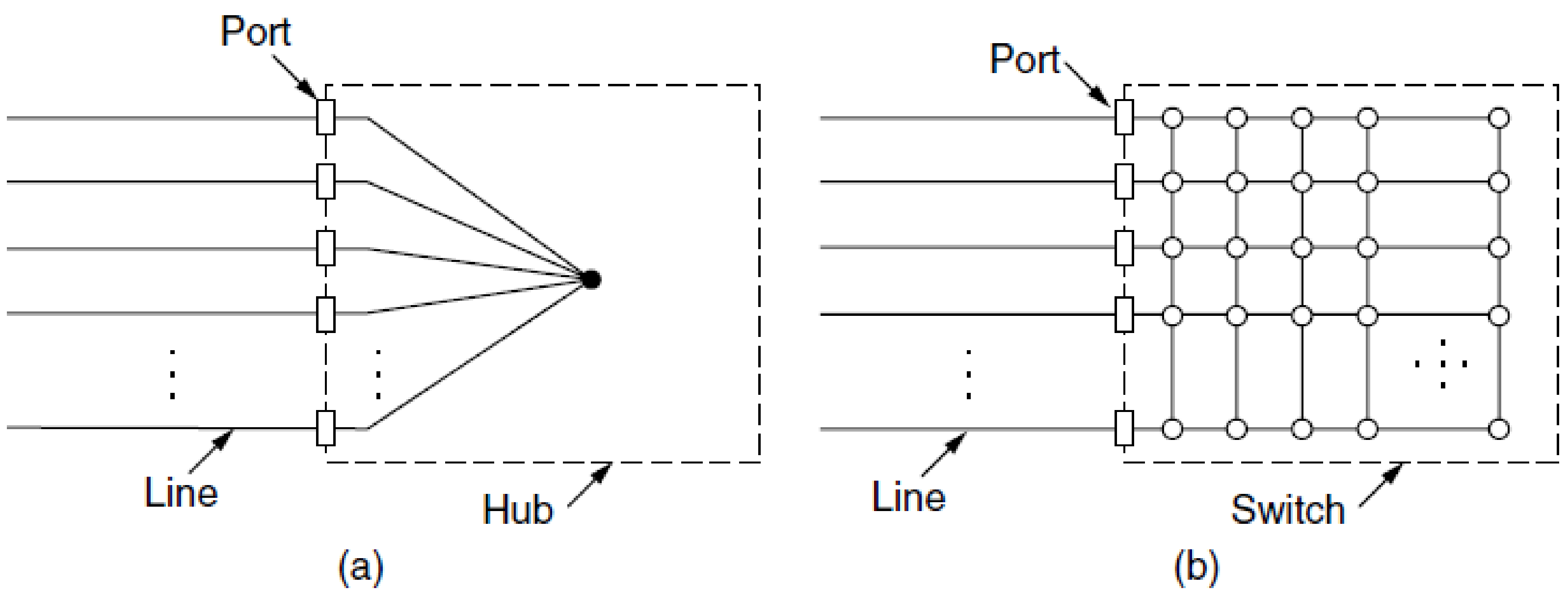
- Original Ethernet is 1-persistent.
- Then modified:
- When collision occurs time is divided into the slots of size propagation delay.
- After i collisions the number of slots to be waited is decided accoring to a random number between 0 – ($2^i$ -1)
- Max slots to wait 1023. A failure report generated after 16th collision.

# Ethernet Performance



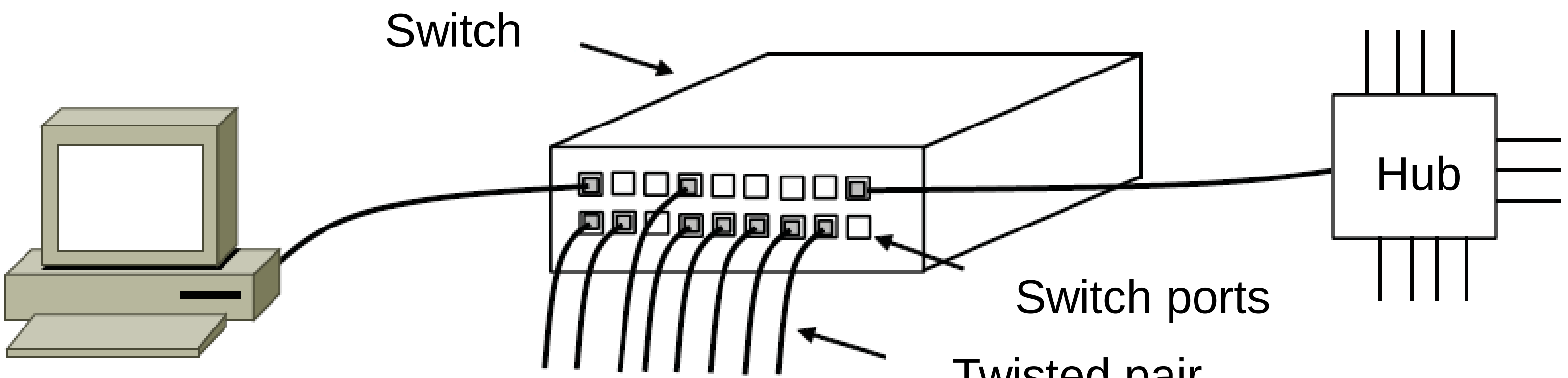

Efficiency of Ethernet at 10 Mbps with 512-bit slot times.

# Switched Ethernet (1)




(a) Hub. (b) Switch.

# Switched Ethernet (2)




An Ethernet switch.

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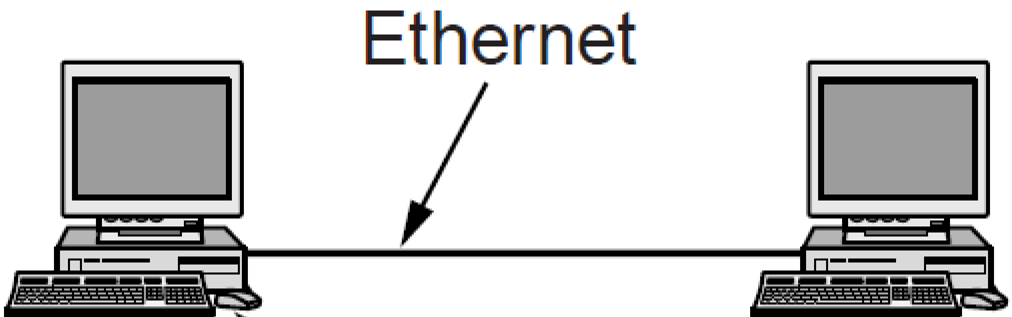
# Fast Ethernet

| 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 |

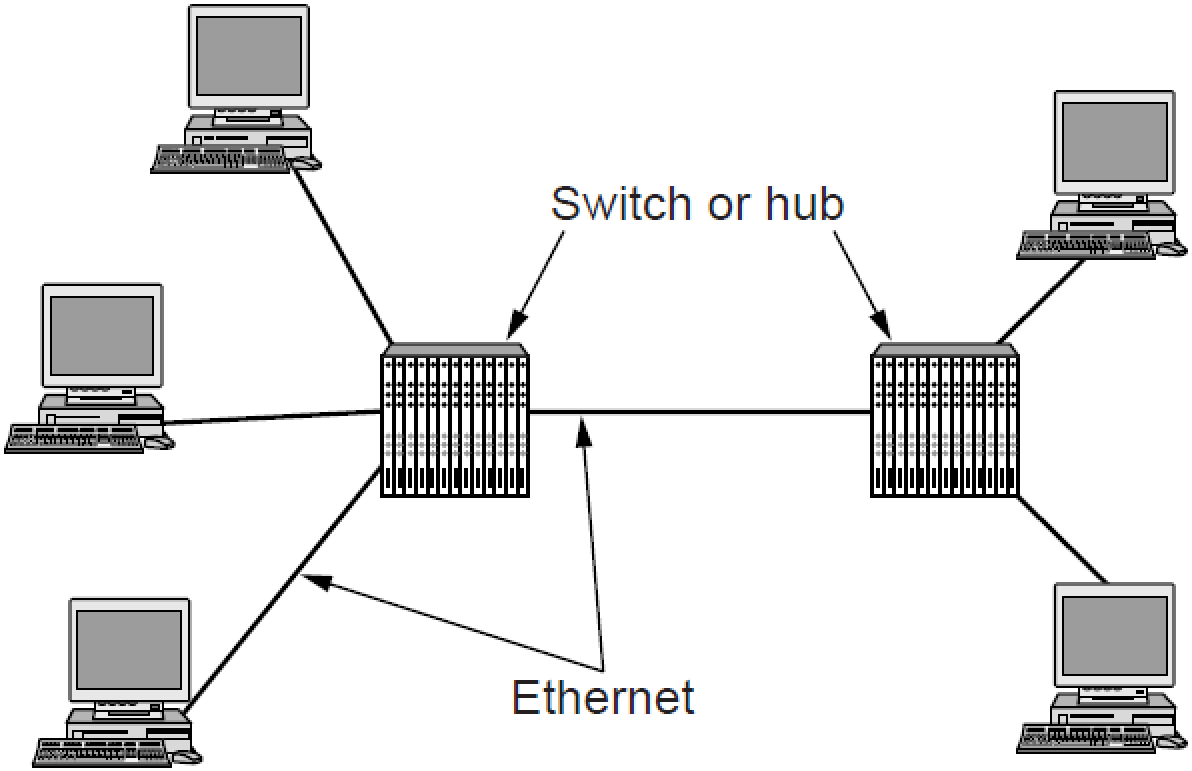
The original fast Ethernet cabling.

# Gigabit Ethernet , READ




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 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 |

Gigabit Ethernet cabling.

# 10 Gigabit Ethernet

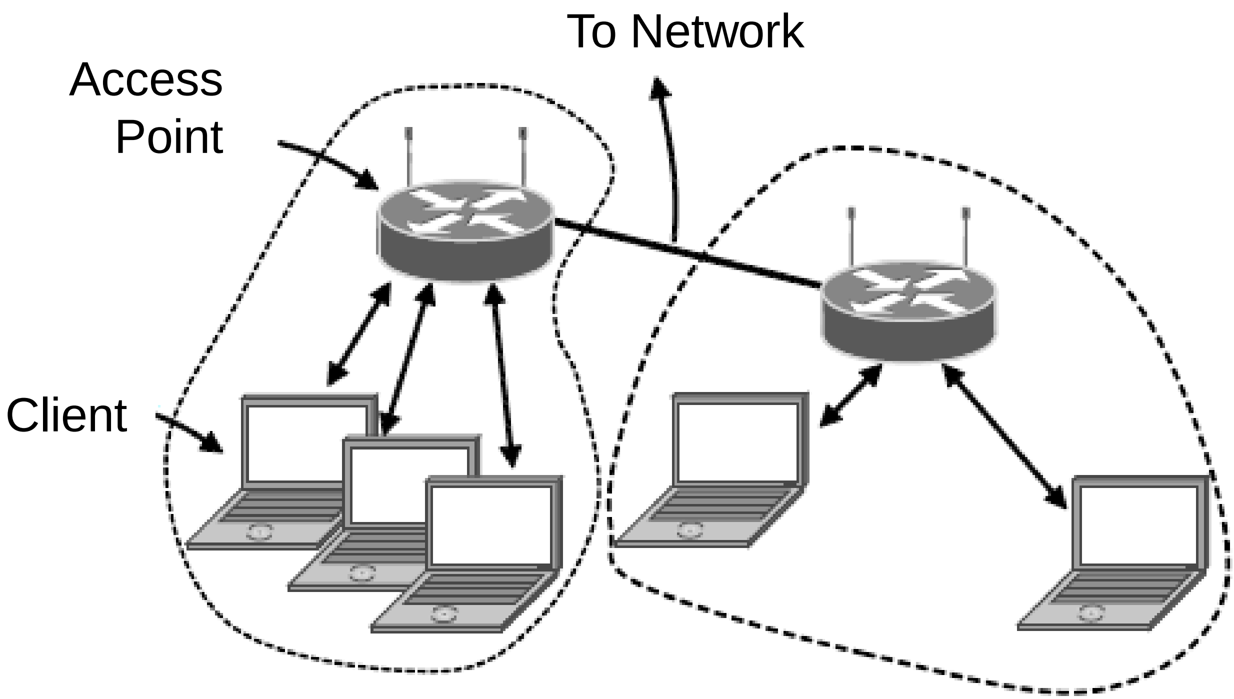
| Name | Cable | Max. segment | Advantages |
|---|---|---|---|
| 10GBase-SR | Fiber optics | Up to 300 m | Multimode fiber (0.85μ) |
| 10GBase-LR | Fiber optics | 10 km | Single-mode fiber (1.3μ) |
| 10GBase-ER | Fiber optics | 40 km | Single-mode fiber (1.5μ) |
| 10GBase-CX4 | 4 Pairs of twinax | 15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

