GOVERNMENT ARTS AND SCIENCE COLLEGE

KOMARAPALAYAM-638 183

CLASS : III B.Sc COMPUTER SCIENCE

SEMESTER : V

UNIT : II

SUBJECT NAME : COMPUTER NETWORS

HANDLED BY

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Unit II

The Data Link Layer

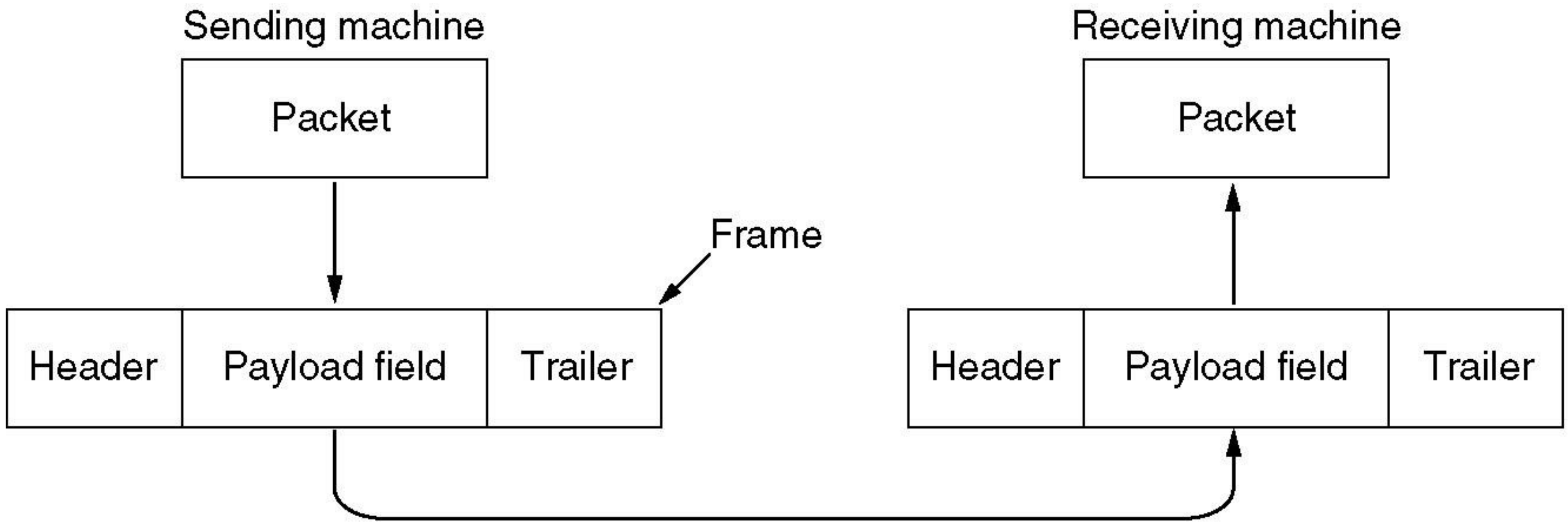
Data Link Layer Design Issues

- Services Provided to the Network Layer
- Framing
- Error Control
- Flow Control

Functions of the Data Link Layer

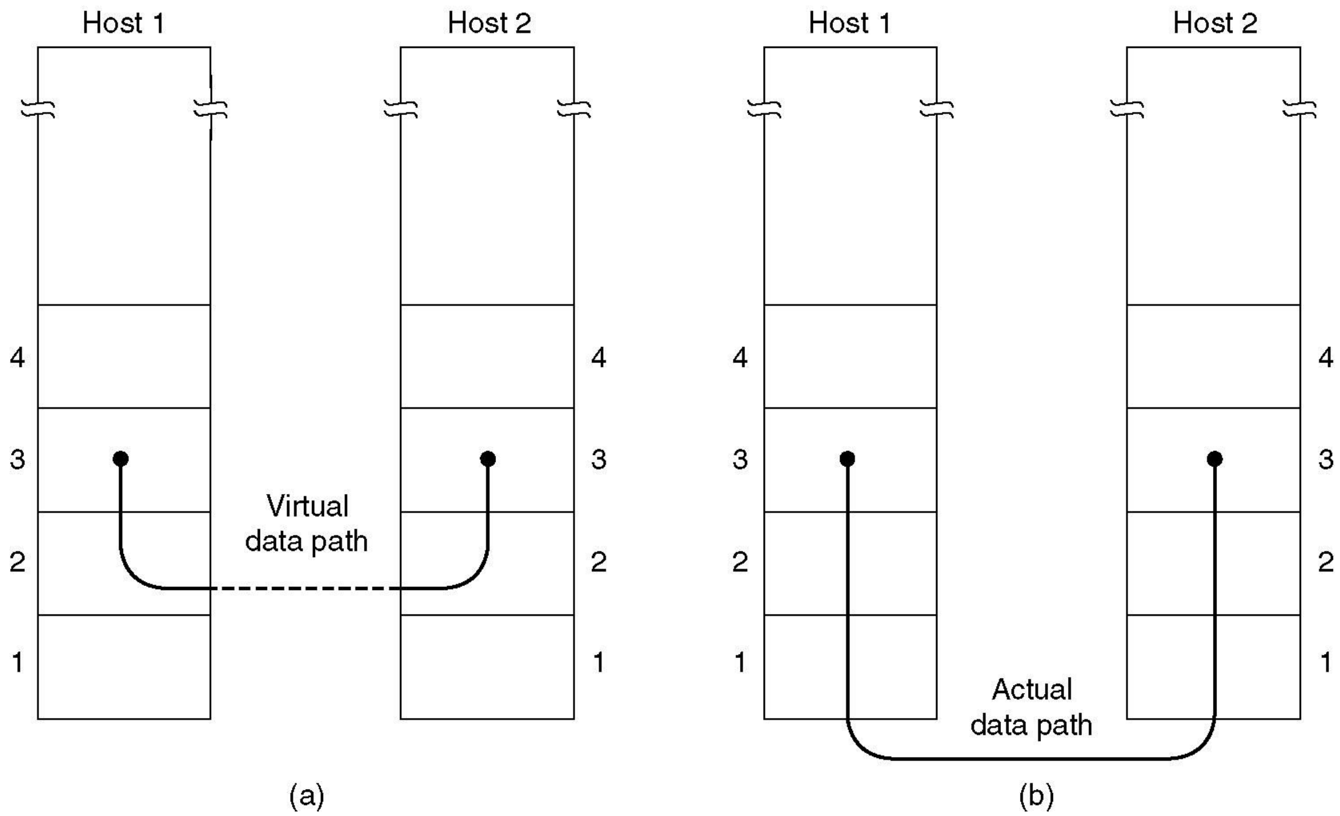
- Provide service interface to the network layer
- Dealing with transmission errors
- Regulating data flow
  - Slow receivers not swamped by fast senders

Functions of the Data Link Layer



Relationship between packets and frames.

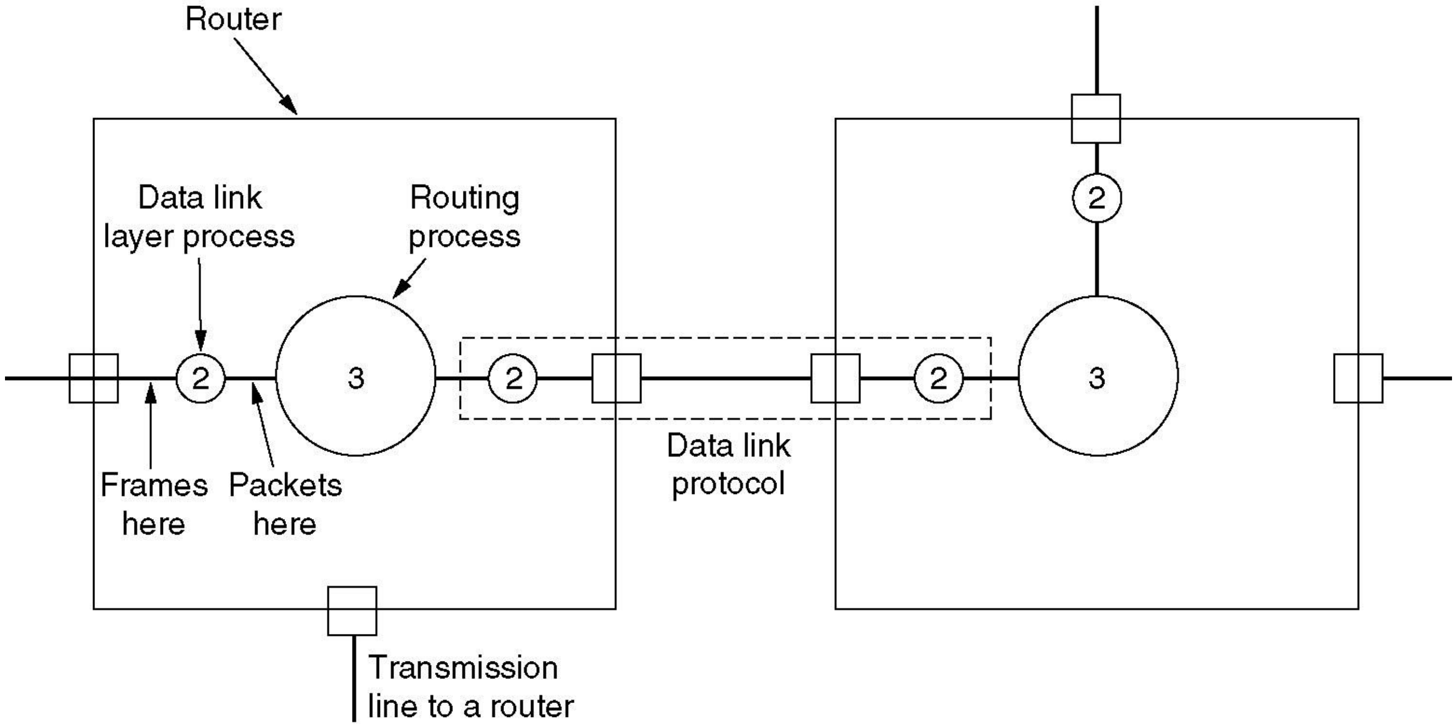
Services Provided to Network Layer



(a) Virtual communication.

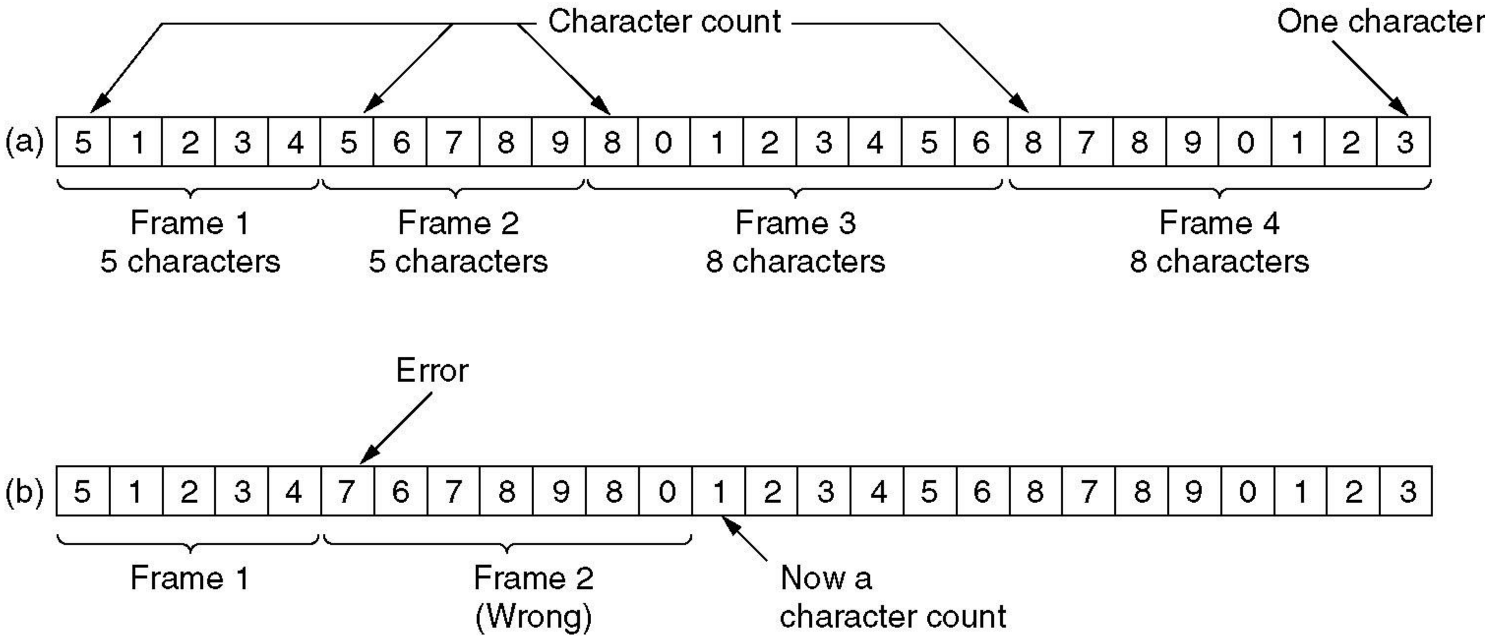
(b) Actual communication.

Services Provided to Network Layer



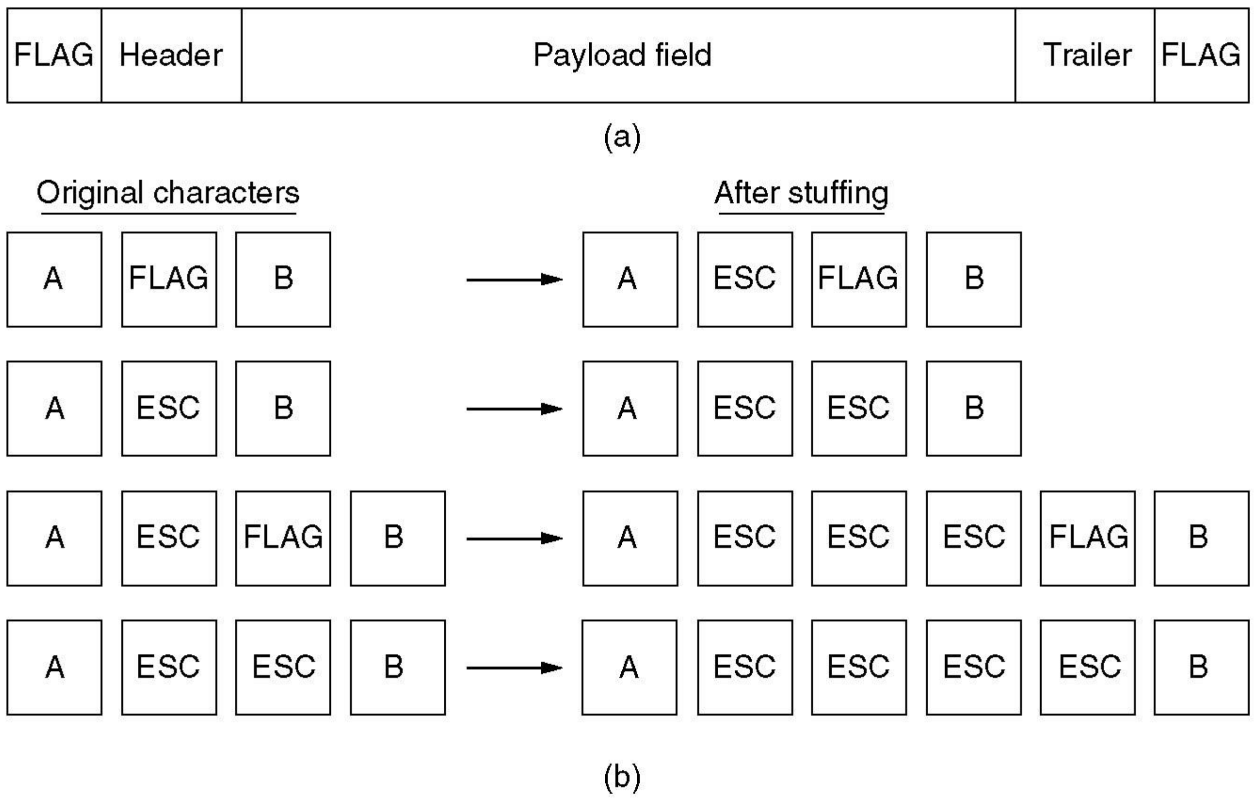
Placement of the data link protocol.

Framing



A character stream. (a) Without errors. (b) With one error.

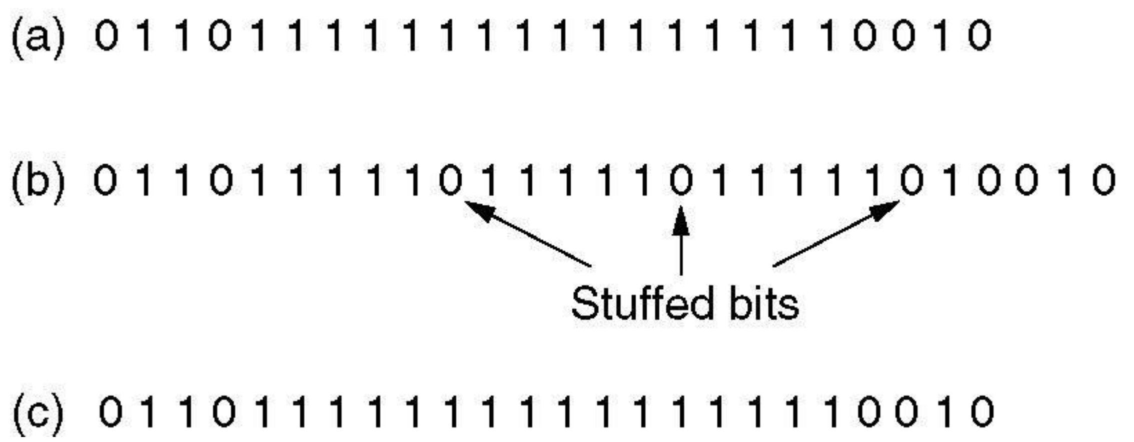
Framing (2)



(a) A frame delimited by flag bytes.

(b) Four examples of byte sequences before and after stuffing.

Framing (3)



Bit stuffing

(a) The original data.

(b) The data as they appear on the line.

(c) The data as they are stored in receiver’s memory after destuffing.

Error Detection and Correction

- Error-Correcting Codes
- Error-Detecting Codes

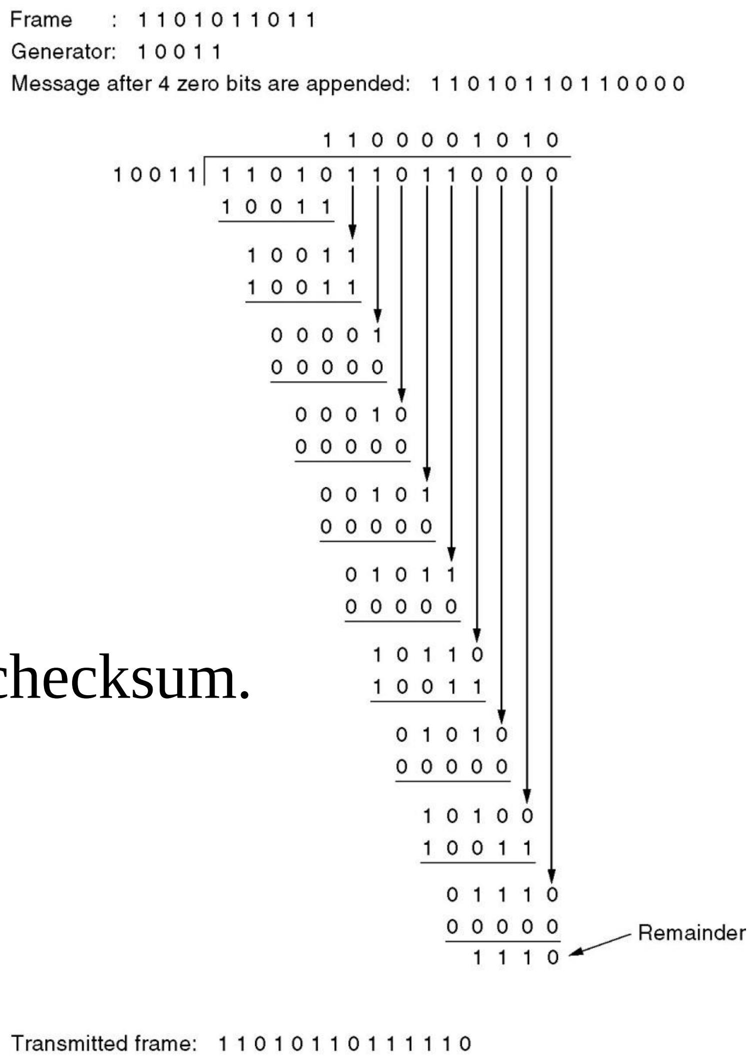
Error-Correcting Codes

Char.	ASCII	Check bits
H	1001000	00110010000
a	1100001	10111001001
m	1101101	11101010101
m	1101101	11101010101
i	1101001	01101011001
n	1101110	01101010110
g	1100111	01111001111
	0100000	10011000000
c	1100011	11111000011
o	1101111	10101011111
d	1100100	11111001100
e	1100101	00111000101

Order of bit transmission

Use of a Hamming code to correct burst errors.

Error-Detecting Codes



Calculation of the polynomial code checksum.

