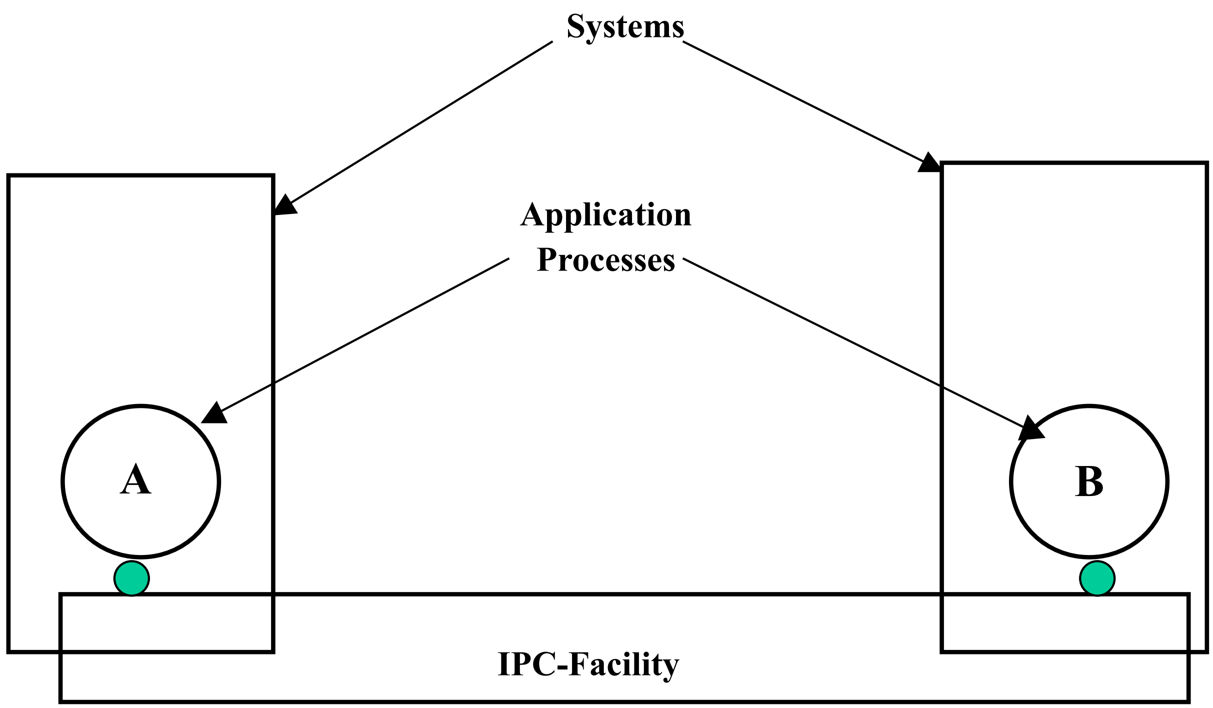
2: Two Application Communicating in Distinct Systems



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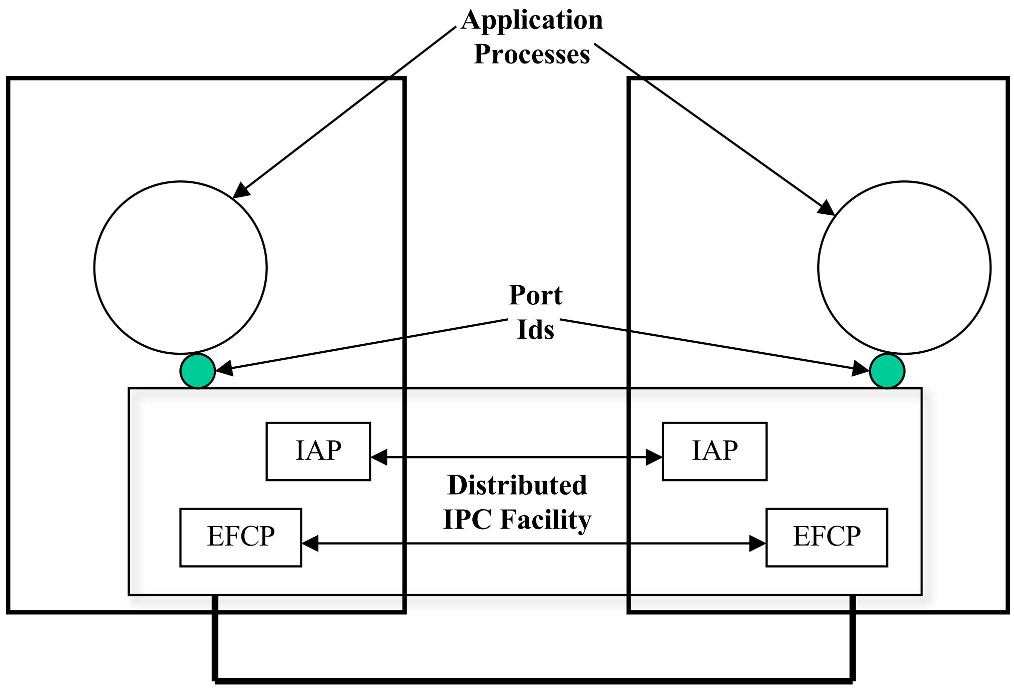
How Does It Work Now?



1) **A** invokes the IPC facility to allocate a channel to **B** by calling an *Allocate*.

2) IPC determines whether it has the resources to honor that request. If so, IPC uses its *search rules* to find **B.** Not finding it locally, the IAP function constructs an IAP PDU and passes it to the EFCP function, which constructs an EFCP PDU with the IAP PDU as the User-Data and sends and sends the EFCP PDU to **B** creating an EFCP connection to use for sending the IAP request. The EFCP function in the other system will process the EFCP PDU to determine the User-Data is good, strips off the EFCP PCI and passes it to the IAP function.

3) The IAP function processes its PDU and looks for B. When it finds **B,** it determines whether **A** has access to **B**. IPC may cause **B** to be instantiated.

4) **B** is notified of the IPC Request from A is and given port ID **b.**

5) If **B** responds positively, IPC reverses the process in 3) and sends an IAP Response, IPC notifies **A** using port-id **a.**

6) to N, **A** and **B** do their *reads* and *writes*. A and B pass PDUs as SDUs to the IPC Facility, which encapsulates them in EFCP PDUs and sends them, the PDUs are received and processed by the EFCP function in the other system, the PCI is stripped off and delivered to the other application. A and B sending PDUs back and forth with data for a while and when they're done.

7) One or both of them do a *Deallocate* on the port-id to release the resources.

Just Like Before . . . .More or Less

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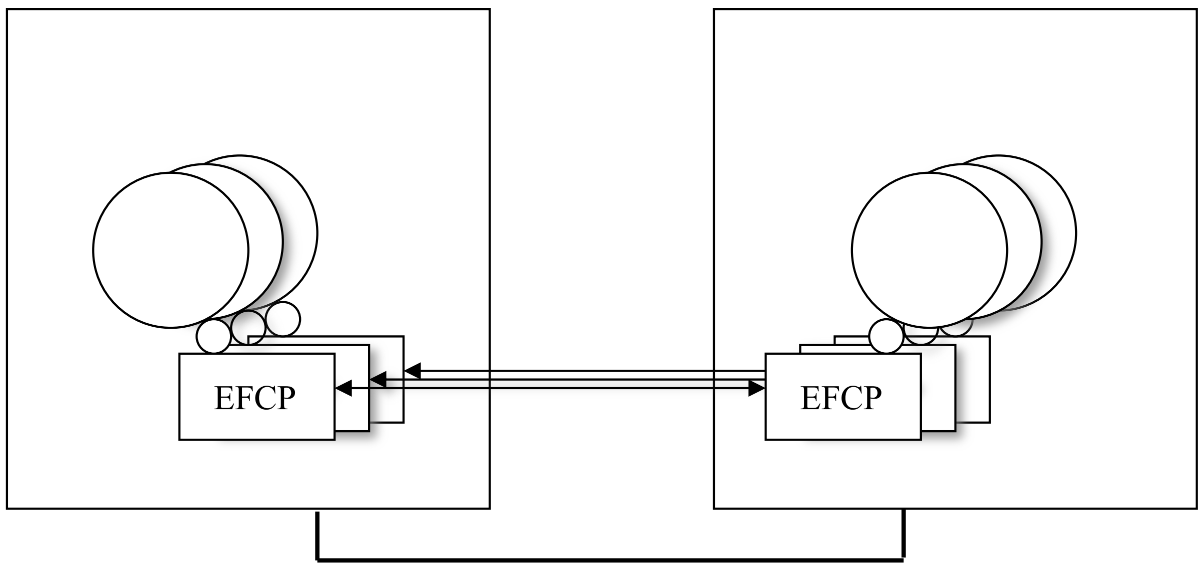
3: Simultaneous Communication Between Two Systems

i.e., multiple applications at the same time

- To support this, we have multiple instances of the EFCP.



Will have to add the ability in EFCP to distinguish one flow from another.

Connection-id

Dest-port	Src-port	Op	Seq #	CRC	Data

Typically use the port-ids of the source and destination.
Also include the port-ids in the information sent in IAP to be used in EFCP synchronization (establishment).

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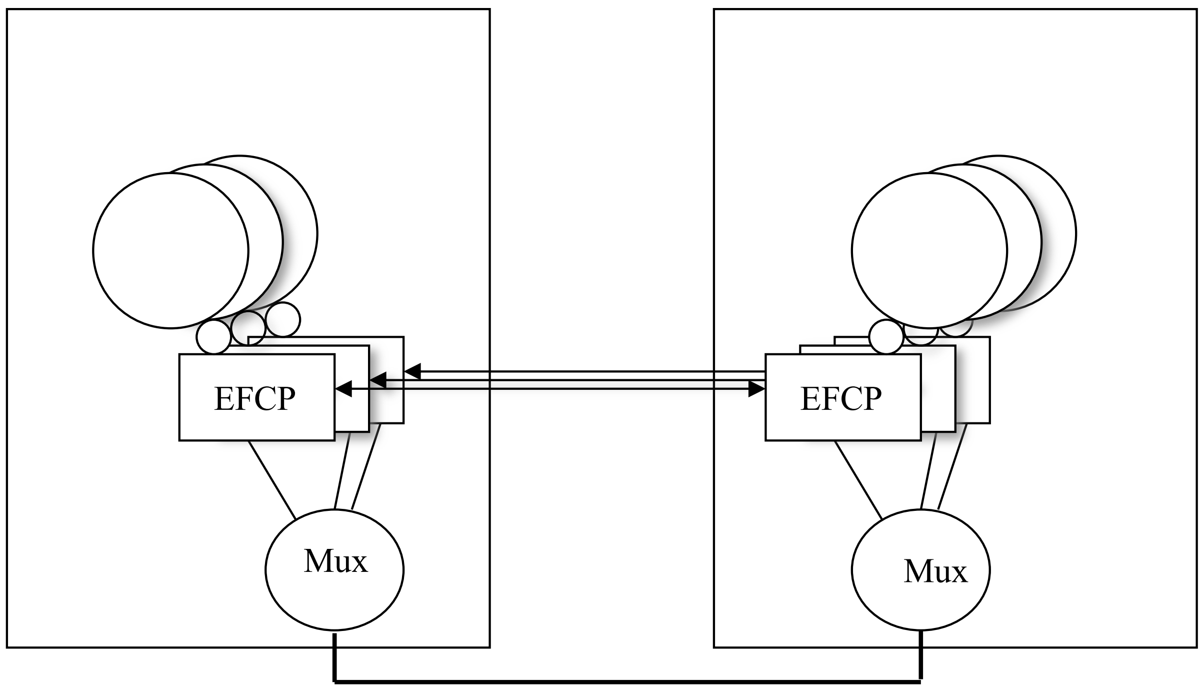
Simultaneous Communication Between Two Systems

i.e. multiple applications at the same time

- In addition to multiple instances of the EFCP.



Will also need an application to manage multiple users of a single resource.
(interesting: the definition of an operating system problem)

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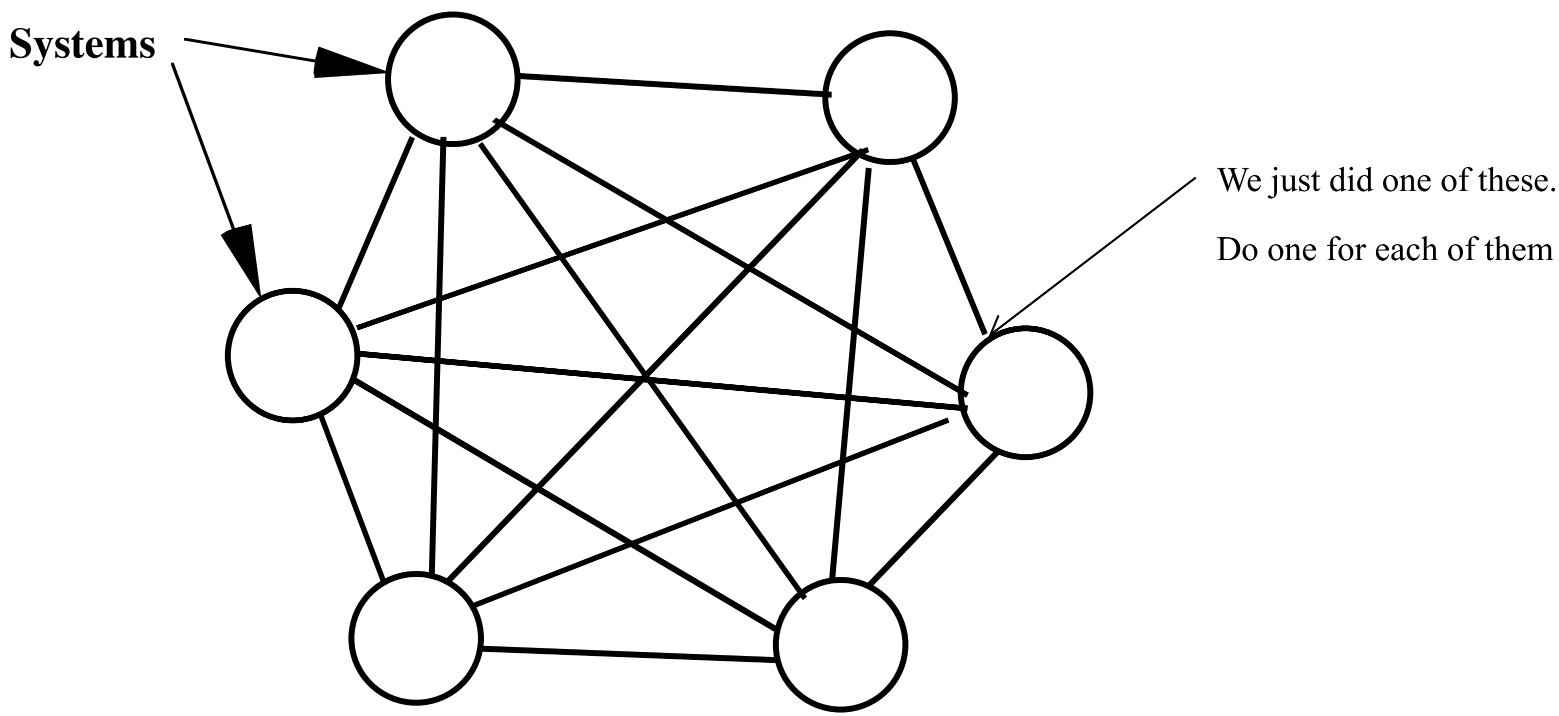
4: Communication with N Systems



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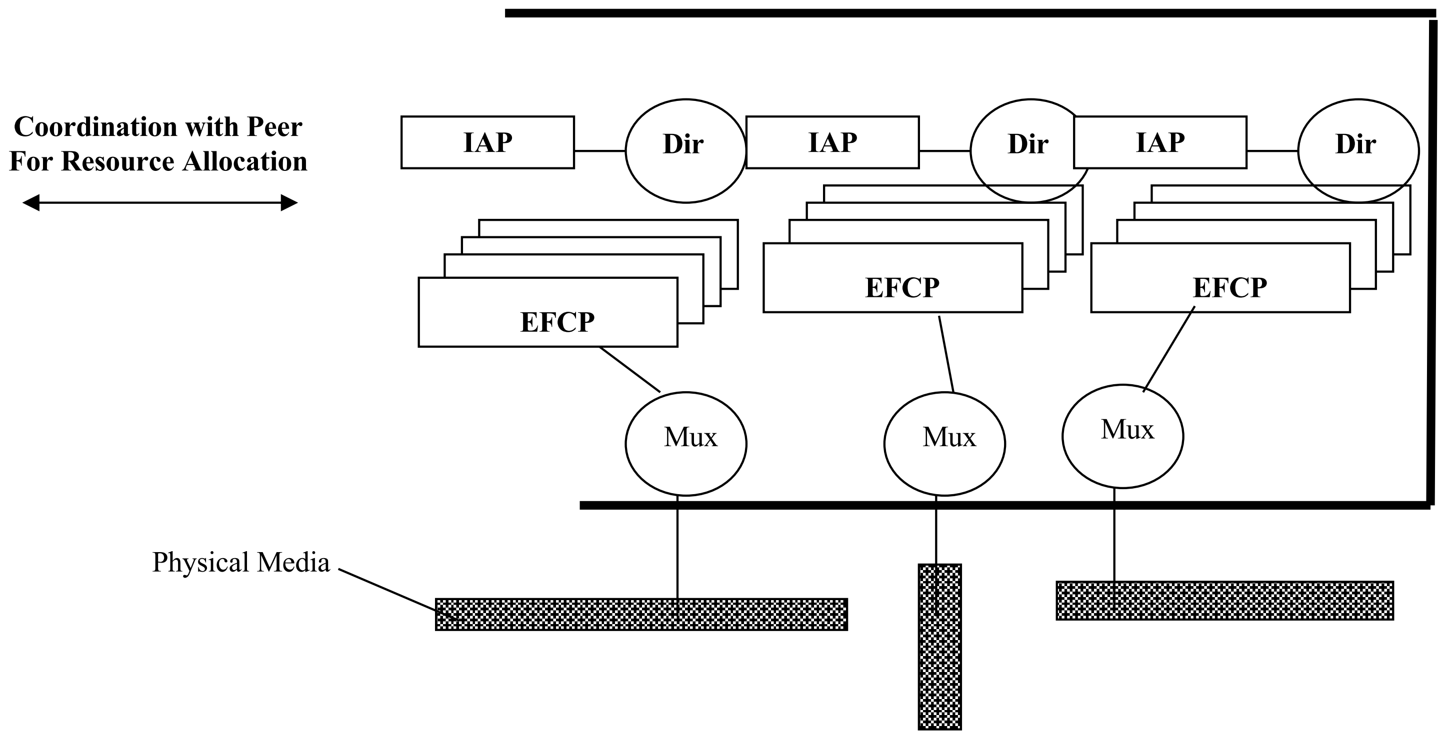
We will Need a Separate Multiplexing Application for each physical media interface.



- There is a common structure here that can be factored out.
- And we need to use IAP to find out what applications are at the other end of the wire.
- And with more systems need better coordination of resources

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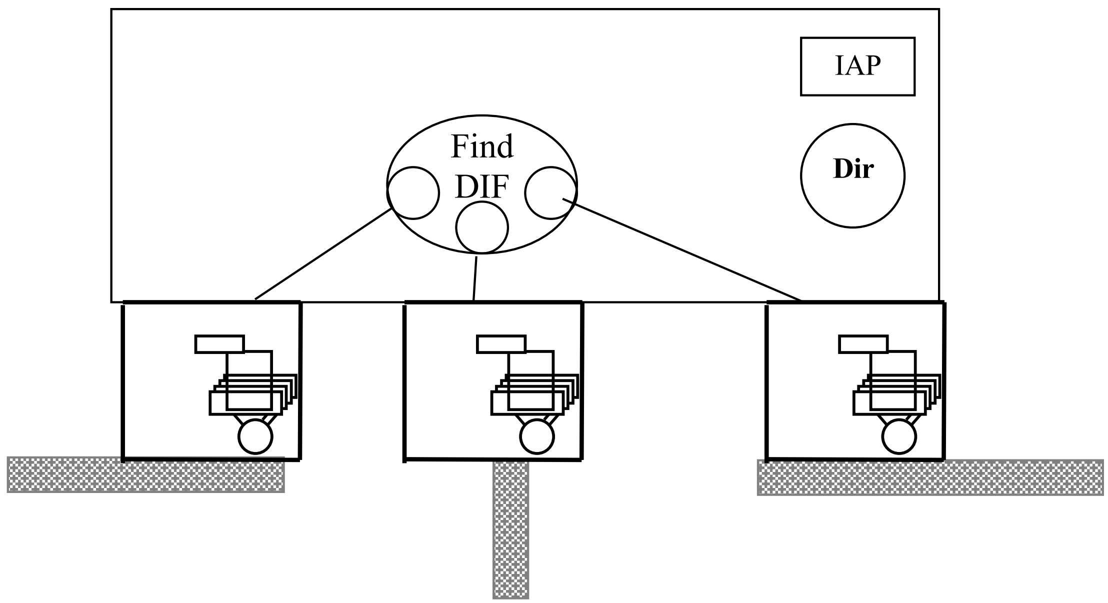
But Applications Shouldn't Have to Know Which Wires to Use!