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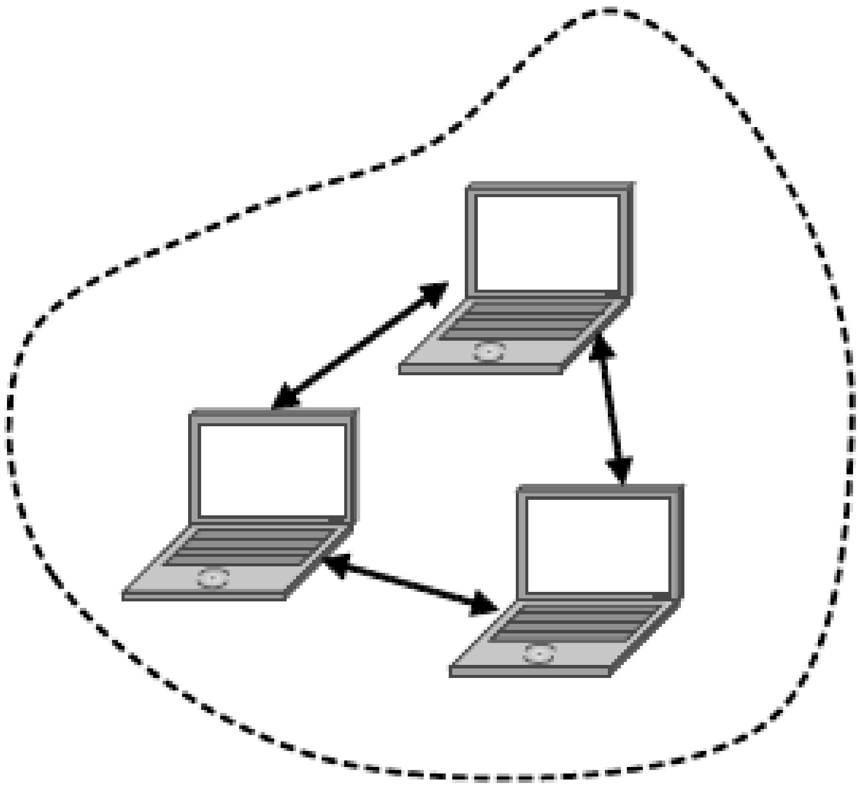
# 802.11 Architecture and Protocol Stack (2)



802.11 architecture – ad-hoc mode

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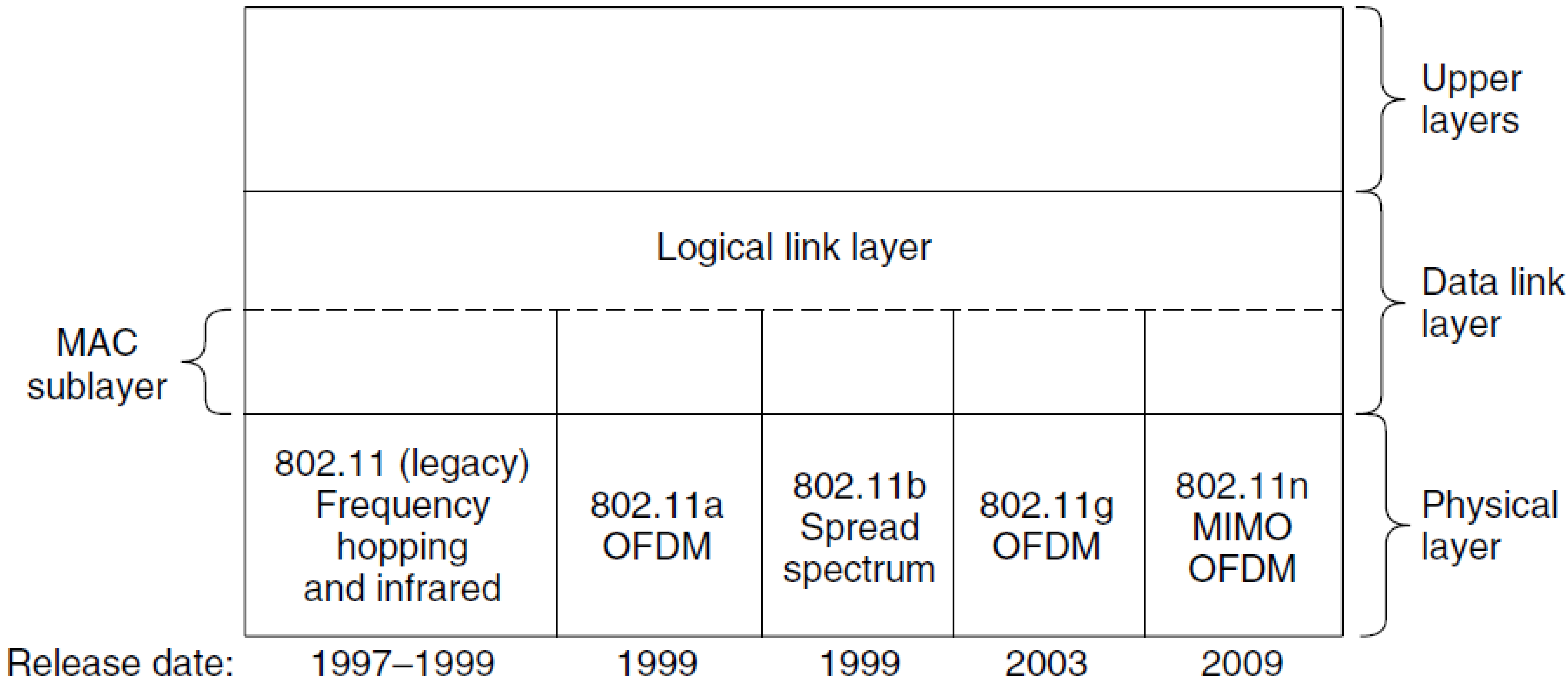
# 802.11 Architecture and Protocol Stack (3)




Part of the 802.11 protocol stack.

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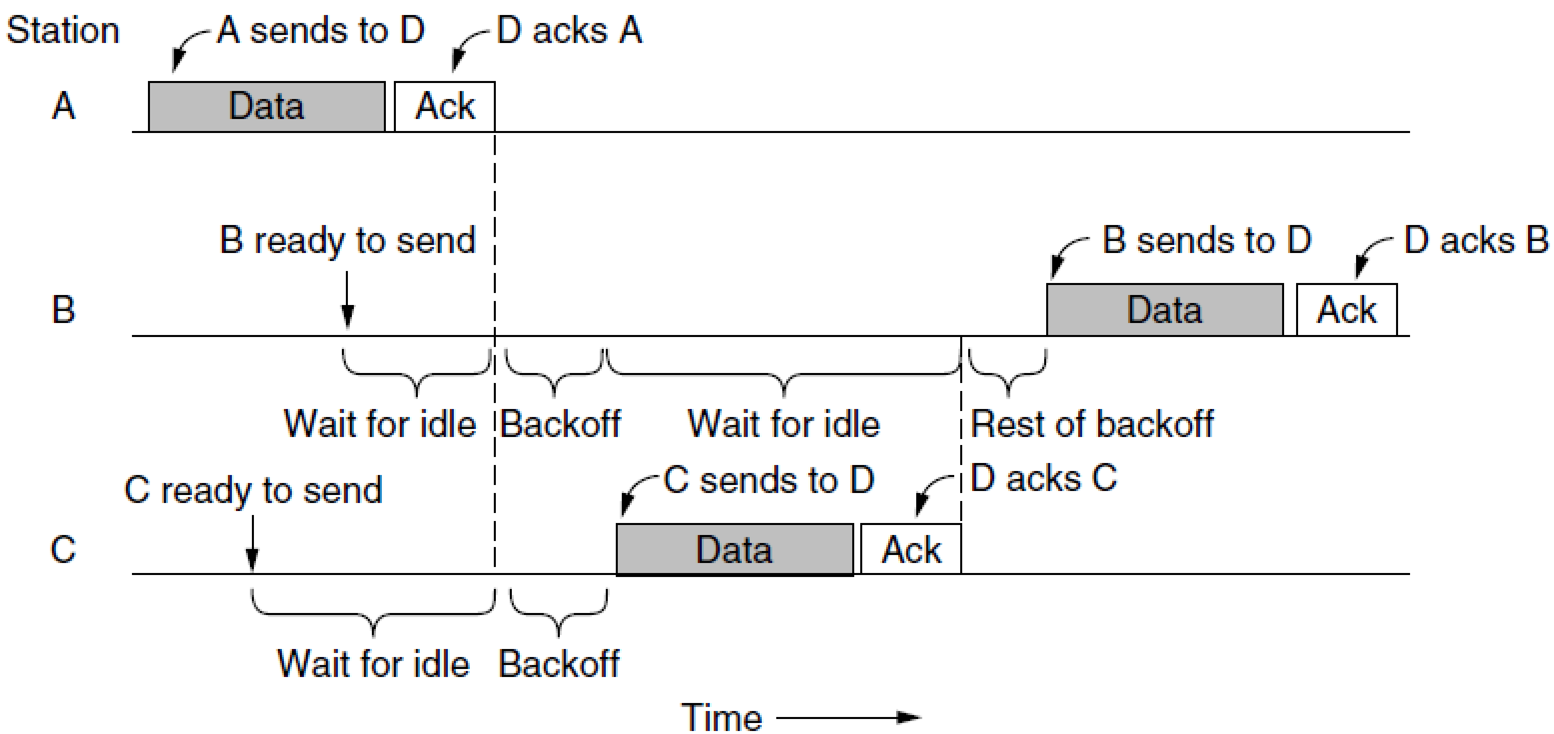
# Mode of operation

a) Distributed Coordination Function (DCF)
b) Point Coordination Function (PCF)

# The 802.11 MAC Sublayer Protocol (1)




Sending a frame with CSMA/CA.