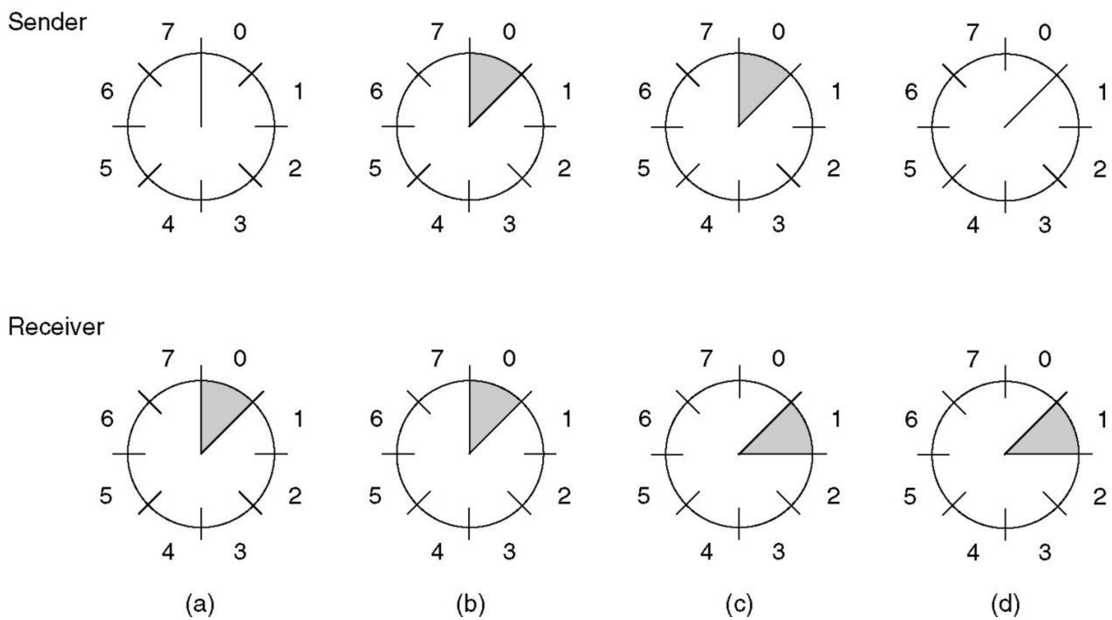
Elementary Data Link Protocols

- An Unrestricted Simplex Protocol
- A Simplex Stop-and-Wait Protocol
- A Simplex Protocol for a Noisy Channel

Sliding Window Protocols

- A One-Bit Sliding Window Protocol
- A Protocol Using Go Back N
- A Protocol Using Selective Repeat

Sliding Window Protocols (2)



A sliding window of size 1, with a 3-bit sequence number.

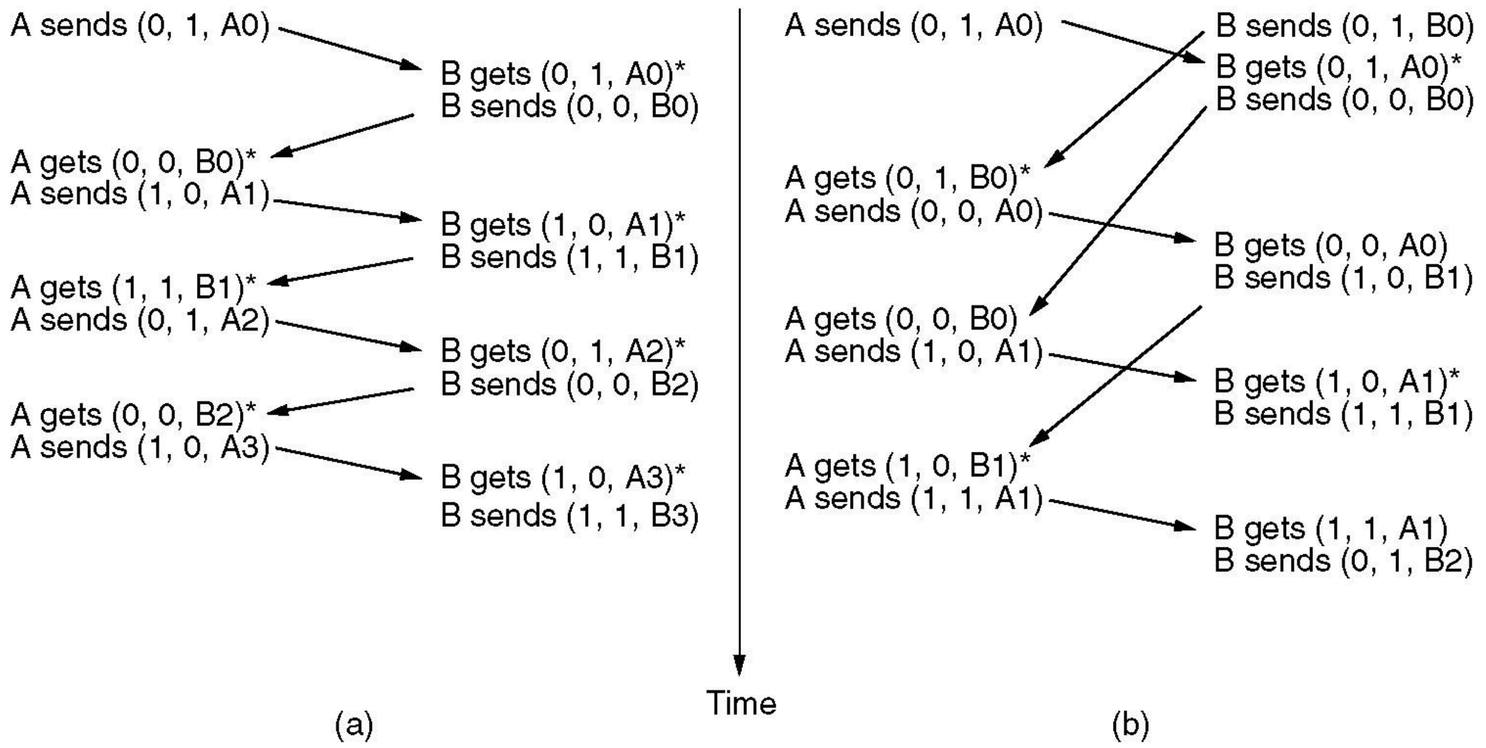
(a) Initially.

(b) After the first frame has been sent.

(c) After the first frame has been received.

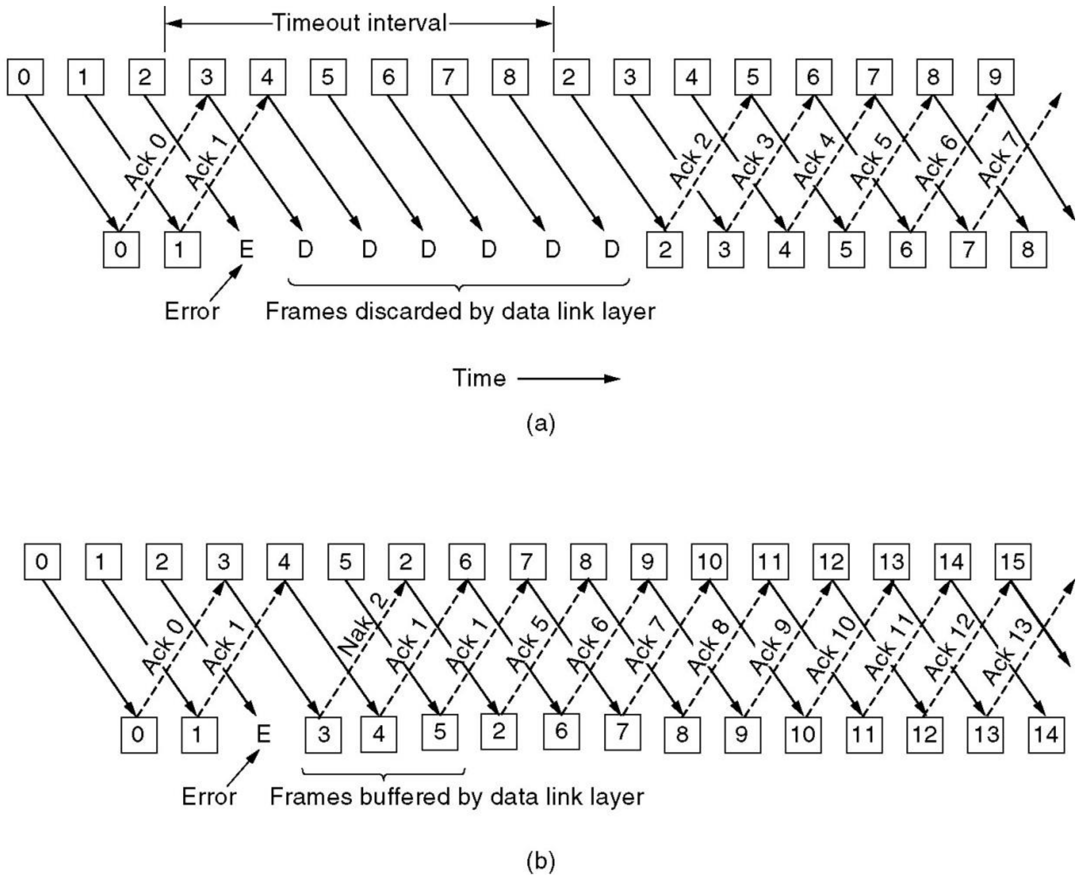
(d) After the first acknowledgement has been received.

A One-Bit Sliding Window Protocol (2)



Two scenarios for protocol 4. (a) Normal case. (b) Abnormal case. The notation is (seq, ack, packet number). An asterisk indicates where a network layer accepts a packet.

A Protocol Using Go Back N

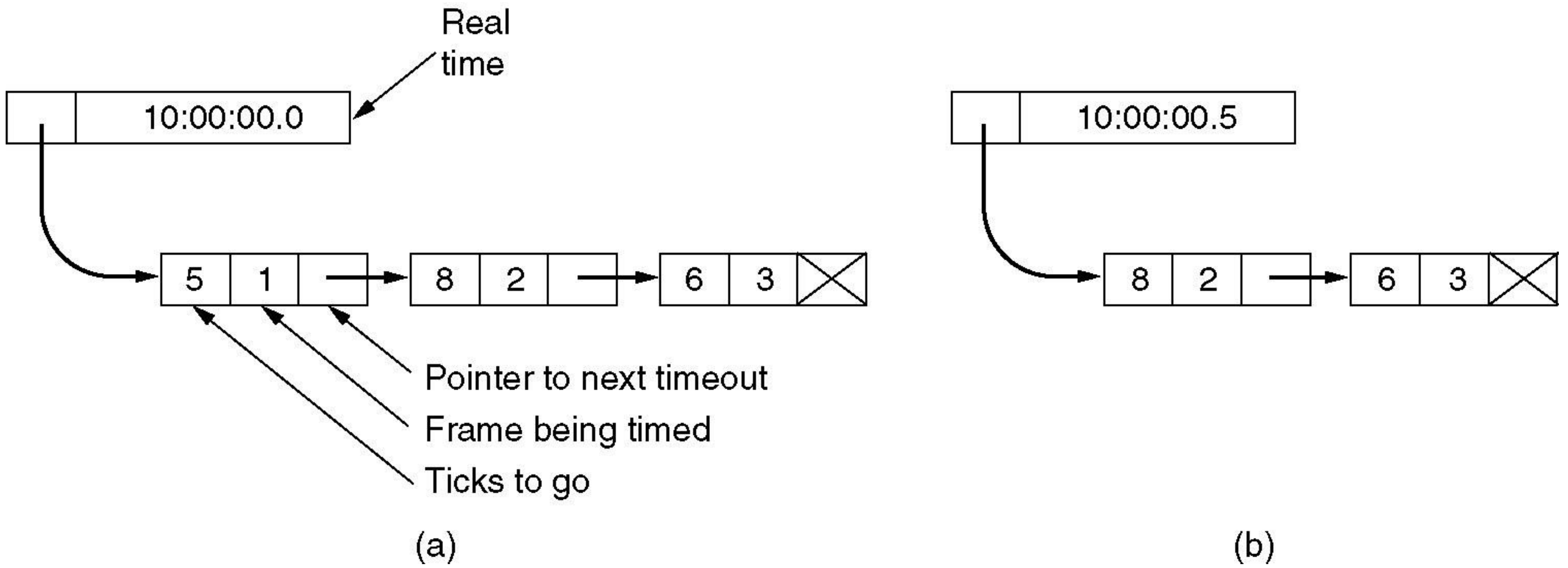


Pipelining and error recovery. Effect on an error when

(a) Receiver's window size is 1.

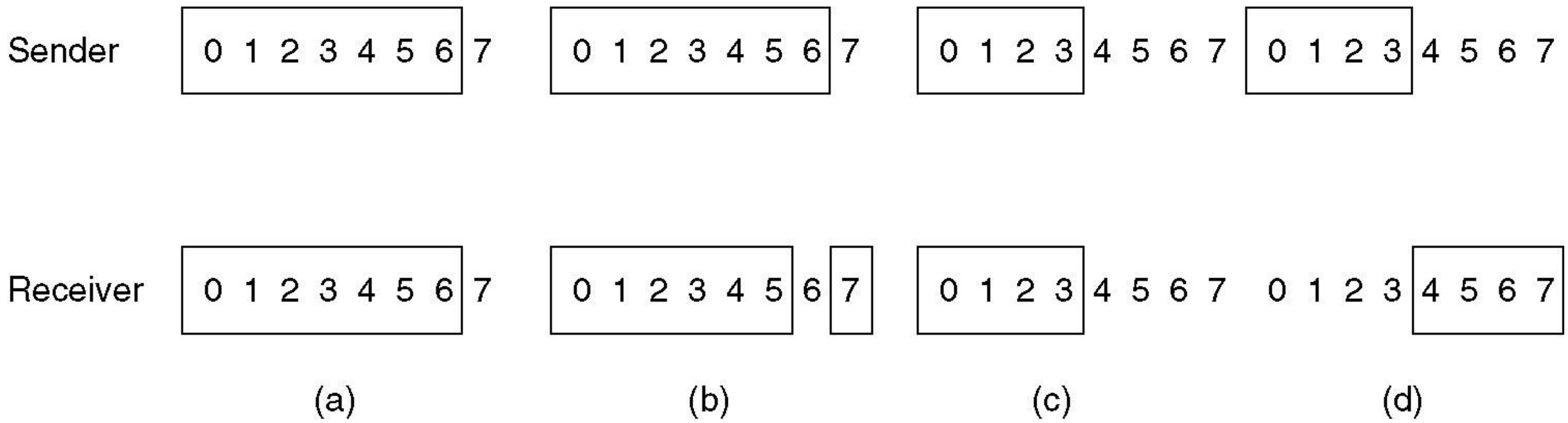
(b) Receiver's window size is large.

Sliding Window Protocol Using Go Back N (2)



Simulation of multiple timers in software.

A Sliding Window Protocol Using Selective Repeat (5)



(a) Initial situation with a window size seven.

(b) After seven frames sent and received, but not acknowledged.

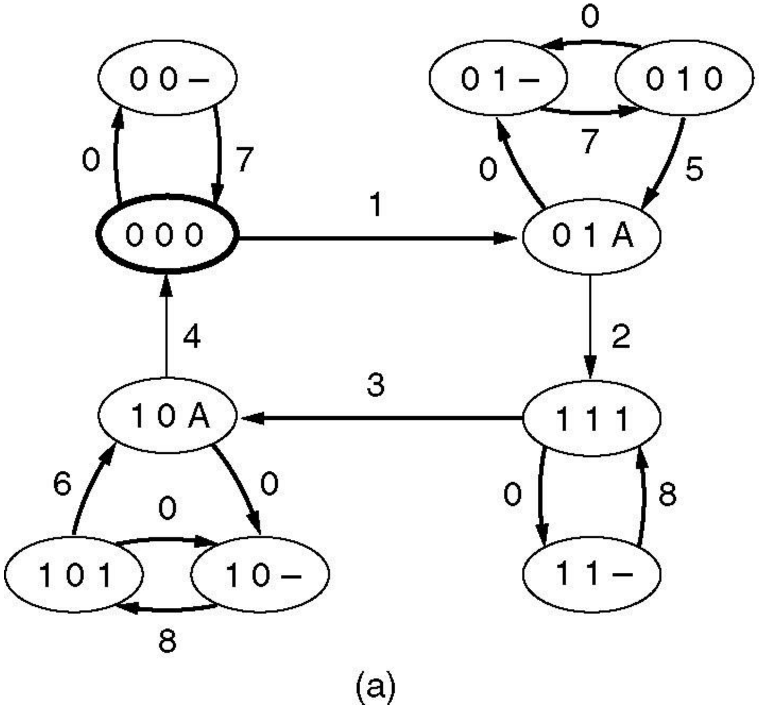
(c) Initial situation with a window size of four.

(d) After four frames sent and received, but not acknowledged.

Protocol Verification

- Finite State Machined Models
- Petri Net Models

Finite State Machined Models

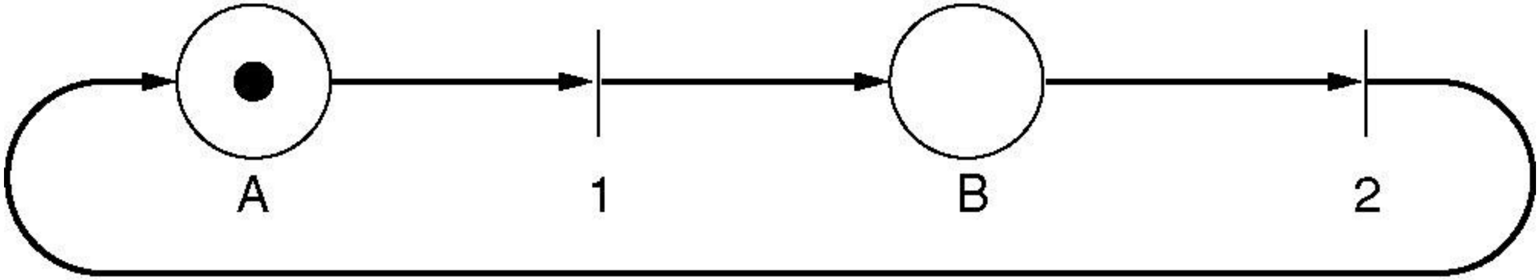


Transition	Who runs?	Frame accepted	Frame emitted	To network layer
0	–	(frame lost)		–
1	R	0	A	Yes
2	S	A	1	–
3	R	1	A	Yes
4	S	A	0	–
5	R	0	A	No
6	R	1	A	No
7	S	(timeout)	0	–
8	S	(timeout)	1	–

(b)

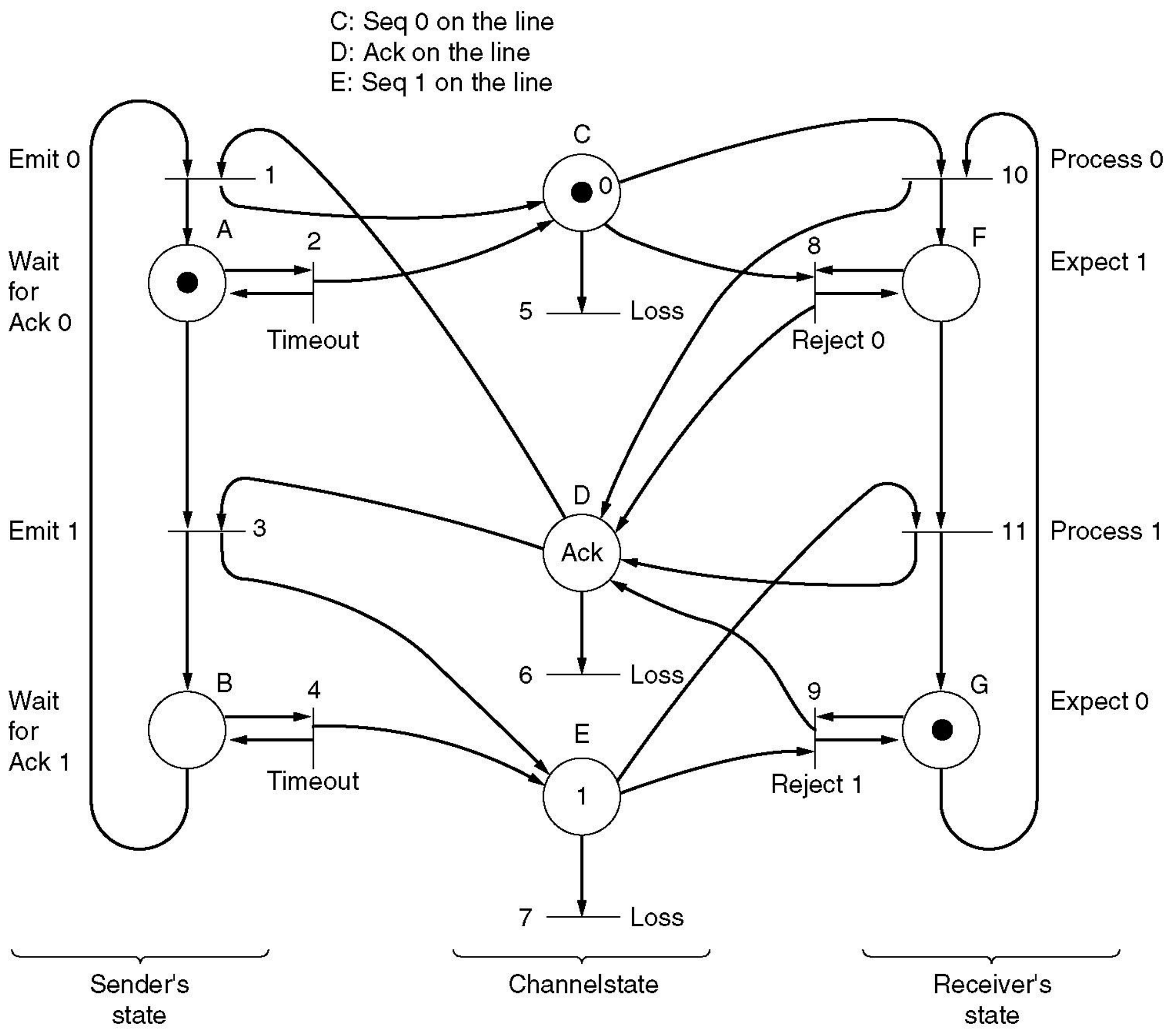
(a) State diagram for protocol 3. (b) Transmissions.