So, with one Distributed IPC Facilities (DIF) for each Interface (wire), we need a function to figure out which wire the requested application is on. This preserves the API the application sees to make it location-independent and look as much like normal file operations as possible.

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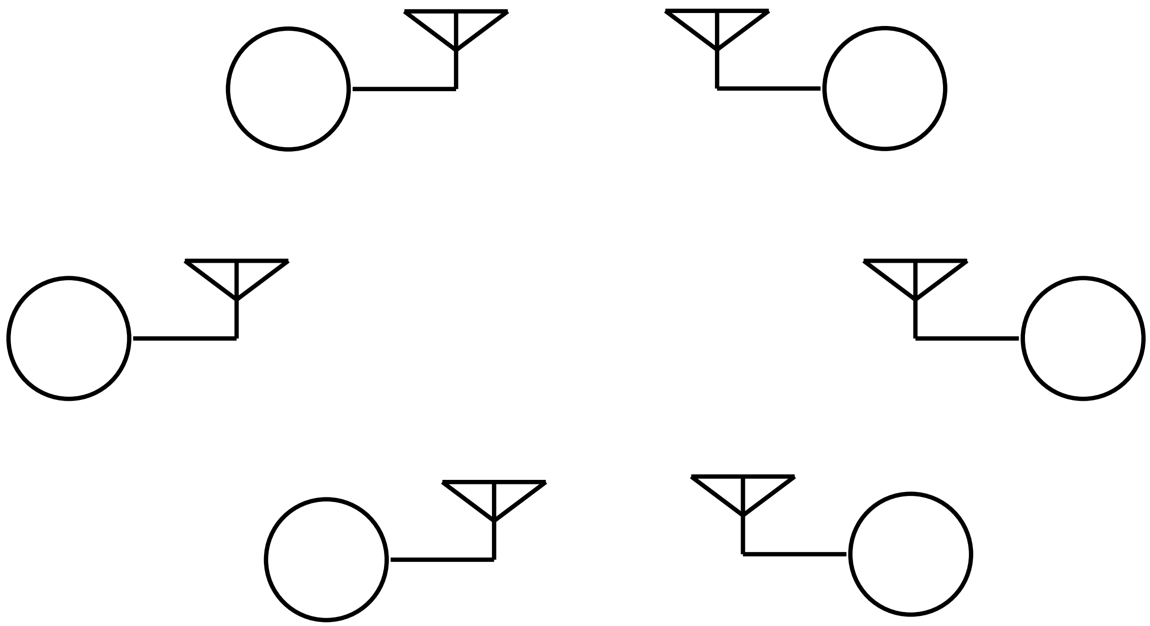
N Systems Using Wireless



This is certainly cheaper. Instead of each node having (N-1) interfaces, each one has 1 interface. However, (why is there always a however?)

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Wireless Introduces New Considerations: I

- Wireless does provide a marked decrease in the complexity.
  - Before each node had (N-1) layers of 2 members each,
  - Now each node has one layer of N members.
    - To the user of this layer, all nodes are one hop away.
- Whenever there is a layer with more than 2 members either with shared media or relaying, we need to label the PDU as to who it is for.
  - Every PDU must carry an identifier to indicate the destination of the PDU. (sometimes called an address)
    - If the layer relays, the identifier indicates where its destination is and when it has reached it.
    - If the layer is a shared media, every node should see every PDU sent, each node need only *recognize* which PDUs are for it.
- We will need to add source and destination "addresses" to all PDUs.

Dest Addr	Src Addr	Dest-port	Src-port	Op	Seq #	CRC	Data

The PDU must be expanded one more time.

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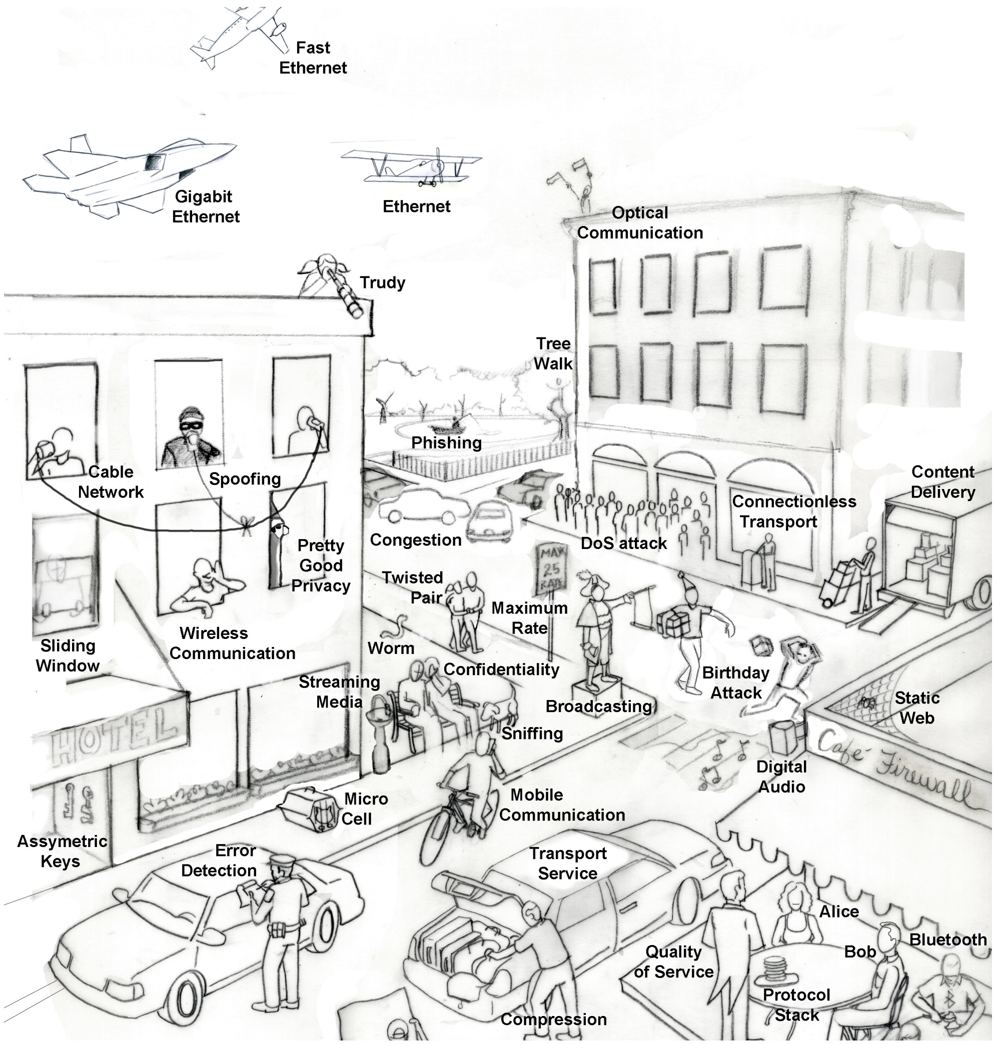
Computer Networking

Sixth edition



Chapter 4

The Medium Access Control Sublayer

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The Channel Allocation Problem

- Static channel allocation
- Assumptions for dynamic channel allocation

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Static Channel Allocation

- Static allocation
  - Poor fit to computer systems with extremely bursty data traffic
  - Performance affected when peak traffic to mean traffic ratios are 1000:1
  - Most channels will be idle most of the time
- Dynamic allocation tries to resolve static allocation problems

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Assumptions for Dynamic Channel Allocation

- Independent traffic
- Single channel
- Observable collisions
- Continuous or slotted time
- 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 of 4)

- Pure ALOHA
- Slotted ALOHA

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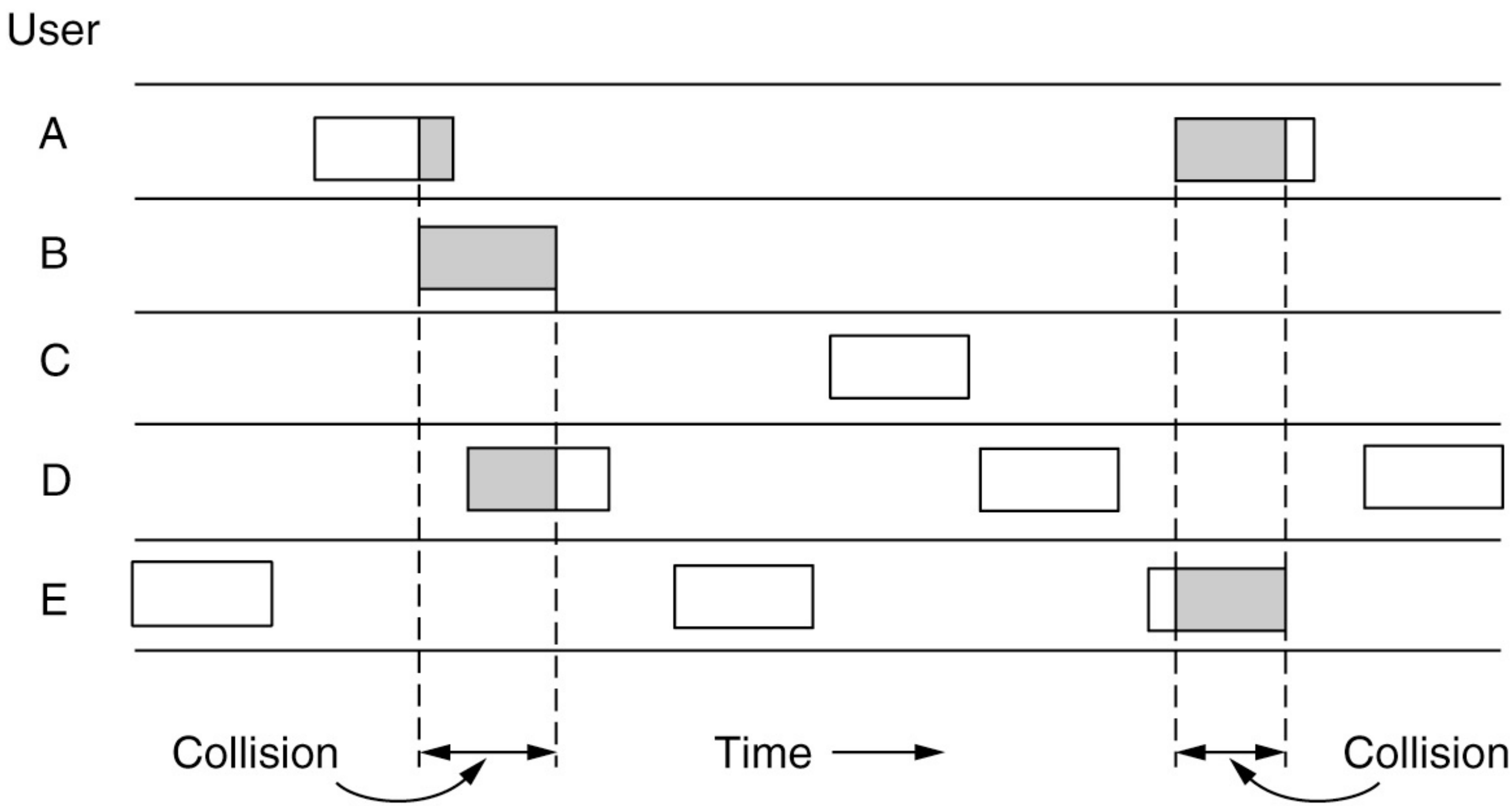
ALOHA (2 of 4)



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

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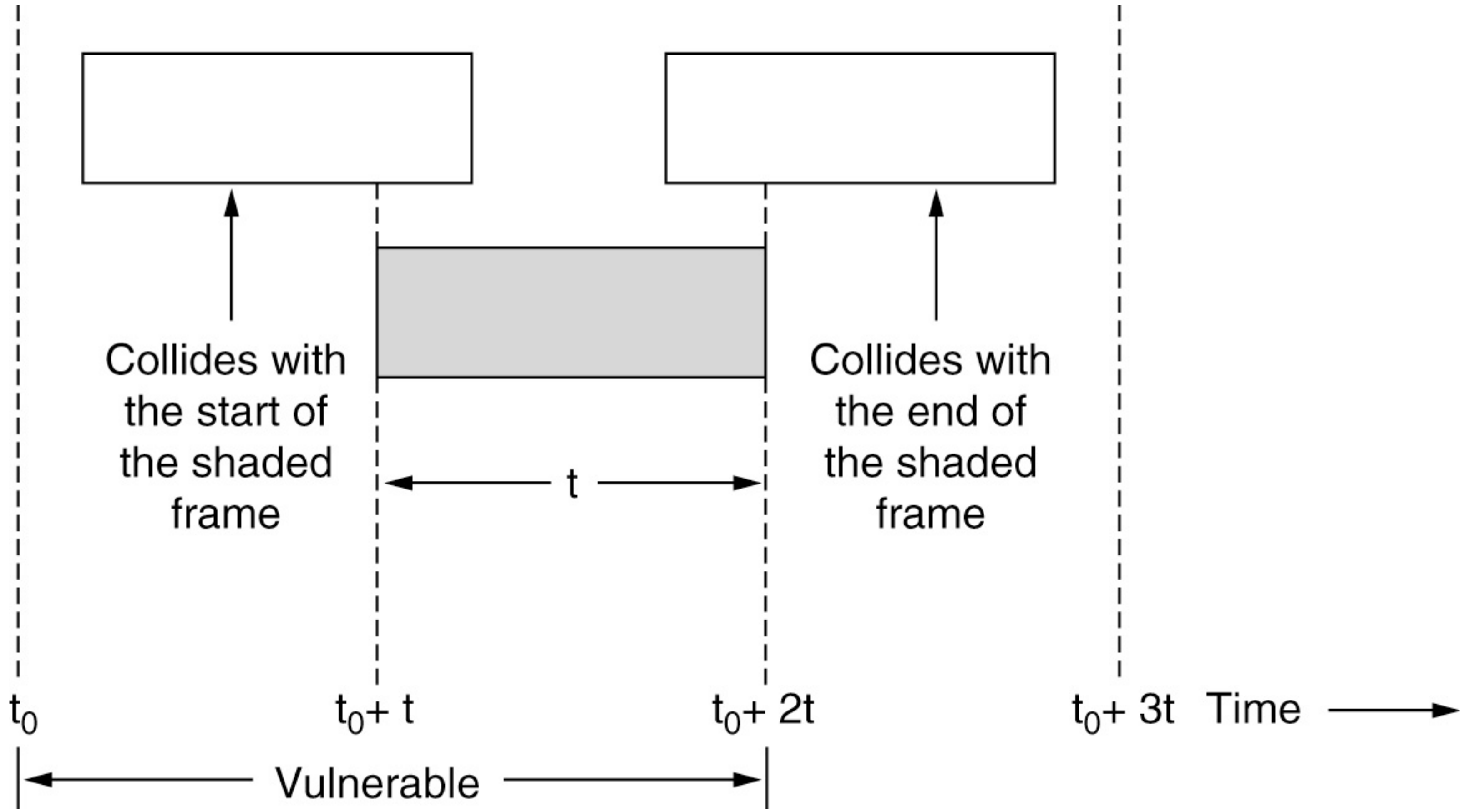
ALOHA (3 of 4)



Vulnerable period for the shaded frame

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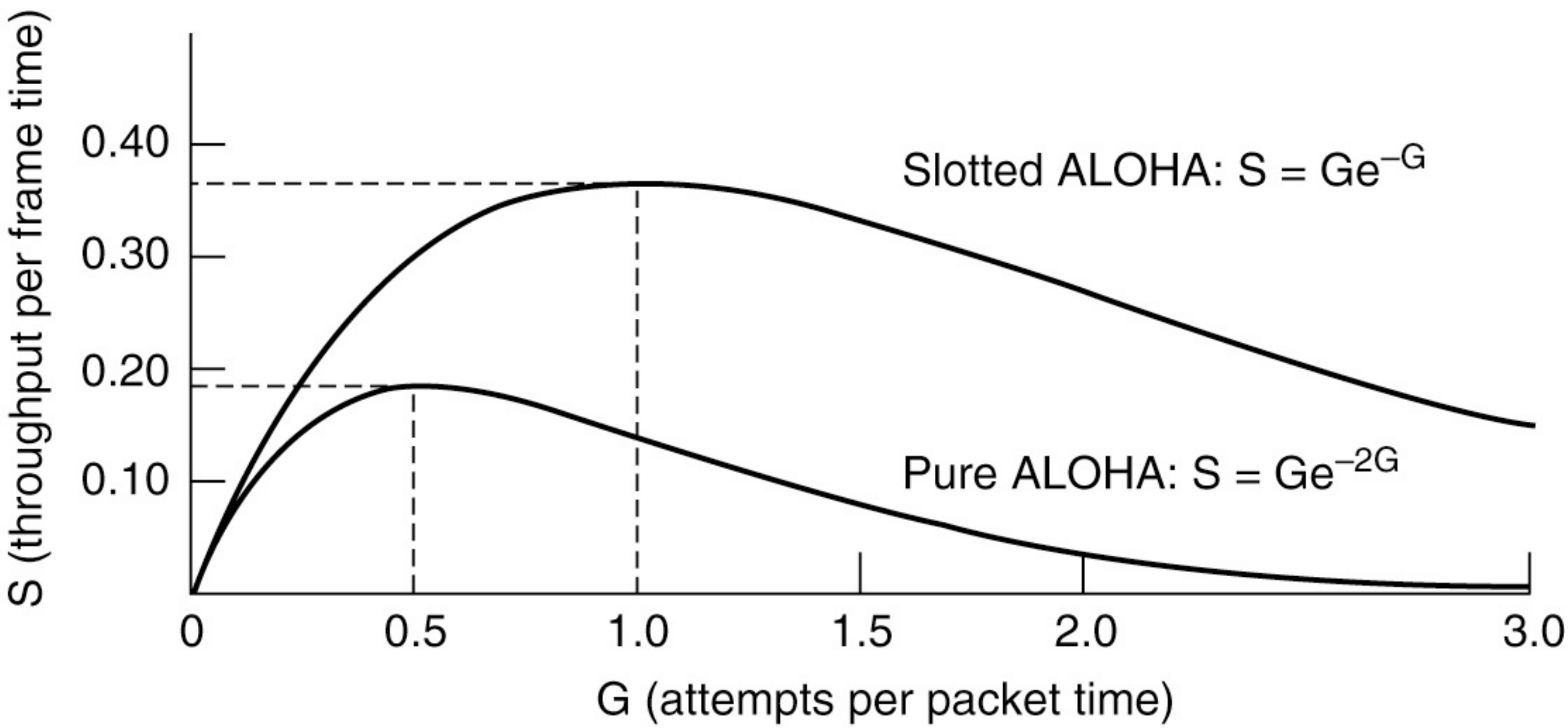
ALOHA (4 of 4)



Throughput versus offered traffic for ALOHA systems

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Carrier Sense Multiple Access Protocols

- Persistent and non-persistent CSMA
  - 1-persistent CSMA (Carrier Sense Multiple Access)
  - Nonpersistent CSMA
  - p-persistent CSMA
- CSMA with collision detection
  - Known as CSMA/CD (CSMA with Collision Detection)
  - Basis of the classic Ethernet LAN