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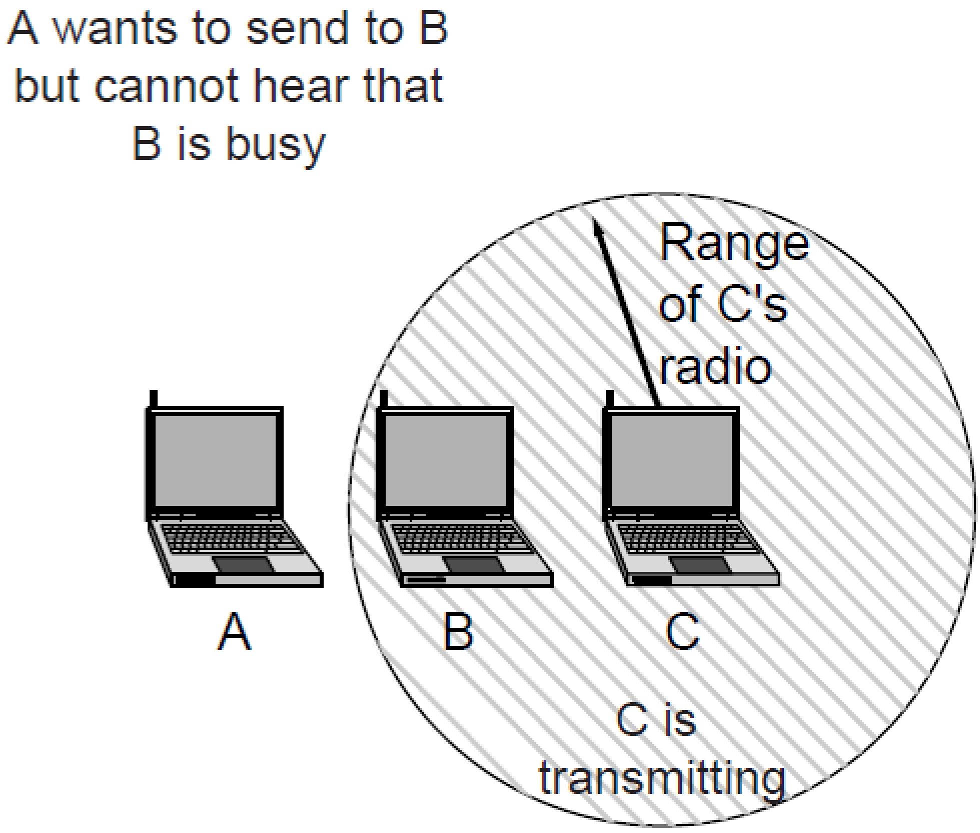
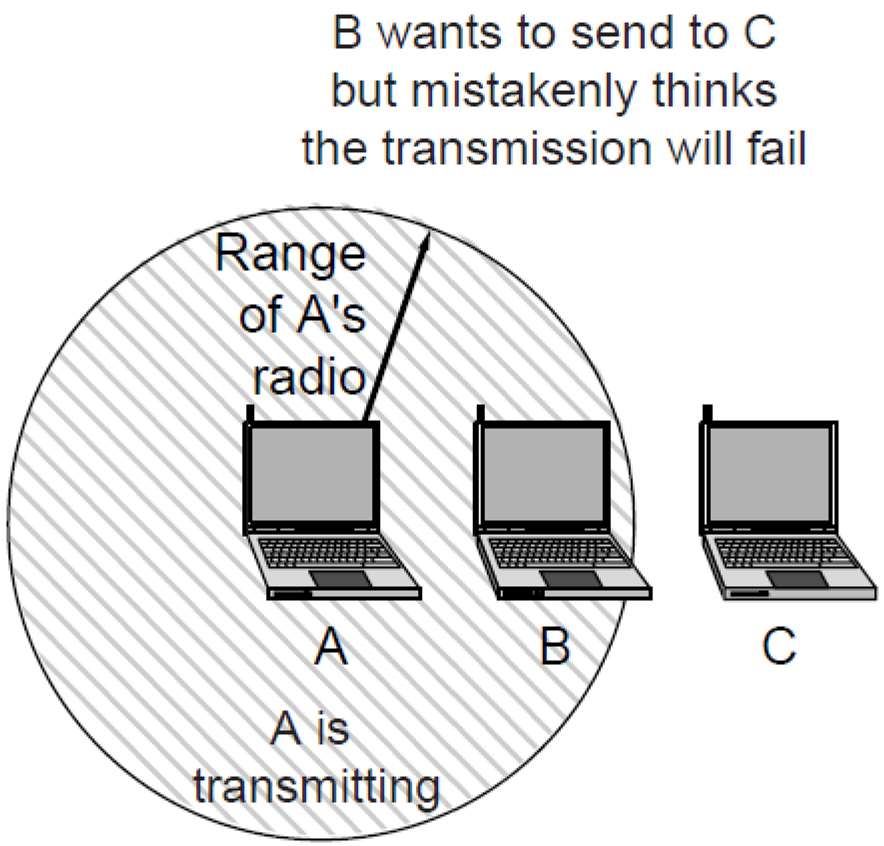
# The 802.11 MAC Sublayer Protocol (2)




The hidden terminal problem.

# The 802.11 MAC Sublayer Protocol (3)




The exposed terminal problem.

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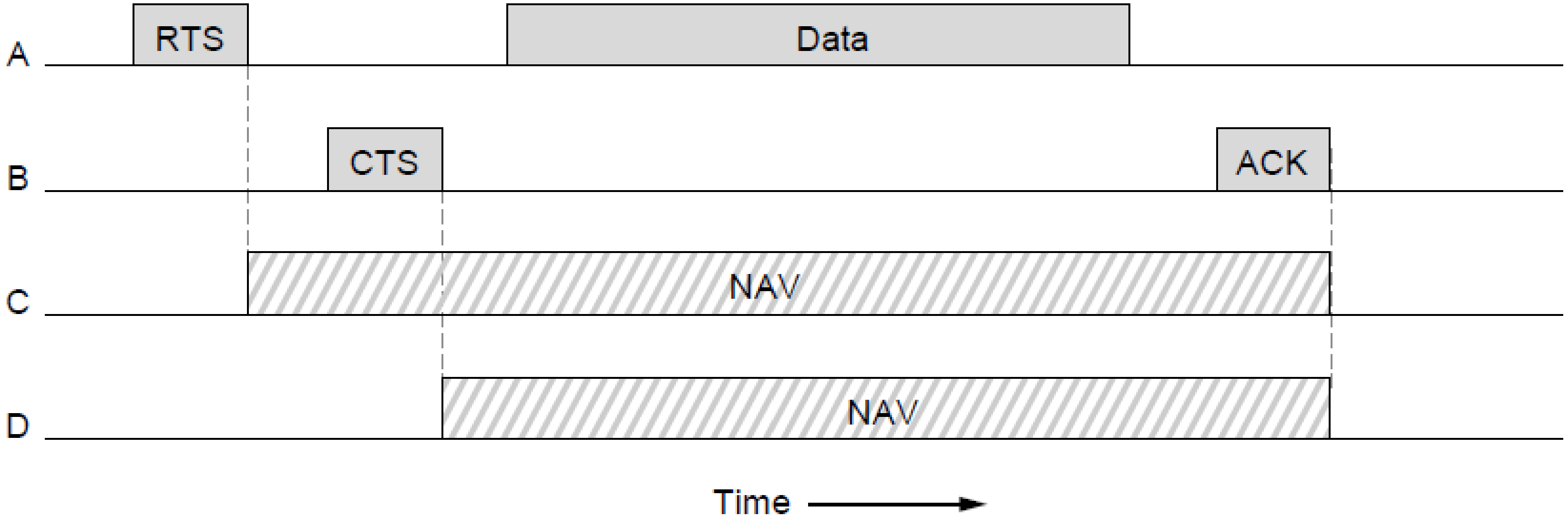
# The 802.11 MAC Sublayer Protocol (4)




The use of virtual channel sensing using CSMA/CA.

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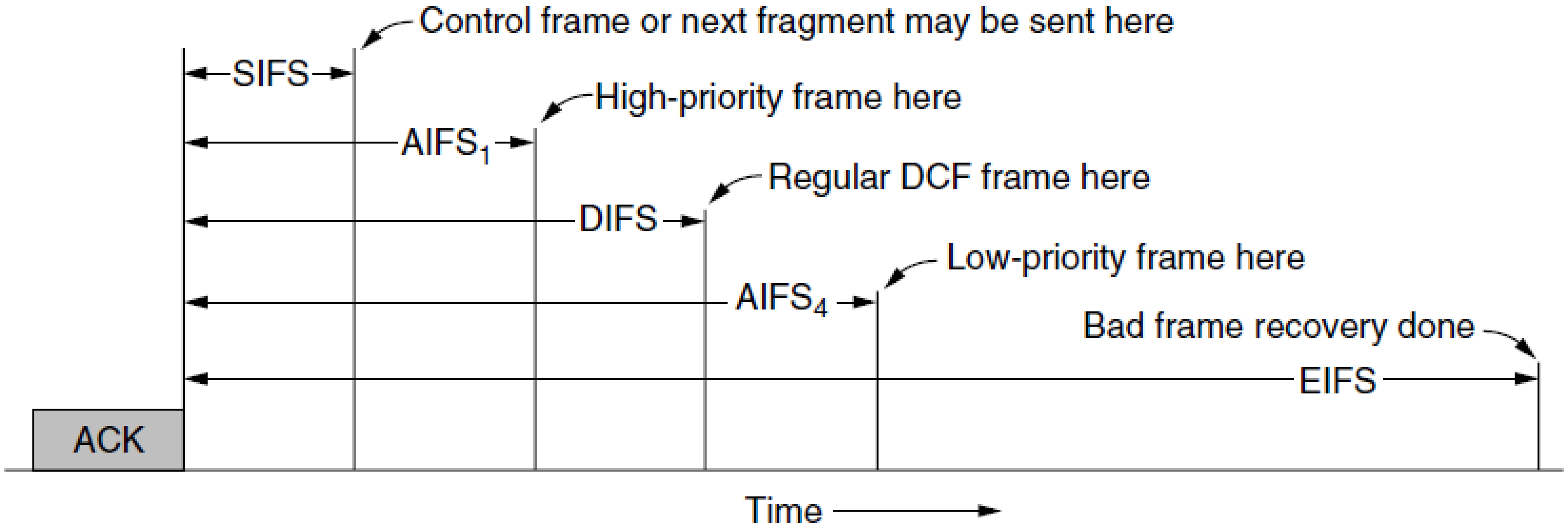
# The 802.11 MAC Sublayer Protocol (5)