Petri Net Models



A Petri net with two places and two transitions.

Petri Net Models (2)

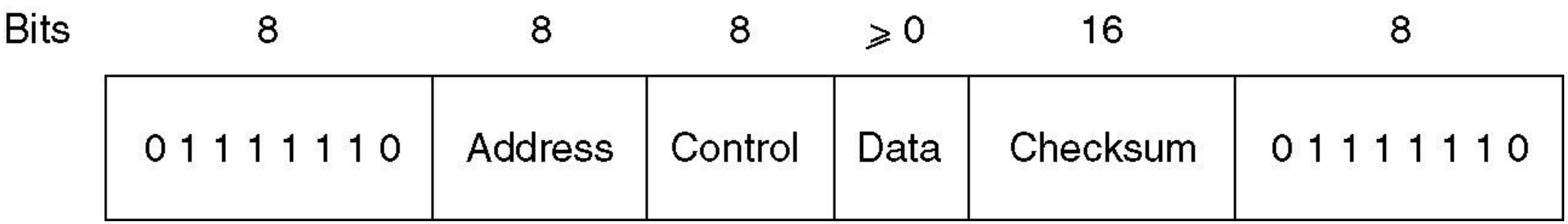


A Petri net model for protocol 3.

Example Data Link Protocols

- HDLC – High-Level Data Link Control
- The Data Link Layer in the Internet

High-Level Data Link Control



Frame format for bit-oriented protocols.

High-Level Data Link Control (2)

Bits	1	3		1	3
(a)	0	Seq		P/F	Next
(b)	1	0	Type	P/F	Next
(c)	1	1	Type	P/F	Modifier

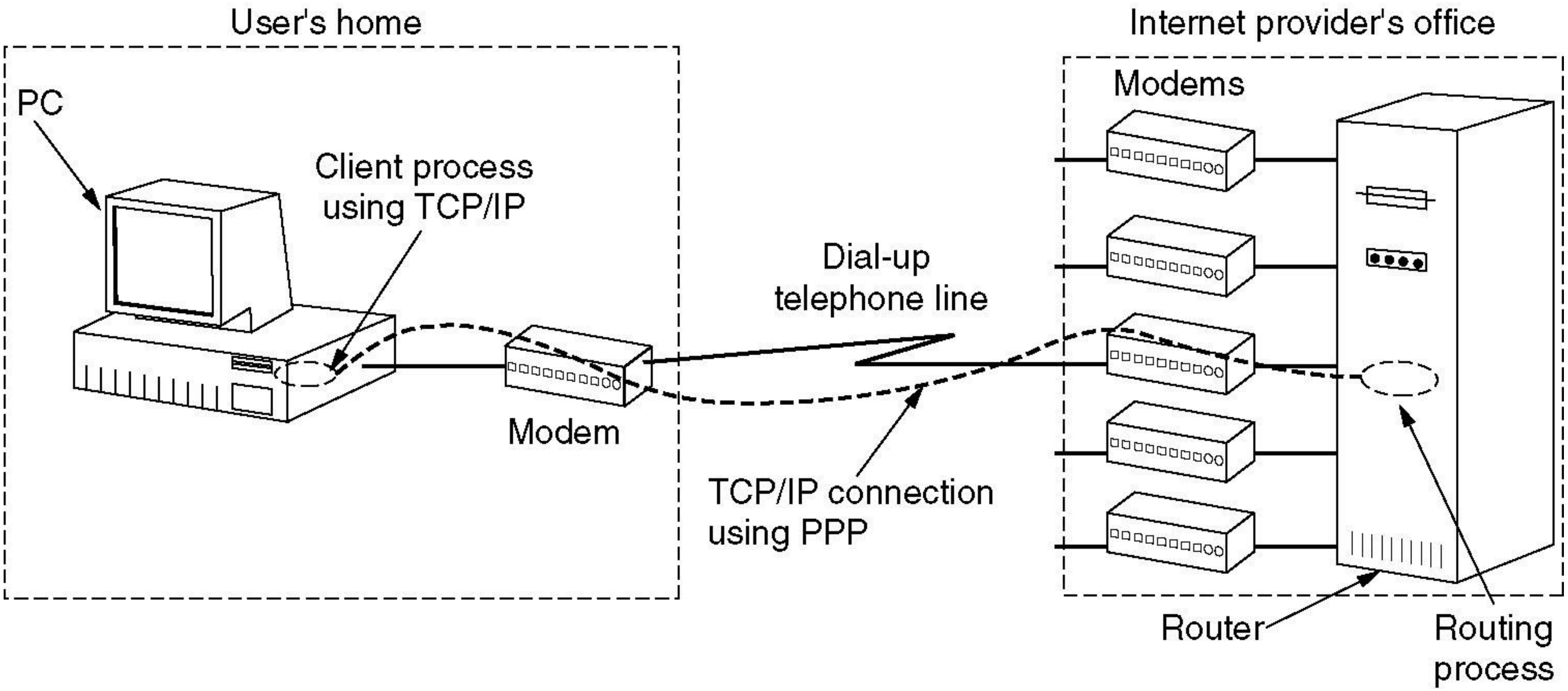
Control field of

(a) An information frame.

(b) A supervisory frame.

(c) An unnumbered frame.

The Data Link Layer in the Internet



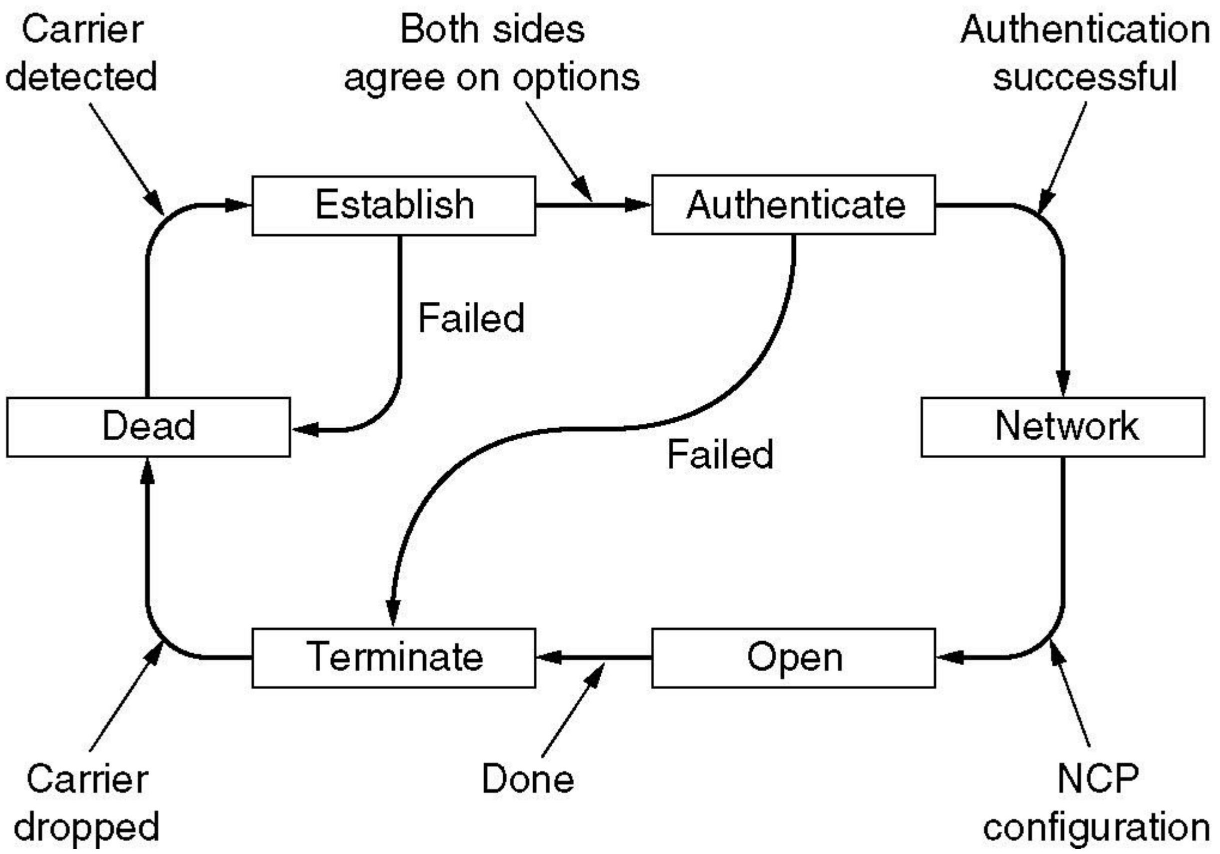
A home personal computer acting as an internet host.

PPP – Point to Point Protocol

Bytes	1	1	1	1 or 2	Variable	2 or 4	1
	Flag 01111110	Address 11111111	Control 00000011	Protocol	Payload	Checksum	Flag 01111110

The PPP full frame format for unnumbered mode operation.

PPP – Point to Point Protocol (2)



A simplified phase diagram for bring a line up and down.

PPP – Point to Point Protocol (3)

Name	Direction	Description
Configure-request	I → R	List of proposed options and values
Configure-ack	I ← R	All options are accepted
Configure-nak	I ← R	Some options are not accepted
Configure-reject	I ← R	Some options are not negotiable
Terminate-request	I → R	Request to shut the line down
Terminate-ack	I ← R	OK, line shut down
Code-reject	I ← R	Unknown request received
Protocol-reject	I ← R	Unknown protocol requested
Echo-request	I → R	Please send this frame back
Echo-reply	I ← R	Here is the frame back
Discard-request	I → R	Just discard this frame (for testing)

The LCP frame types.

The Medium Access Control Sublayer

The Channel Allocation Problem

- Static Channel Allocation in LANs and MANs
- Dynamic Channel Allocation in LANs and MANs

Static Channel Allocation in LANs and MANs

Static channel allocation is a traditional method of channel allocation in which a fixed portion of the frequency channel is allotted to each user, who may be base stations, access points or terminal equipment.

Dynamic Channel Allocation in LANs and MANs

1. Station Model.

2. Single Channel Assumption.

3. Collision Assumption.

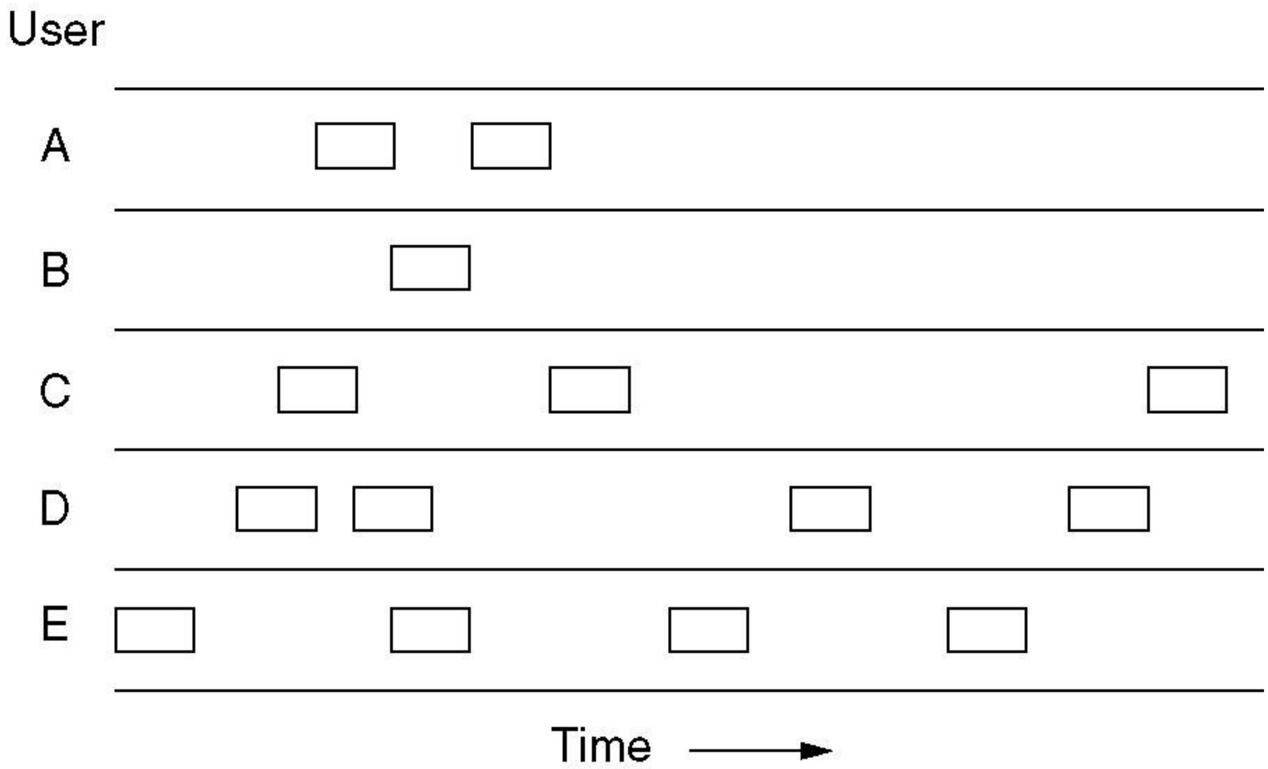
4. (a) Continuous Time.
   (b) Slotted Time.

5. (a) Carrier Sense.
   (b) No Carrier Sense.

Multiple Access Protocols

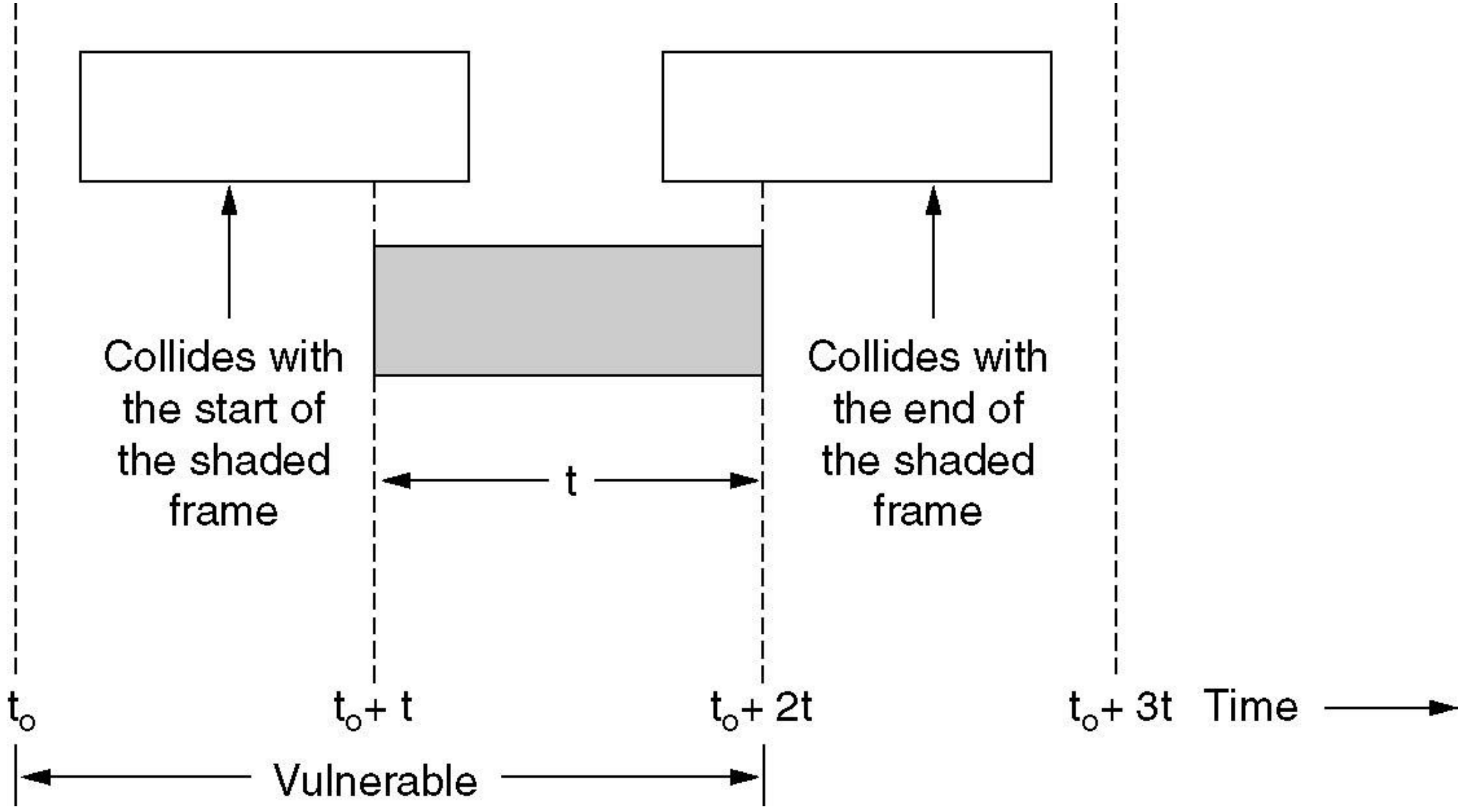
- ALOHA
- Carrier Sense Multiple Access Protocols
- Collision-Free Protocols
- Limited-Contention Protocols
- Wavelength Division Multiple Access Protocols
- Wireless LAN Protocols

Pure ALOHA



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

Pure ALOHA (2)



Vulnerable period for the shaded frame.

What is the max. throughput of Pure ALOHA?

How to control G to get maximum S? $d(f \bullet g) = df \bullet g + f \bullet dg$

$$\frac{dS}{dG} = \frac{d(Ge^{-2G})}{dG} = e^{-2G} + (-2)e^{-2G}G = e^{-2G}(1-2G)$$

Let $\frac{dS}{dG} = 0 \rightarrow G = \frac{1}{2}$, Smax $= \frac{1}{2e} \cong 0.184$

The best we can hope for the channel utilization is 18.4%.

Is 18.4% channel utilization for the ALOHA system too low?

For a terminal user sends 60 character/msg every 2 min.,

input rate is 0.5 char/sec = 5 bits/sec (assume 10 bit async. transmission)

For 4800 bps channel and 10% utilization, it can support 96 interactive users.

For bursty, interactive traffic, pure ALOHA is sufficient and simple.

Slotted ALOHA

Transmission time is divided into slots. Stations with data to transmit will wait until the starting time of a slot. Time of vulnerable period is reduced to 1 frame (slot) time.

(Require synchronization devices, e.g., a central station broadcasts the clock signal to all stations for synchronizing the slots.)

Pr[k] = $\frac{(G)^k}{k!} e^{-G}$

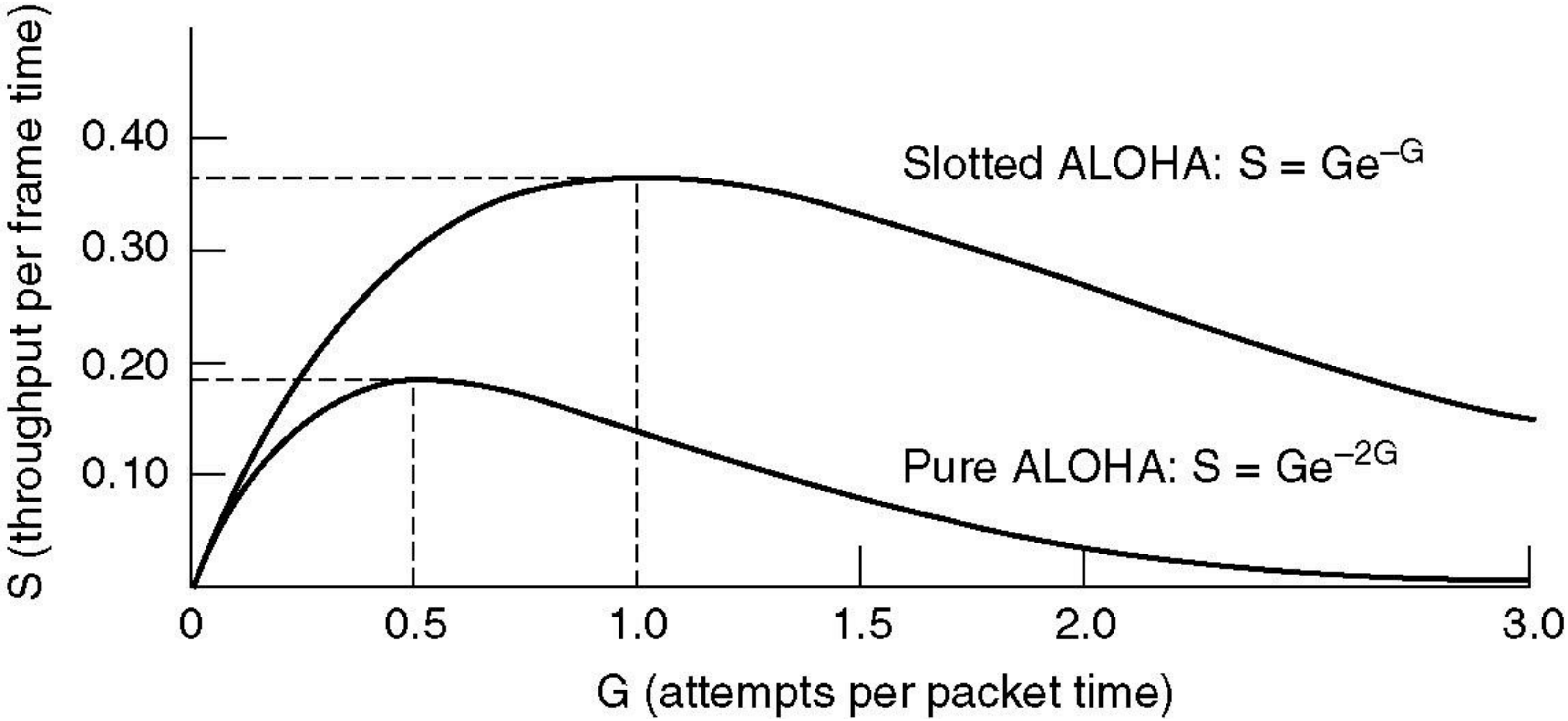
P_0 = Pr[0] = e^{-G}

$S = GP_0 = Ge^{-G}$.

$$\frac{dS}{dG} = \frac{d(Ge^{-G})}{dG} = e^{-G} + (-1)e^{-G}G = e^{-G}(1-G)$$

Let $\frac{dS}{dG} = 0$ → $G = 1$, Smax = $\frac{1}{e} \cong 0.368$

PURE ALOHA vs. Slotted ALOHA



Throughput versus offered traffic for ALOHA systems.