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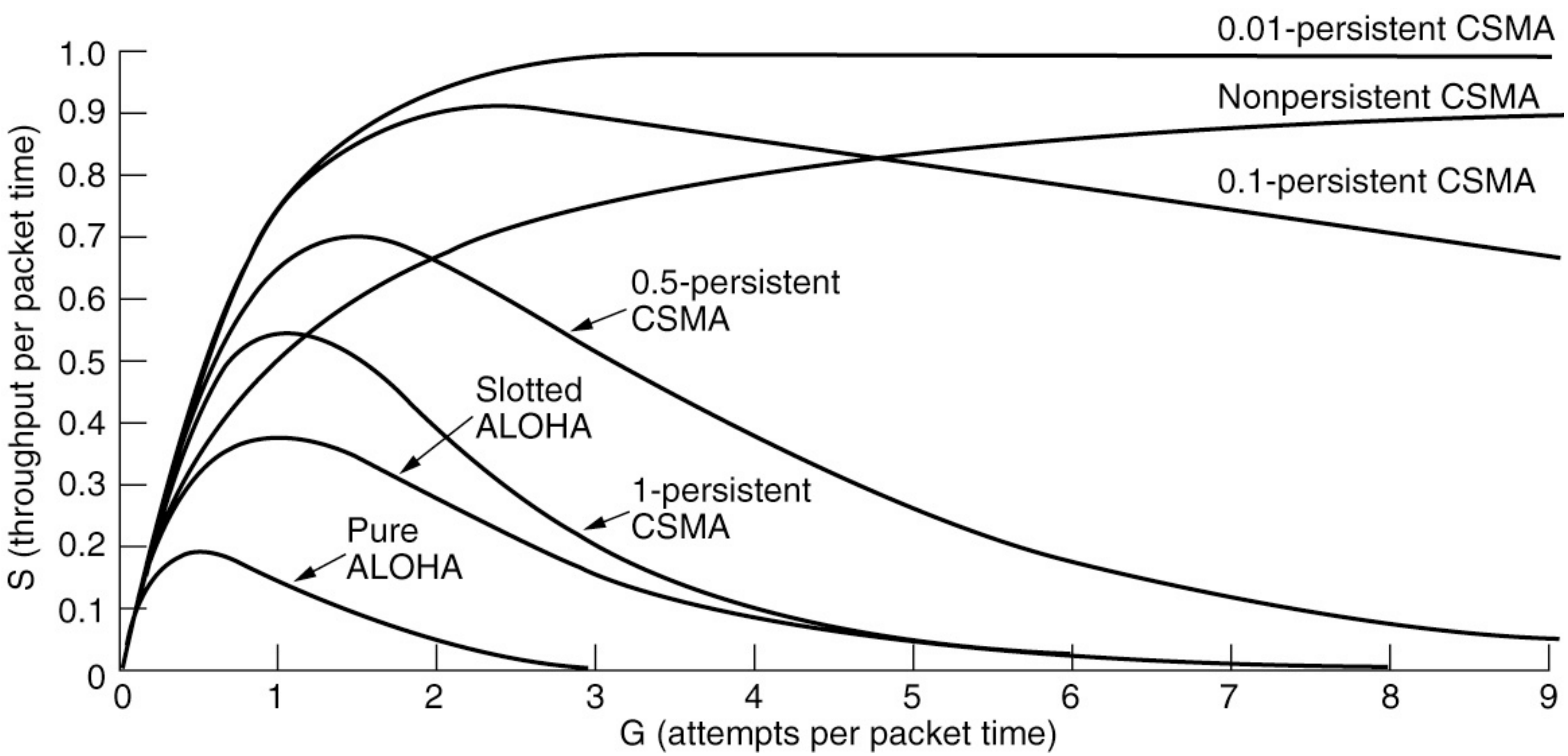
Persistent and Nonpersistent CSMA



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

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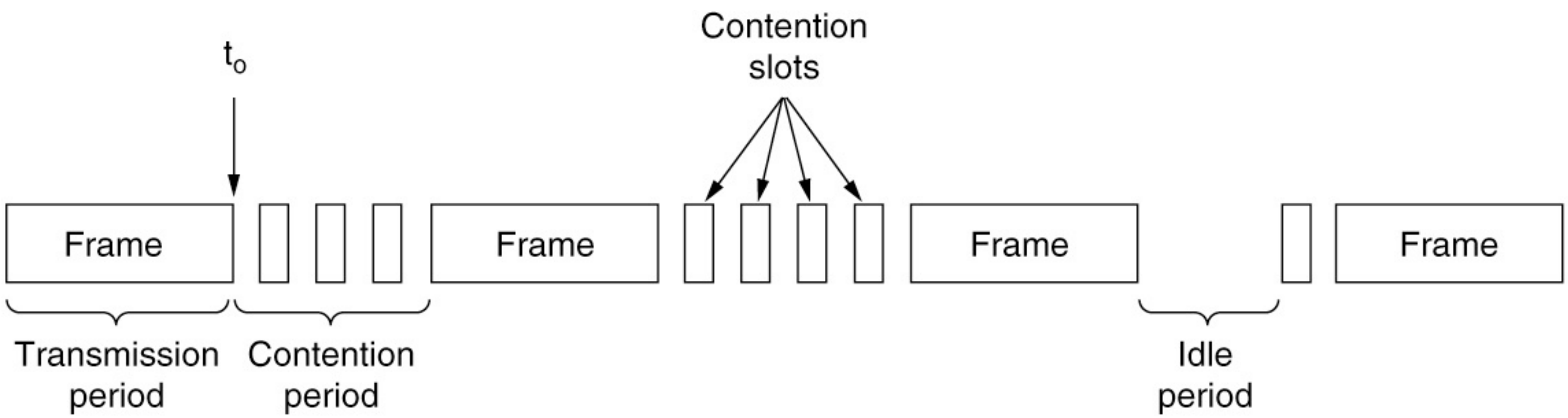
CSMA with Collision Detection



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

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Collision-Free Protocols

- Bit-map protocol
  - Basic bit-map method
  - Reservation protocols
    - The desire to transmit is broadcast before the actual transmission
- Token passing
  - Token bus
  - FDDI (Fiber Distributed Data Interface)
  - RPR (Resilient Packet Ring)
    - Defined as IEEE 802.17 to standardize the mix of metropolitan area rings in use by ISPs
- Binary countdown

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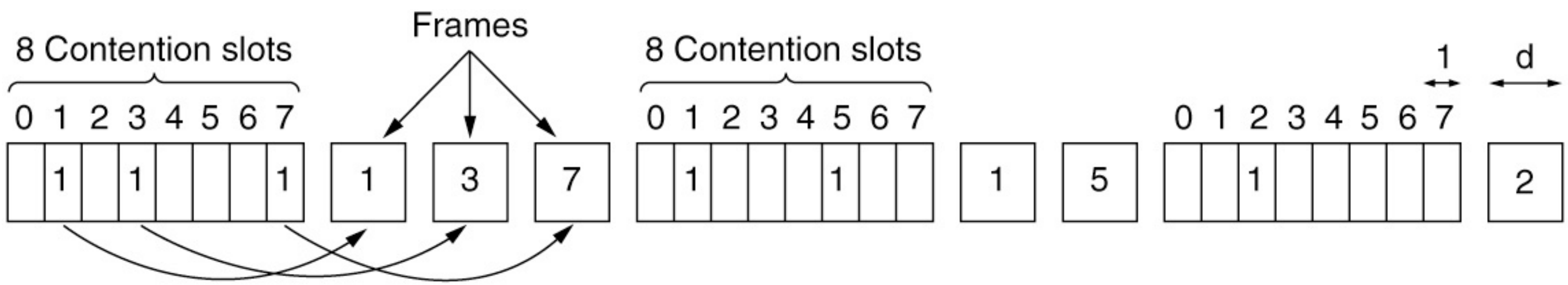
A Bit-Map Protocol



The basic bit-map protocol

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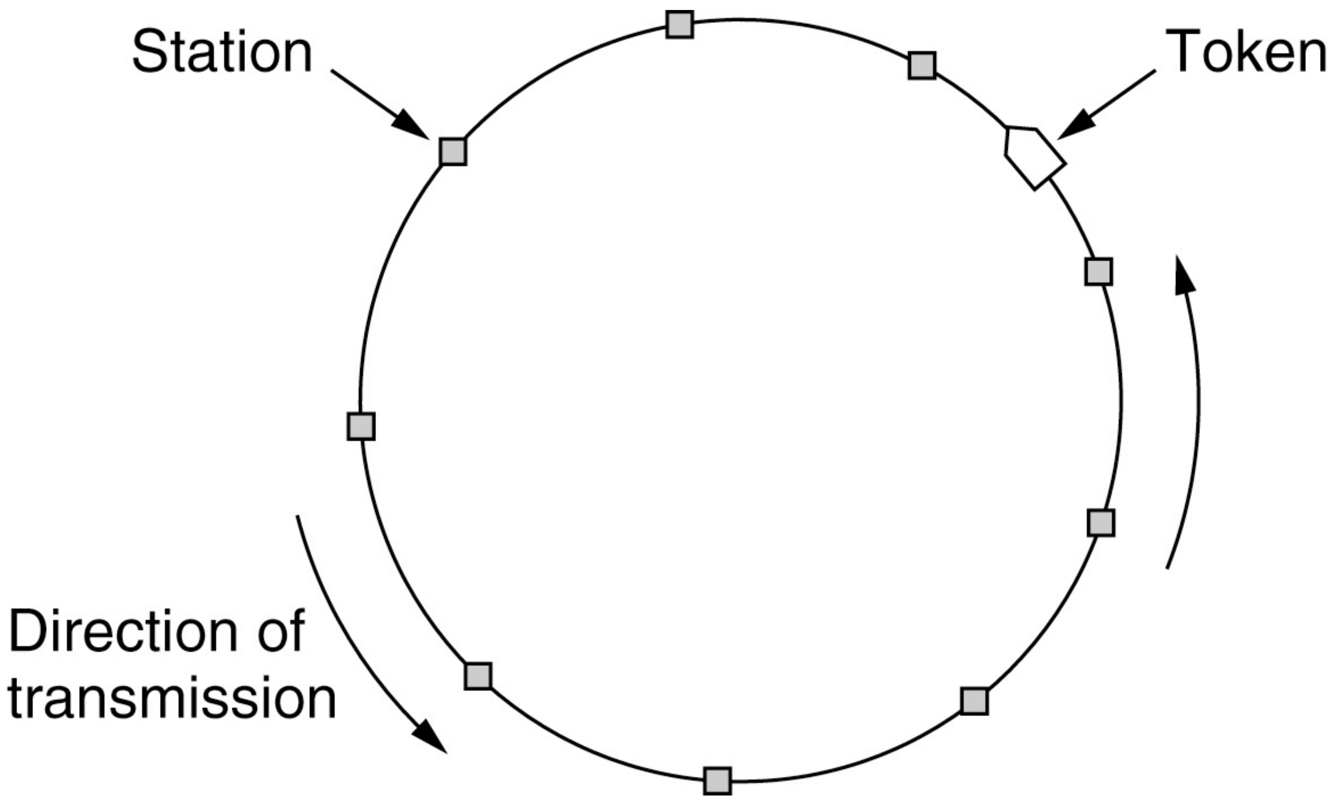
Token Passing



Token ring

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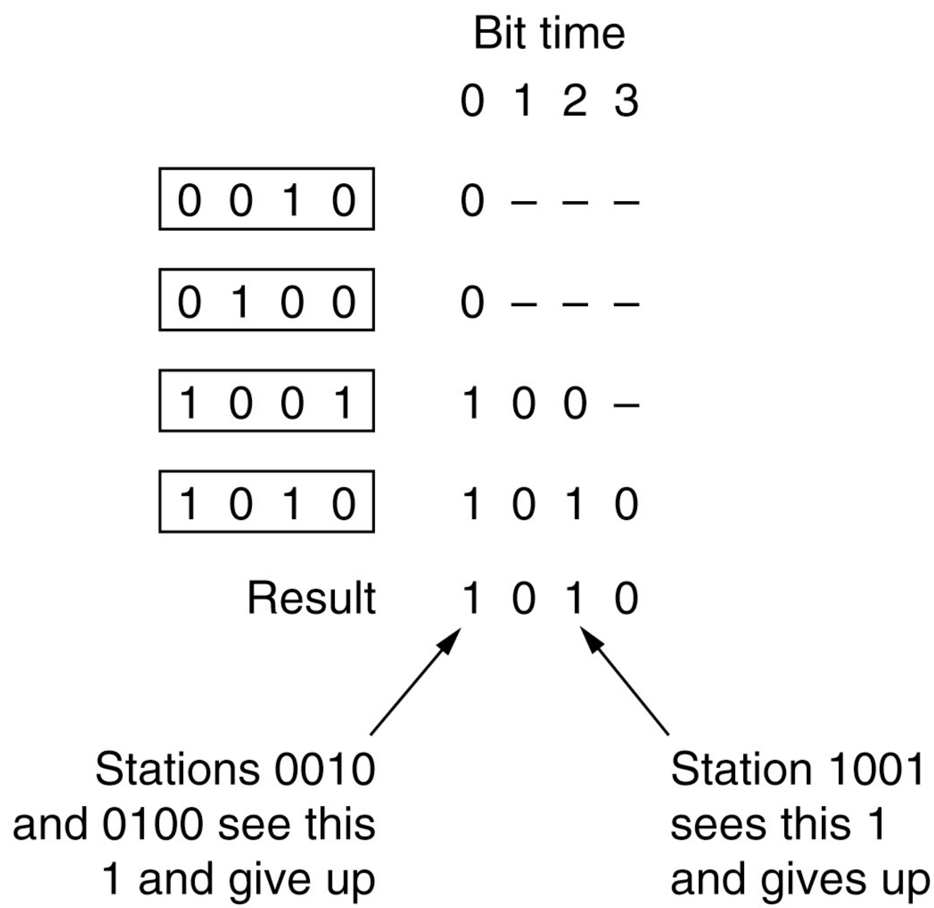
Binary Countdown



The binary countdown protocol. A dash indicates silence.

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Limited-Contention Protocols (1 of 2)

- Combines the best properties of the contention and collision-free protocols
- Limited-contention protocol
  - Use contention at low load to provide low delay
  - Used a collision-free technique at high load to provide good channel efficiency
  - Asymmetric protocols
- Review performance of the symmetric protocols first
- The adaptive tree-walk protocol

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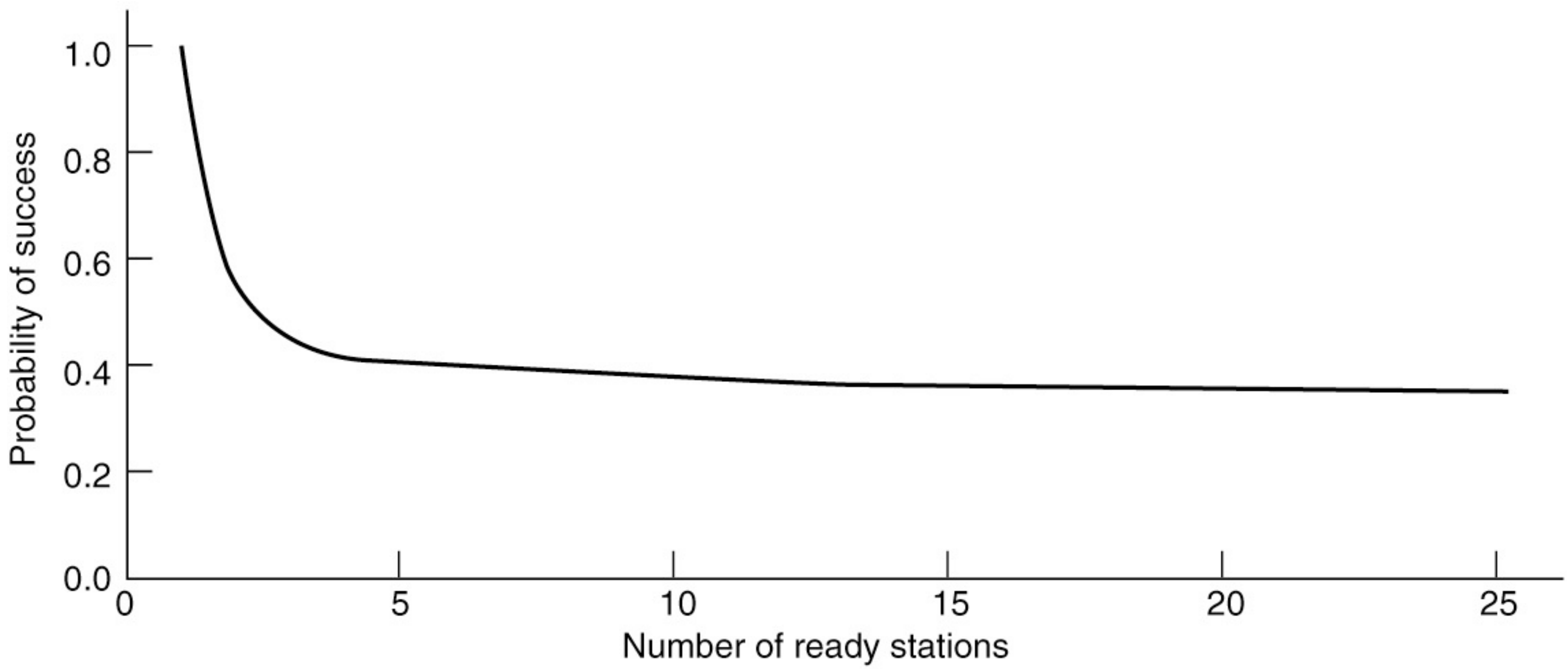
Limited-Contention Protocols (2 of 2)



Acquisition probability for a symmetric contention channel

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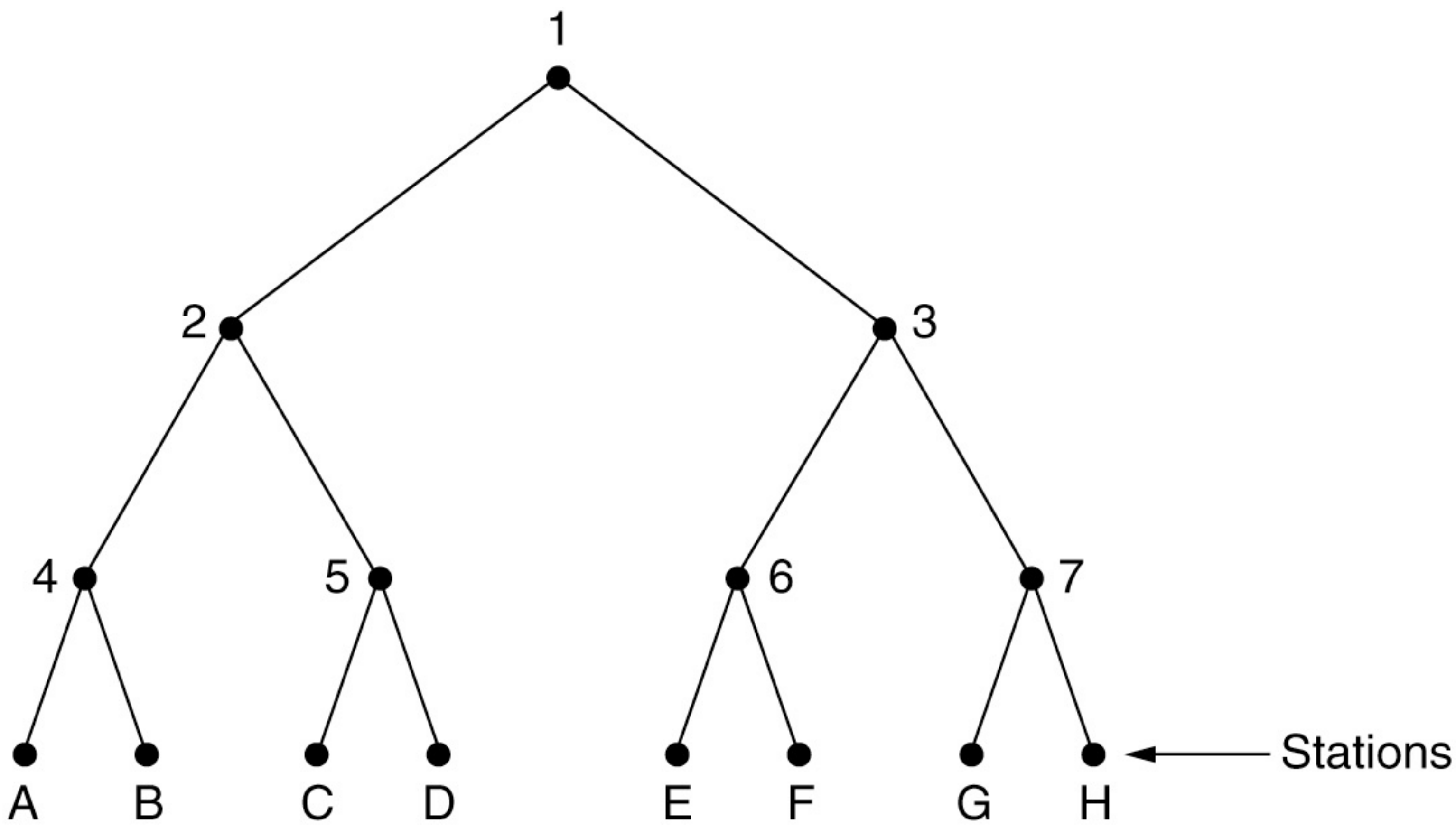
The Adaptive Tree-Walk Protocol