Interframe spacing in 802.11

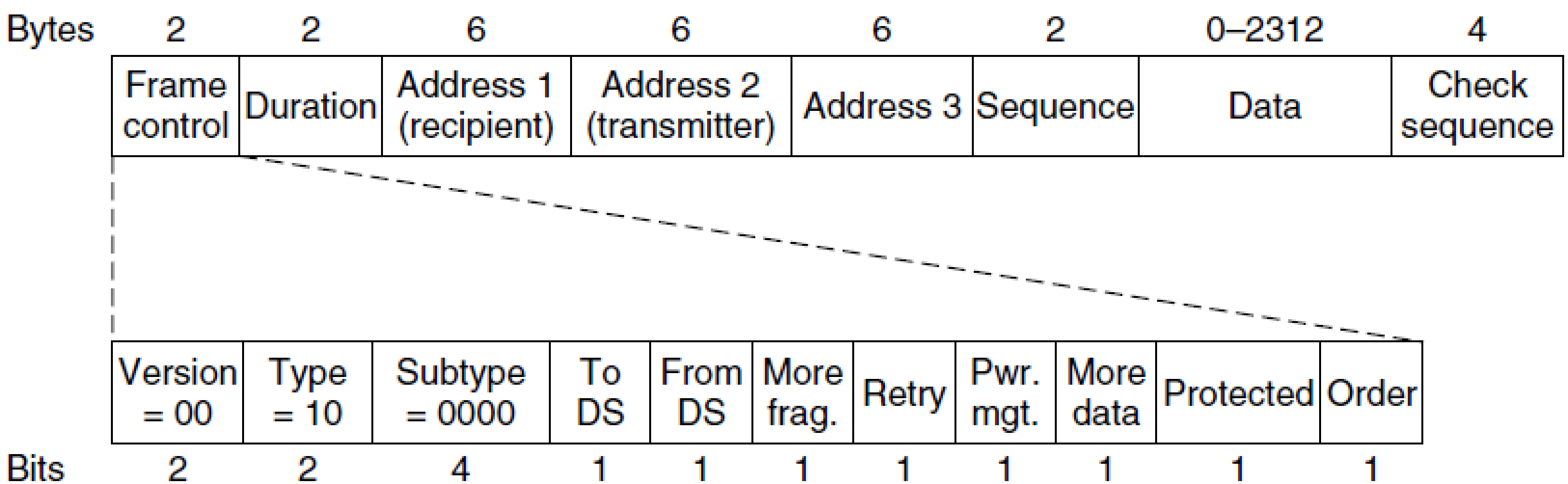
SIFS: Short InterFrame Spacing

AIFS:Arbitration InterFrame Spacing

DIFS: DCF InterFrame Spacing

EIFS: Extended InterFrame Spacing

# 802.11 Frame Structure




Format of the 802.11 data frame

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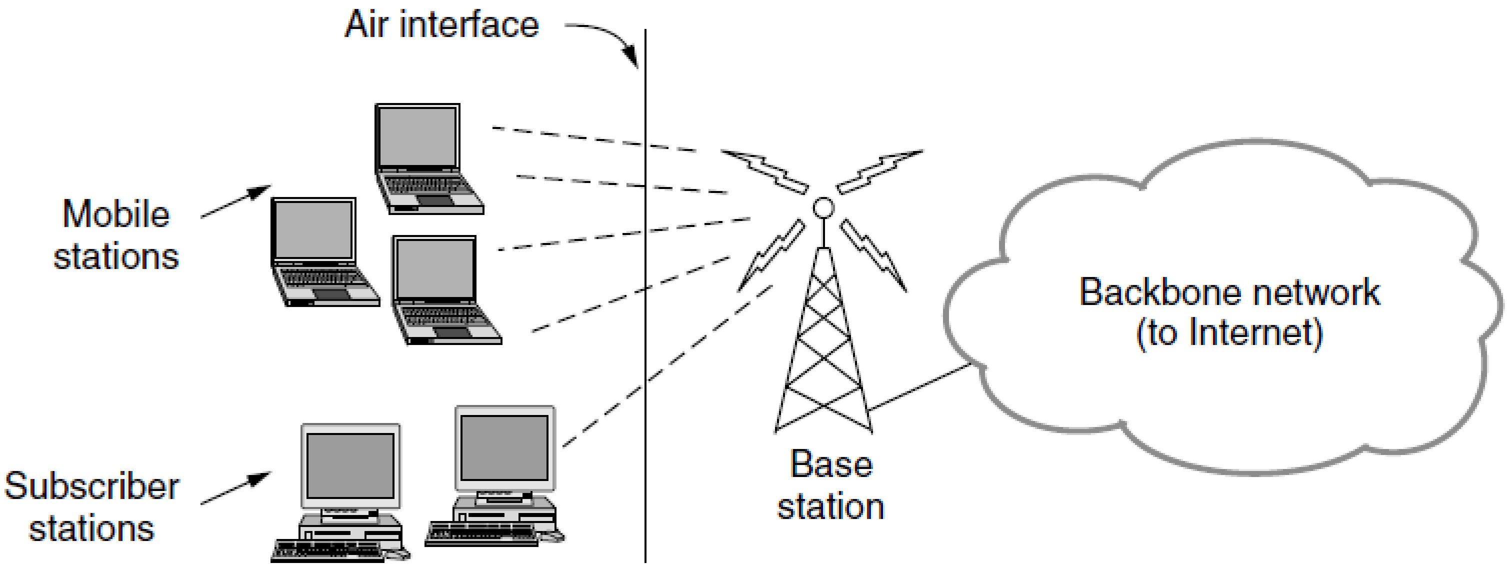
# Broadband Wireless (SKIPPED)

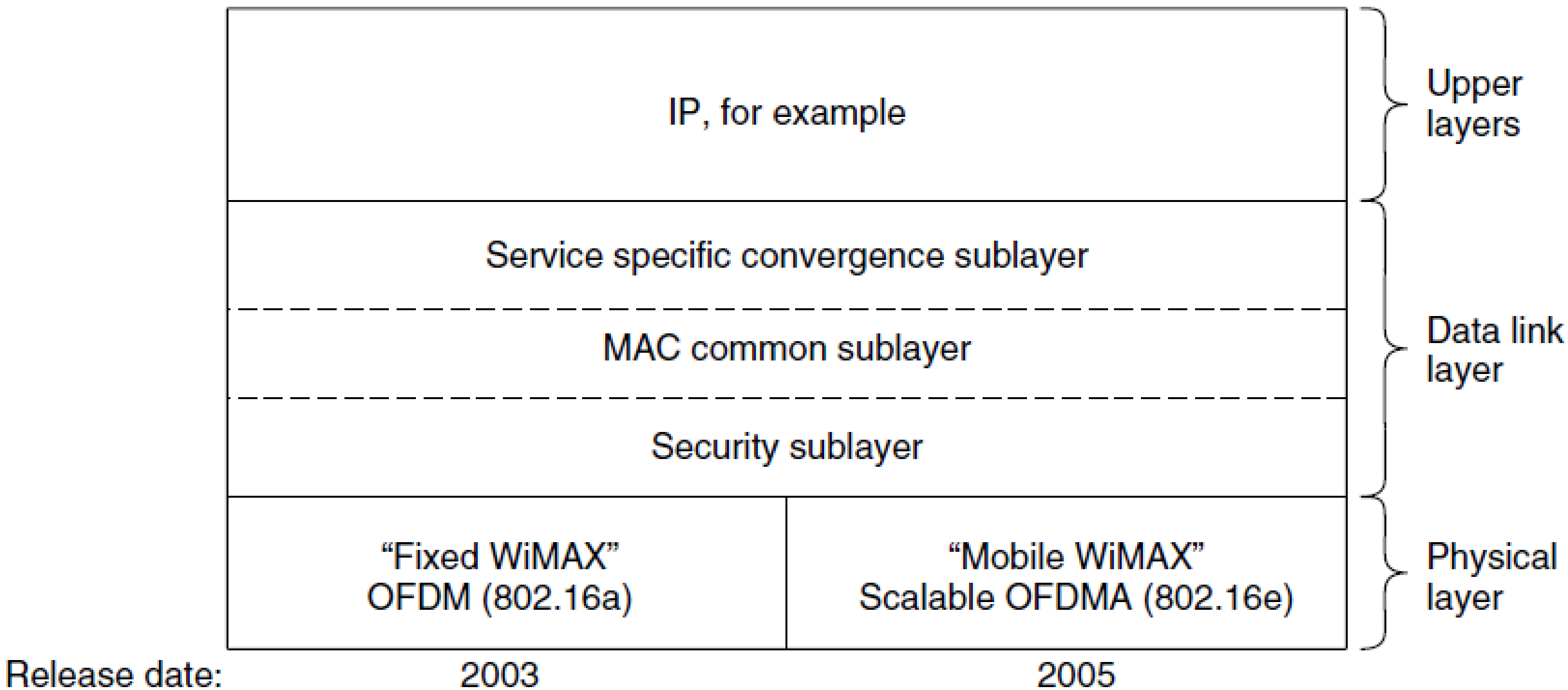
- Comparison of 802.16 with 802.11, 3G
- 802.16 architecture and protocol stack
- 802.16 physical layer
- 802.16 frame structure

# Comparison of 802.16 with 802.11 and 3G




The 802.16 architecture

# 802.16 Architecture and Protocol Stack




The 802.16 protocol stack

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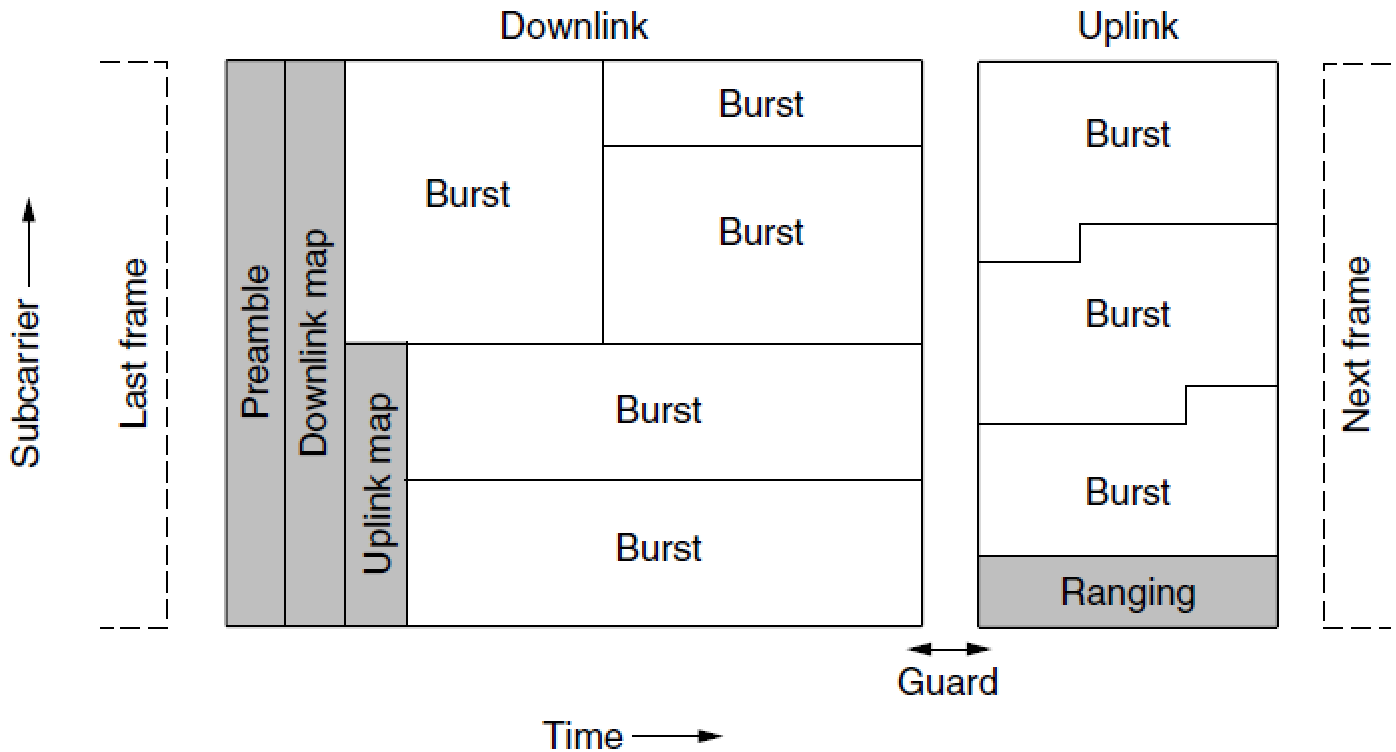
# 802.16 Physical Layer




Frames structure for OFDMA with time division duplexing.

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# 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.

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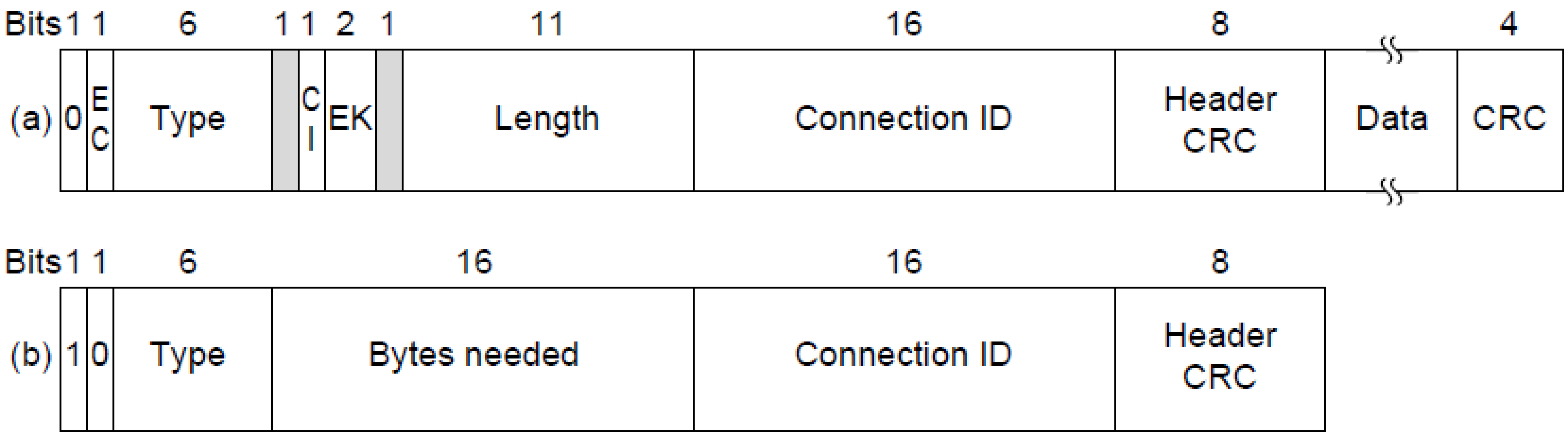
# 802.16 Frame Structure