Carrier Sense MA protocols

Protocols in which stations listen for a carrier (i.e. a transmission medium) and act accordingly, e.g. MA protocols used by LANs.

1-Persistent CSMA

When a station has data to send, it listens to the channel.

If the channel is busy, it waits until channel idle.

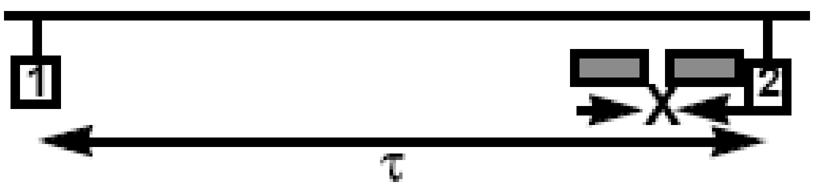
When the channel is idle, it transmits a frame (with probability = 1).

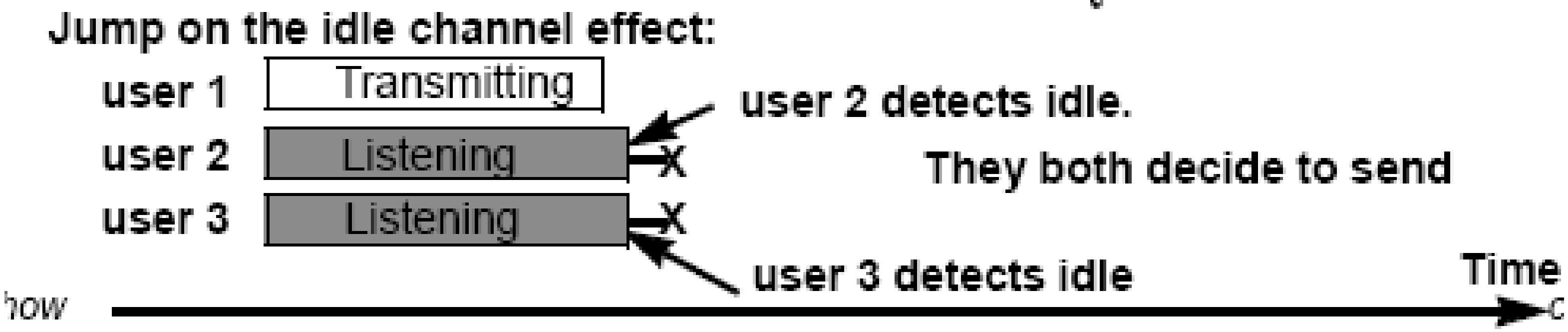
Propagation delay effect:

At t0, station 1 detects idle and sends a frame.

At t0+τ−ε, station 2 detects idle and sends a frame.2

At t0+τ, station 2 detects collision.





Carrier Sense MA Protocols(2)

At $t0+\tau-\varepsilon+\tau$, station 1 detects collision.

In worst case, only about 2τ time later can station 1 detect the collision.

The longer the cable, the longer stations have to wait to be sure that there is no collision.

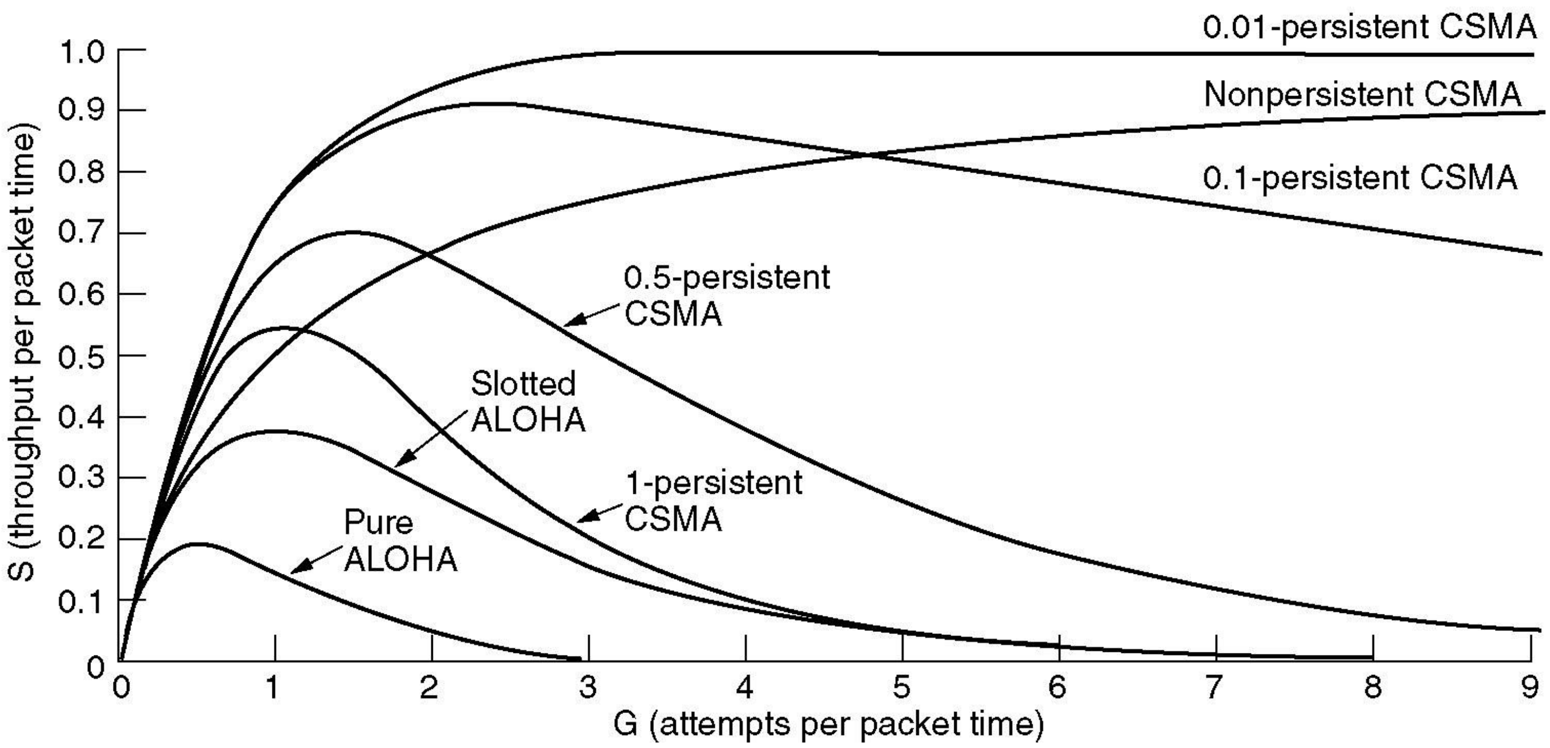
Non-persistent CSMA

- **If the channel is busy, it waits for random period then sense the channel again.**
- Better channel utilization but longer delays than 1-persistent CSMA.

p-persistent CSMA (applies to slotted channel)

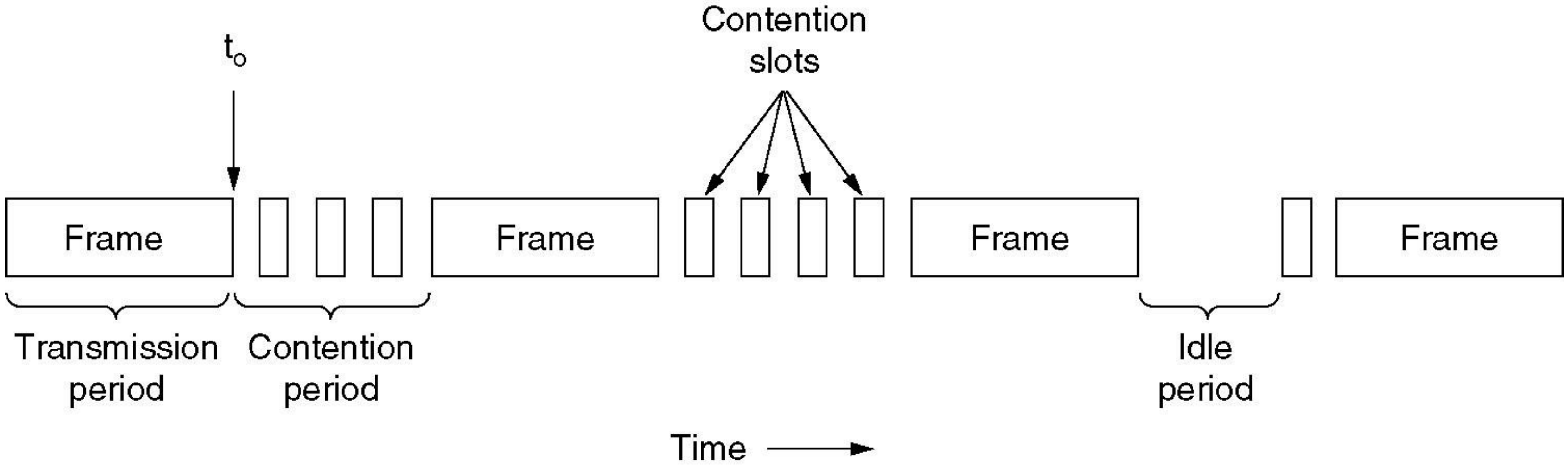
- **If the channel is idle, it transmits with prob = p (with 1-p, it defers until next slot).**
- **If the next slot is idle again, do the same thing.**

Persistent and Nonpersistent CSMA



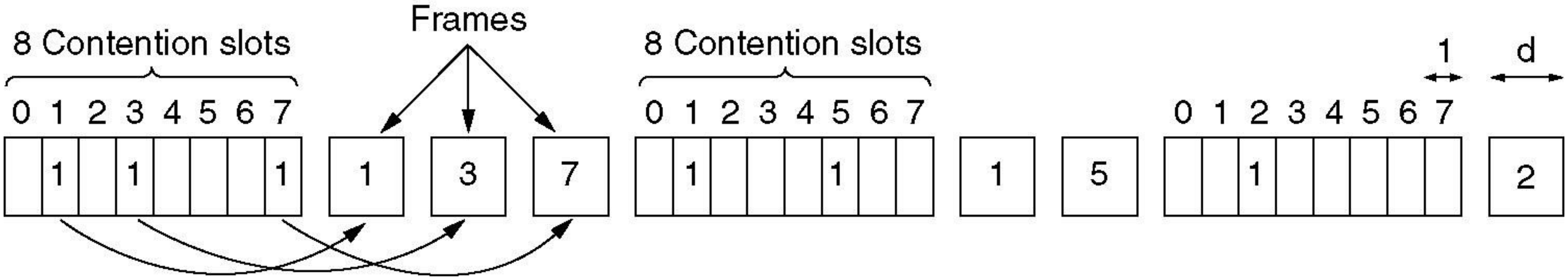
Comparison of the channel utilization versus load for various random access protocols. **Smaller p has better throughput but at what cost?**

CSMA with Collision Detection



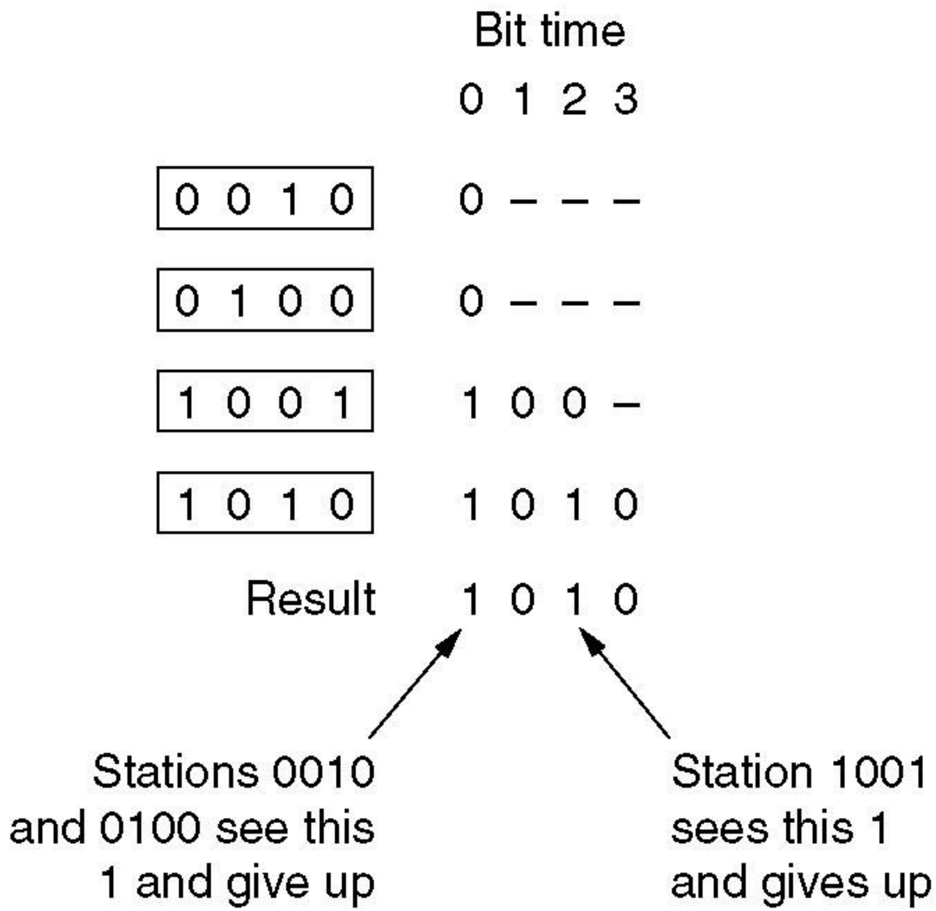
CSMA/CD can be in one of three states: contention, transmission, or idle.

Collision-Free Protocols



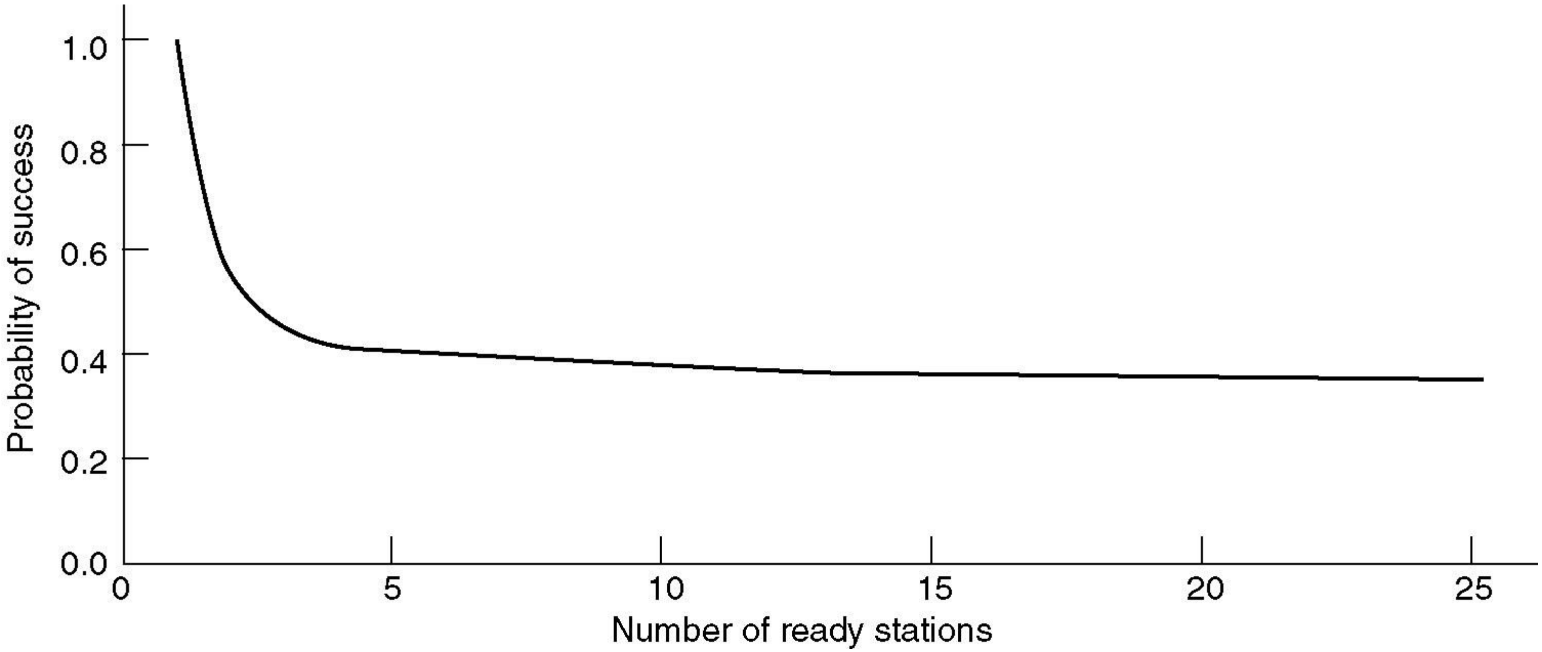
The basic bit-map protocol.

Collision-Free Protocols (2)



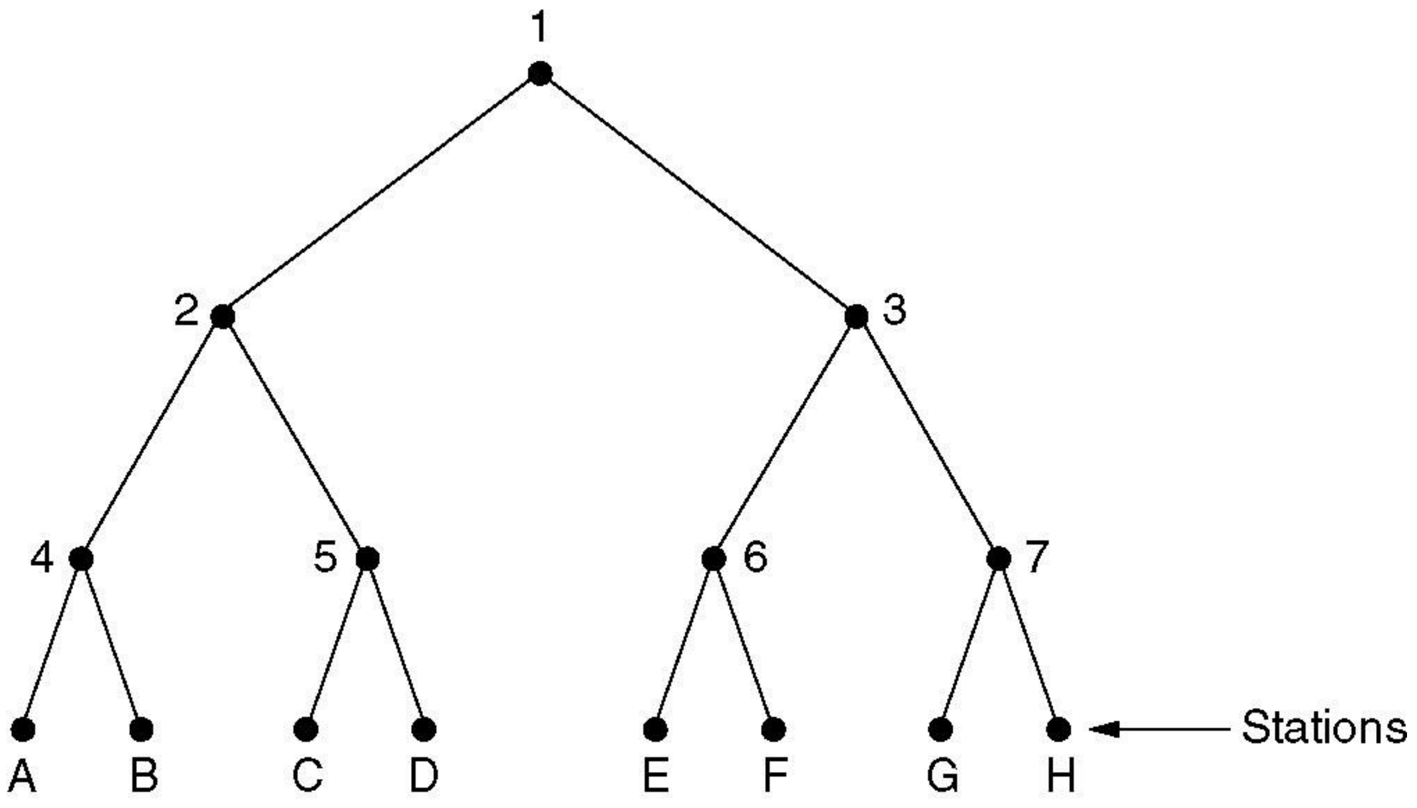
The binary countdown protocol. A dash indicates silence.