The tree for eight stations

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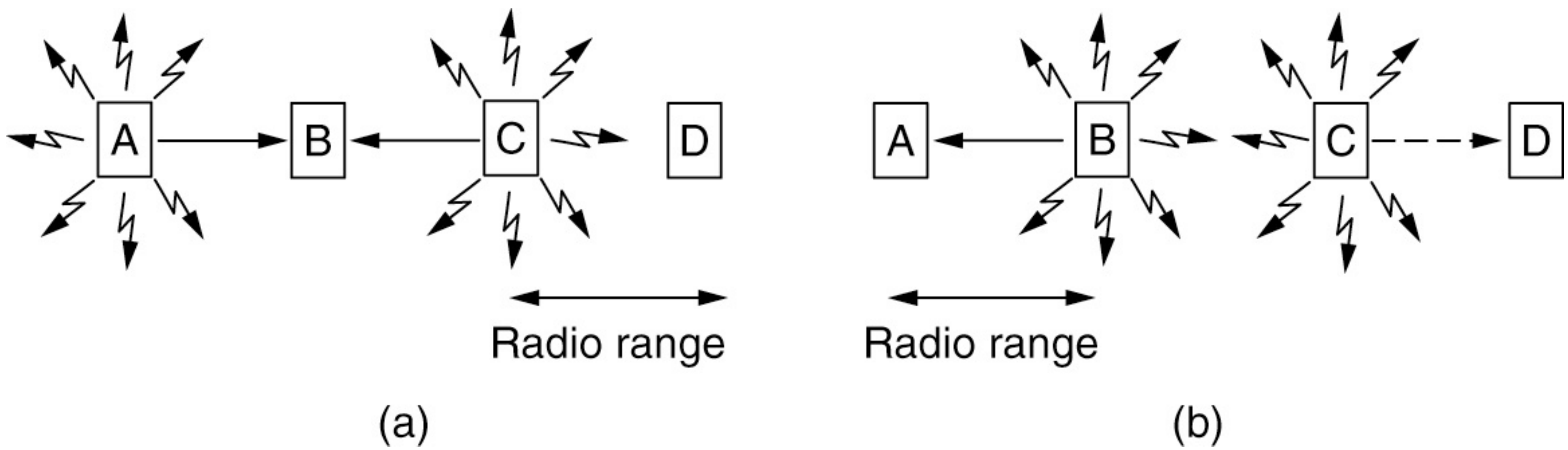
Wireless LAN Protocols (1 of 2)



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

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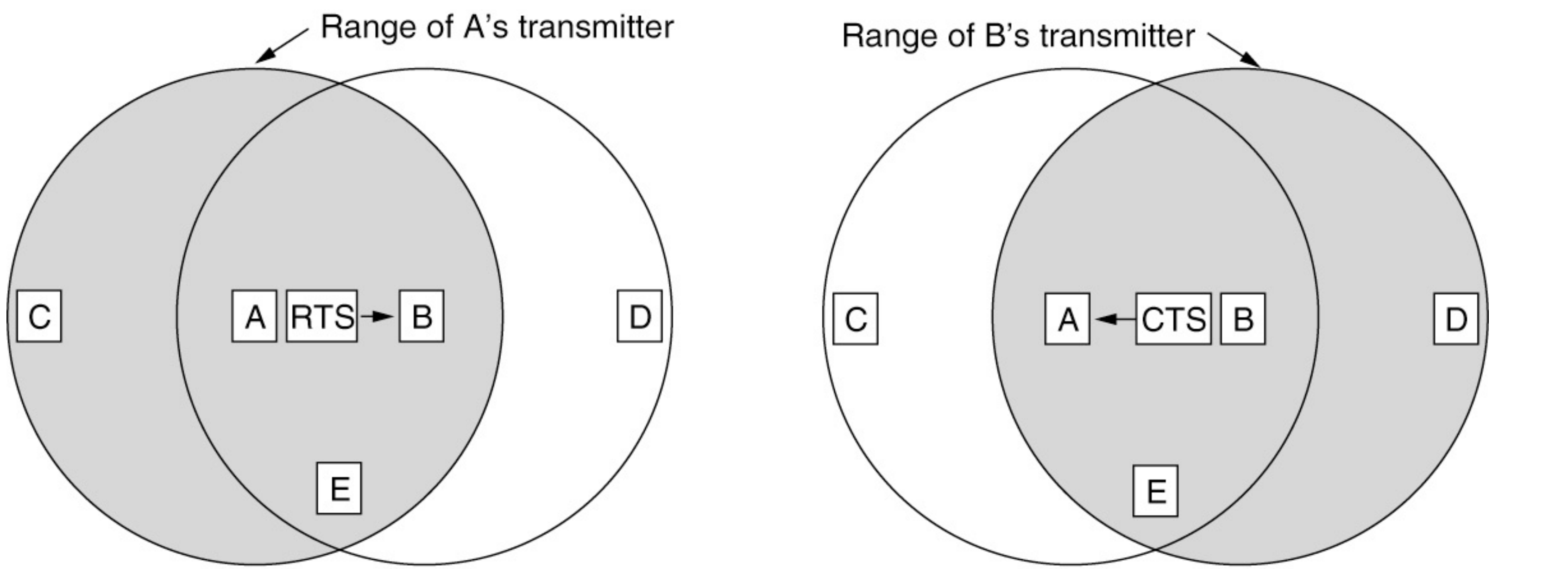
Wireless LAN Protocols (2 of 2)



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

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Ethernet (1 of 2)

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

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Ethernet (2 of 2)

- Gigabit Ethernet
- 10-Gigabit Ethernet
- 40- and 100-Gigabit Ethernet
- Retrospective on Ethernet

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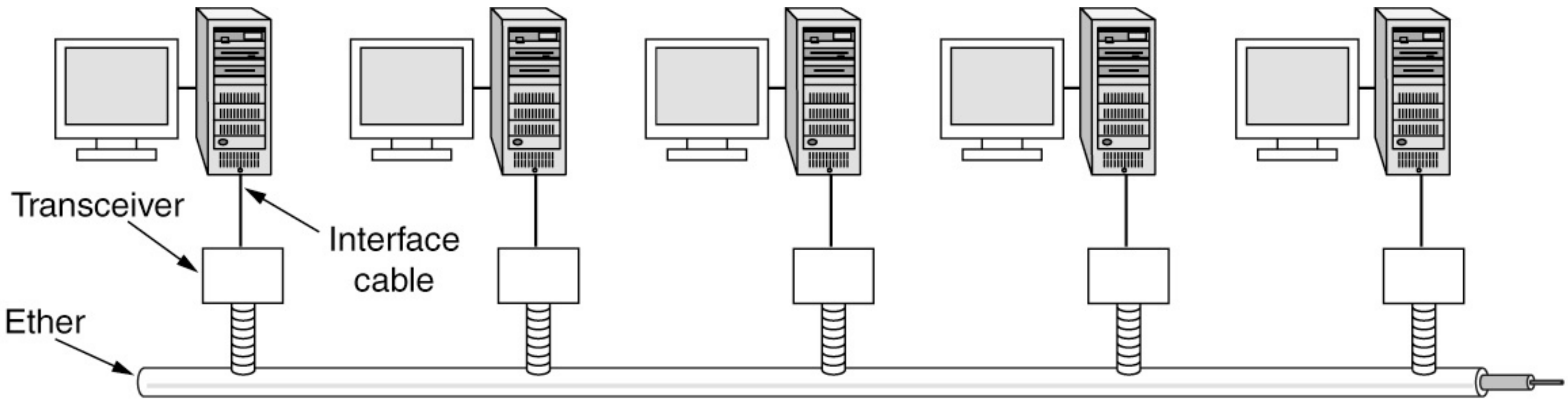
Classic Ethernet Physical Layer



Architecture of classic Ethernet

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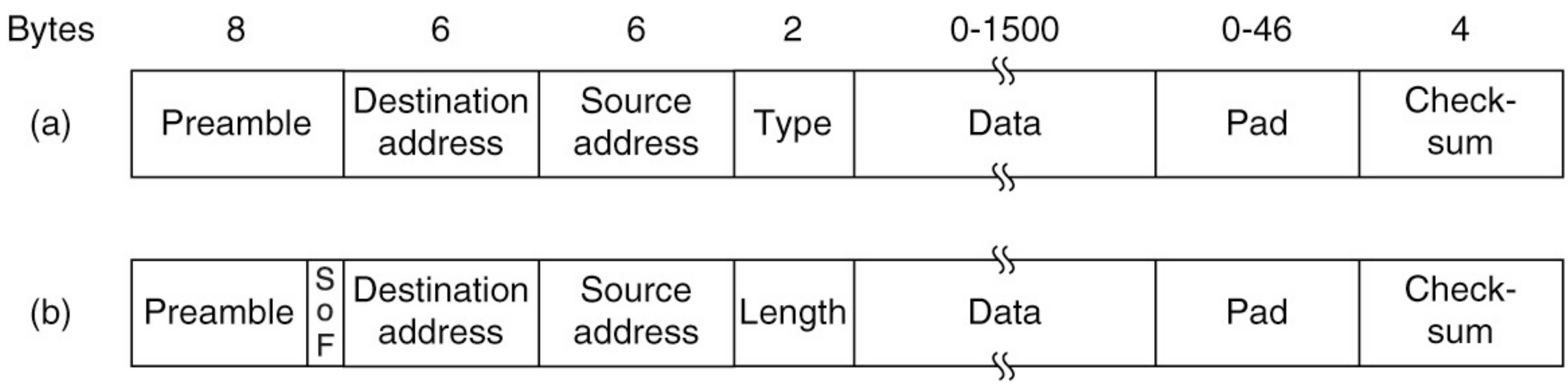
Classic Ethernet MAC Sublayer Protocol (1 of 2)



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

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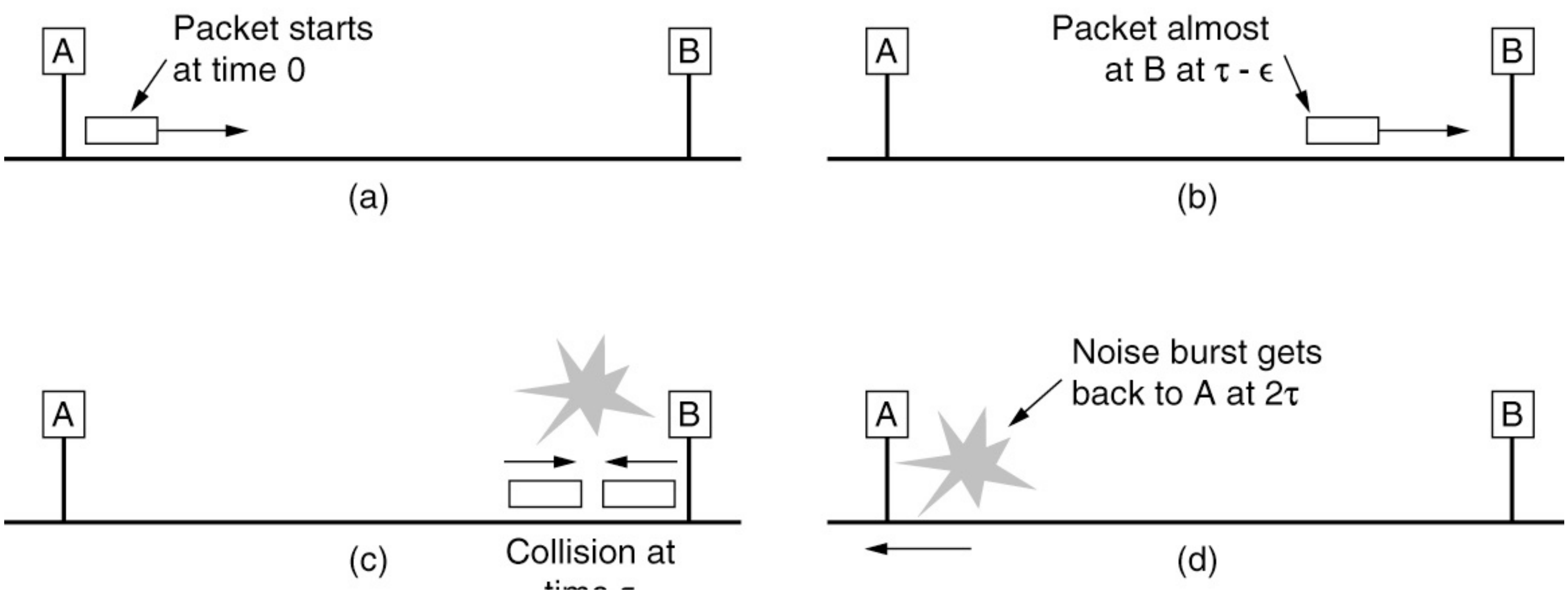
Classic Ethernet MAC Sublayer Protocol (2 of 2)



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

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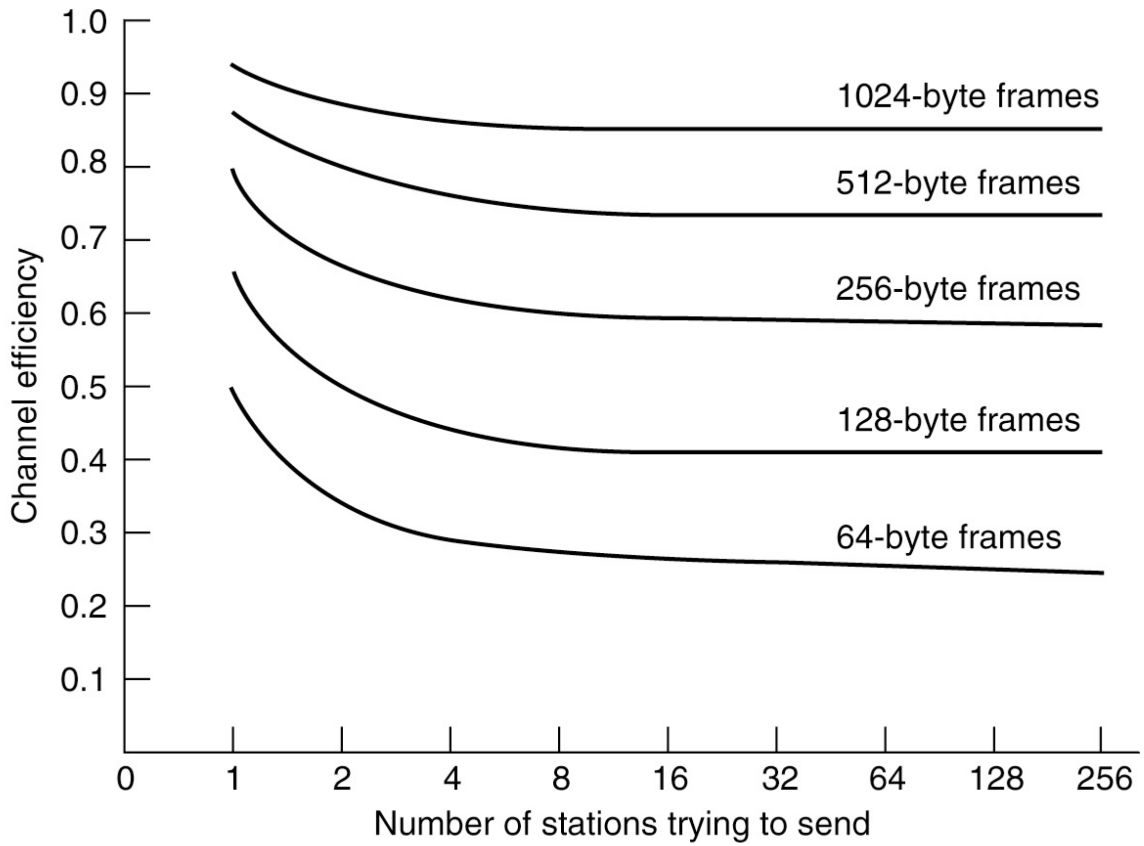
Ethernet Performance



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

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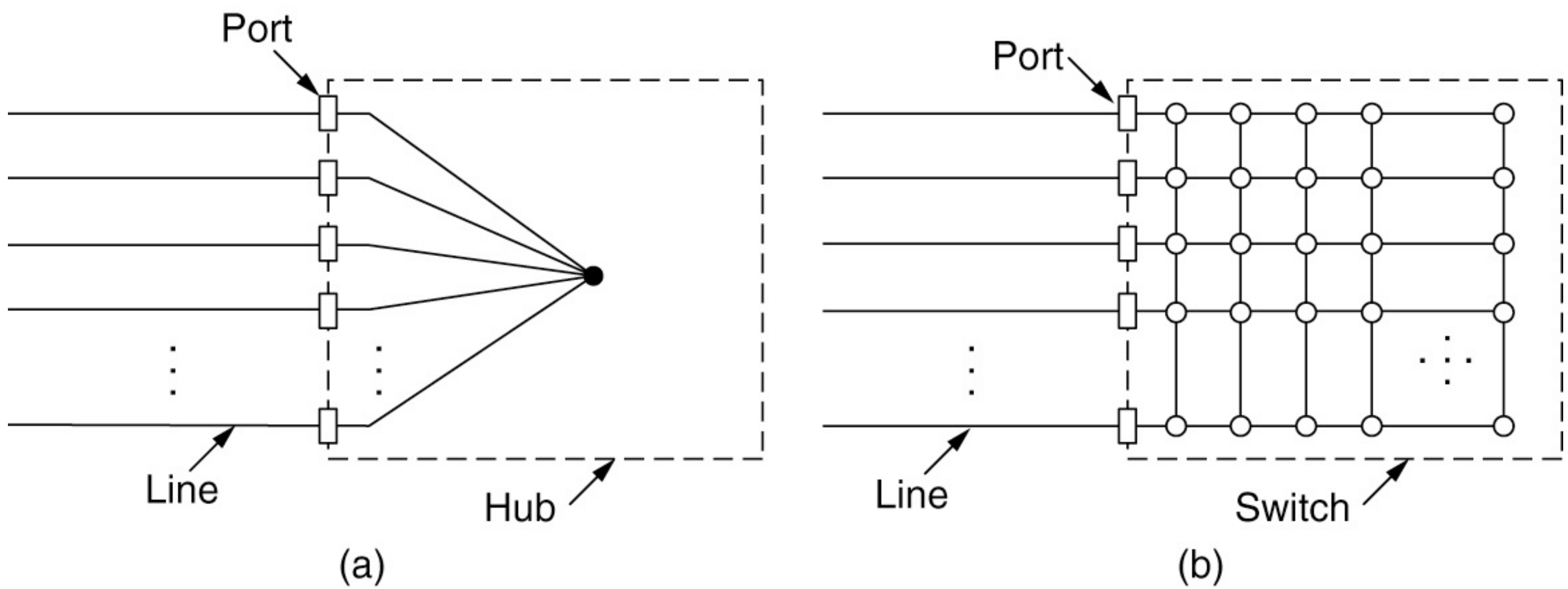
Switched Ethernet (1 of 2)



(a) Hub. (b) Switch.