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

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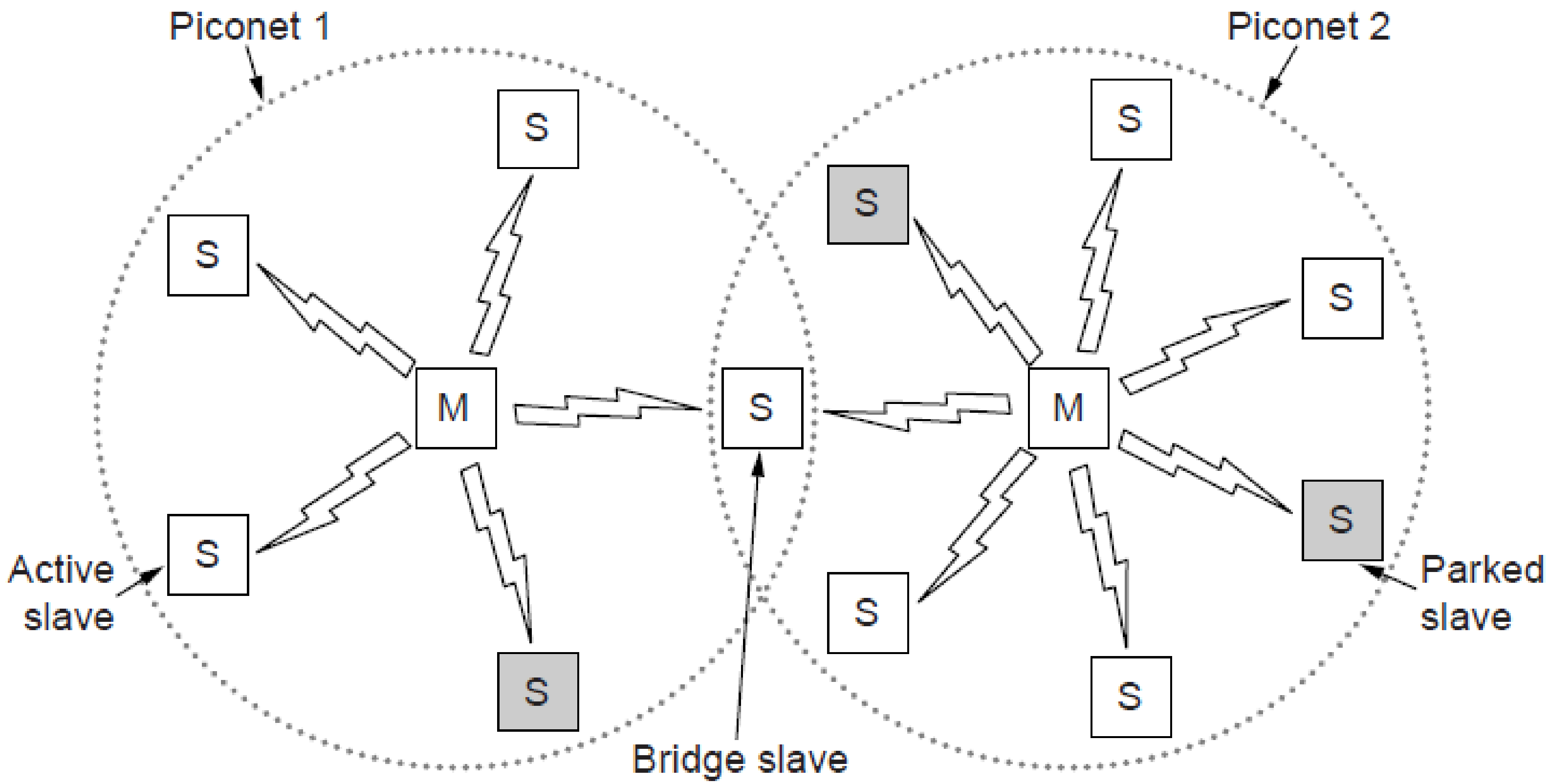
# Bluetooth

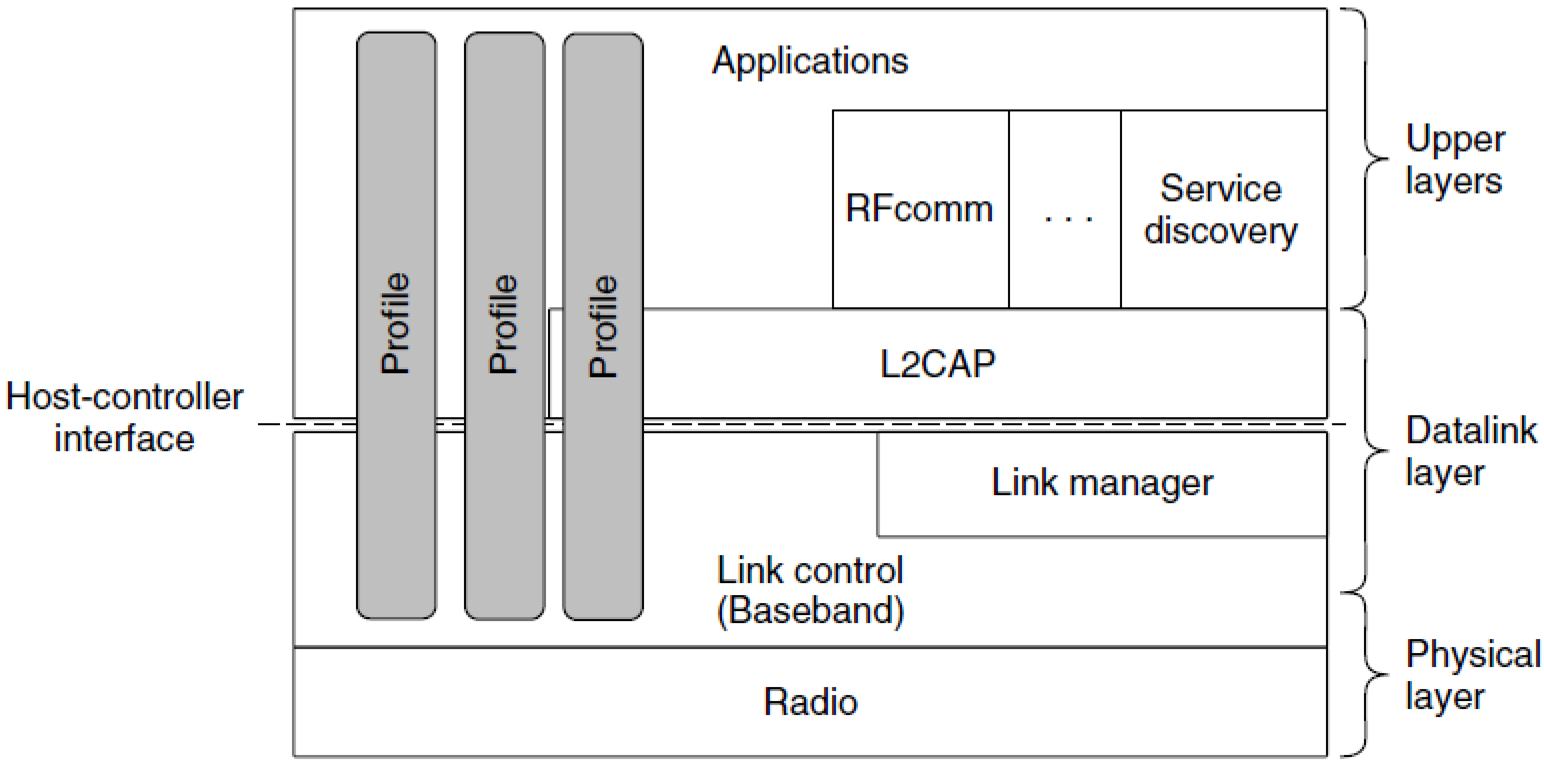
- Architecture
- Applications
- Protocol stack
- Radio layer
- Link layers
- Frame structure

# Bluetooth Architecture




Two piconets can be connected to form a scatternet

# Bluetooth Protocol Stack




The Bluetooth protocol architecture.

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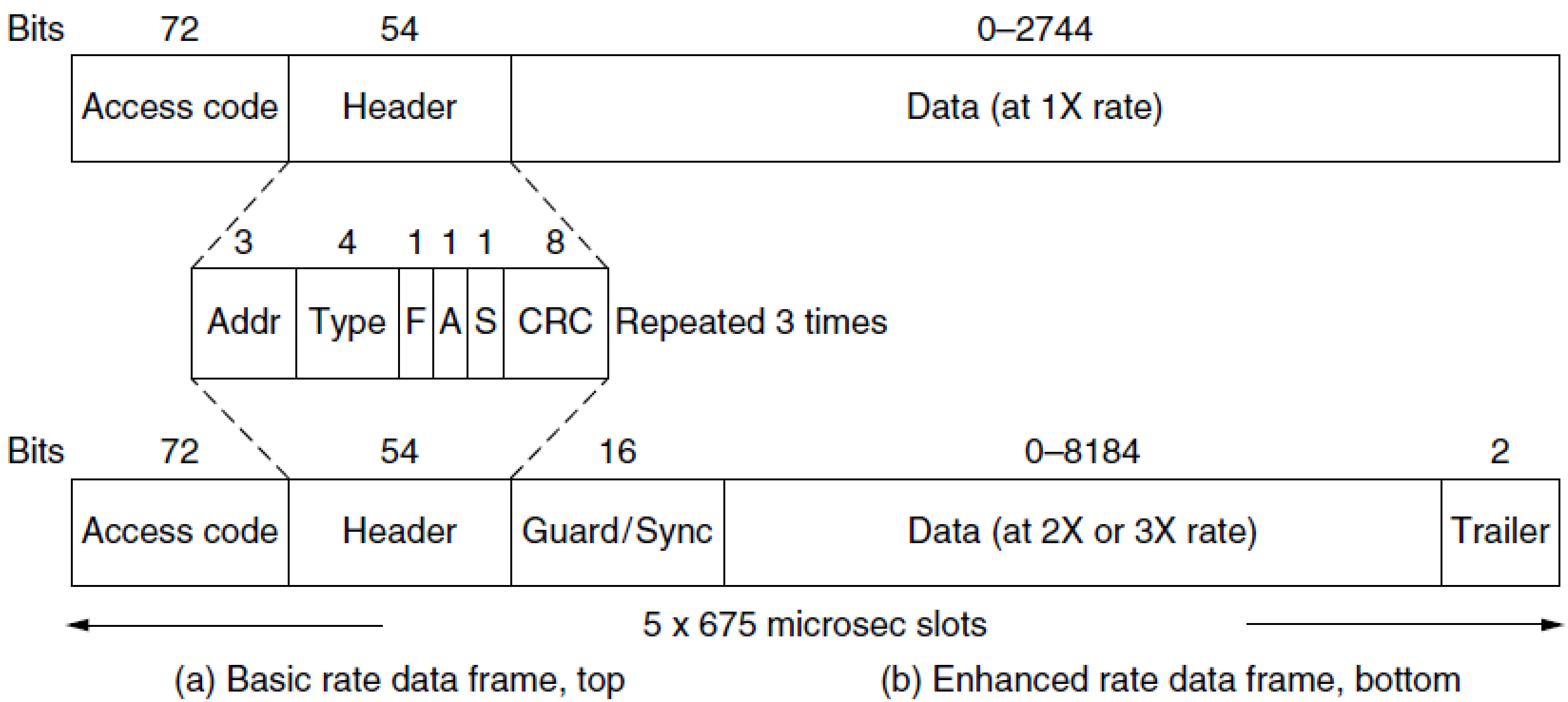
# Bluetooth Frame Structure