Limited-Contention Protocols



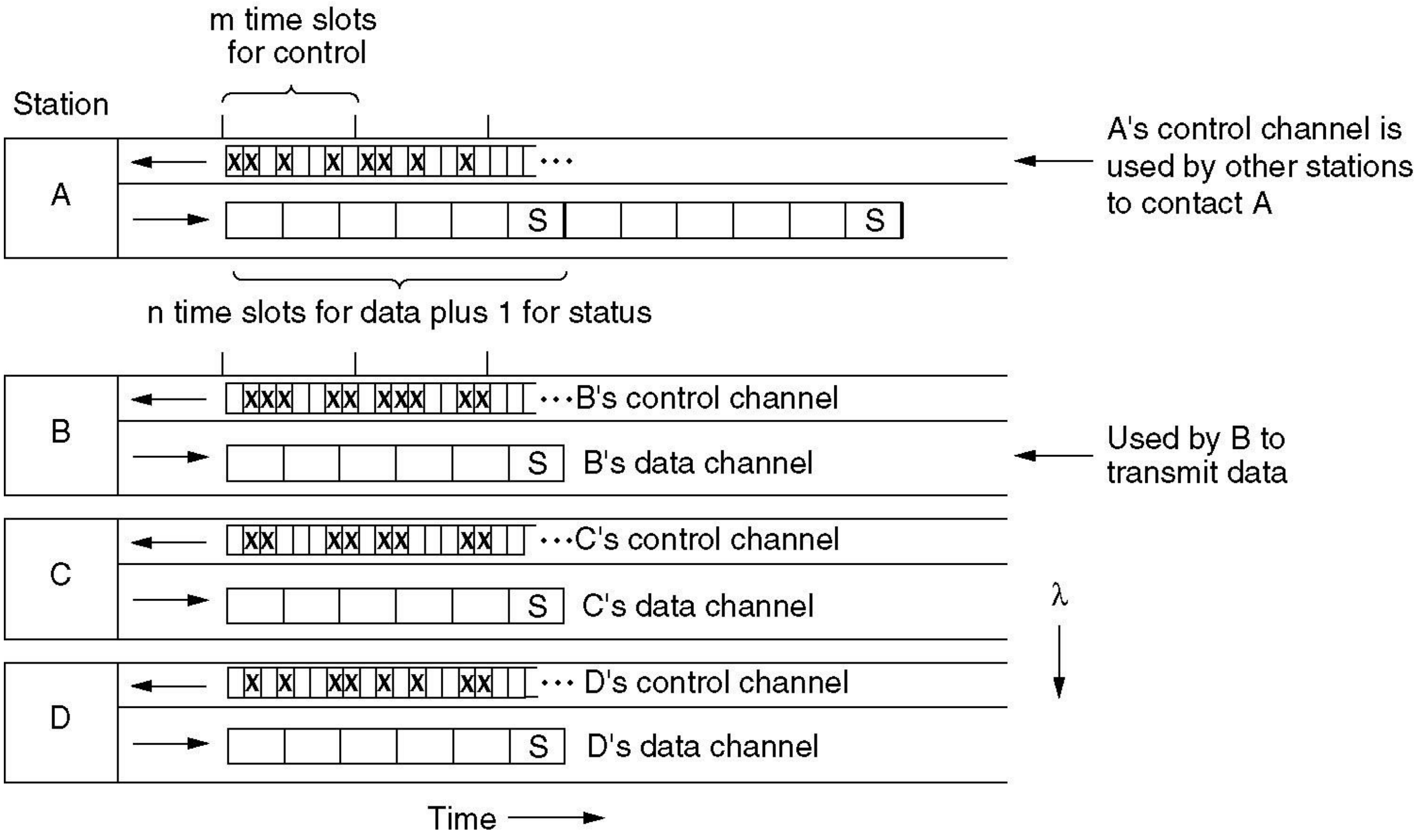
Acquisition probability for a symmetric contention channel.

Adaptive Tree Walk Protocol



The tree for eight stations.

Wavelength Division Multiple Access Protocols

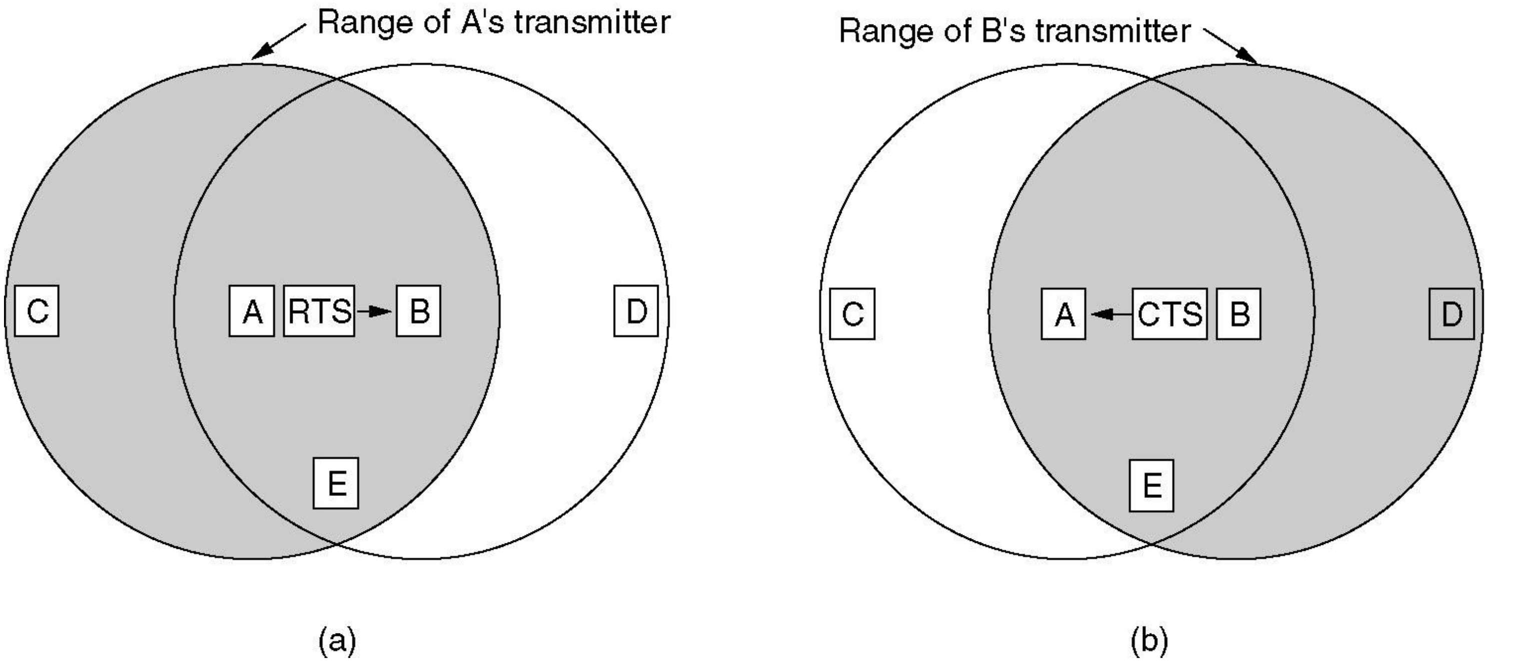


Wavelength division multiple access.

Wireless LAN Protocols

A wireless LAN. (a) A transmitting. (b) B transmitting.

Wireless LAN Protocols (2)



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

Ethernet

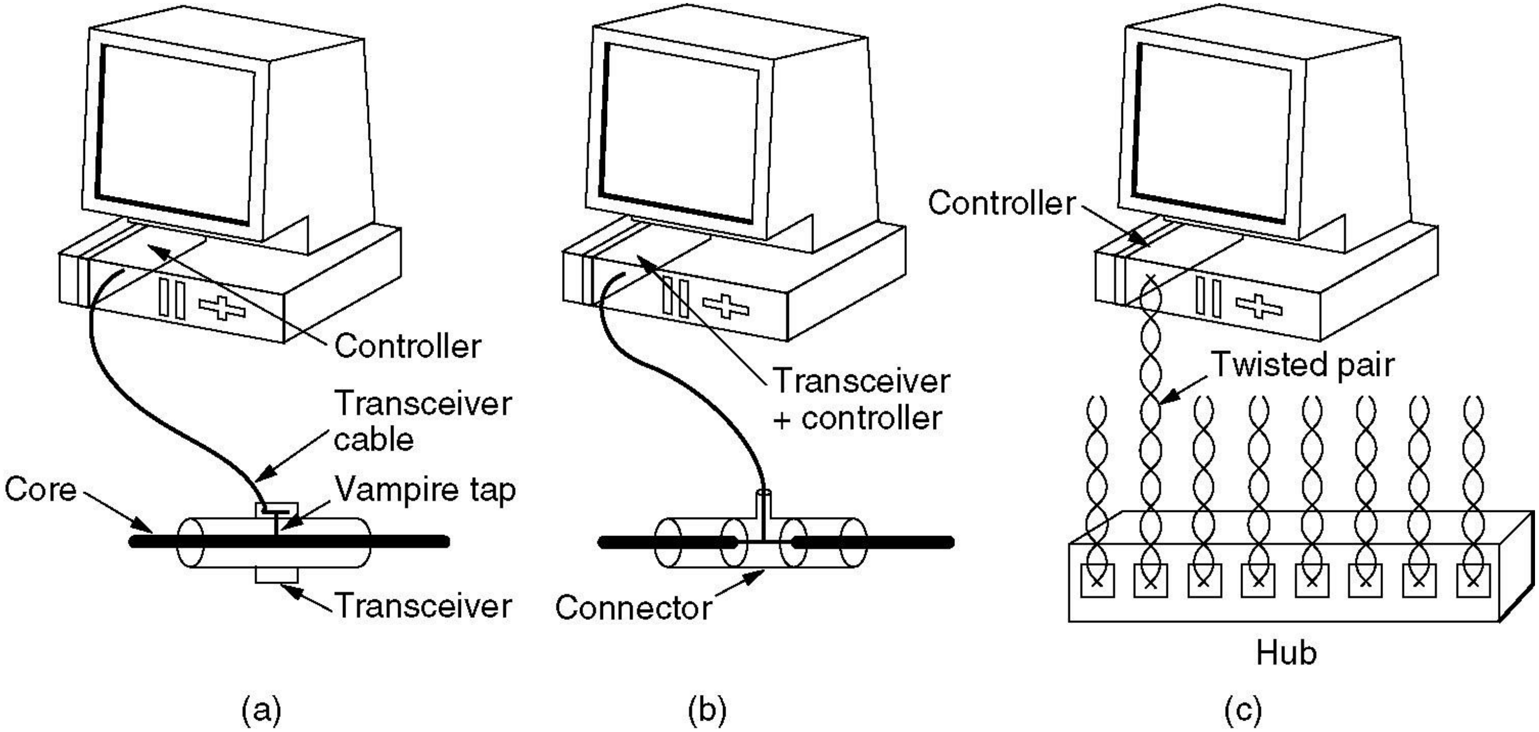
- Ethernet Cabling
- Manchester Encoding
- The Ethernet MAC Sublayer Protocol
- The Binary Exponential Backoff Algorithm
- Ethernet Performance
- Switched Ethernet
- Fast Ethernet
- Gigabit Ethernet
- IEEE 802.2: Logical Link Control
- Retrospective on Ethernet

Ethernet Cabling

Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings

The most common kinds of Ethernet cabling.

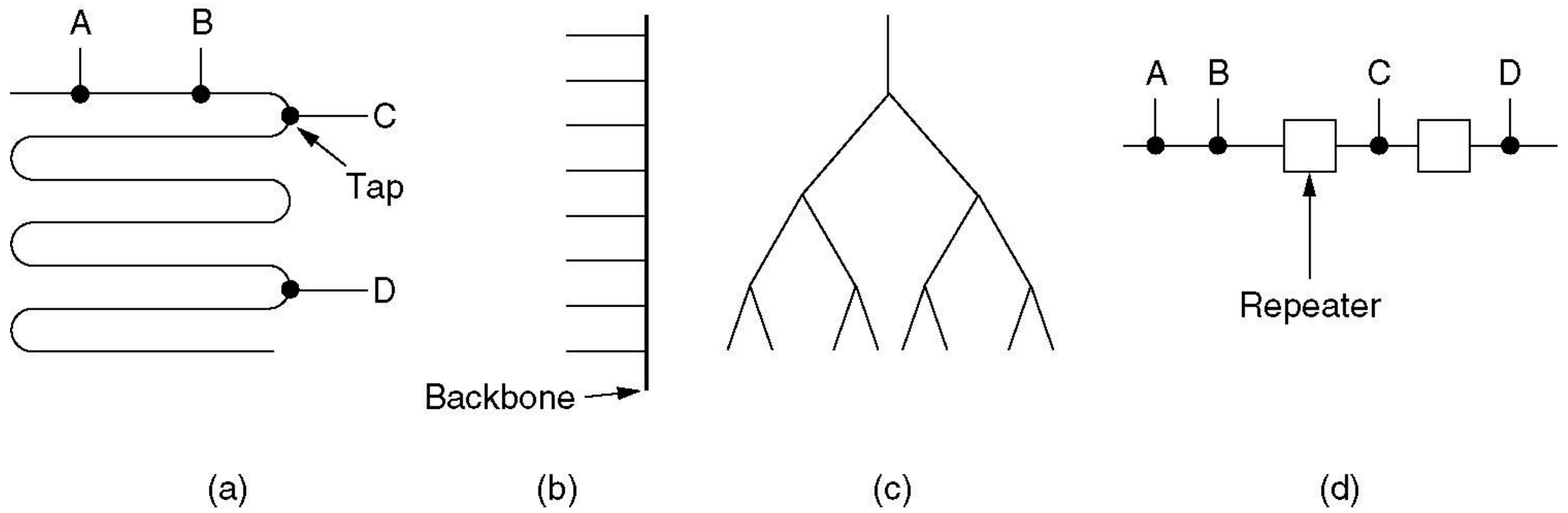
Ethernet Cabling (2)



Three kinds of Ethernet cabling.

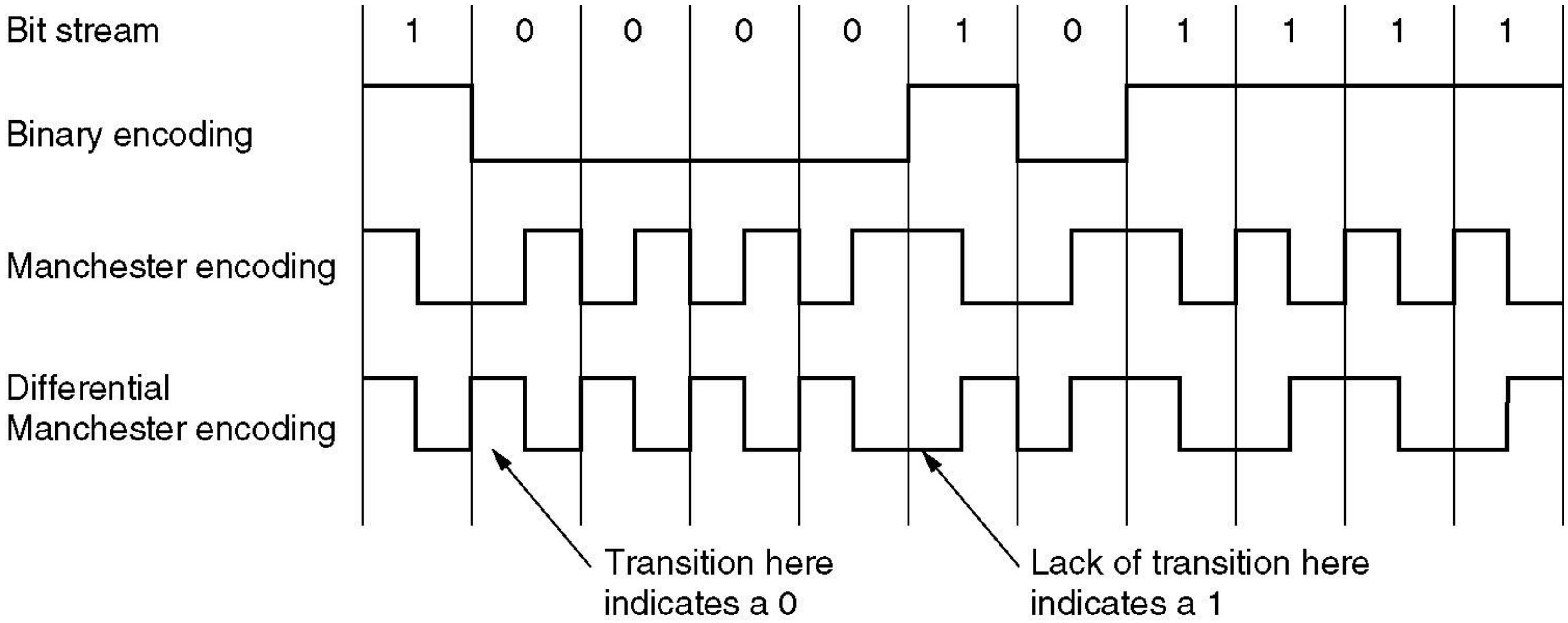
(a) 10Base5, (b) 10Base2, (c) 10Base-T.

Ethernet Cabling (3)



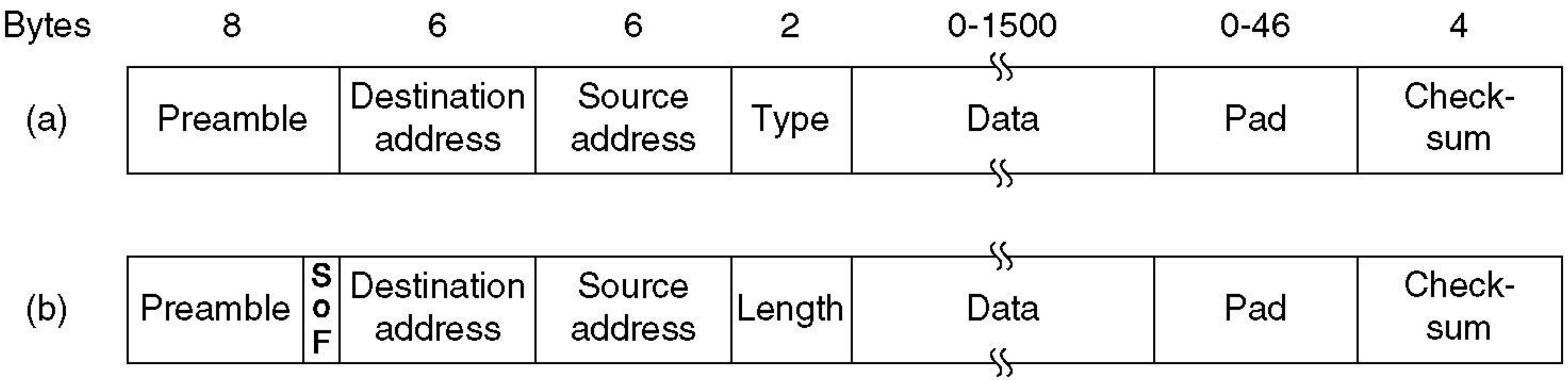
Cable topologies. (a) Linear, (b) Spine, (c) Tree, (d) Segmented.