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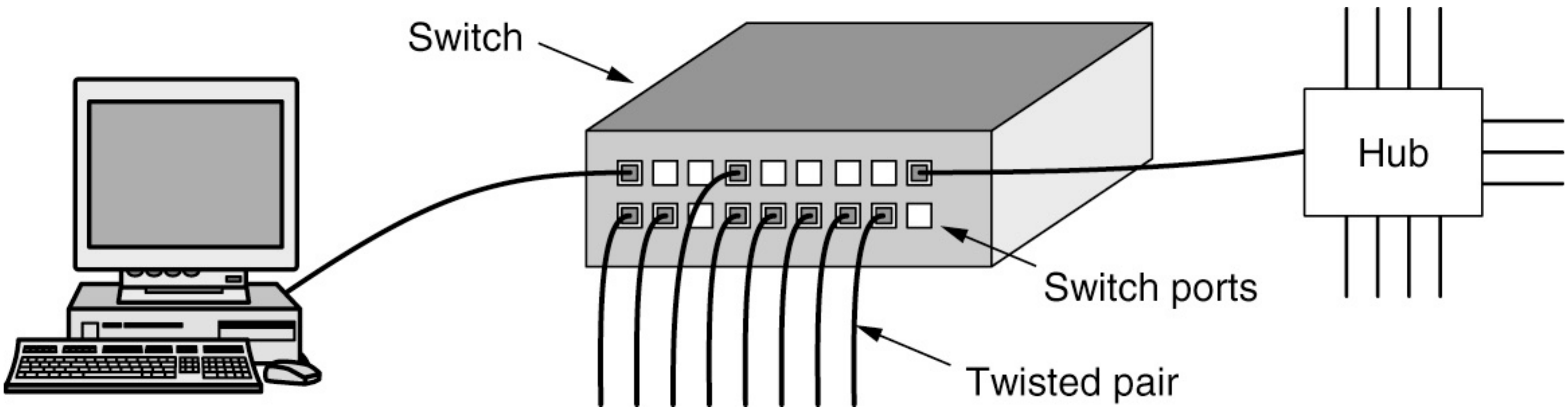
Switched Ethernet (2 of 2)



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

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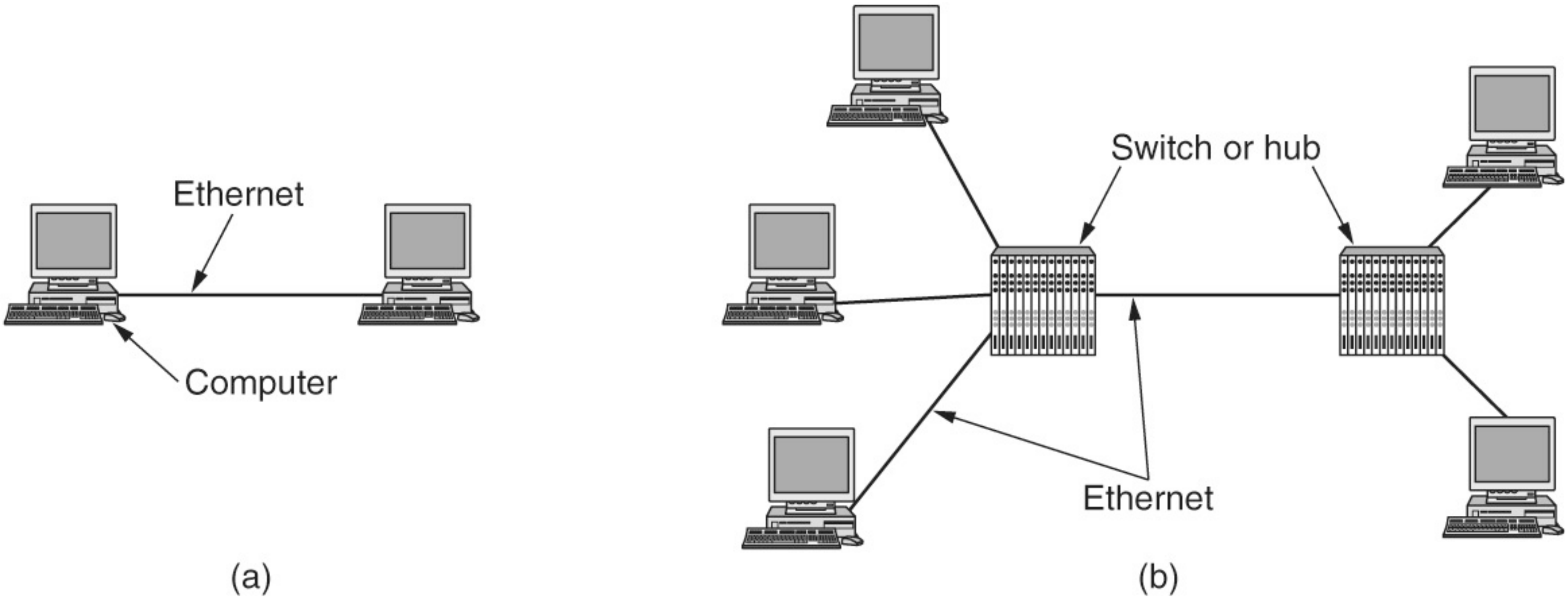
Gigabit Ethernet (1 of 2)



(a) A two-station Ethernet. (b) A multistation Ethernet.

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Gigabit Ethernet (2 of 2)

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

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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

10-Gigabit Ethernet cabling

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Wireless LANs

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

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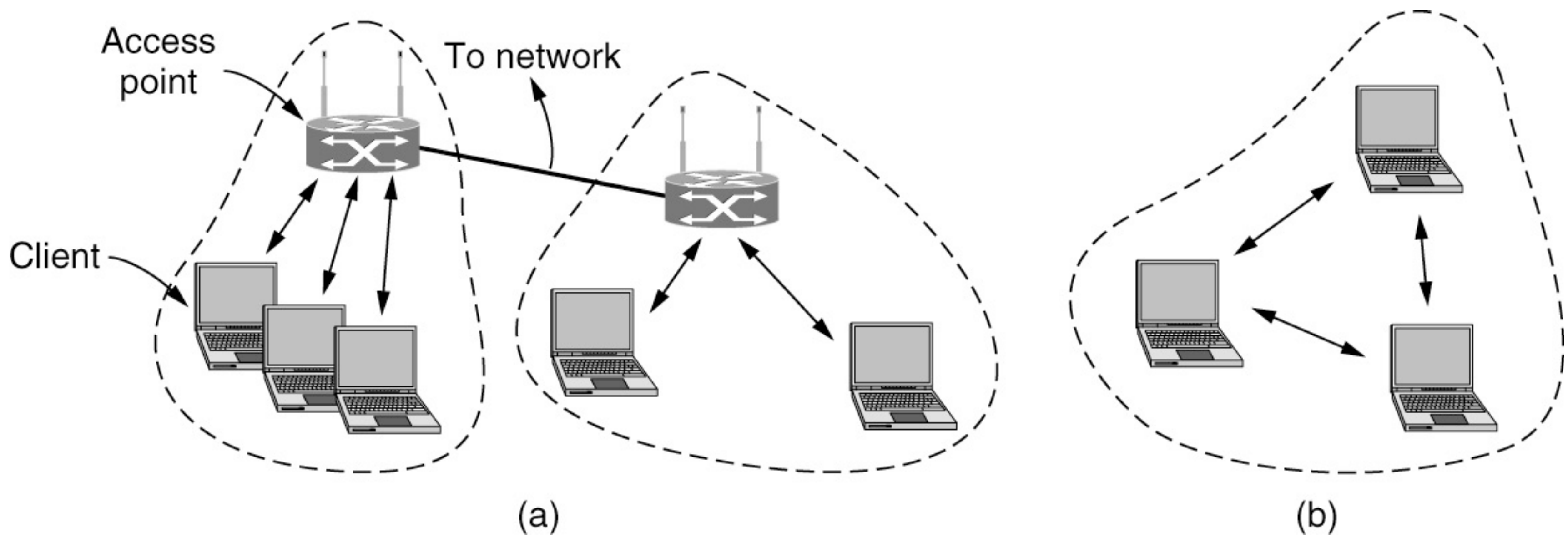
The 802.11 Architecture and Protocol Stack (1 of 2)



802.11 architecture. (a) Infrastructure mode. (b) Ad-hoc mode.

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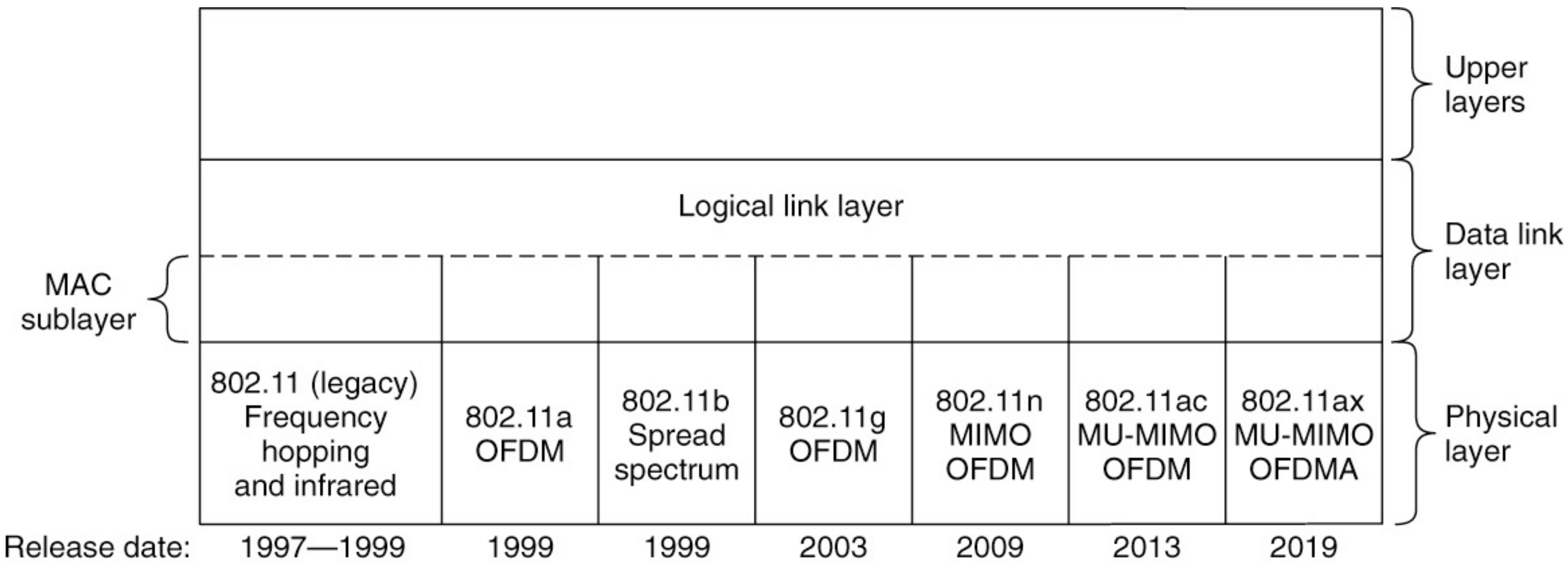
The 802.11 Architecture and Protocol Stack (2 of 2)



Part of the 802.11 protocol stack

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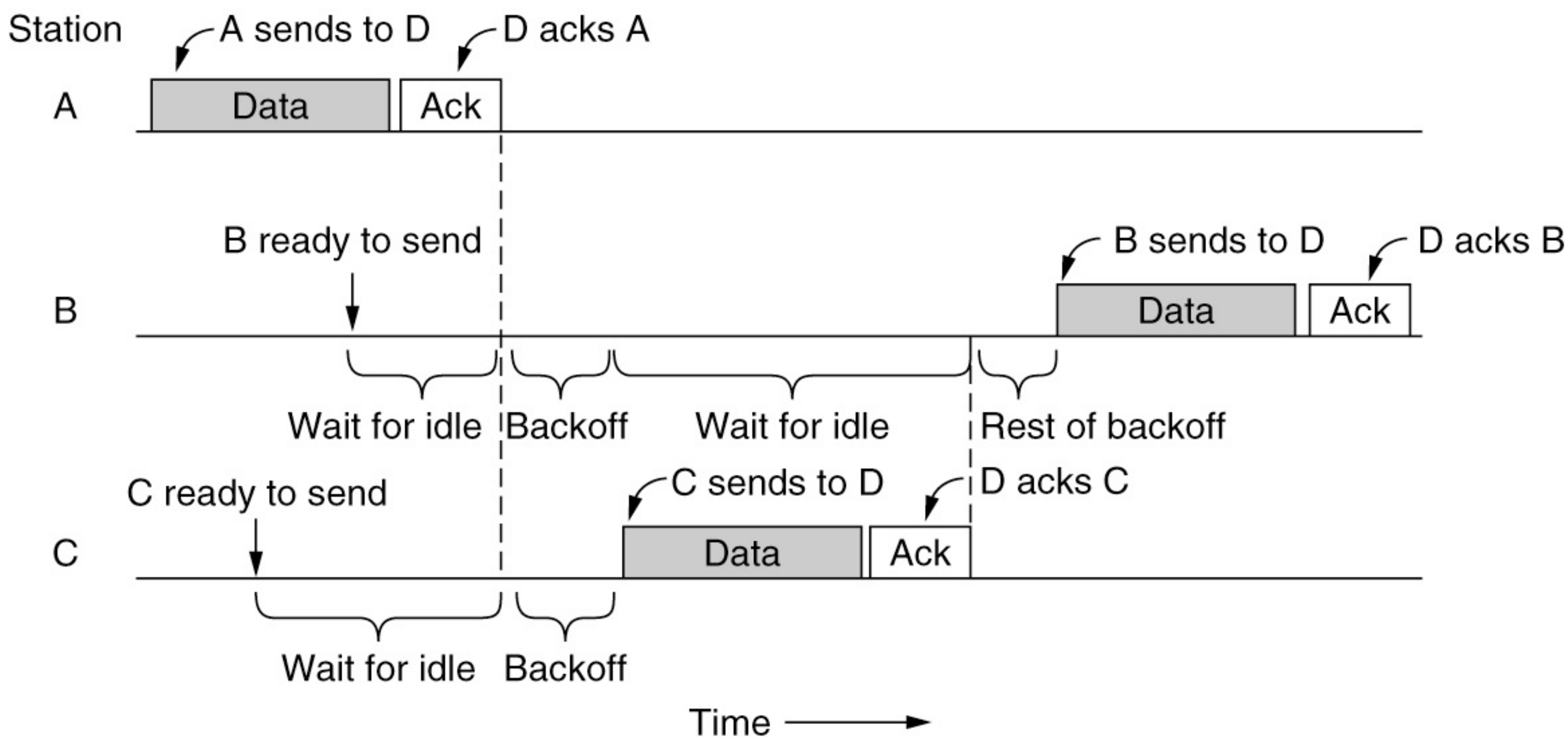
The 802.11 MAC Sublayer Protocol (1 of 4)



Sending a frame with CSMA/CA

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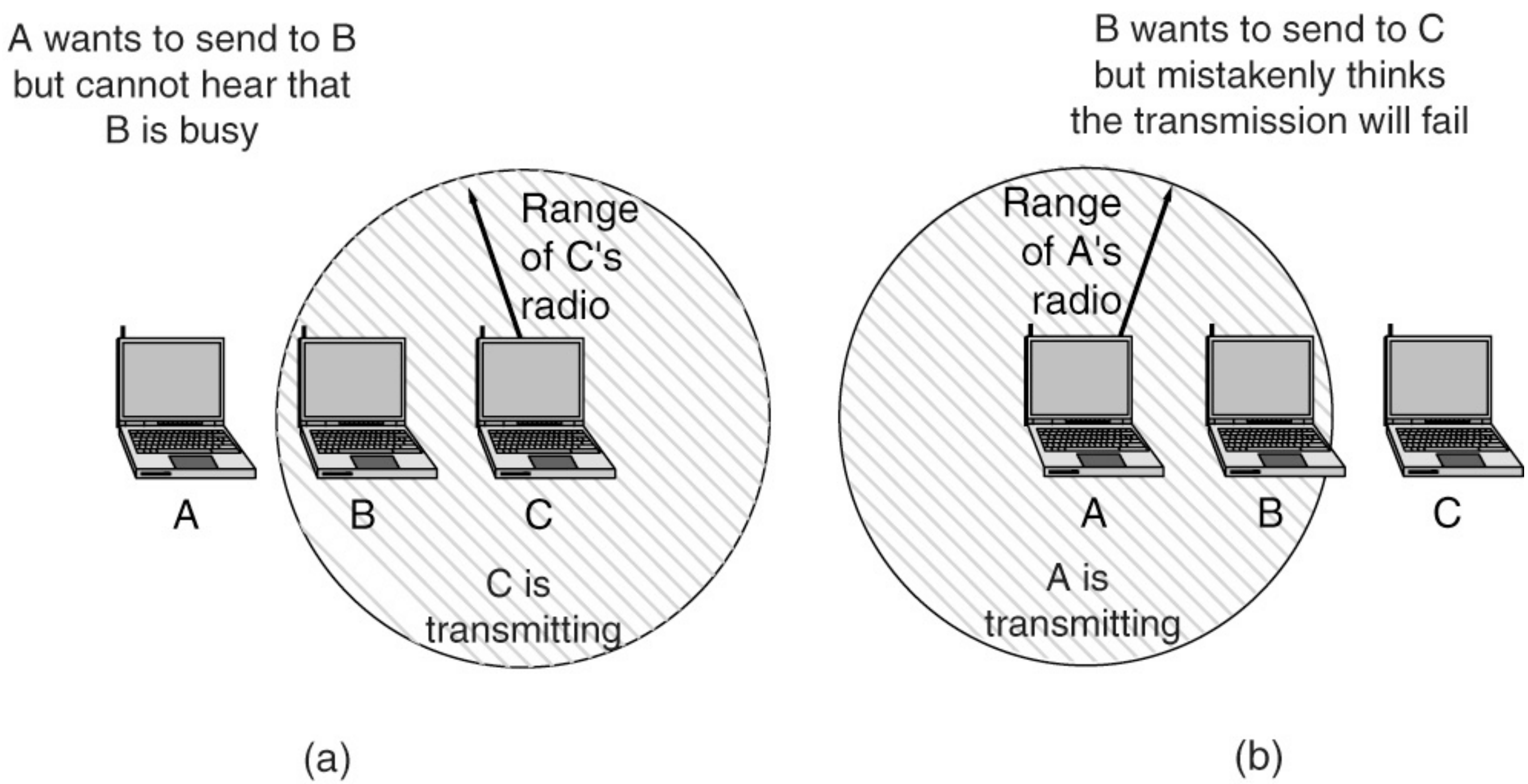
The 802.11 MAC Sublayer Protocol (2 of 4)



(a) The hidden terminal problem. (b) The exposed terminal problem.