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

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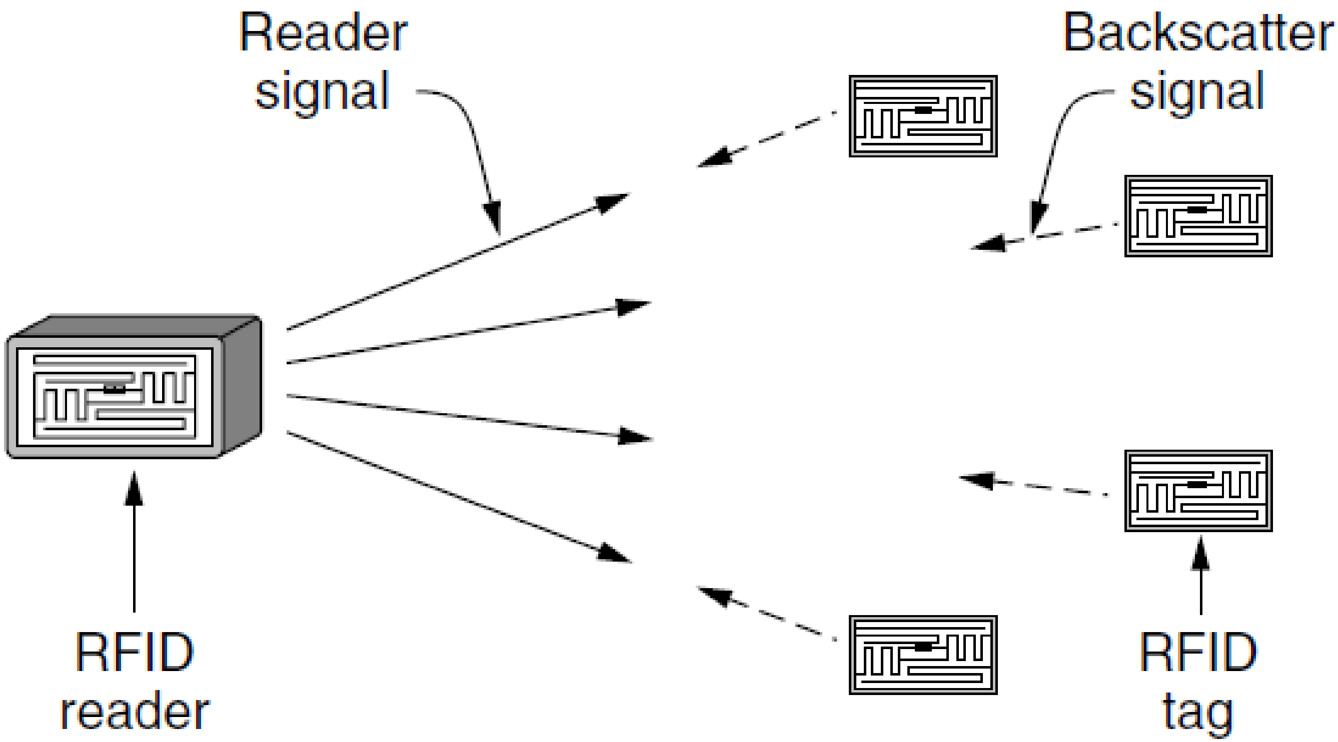
# RFID

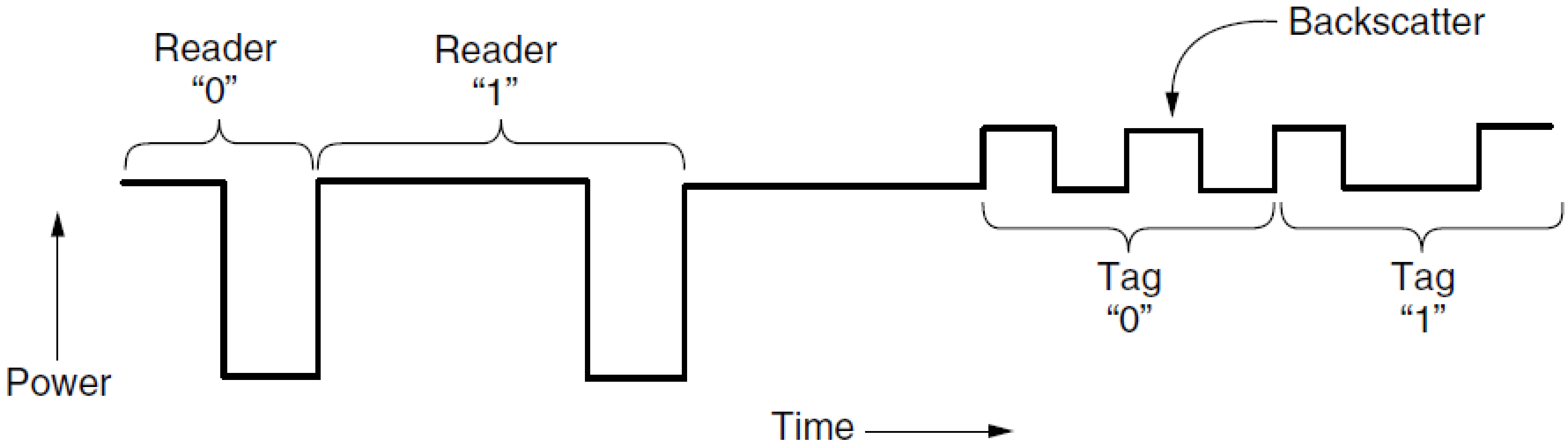
- EPC Gen 2 architecture
- EPC Gen 2 physical layer
- EPC Gen 2 tag identification layer
- Tag identification message formats

# EPC Gen 2 Architecture




RFID architecture.

# EPC Gen 2 Physical Layer




Reader and tag backscatter signals.

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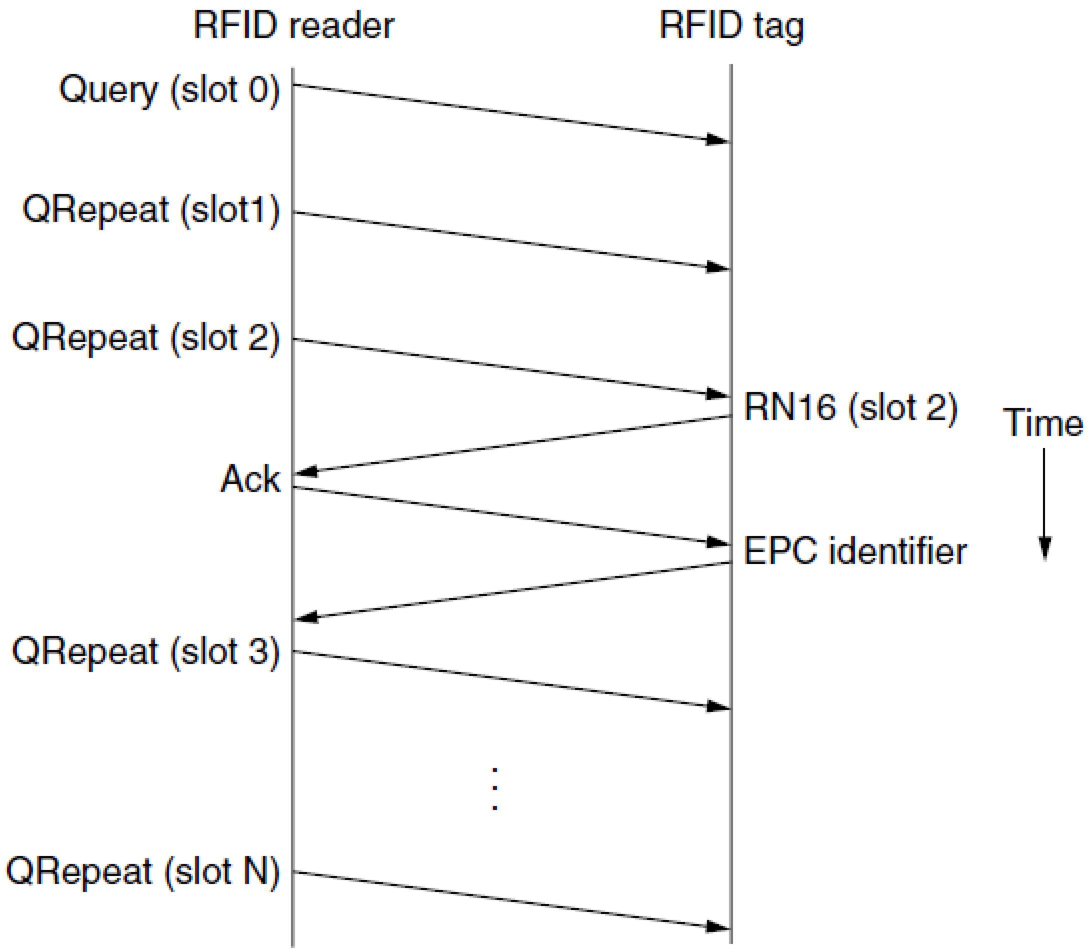
# EPC Gen 2 Tag Identification Layer




Example message exchange to identify a tag.

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# Tag Identification Message Formats

| Bits | 4 | 1 | 2 | 1 | 2 | 2 | 1 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|
| | Command 1000 | DR | M | TR | Sel | Session | Target | Q | CRC |
| | | Physical parameters | | | Tag selection | | | | |

Format of the Query message.

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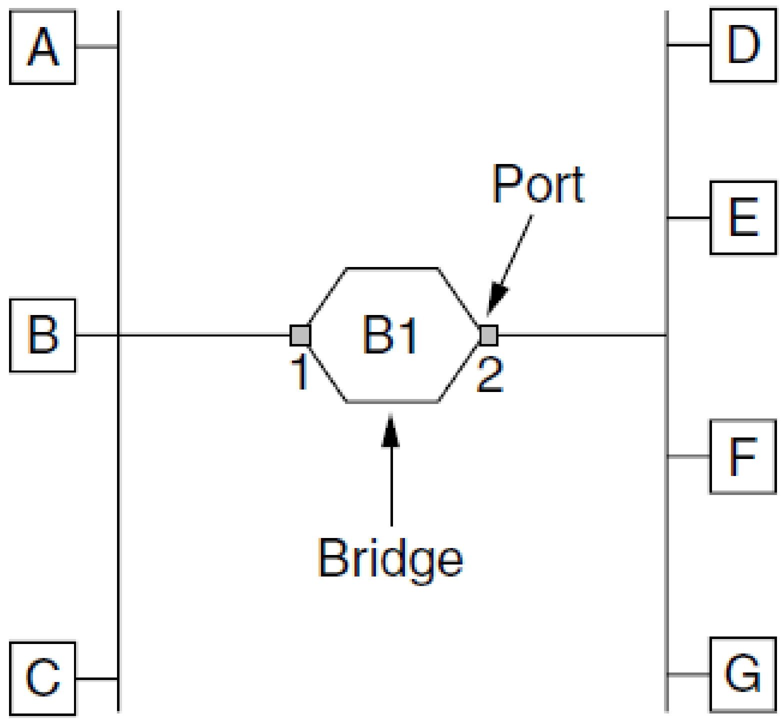
# Data Link Layer Switching

- 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

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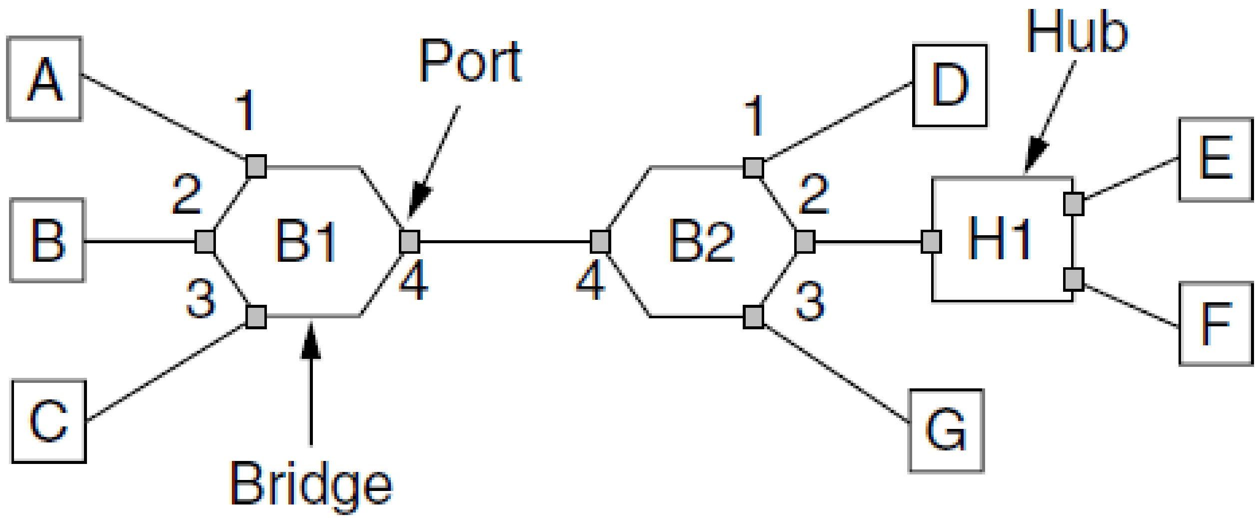
# Learning Bridges (2)