Ethernet Cabling (4)



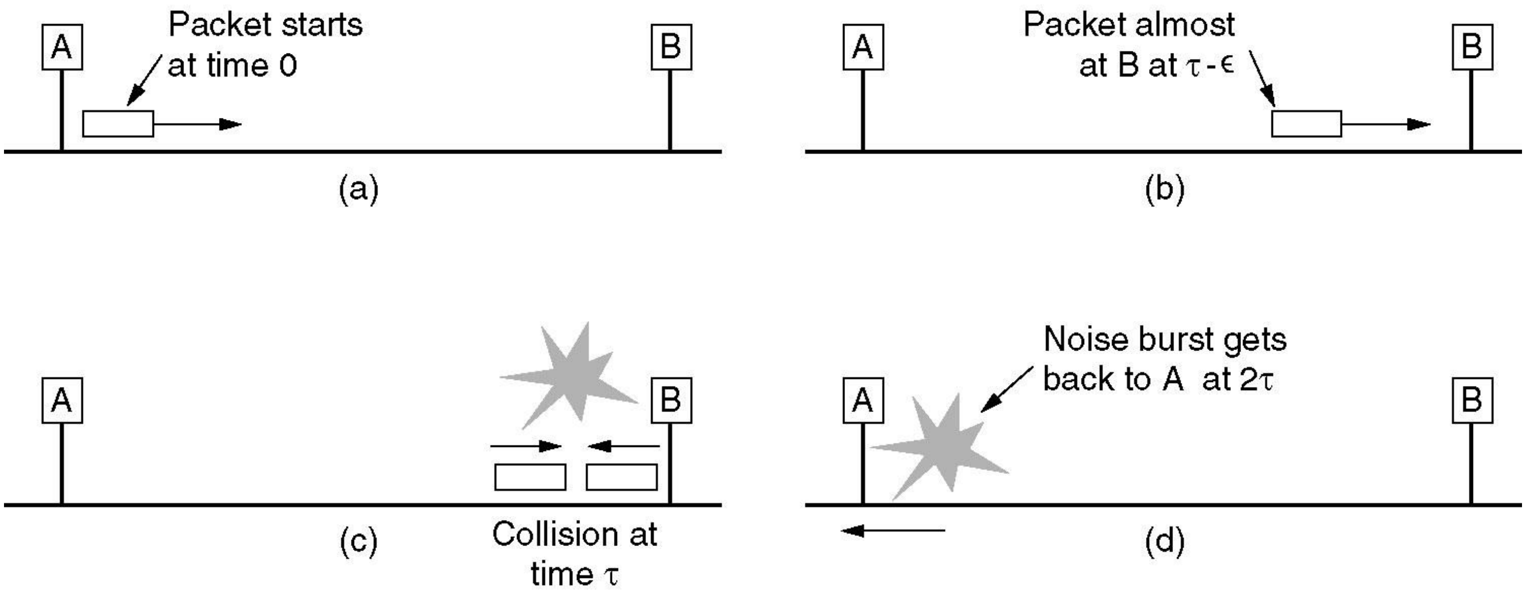
(a) Binary encoding, (b) Manchester encoding,
(c) Differential Manchester encoding.

Ethernet MAC Sublayer Protocol



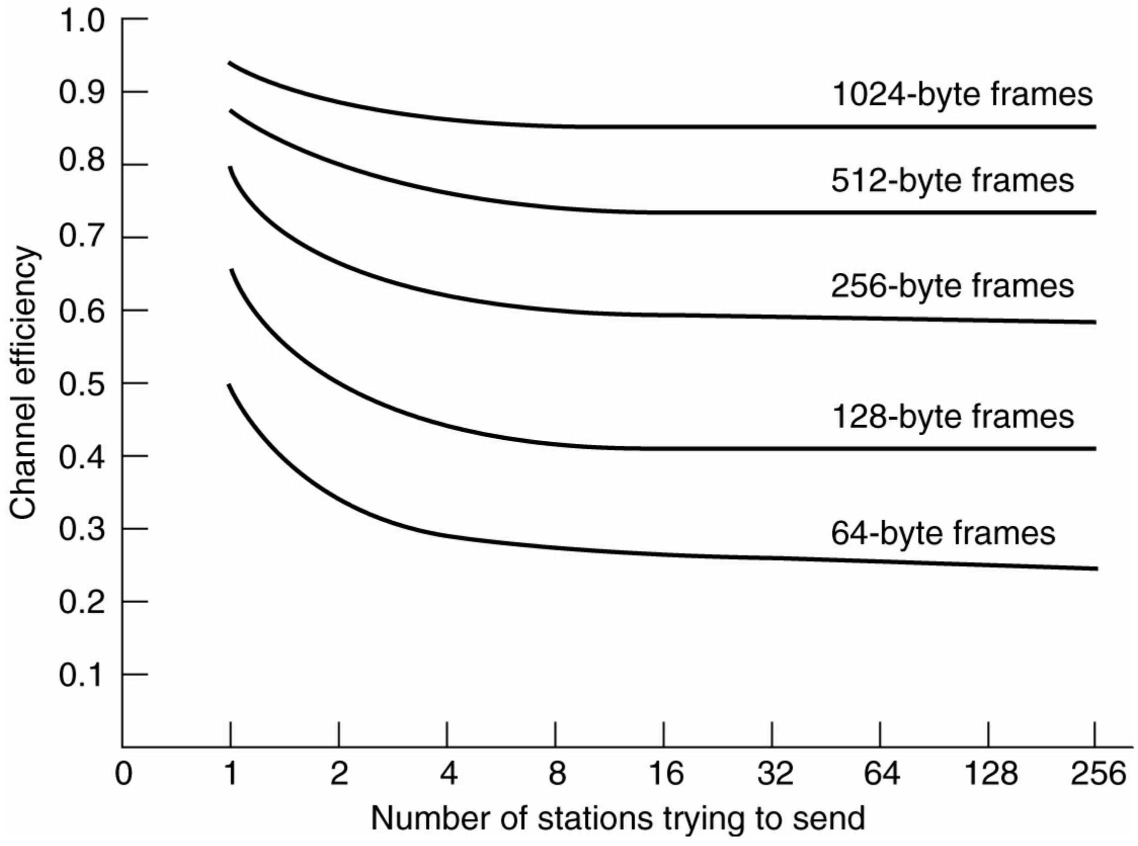
Frame formats. (a) DIX Ethernet, (b) IEEE 802.3.

Ethernet MAC Sublayer Protocol (2)



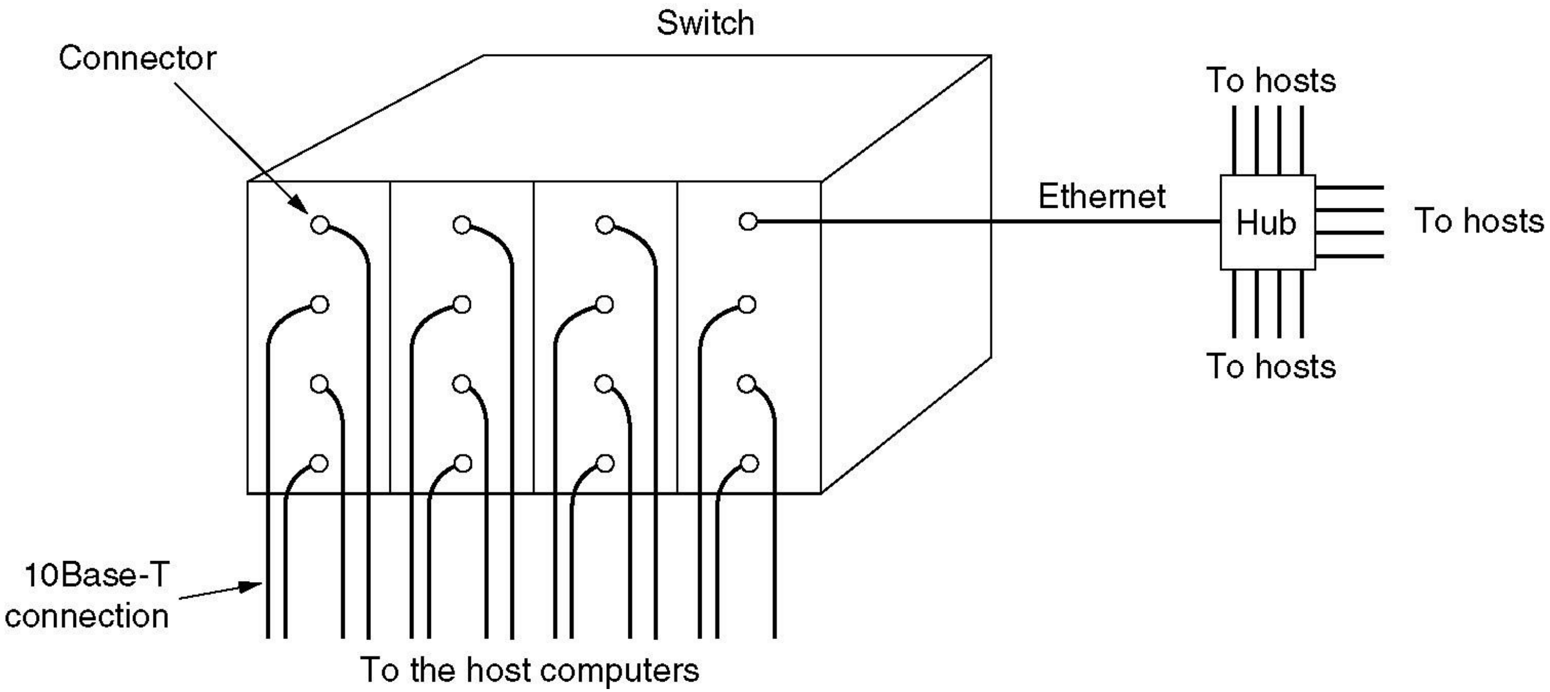
Collision detection can take as long as 2τ.

Ethernet Performance



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

Switched Ethernet



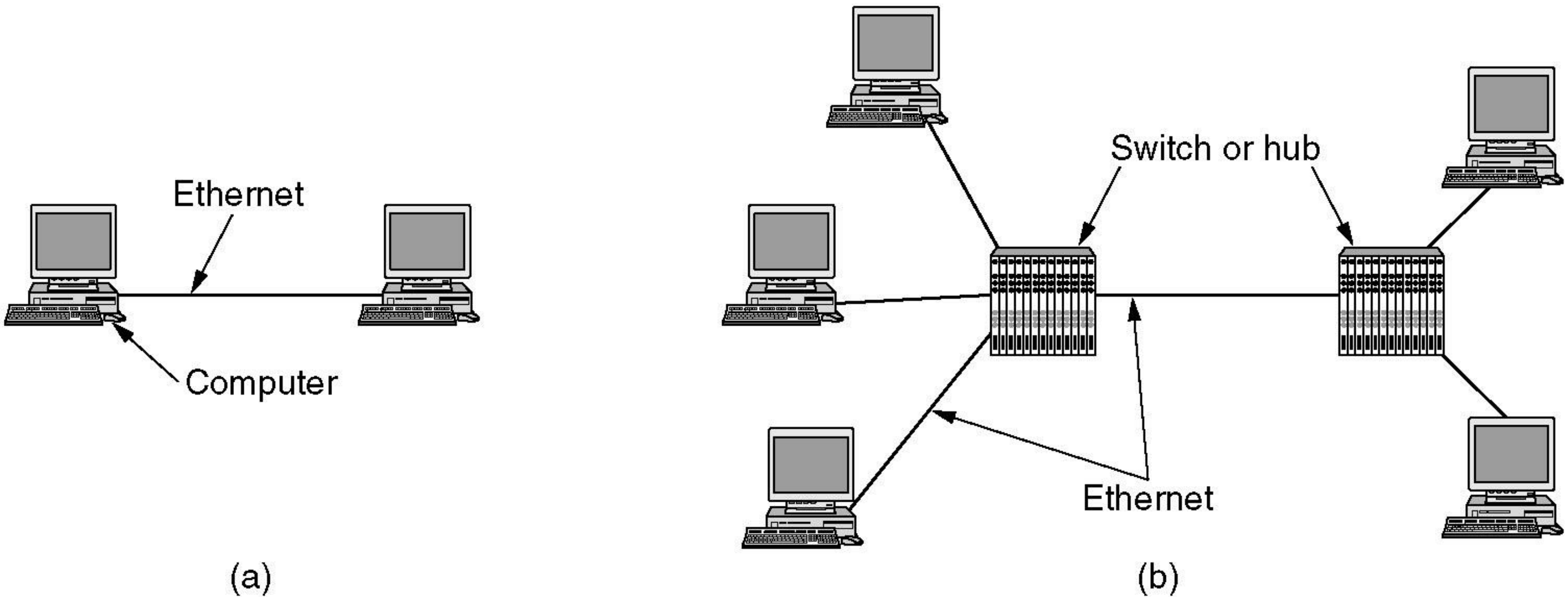
A simple example of switched Ethernet.

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
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

The original fast Ethernet cabling.

Gigabit Ethernet



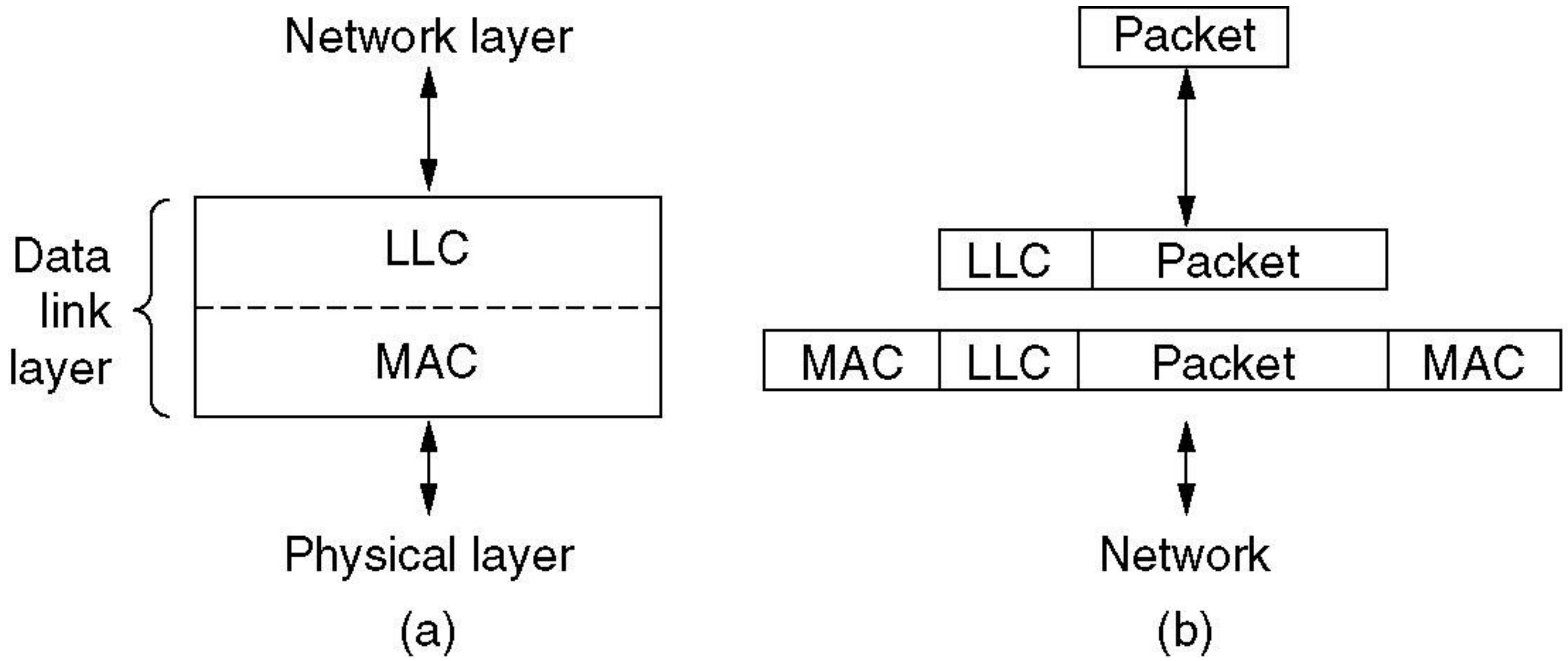
(a) A two-station Ethernet. (b) A multistation Ethernet.

Gigabit Ethernet (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.

IEEE 802.2: Logical Link Control

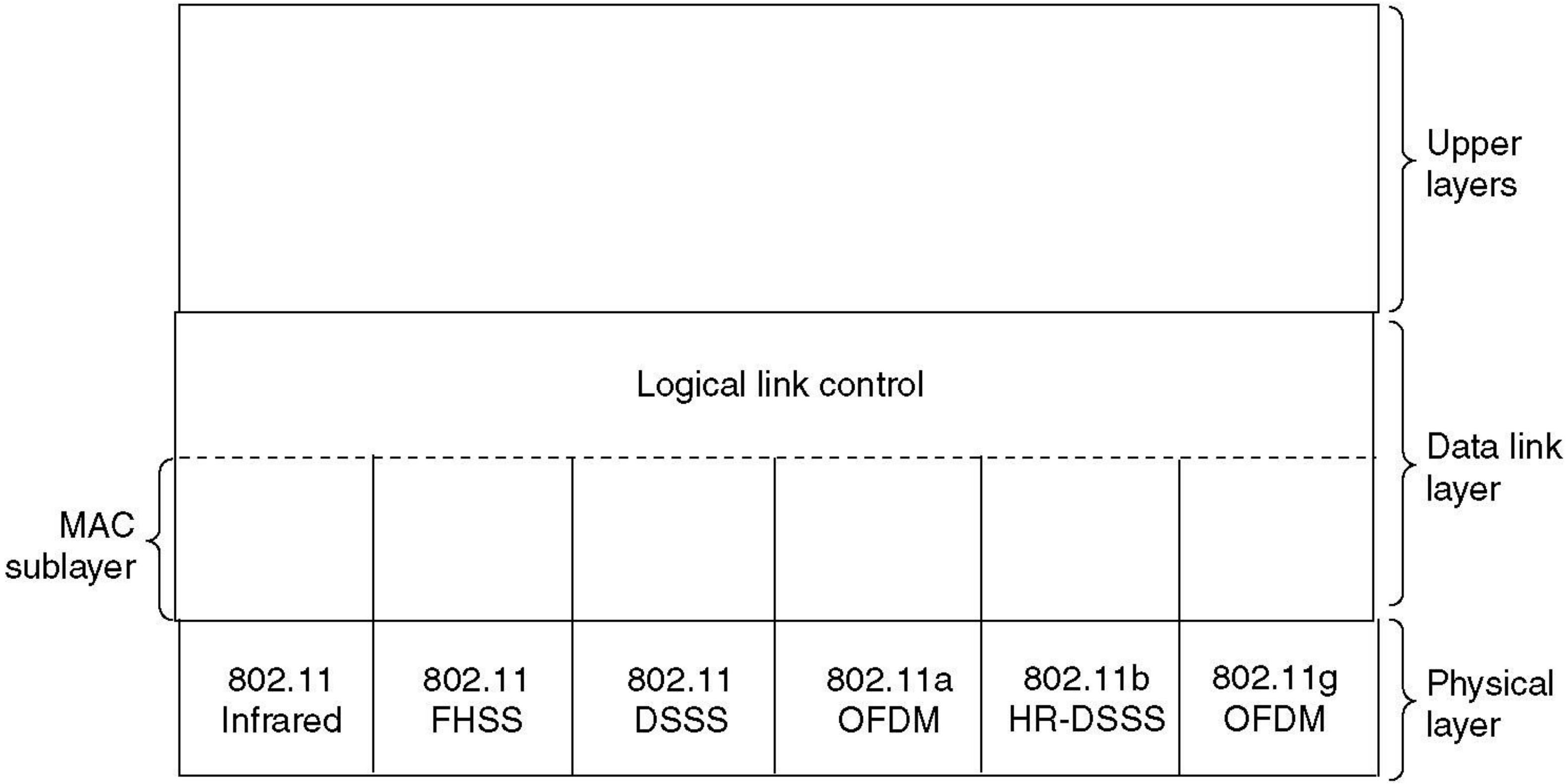


(a) Position of LLC. (b) Protocol formats.