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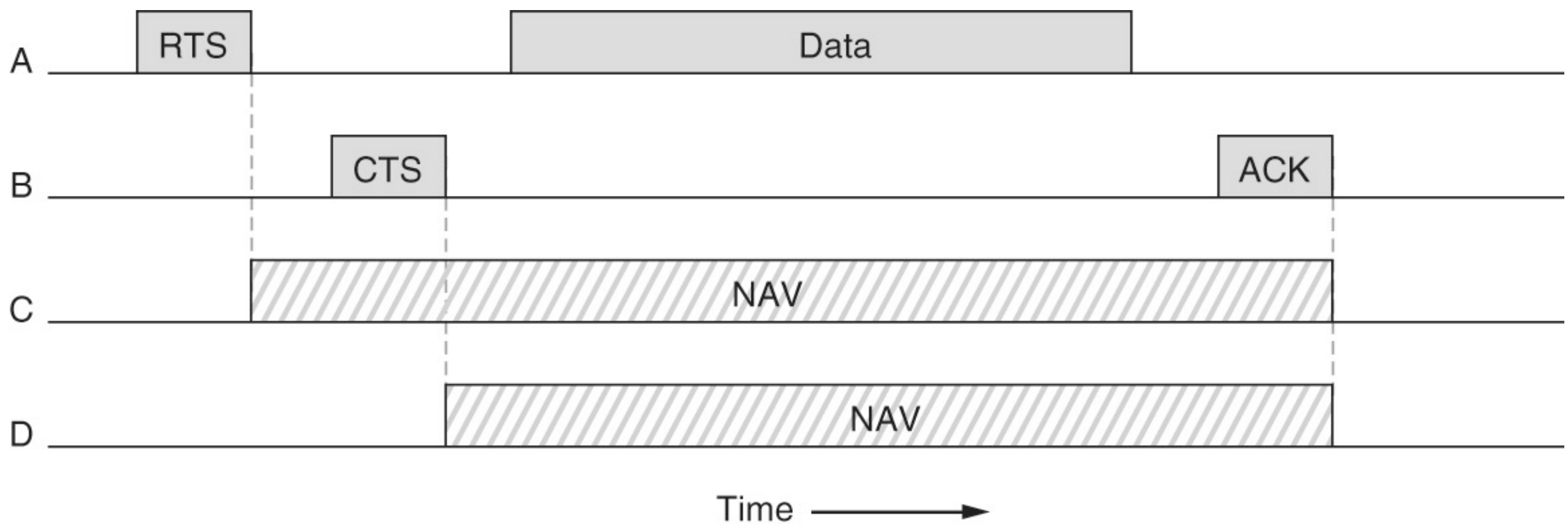
The 802.11 MAC Sublayer Protocol (3 of 4)



Virtual channel sensing using CSMA/CA

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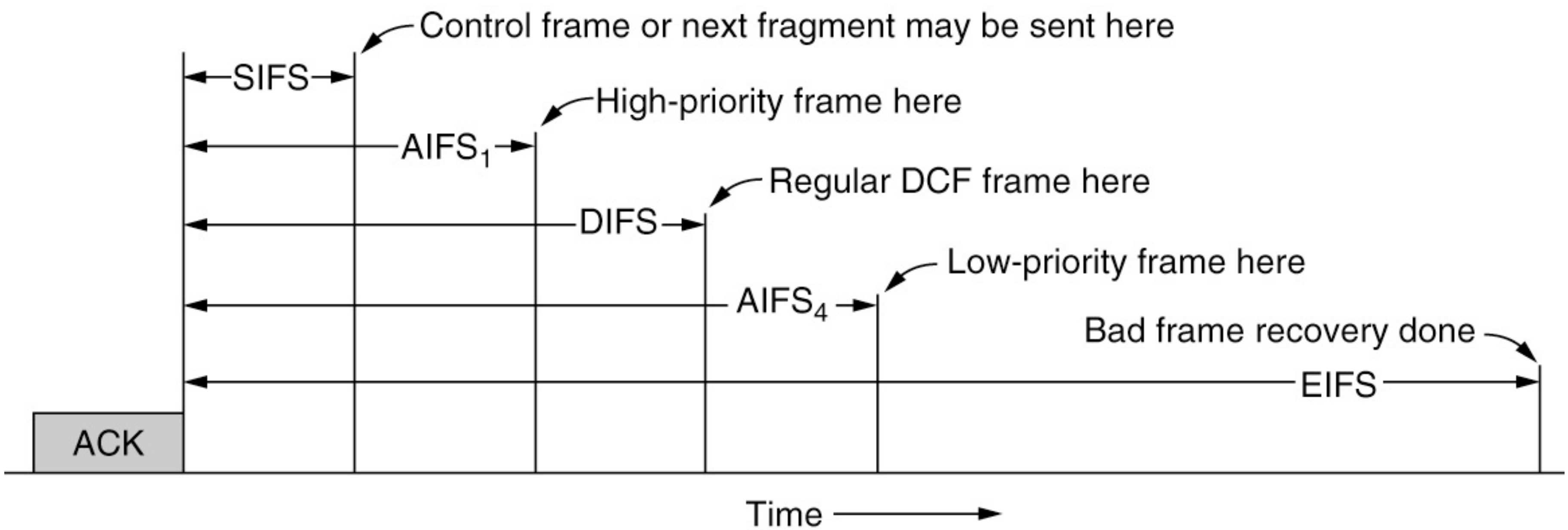
The 802.11 MAC Sublayer Protocol (4 of 4)



Interframe spacing in 802.11

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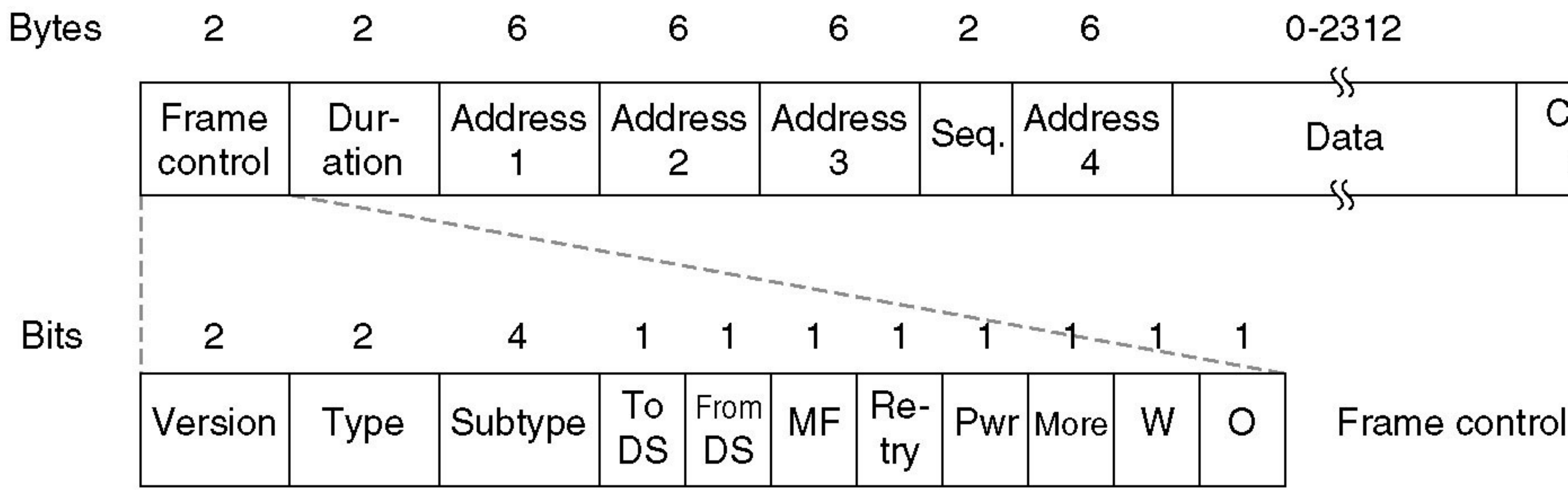
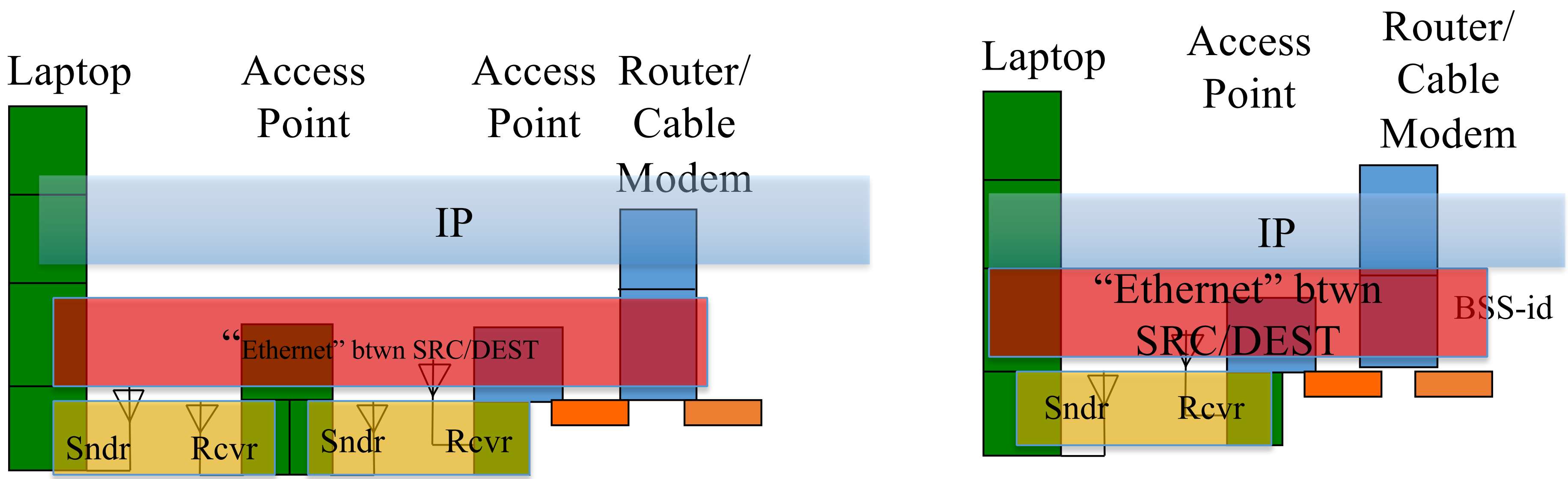
The 802.11 Frame Structure



The 802.11 data frame.

Why So Many Addresses?



- In the general case, there may be forwarding across access points. So the first two addresses would be SNDR/RCVR
- and would change at every hop.
- Over the top is a logical Ethernet that is continuous with the Wired Ethernet connecting the last Access Point to the Router.
- So it has SRC (laptop) and DEST (the next hop, the Router). Hence 4 addresses are necessary in general.
- However, the most common configuration is a Laptop wirelessly associated with an Access Point connected to a Router/Cable Modem. In this case, the SRC and SNDR addresses are the same, so only 3 addresses are necessary.
- (Note that in the general case, on the first hop Src and Sndr are the same; and on the last hop Rcvr and Dest are the same. So the 3-address form could be used. In between all of the addresses are all different, so 4 are necessary.)

Services

- Association and data delivery
- Security and privacy
- Prioritization and power control

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Bluetooth

- Bluetooth architecture
- Bluetooth applications
- Bluetooth protocol stack
- Bluetooth radio layer
- Bluetooth link layers
- Bluetooth frame structure
- Bluetooth 5

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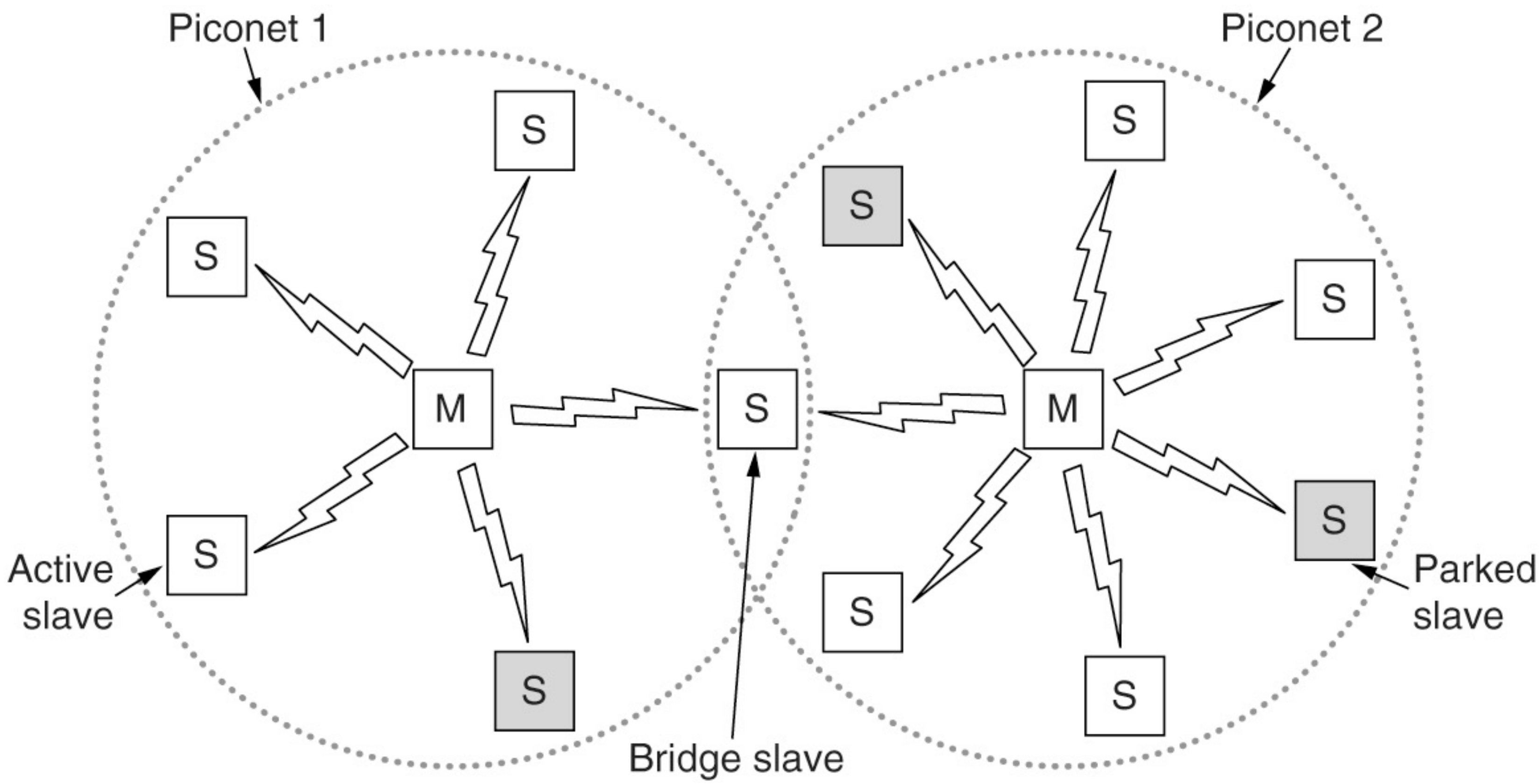
Bluetooth Architecture



Two piconets can be connected to form a scatternet

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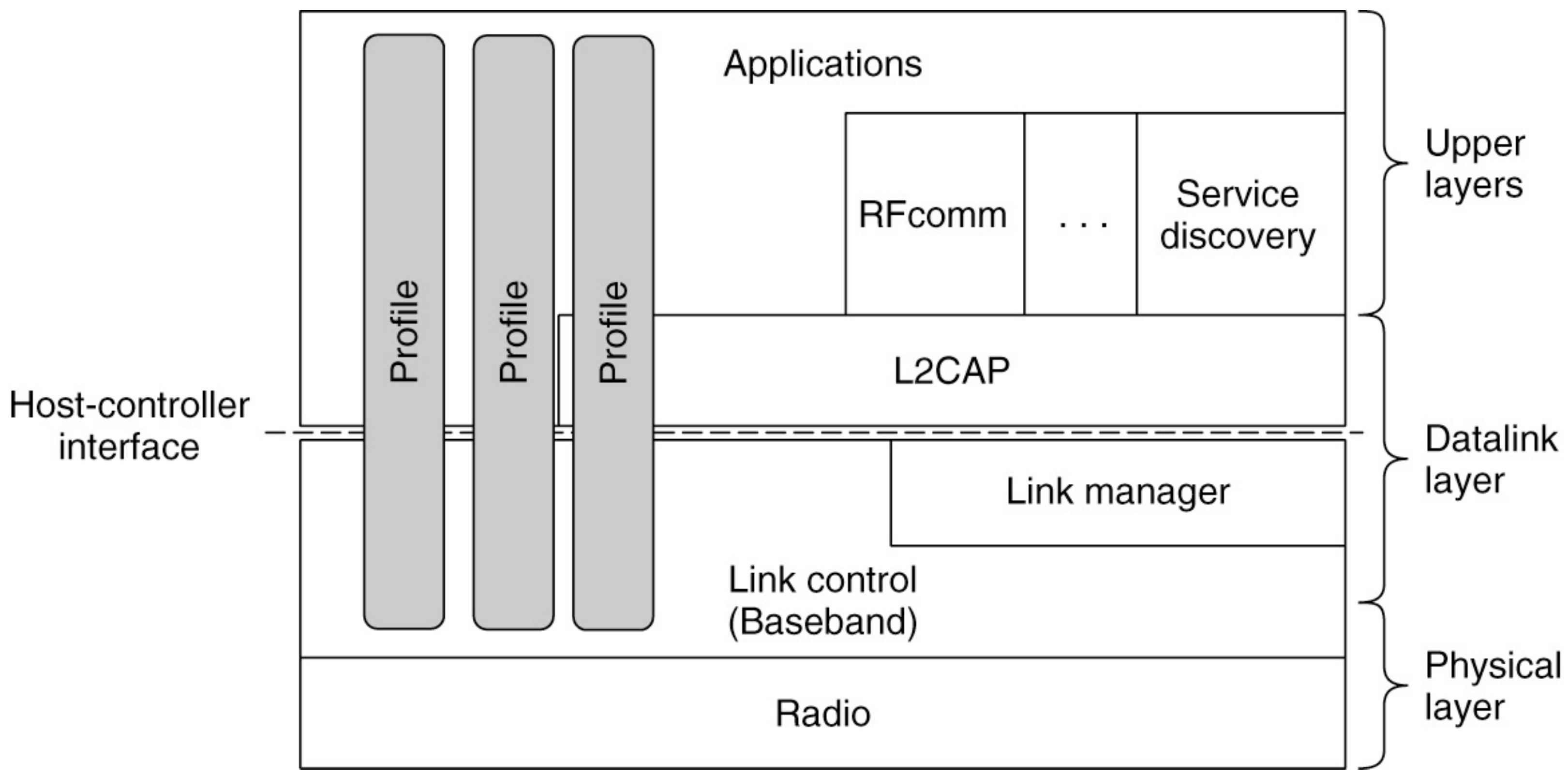
The Bluetooth Protocol Stack



The Bluetooth protocol architecture

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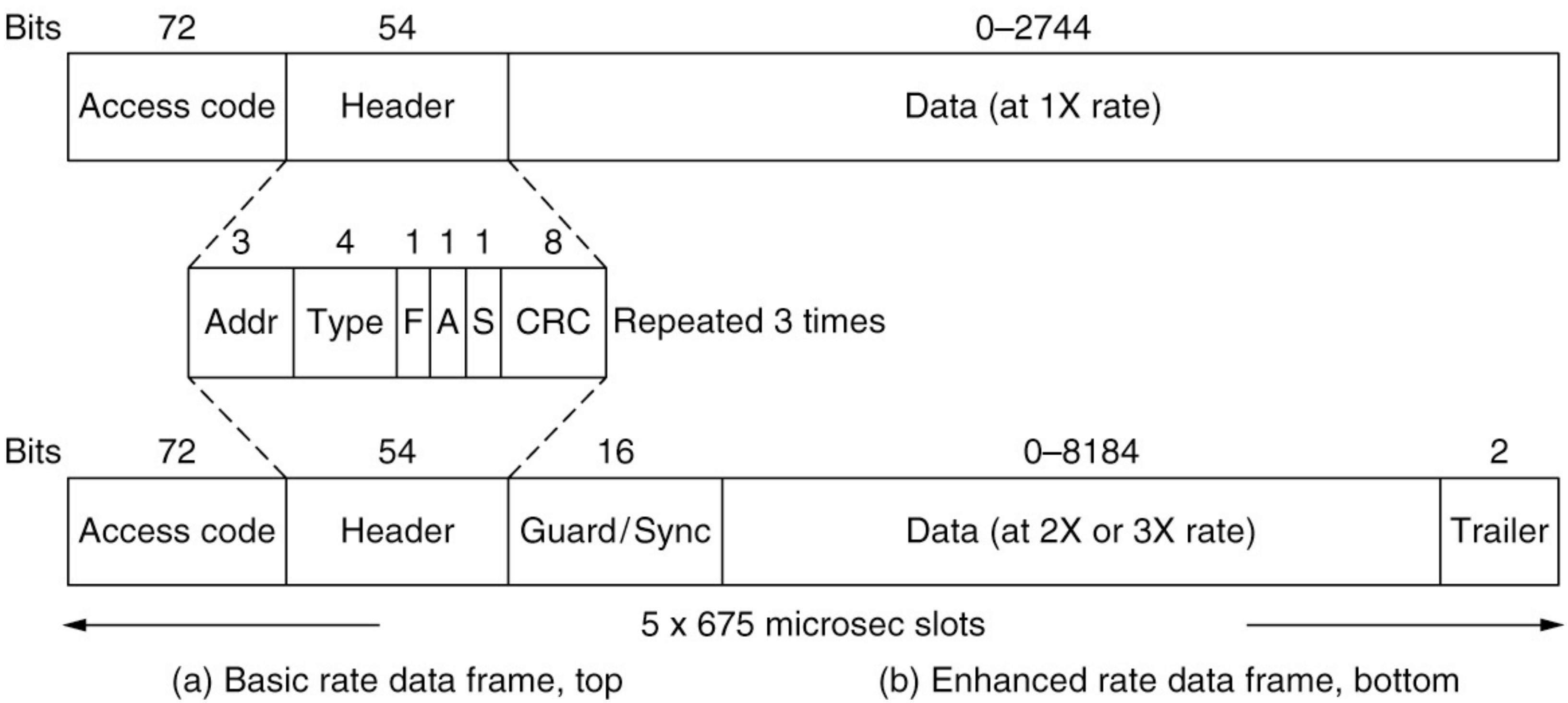
The Bluetooth Frame Structure