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

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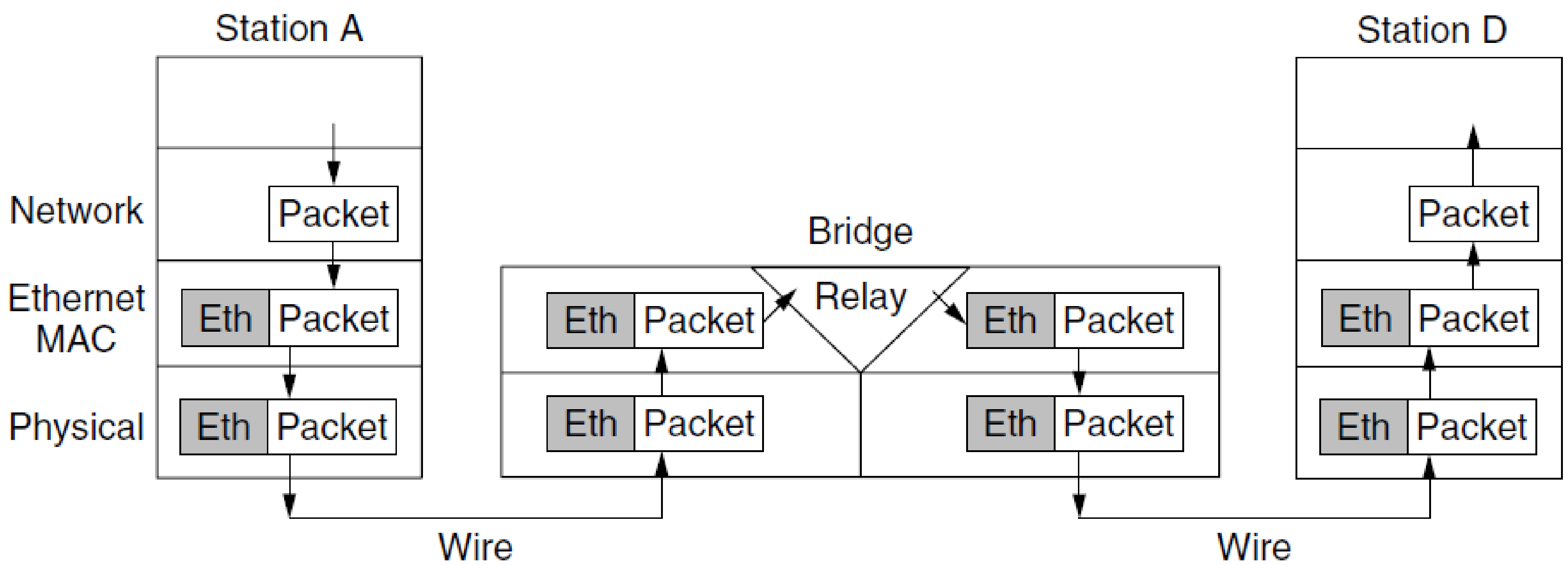
# Learning Bridges (3)




Protocol processing at a bridge.

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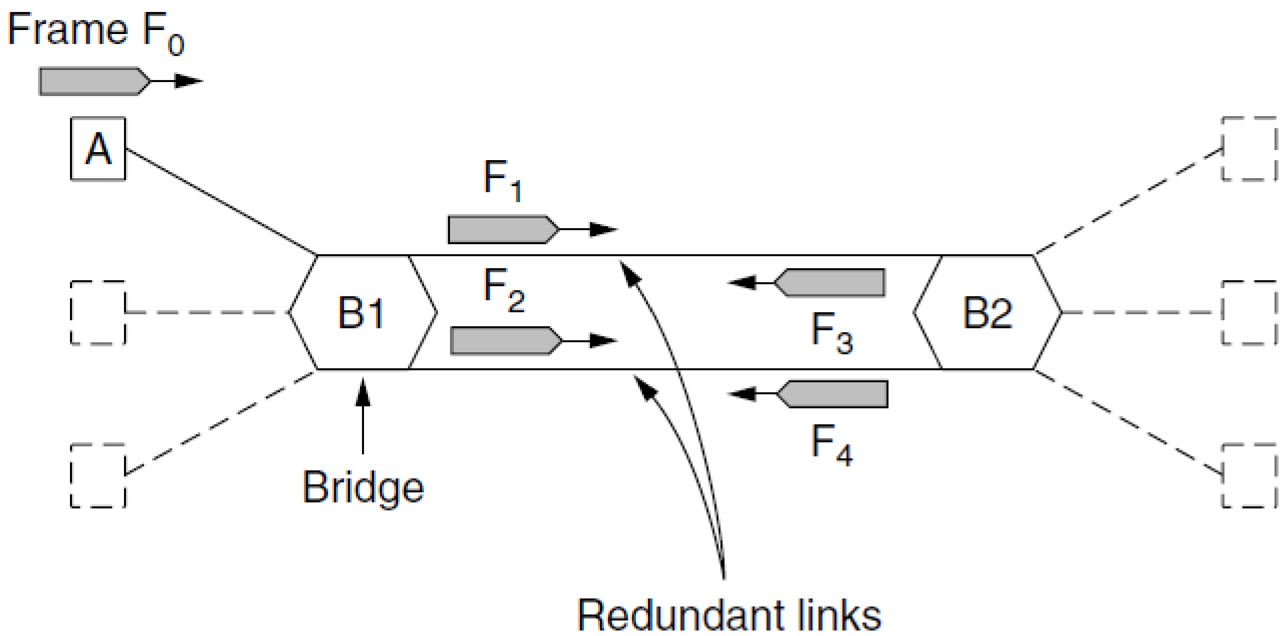
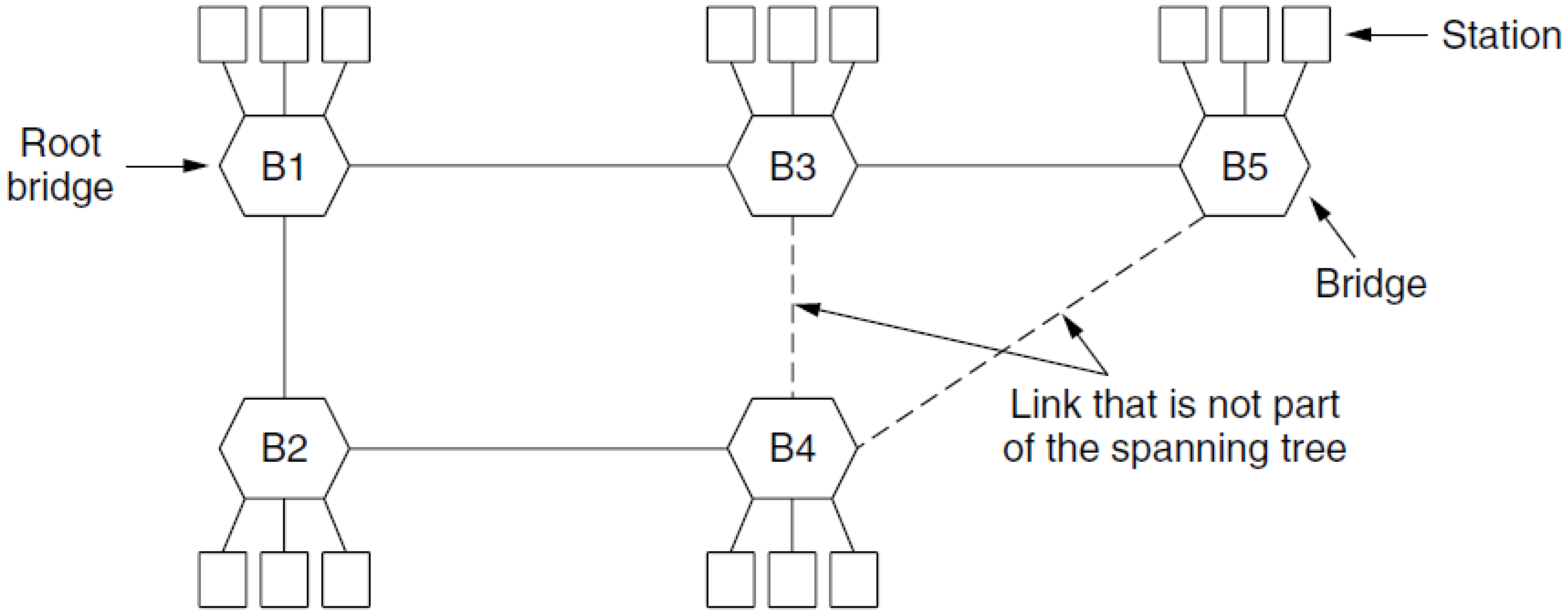
# Spanning Tree Bridges (1)




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.

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# 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.*