Wireless LANs

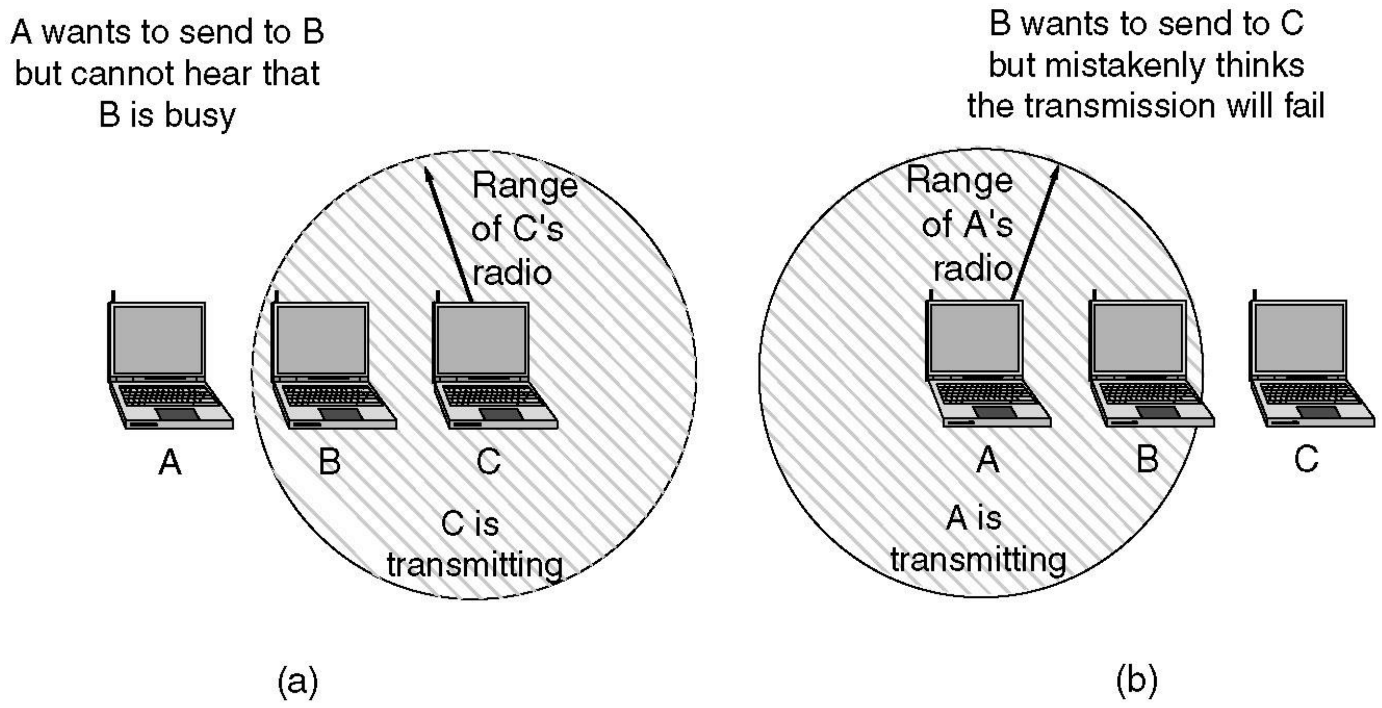
- The 802.11 Protocol Stack
- The 802.11 Physical Layer
- The 802.11 MAC Sublayer Protocol
- The 802.11 Frame Structure
- Services

The 802.11 Protocol Stack



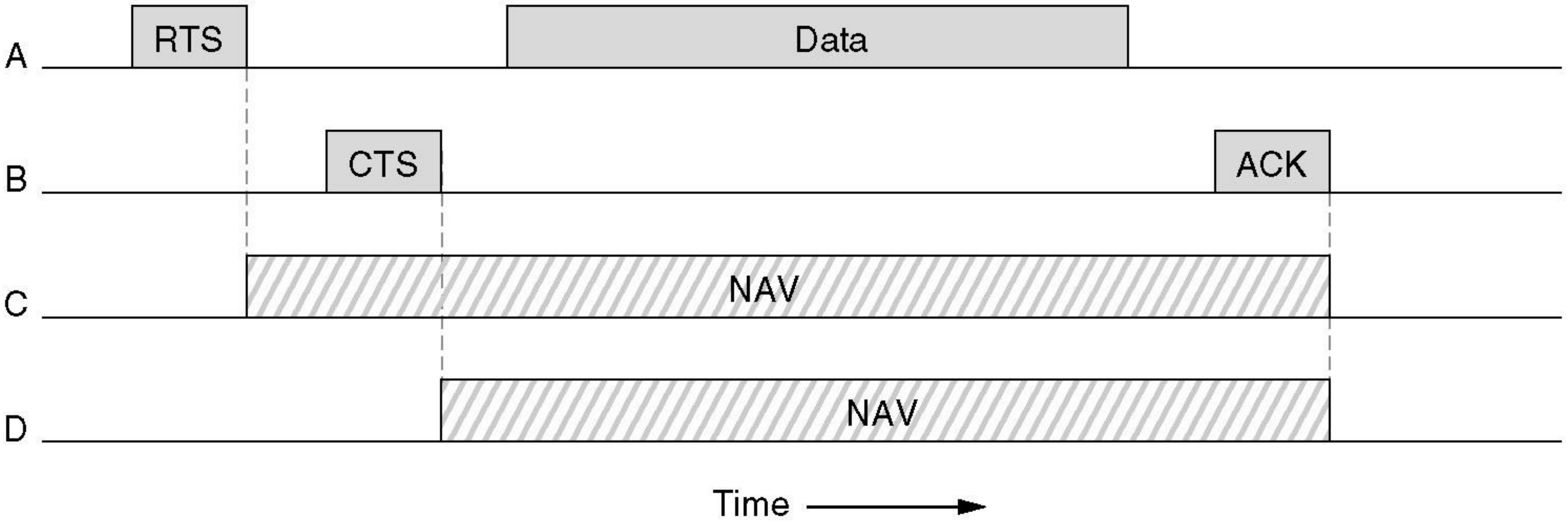
Part of the 802.11 protocol stack.

The 802.11 MAC Sublayer Protocol



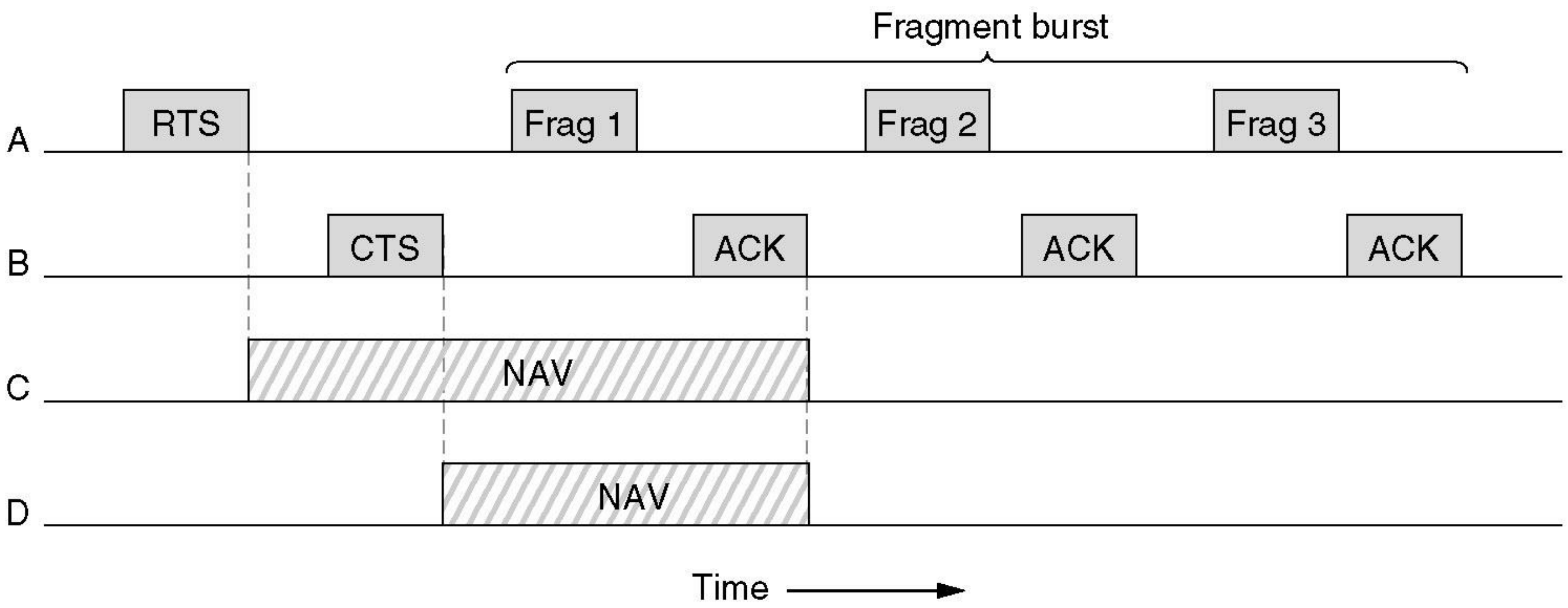
(a) The hidden station problem.
(b) The exposed station problem.

The 802.11 MAC Sublayer Protocol (2)



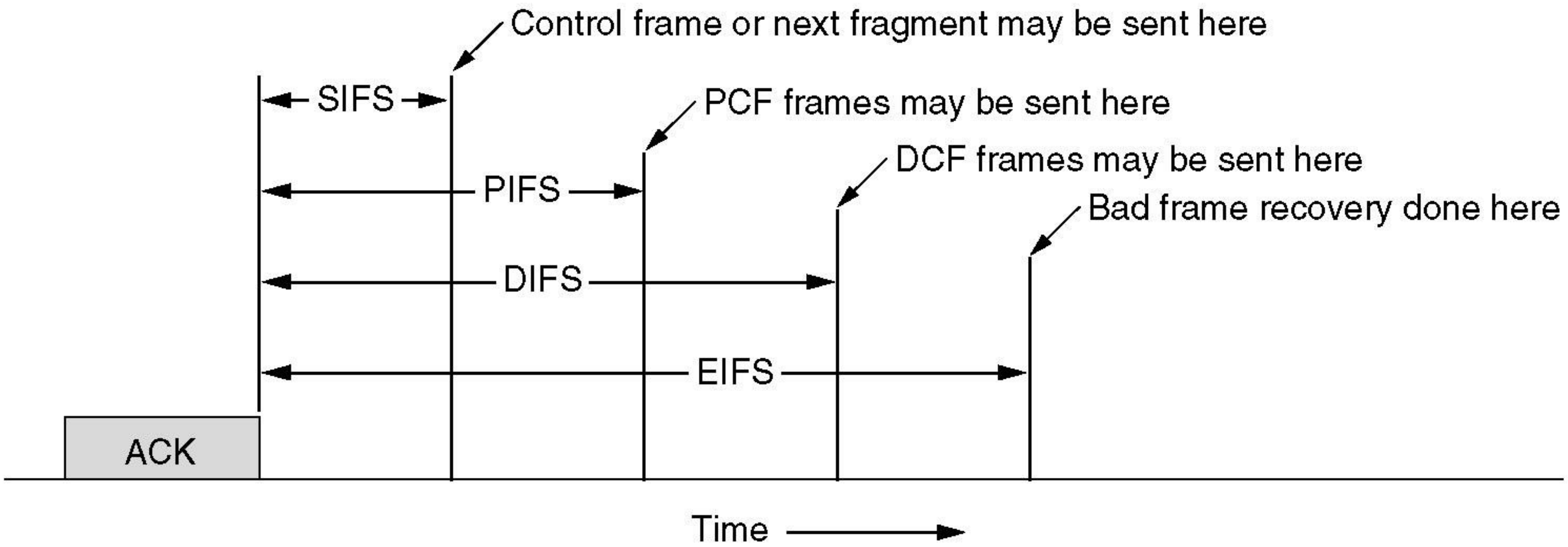
The use of virtual channel sensing using CSMA/CA.

The 802.11 MAC Sublayer Protocol (3)



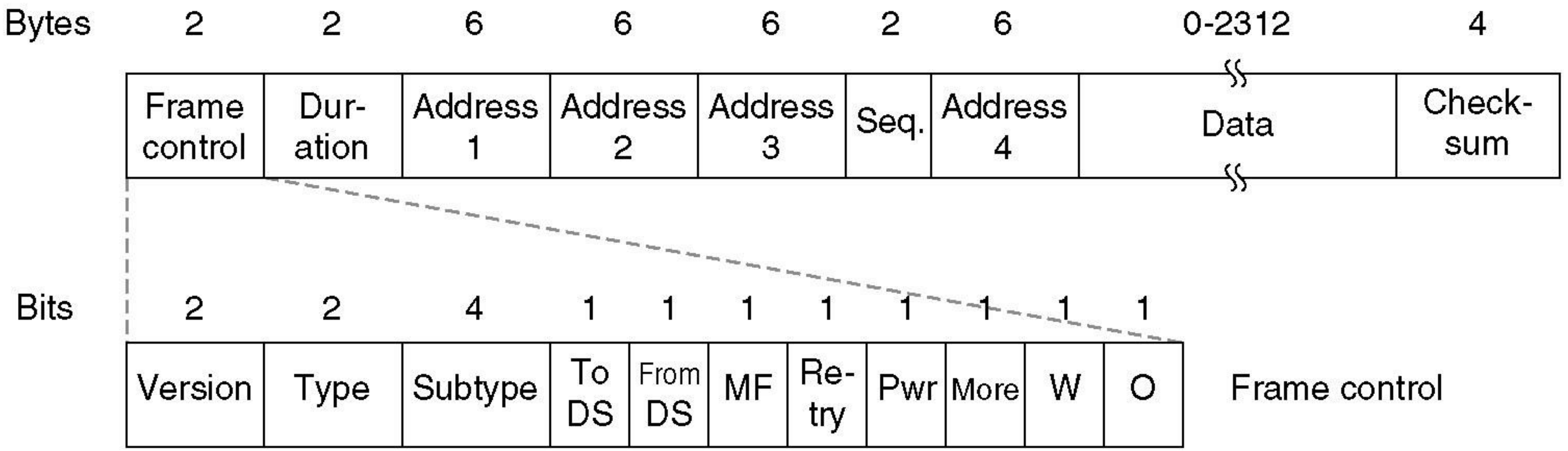
A fragment burst.

The 802.11 MAC Sublayer Protocol (4)



Interframe spacing in 802.11.

The 802.11 Frame Structure



The 802.11 data frame.

802.11 Services

Distribution Services

- Association
- Disassociation
- Reassociation
- Distribution
- Integration

802.11 Services

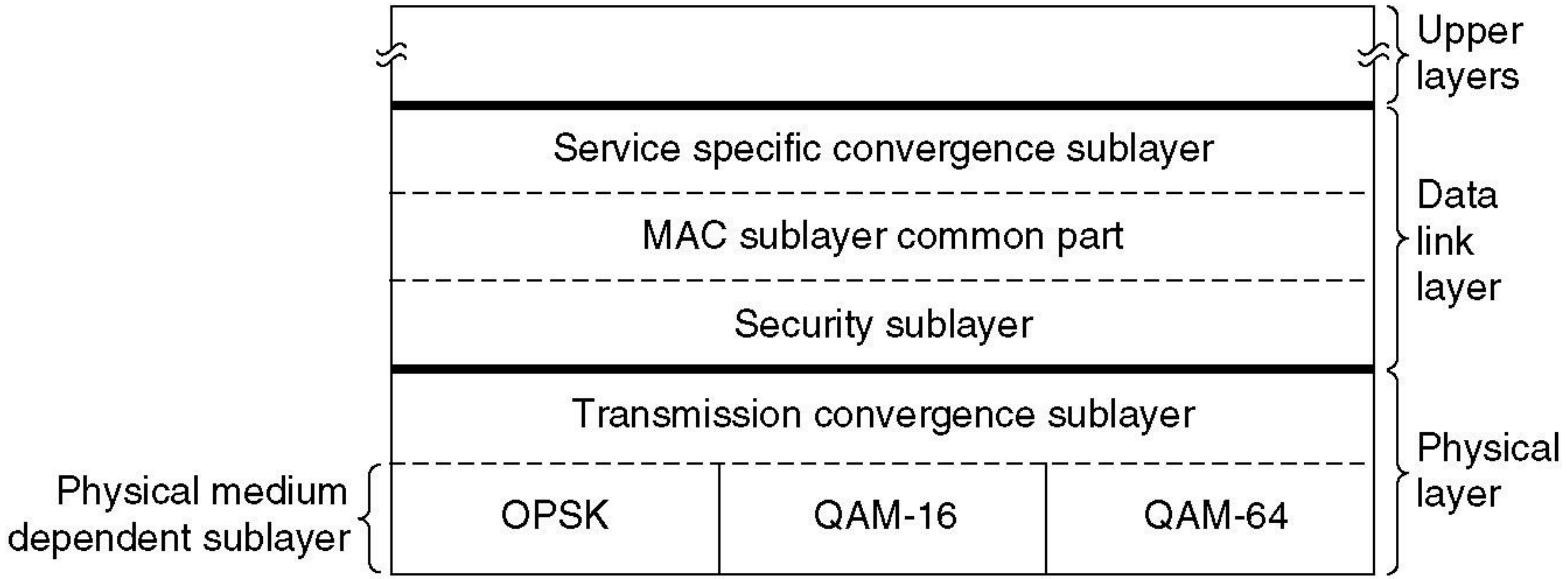
Intracell Services

- Authentication
- Deauthentication
- Privacy
- Data Delivery

Broadband Wireless

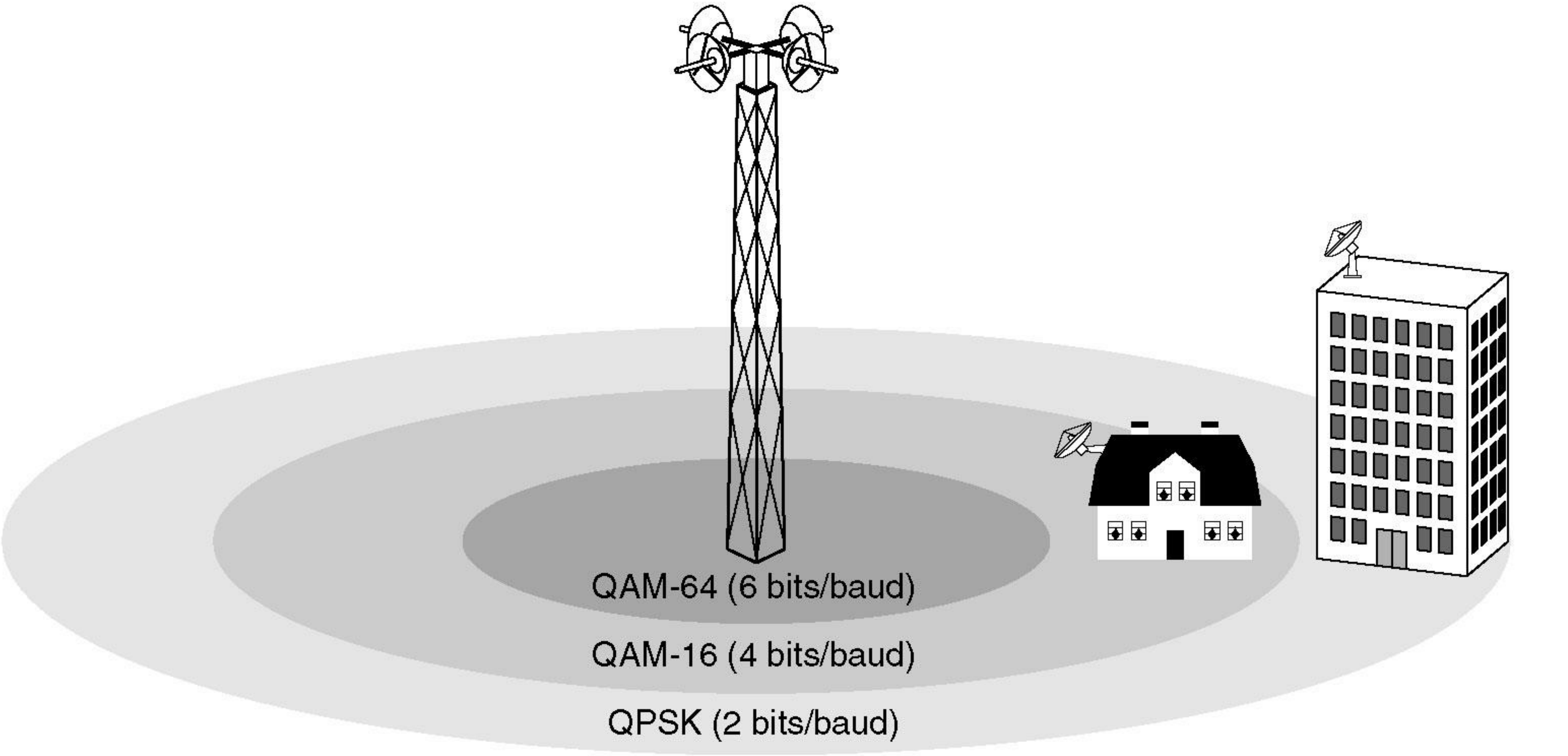
- Comparison of 802.11 and 802.16
- The 802.16 Protocol Stack
- The 802.16 Physical Layer
- The 802.16 MAC Sublayer Protocol
- The 802.16 Frame Structure

The 802.16 Protocol Stack



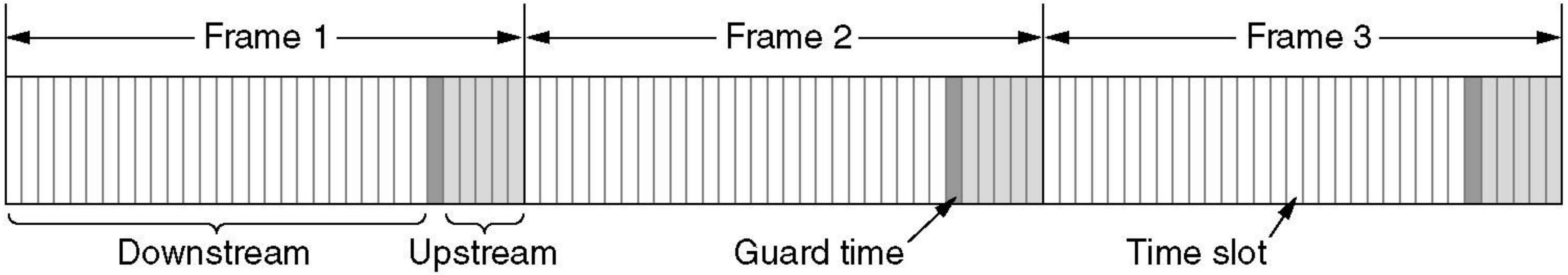
The 802.16 Protocol Stack.

The 802.16 Physical Layer



The 802.16 transmission environment.