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

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Bluetooth 5

- Support for Internet of Things devices
- Speed increased from 1 Mbps to 2 Mbps
- Message size has gone up from 31 bytes to 255 bytes
- Range indoors has gone up from 10 m to 40 m
- Power requirements have been reduced slightly
- Range of the beacons has gone up slightly
- Slightly better security

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DOCSIS

- Overview
  - MAC sublayer performs channel allocation, configuration of quality of service, unique forwarding model
  - Uses a standard MAC frame format
- Ranging
  - Cable modem transmits a ranging request
  - CMTS (headend) determines the network delay to the cable modem and performs necessary power adjustment
- Channel bandwidth allocation
  - Service flows
  - Request-grant process and low-latency DOCSIS

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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
  - The IEEE 802.1Q standard

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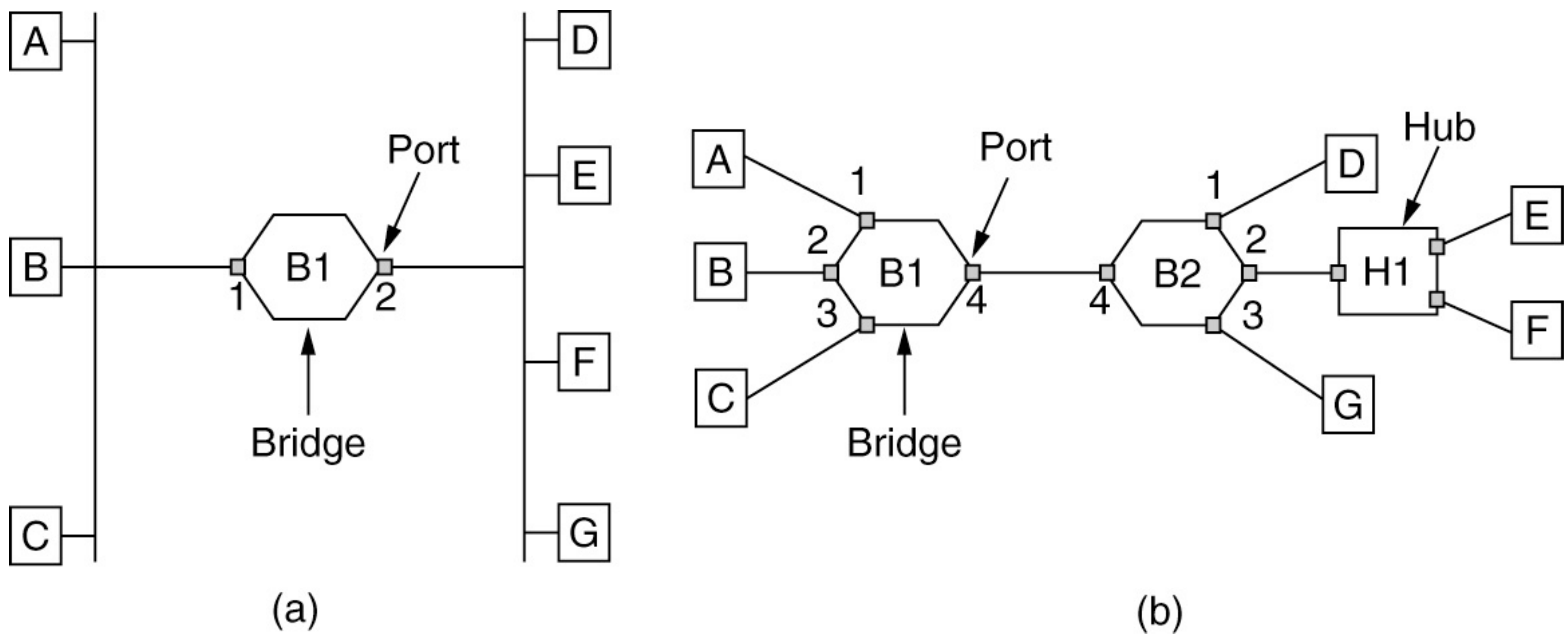
Learning Bridges (1 of 2)



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

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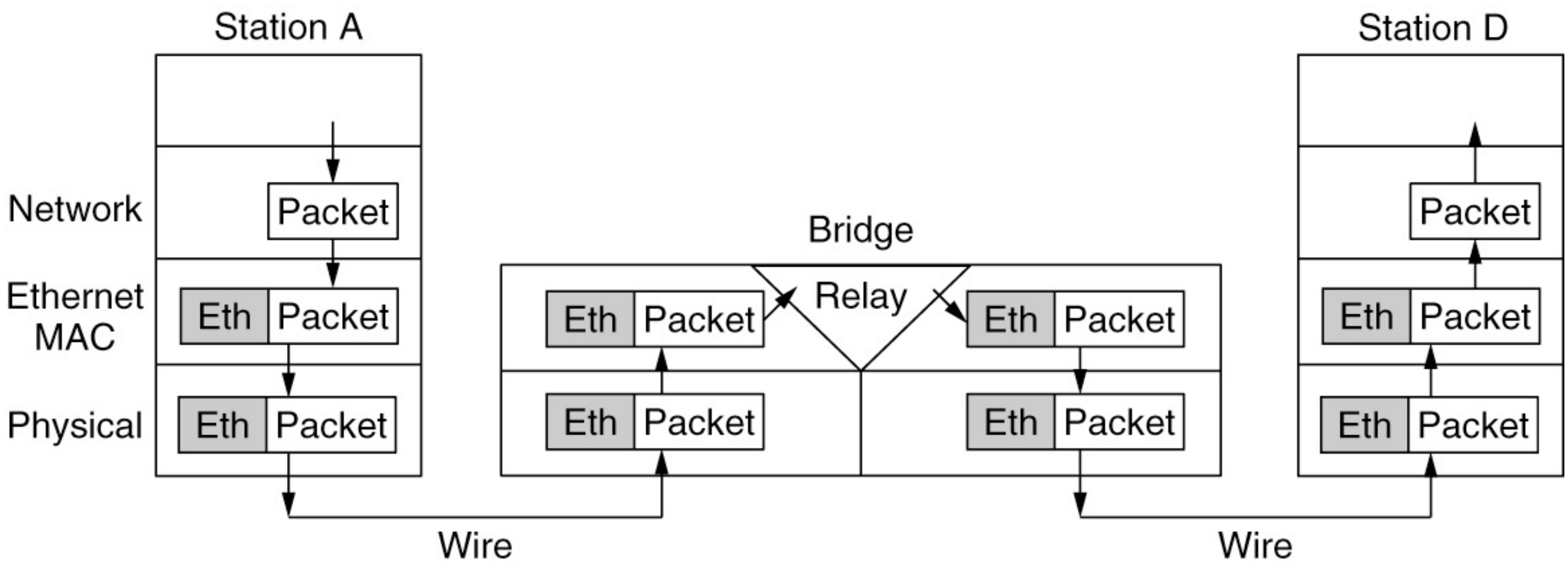
Learning Bridges (2 of 2)



Protocol processing at a bridge

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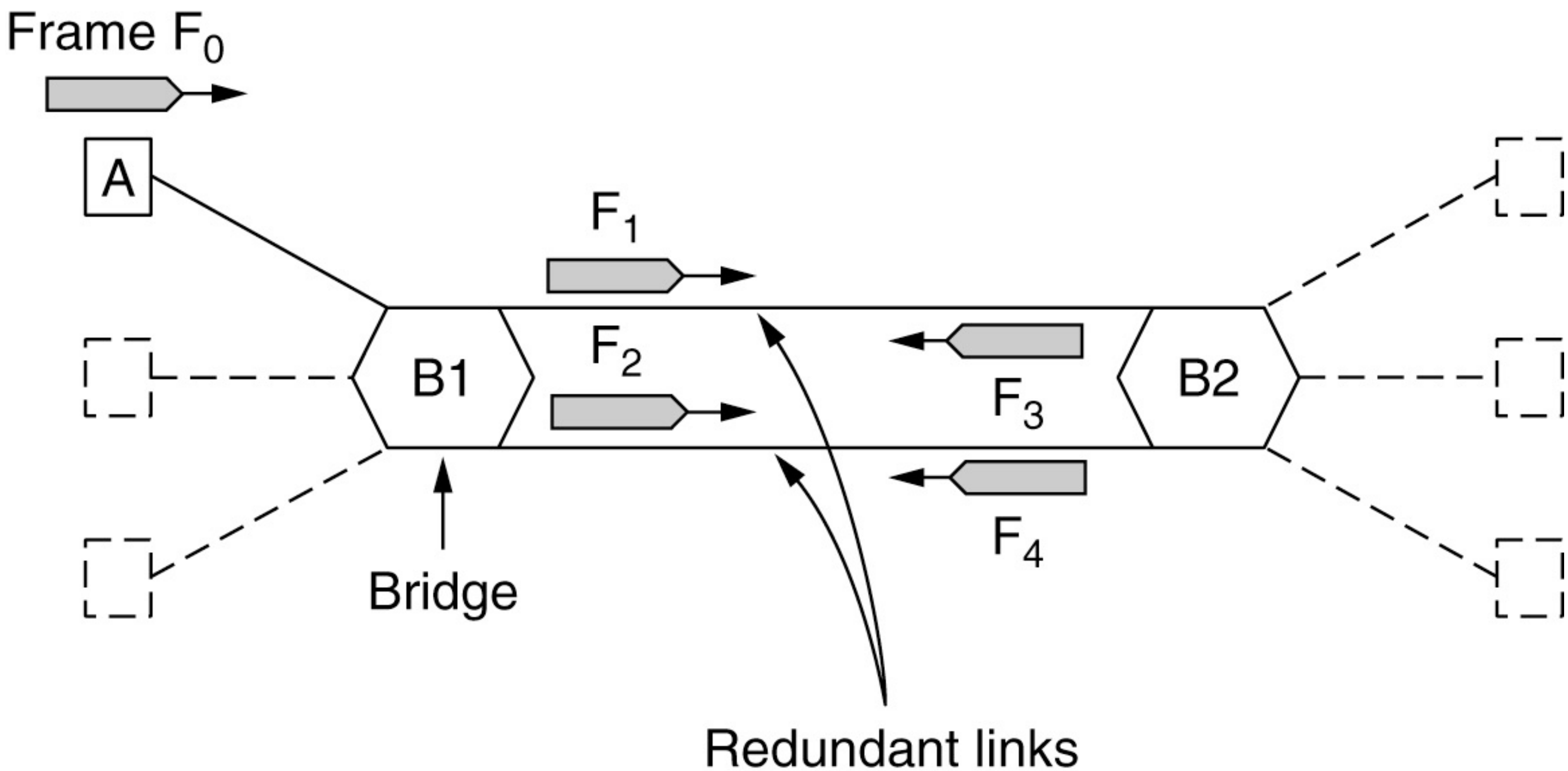
Spanning-Tree Bridges (1 of 2)



Bridges with two parallel links

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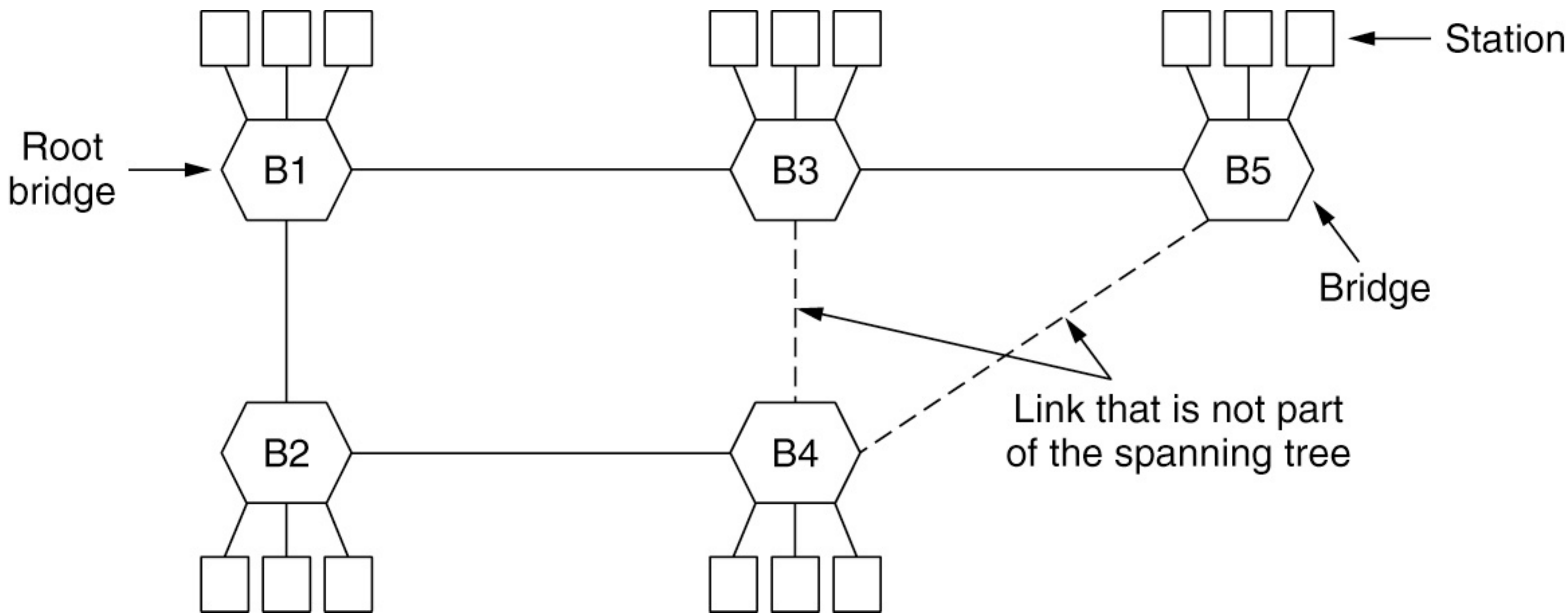
Spanning-Tree Bridges (2 of 2)



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

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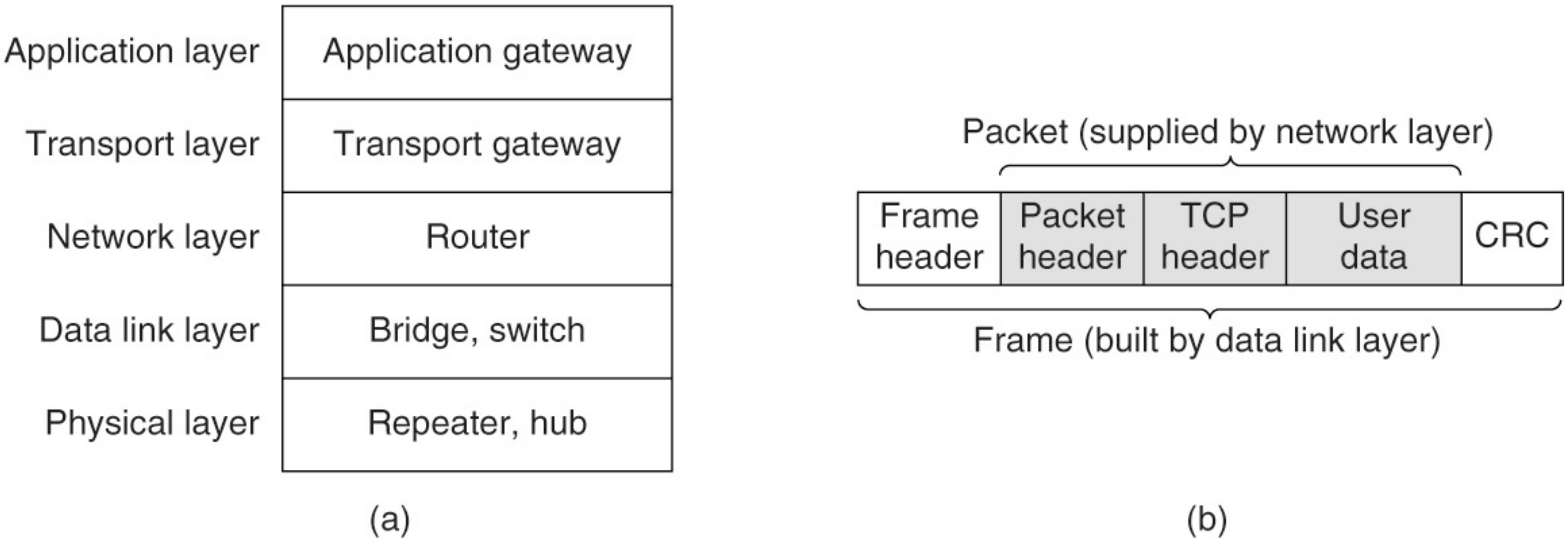
Repeaters, Hubs, Bridges, Switches, Routers, and Gateways



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

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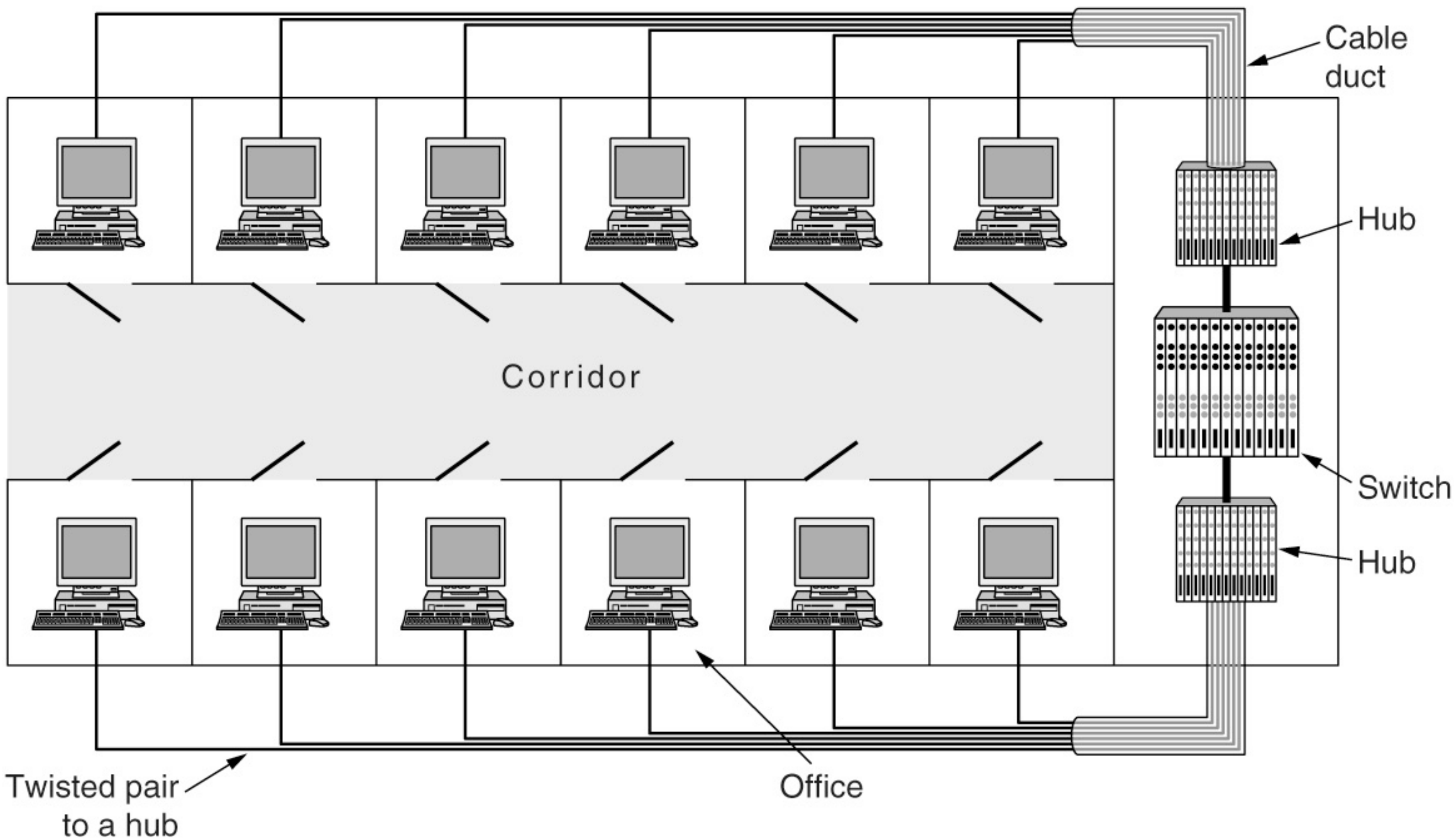
Virtual LANs (1 of 2)