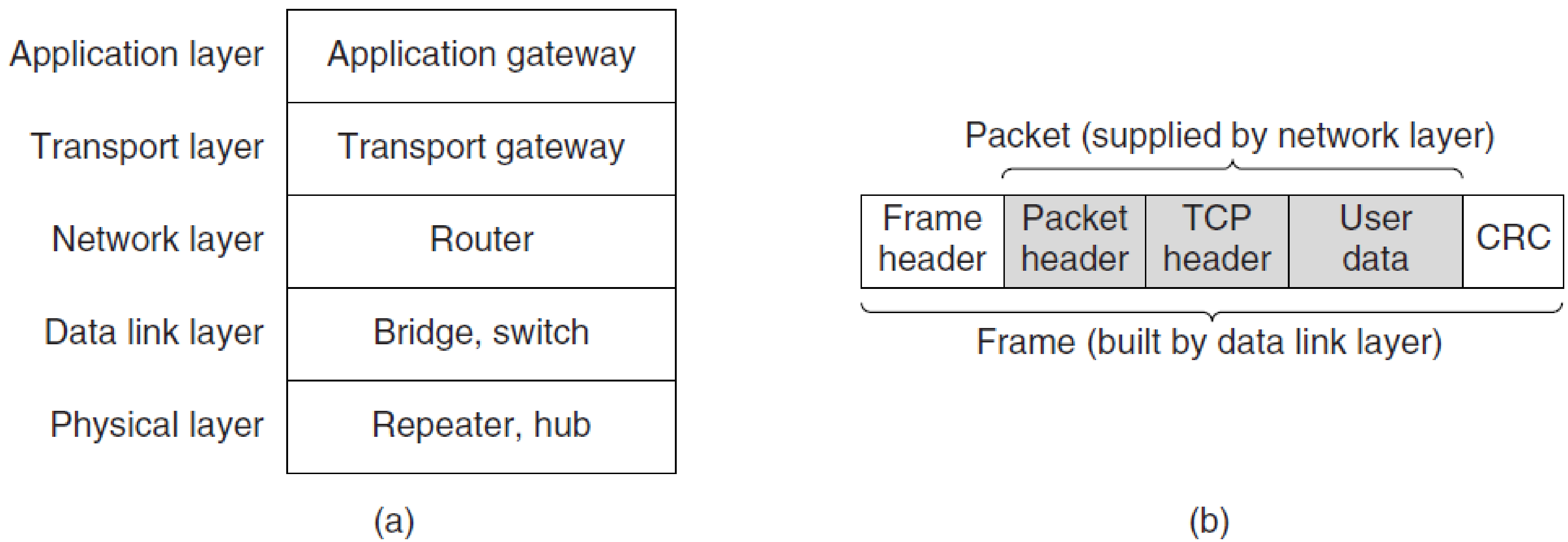
*Least cost paths from Root are traced*

*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




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

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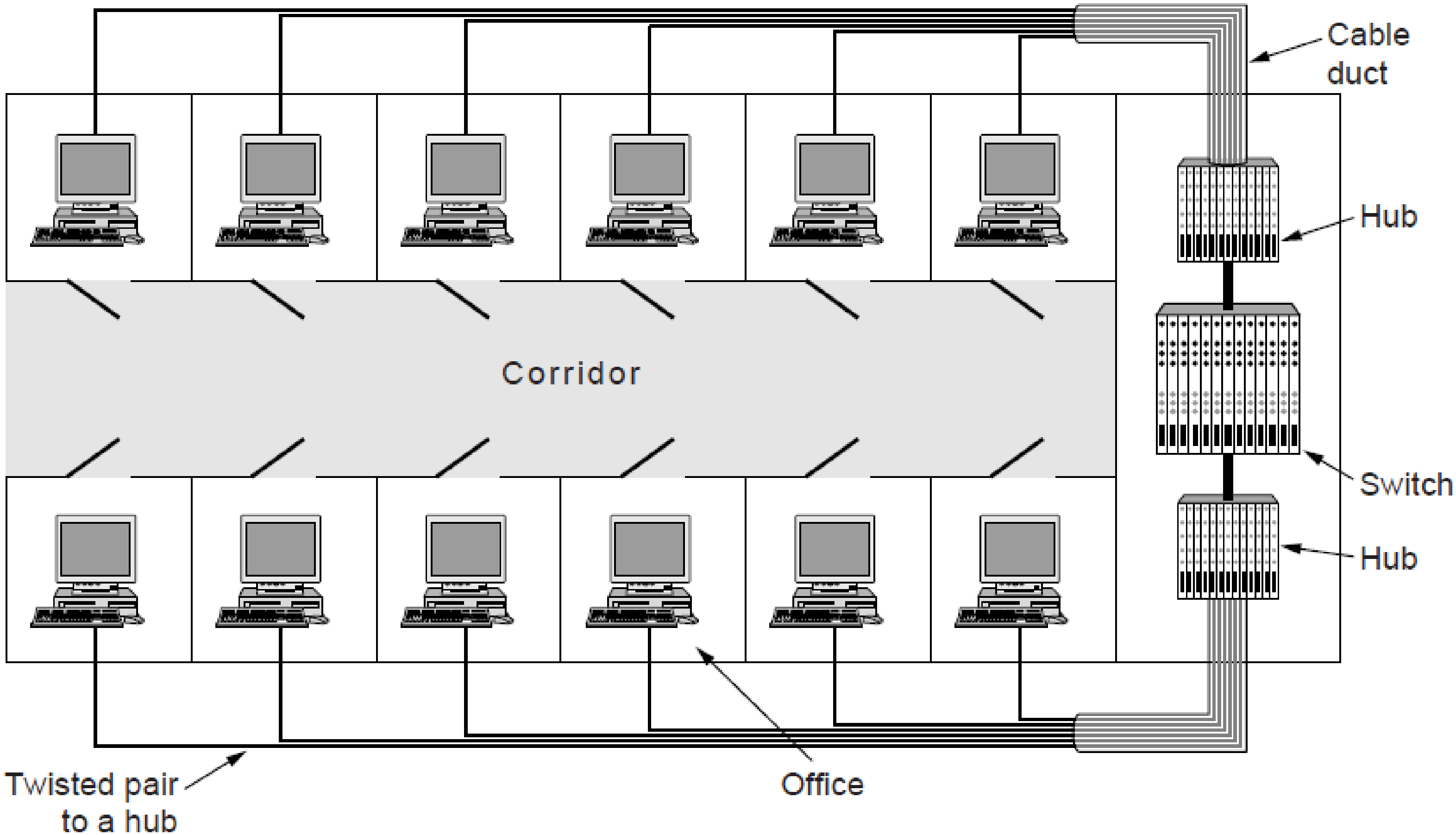
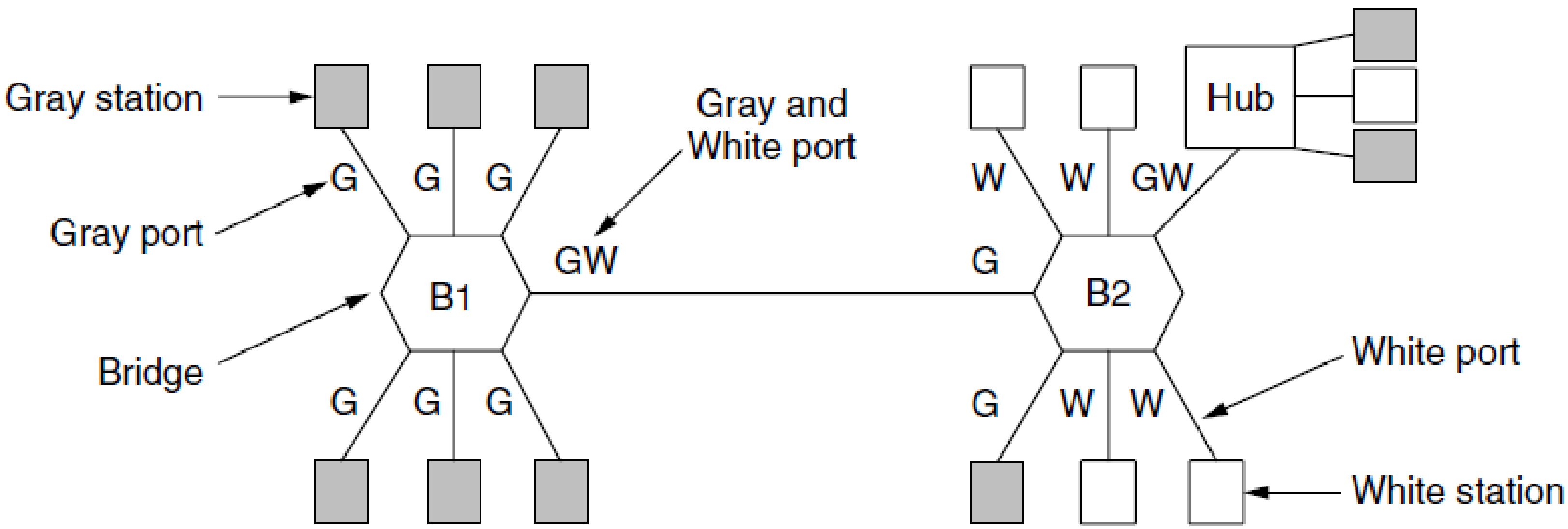
# Virtual LANs (1)



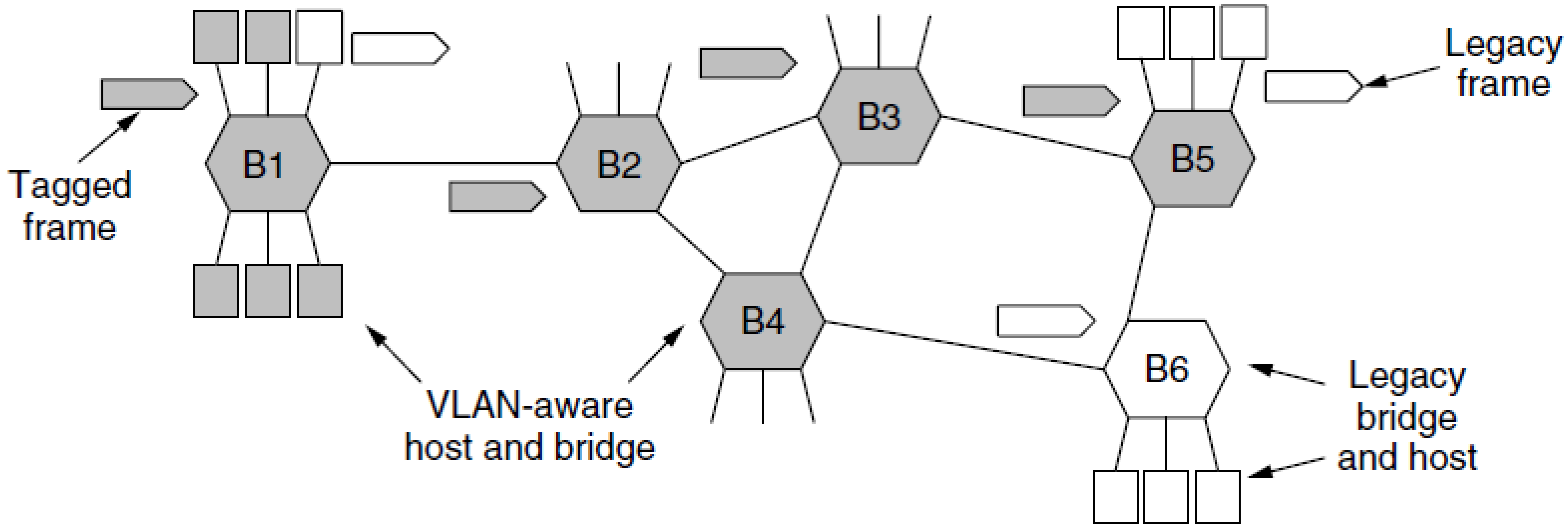

A building with centralized wiring using hubs and a switch.

# 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.

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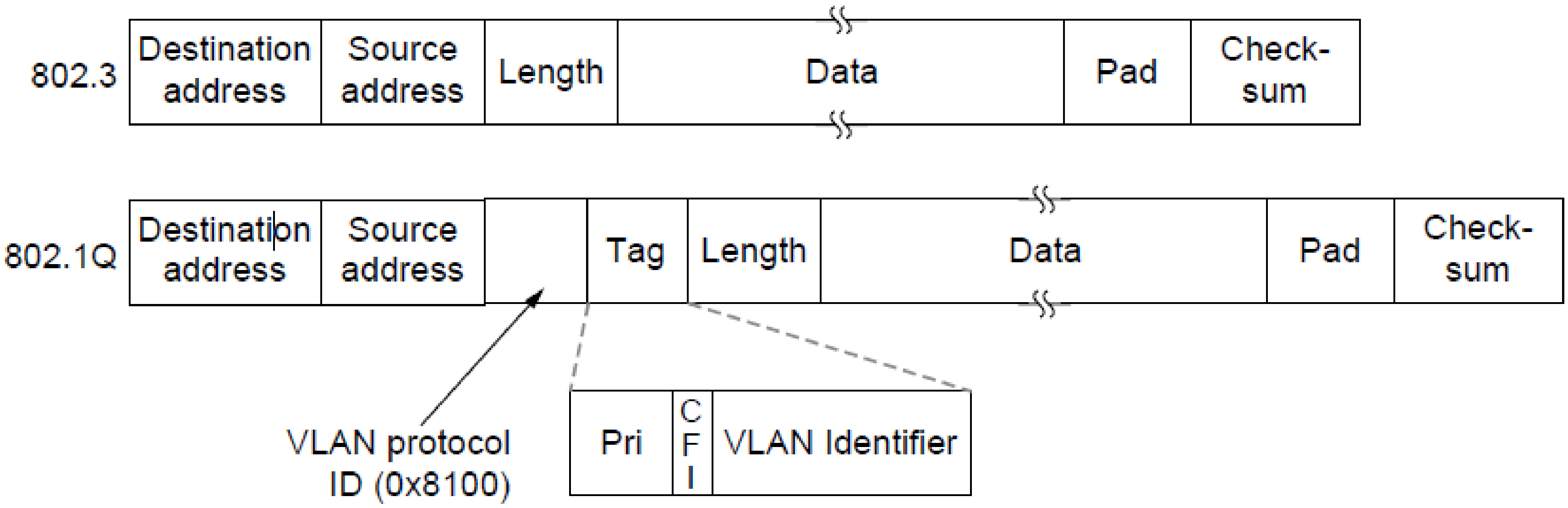
# The IEEE 802.1Q Standard (2)




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

# End

Chapter 4