A building with centralized wiring using hubs and a switch

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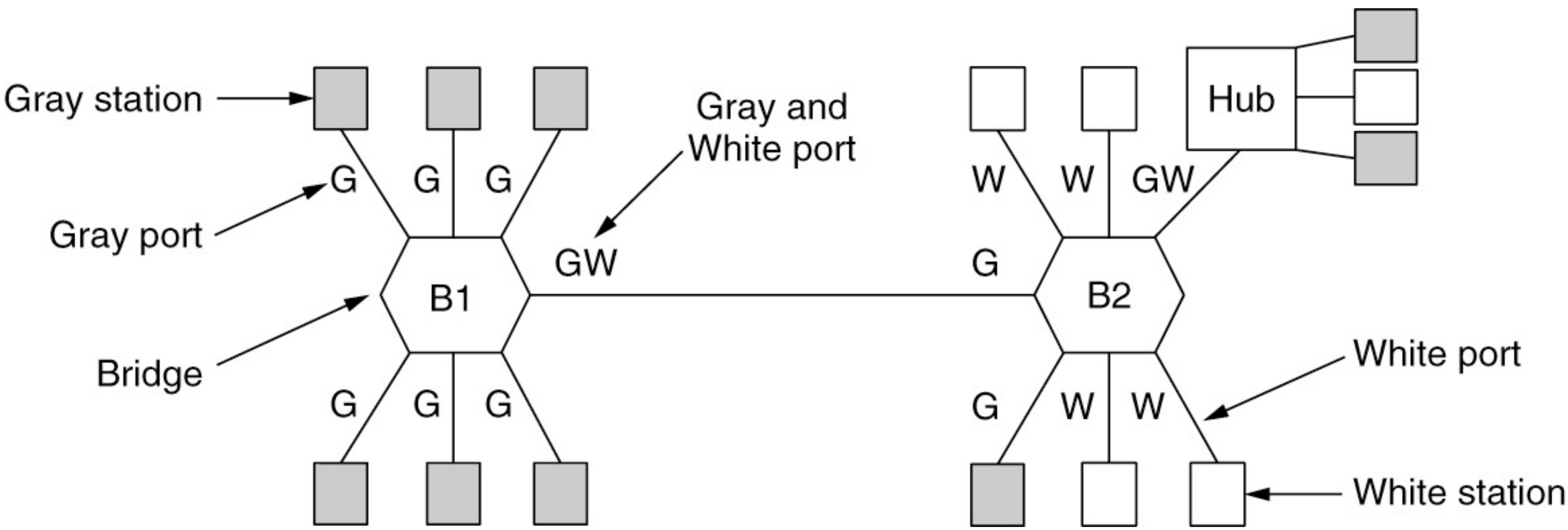
Virtual LANs (2 of 2)



Two VLANs, gray and white, on a bridged LAN

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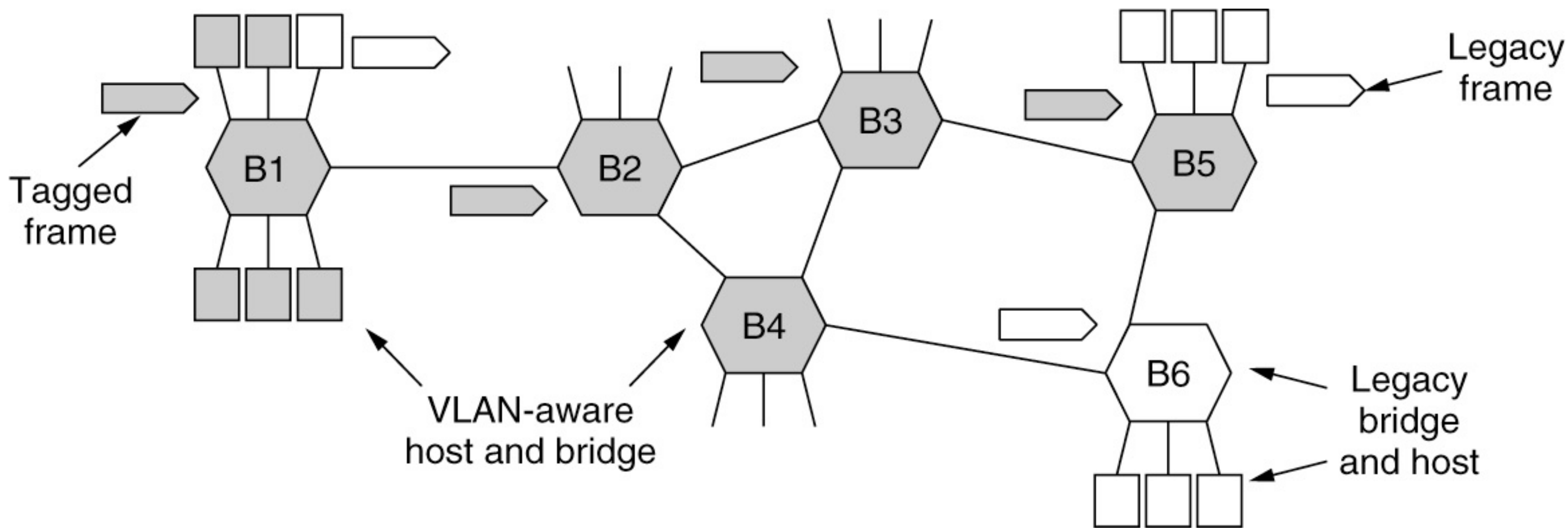
The IEEE 802.1Q Standard (1 of 2)



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

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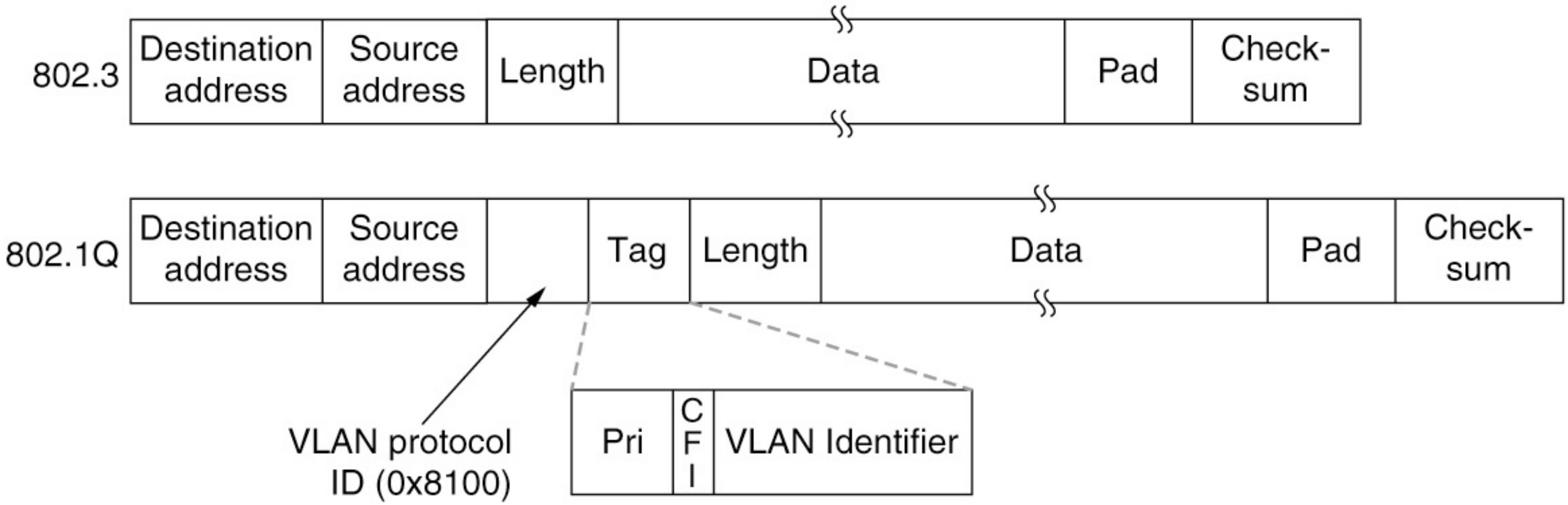
The IEEE 802.1Q Standard (2 of 2)



The 802.3 (legacy) and 802.1Q Ethernet frame formats

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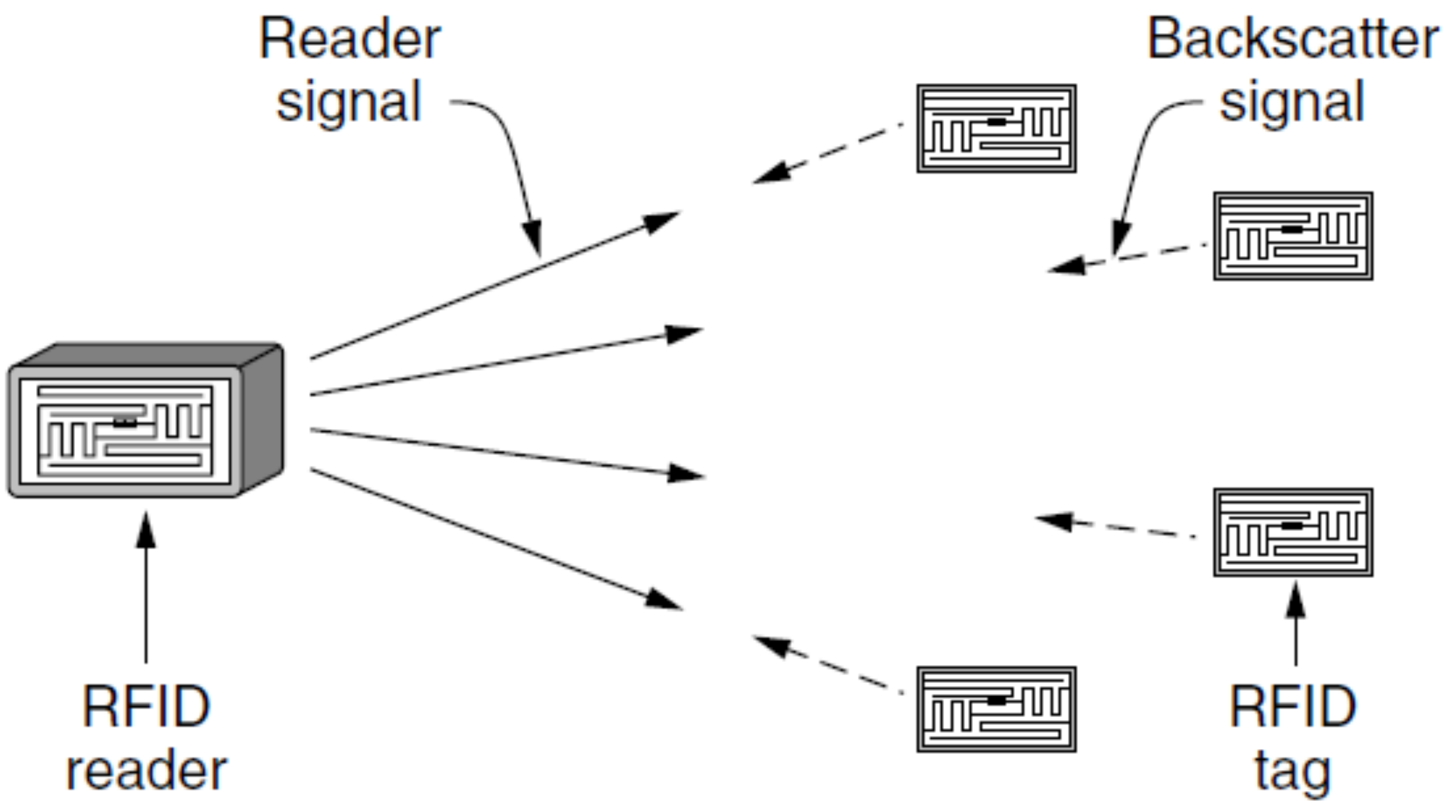
RFID

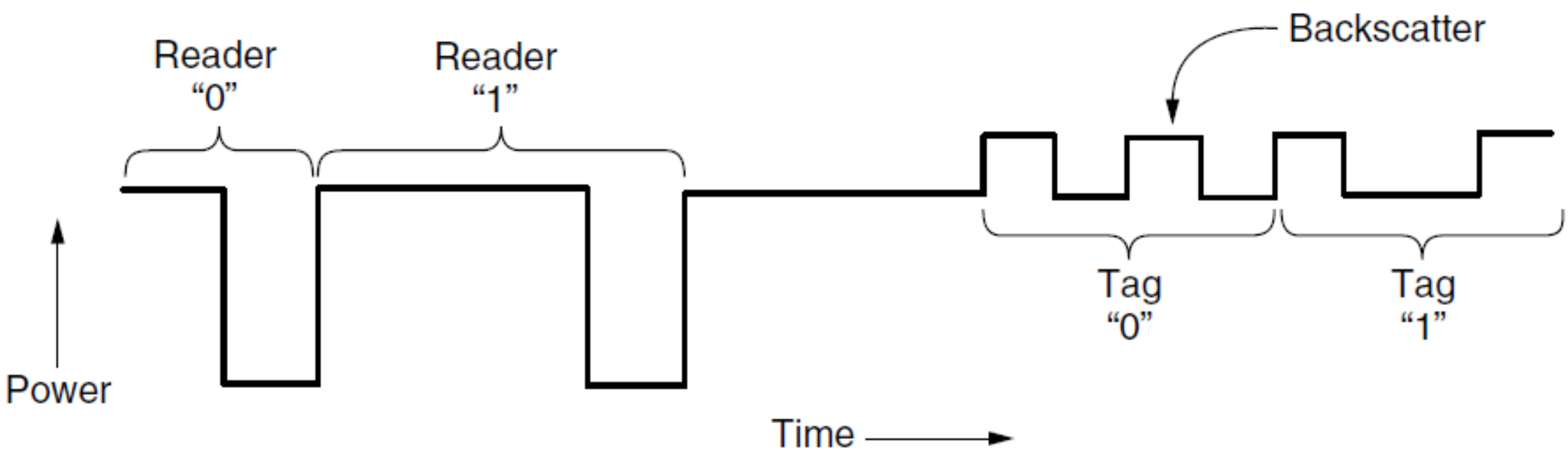
- EPC Gen 2 architecture
- EPC Gen 2 physical layer
- EPC Gen 2 tag identification layer
- Tag identification message formats

EPC Gen 2 Architecture



RFID architecture.

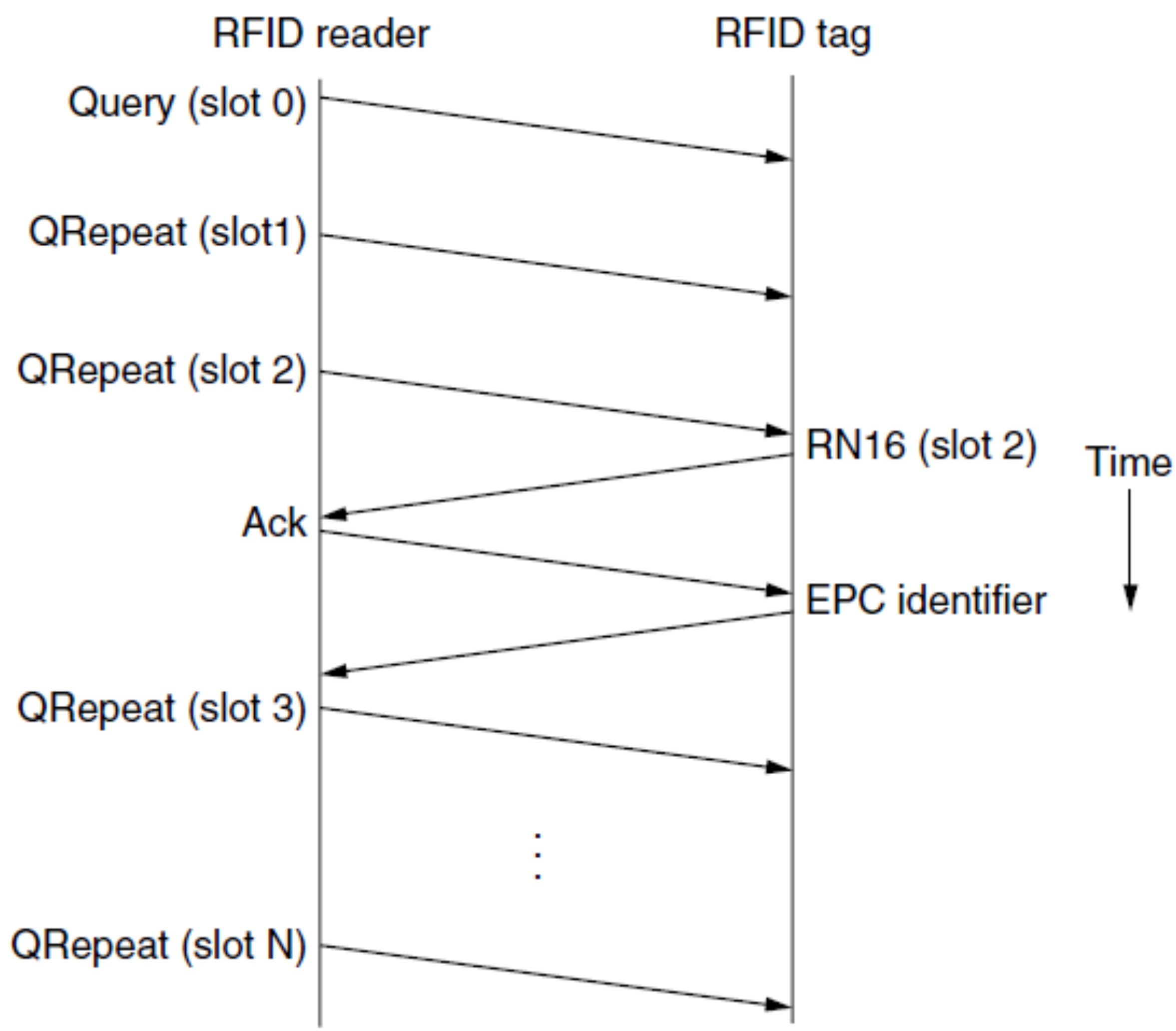
EPC Gen 2 Physical Layer



Reader and tag backscatter signals.

Computer Networks, Fifth Edition by Andrew Tanenbaum and David Wetherall, © Pearson Education-Prentice Hall, 2011

EPC Gen 2 Tag Identification Layer



Example message exchange to identify a tag.

Computer Networks, Fifth Edition by Andrew Tanenbaum and David Wetherall, © Pearson Education-Prentice Hall, 2011

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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