The 802.16 Physical Layer (2)



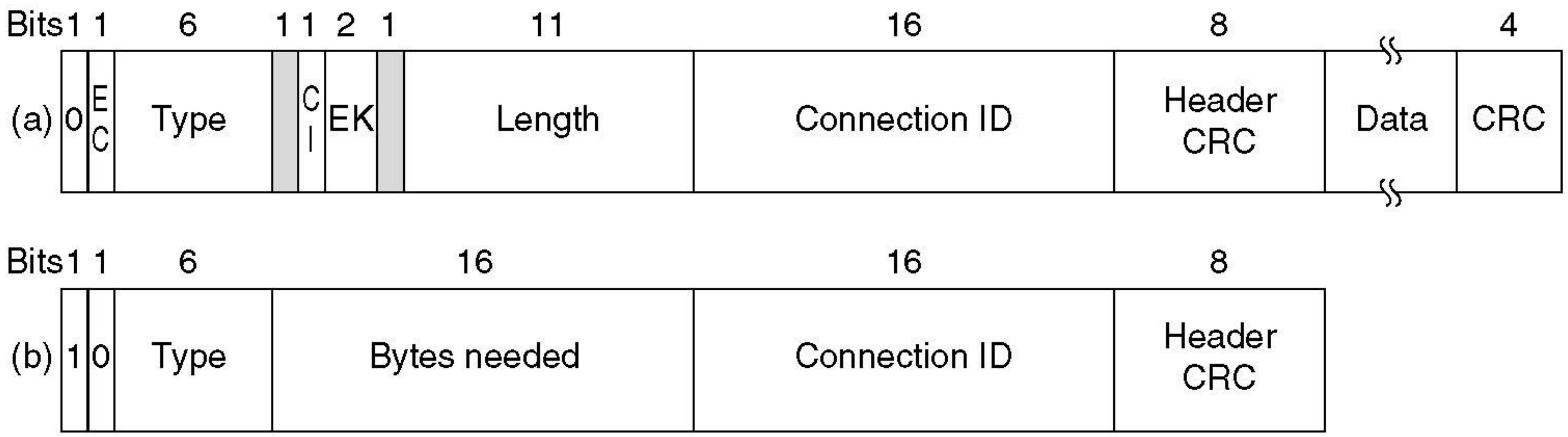
Frames and time slots for time division duplexing.

The 802.16 MAC Sublayer Protocol

Service Classes

- Constant bit rate service
- Real-time variable bit rate service
- Non-real-time variable bit rate service
- Best efforts service

The 802.16 Frame Structure

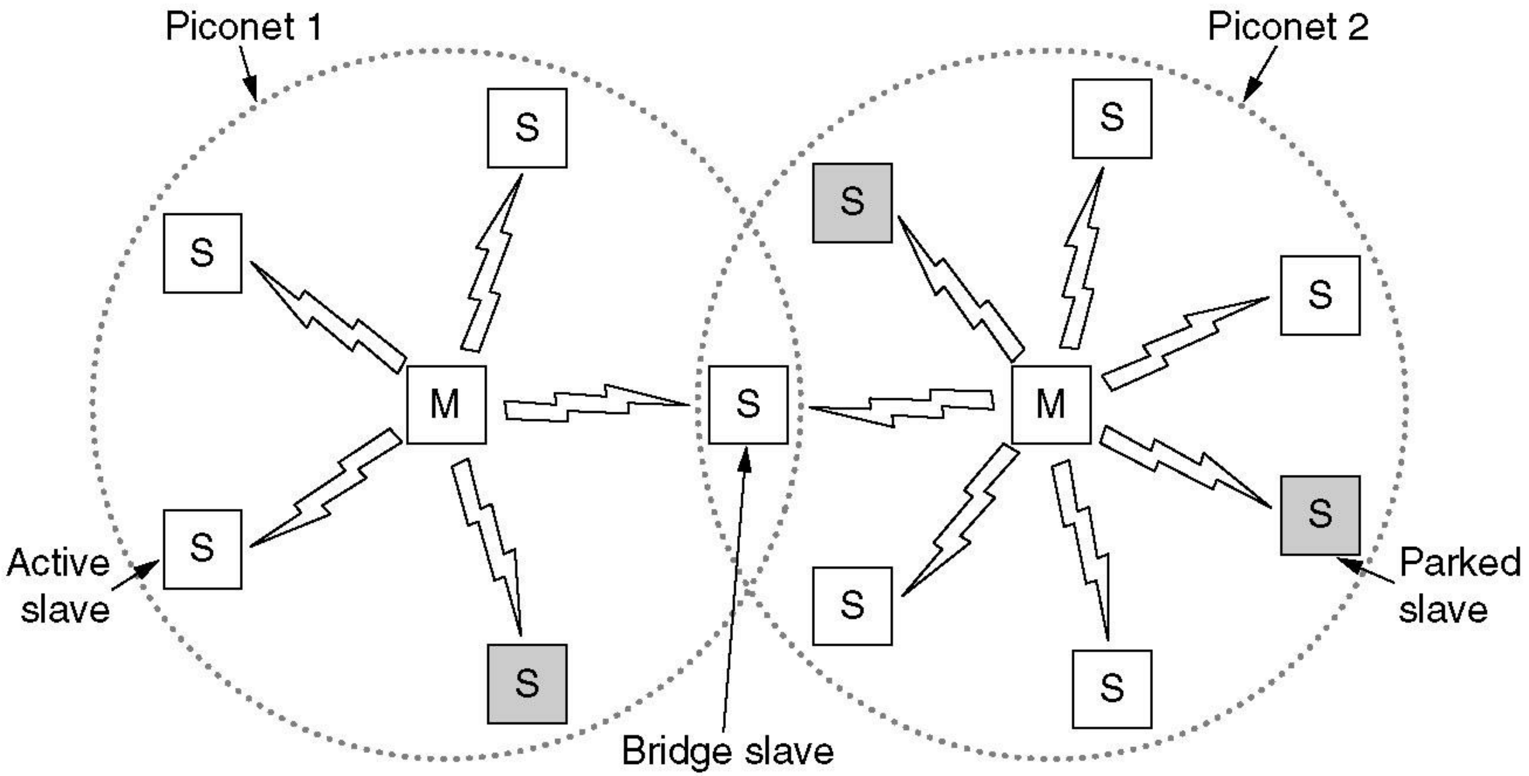


(a) A generic frame. (b) A bandwidth request frame.

Bluetooth

- Bluetooth Architecture
- Bluetooth Applications
- The Bluetooth Protocol Stack
- The Bluetooth Radio Layer
- The Bluetooth Baseband Layer
- The Bluetooth L2CAP Layer
- The Bluetooth Frame Structure

Bluetooth Architecture



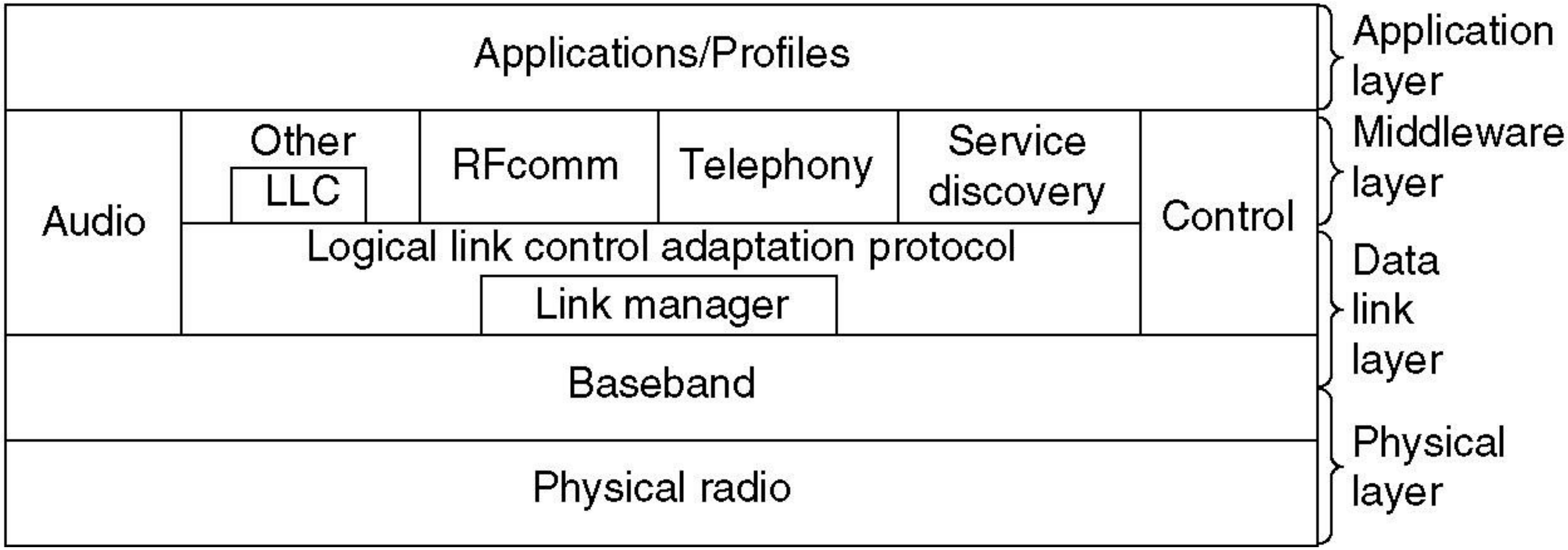
Two piconets can be connected to form a scatternet.

Bluetooth Applications

Name	Description
Generic access	Procedures for link management
Service discovery	Protocol for discovering offered services
Serial port	Replacement for a serial port cable
Generic object exchange	Defines client-server relationship for object movement
LAN access	Protocol between a mobile computer and a fixed LAN
Dial-up networking	Allows a notebook computer to call via a mobile phone
Fax	Allows a mobile fax machine to talk to a mobile phone
Cordless telephony	Connects a handset and its local base station
Intercom	Digital walkie-talkie
Headset	Intended for hands-free voice communication
Object push	Provides a way to exchange simple objects
File transfer	Provides a more general file transfer facility
Synchronization	Permits a PDA to synchronize with another computer

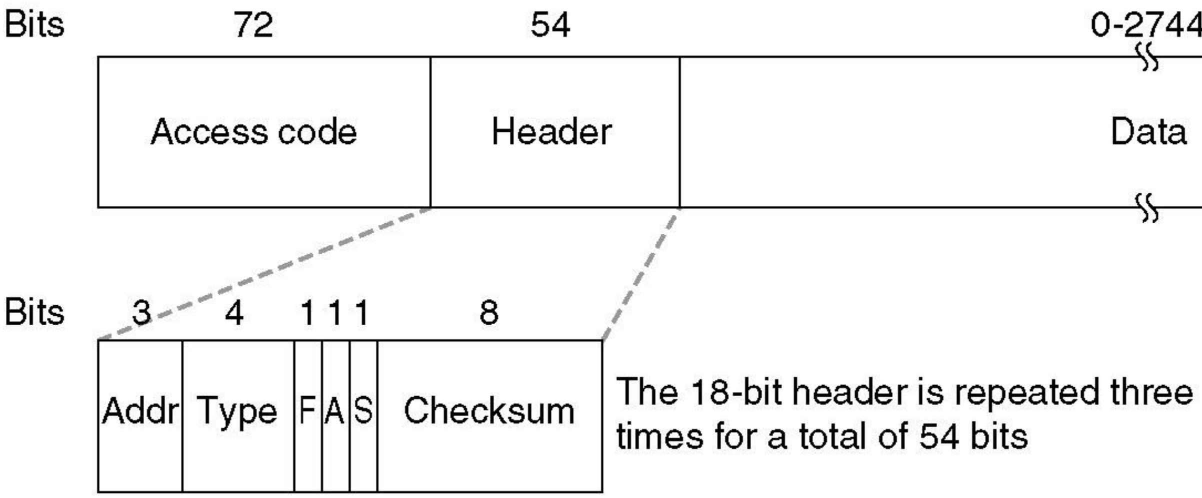
The Bluetooth profiles.

The Bluetooth Protocol Stack



The 802.15 version of the Bluetooth protocol architecture.

The Bluetooth Frame Structure

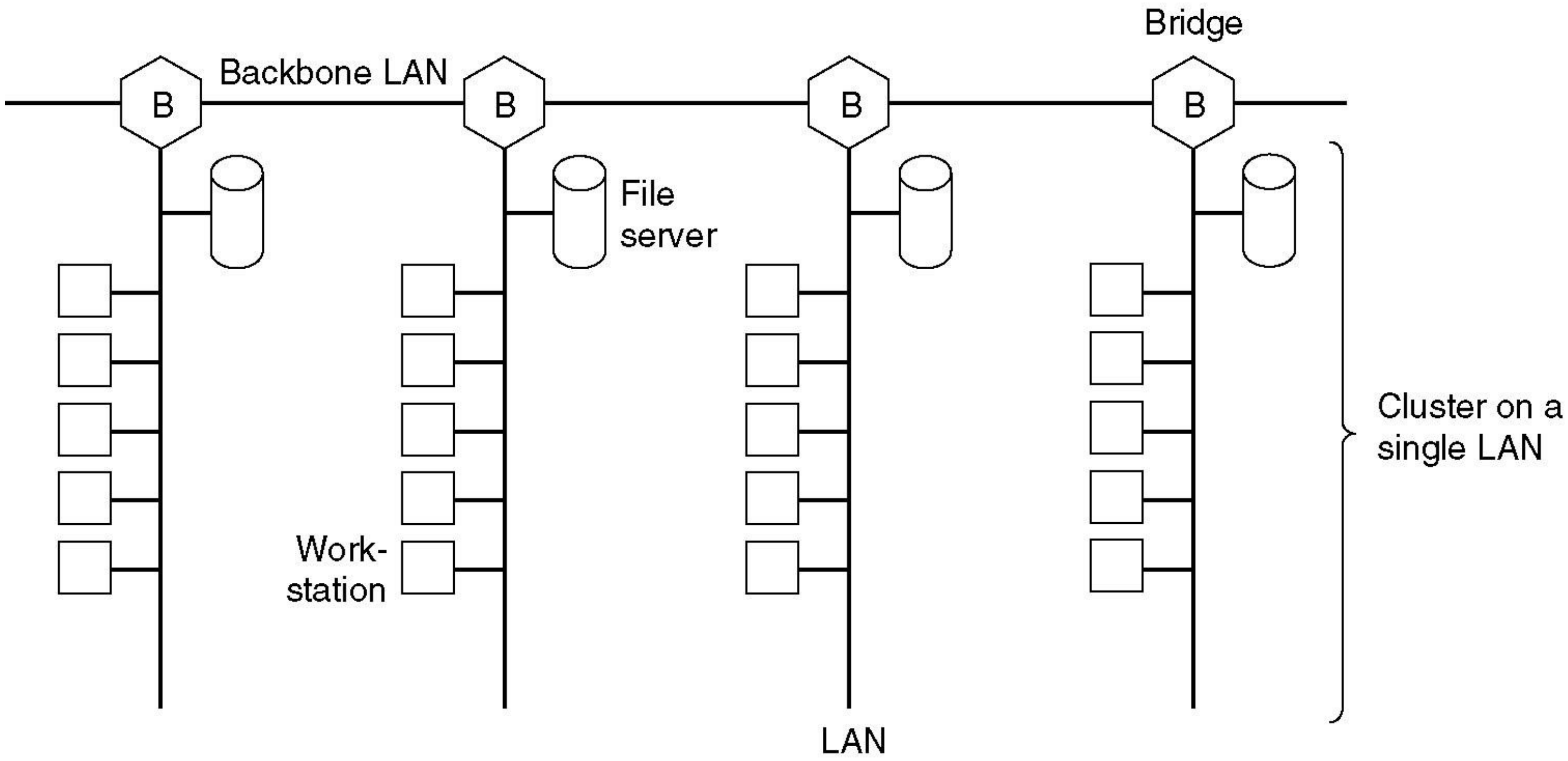


A typical Bluetooth data frame.

Data Link Layer Switching

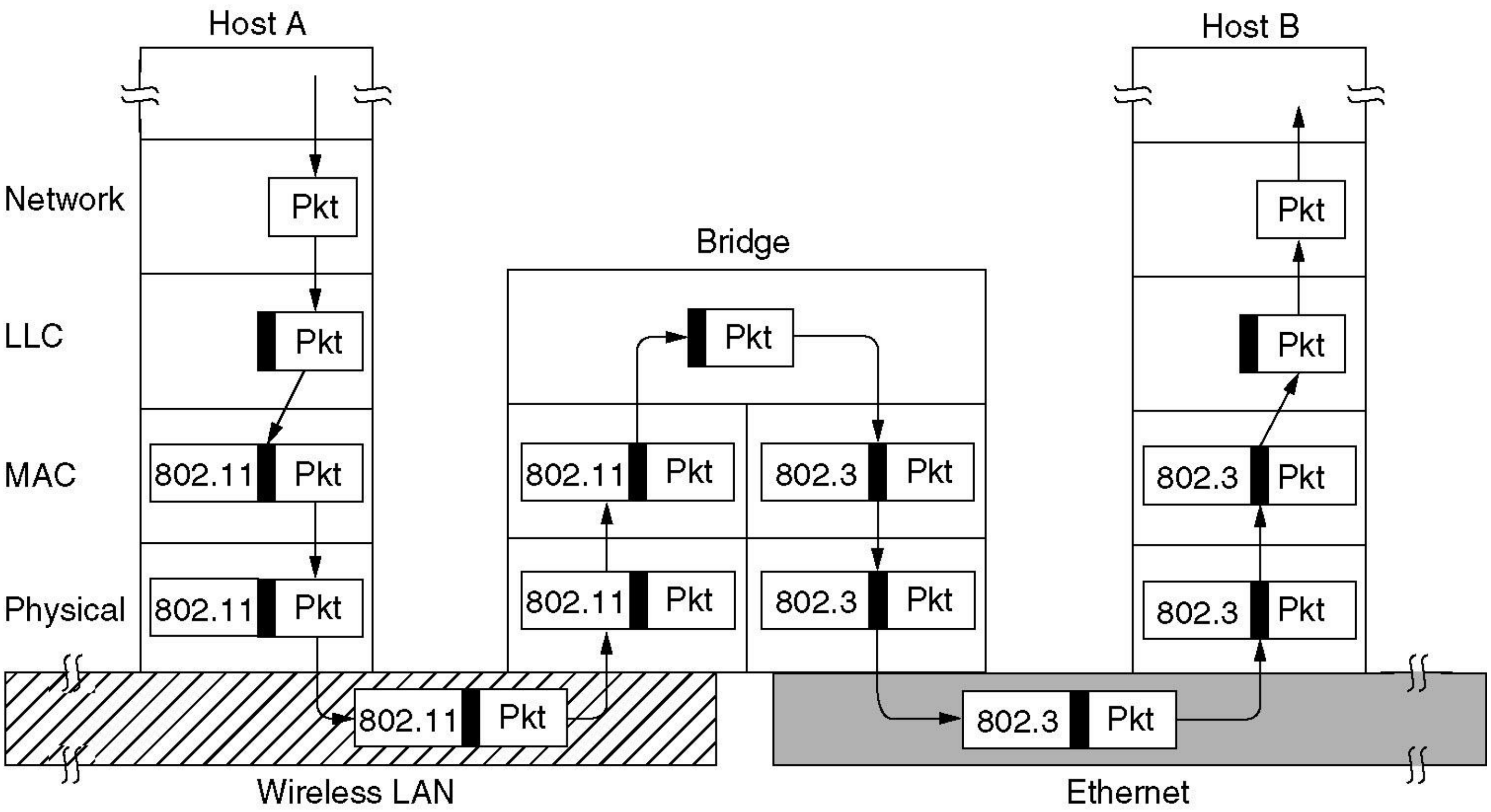
- Bridges from 802.x to 802.y
- Local Internetworking
- Spanning Tree Bridges
- Remote Bridges
- Repeaters, Hubs, Bridges, Switches, Routers, Gateways
- Virtual LANs

Data Link Layer Switching



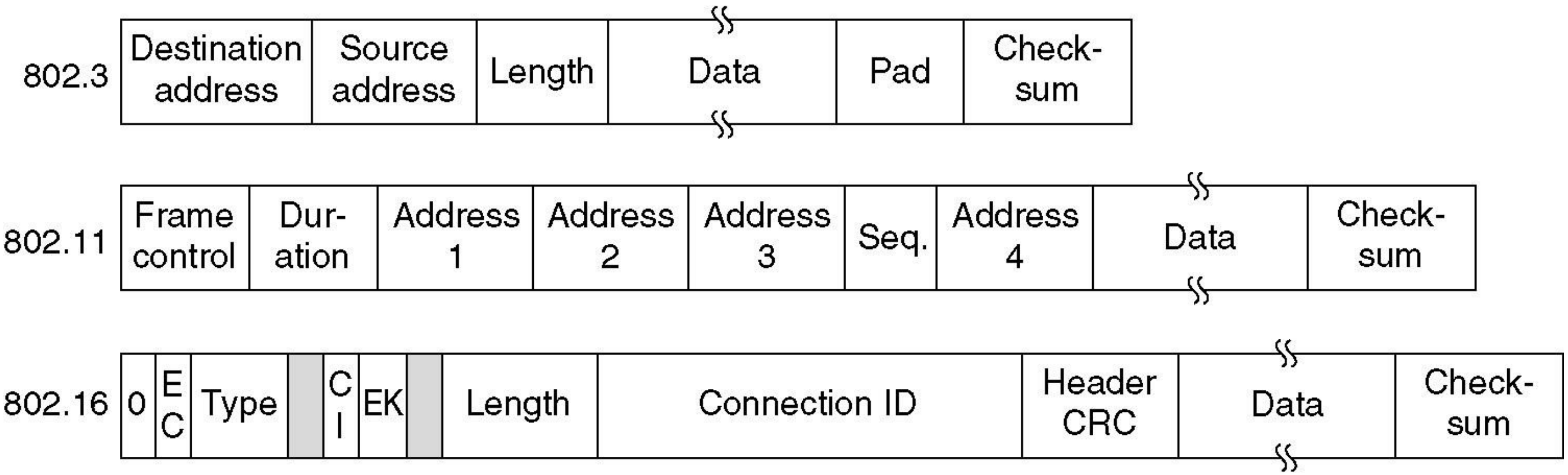
Multiple LANs connected by a backbone to handle a total load higher than the capacity of a single LAN.

Bridges from 802.x to 802.y



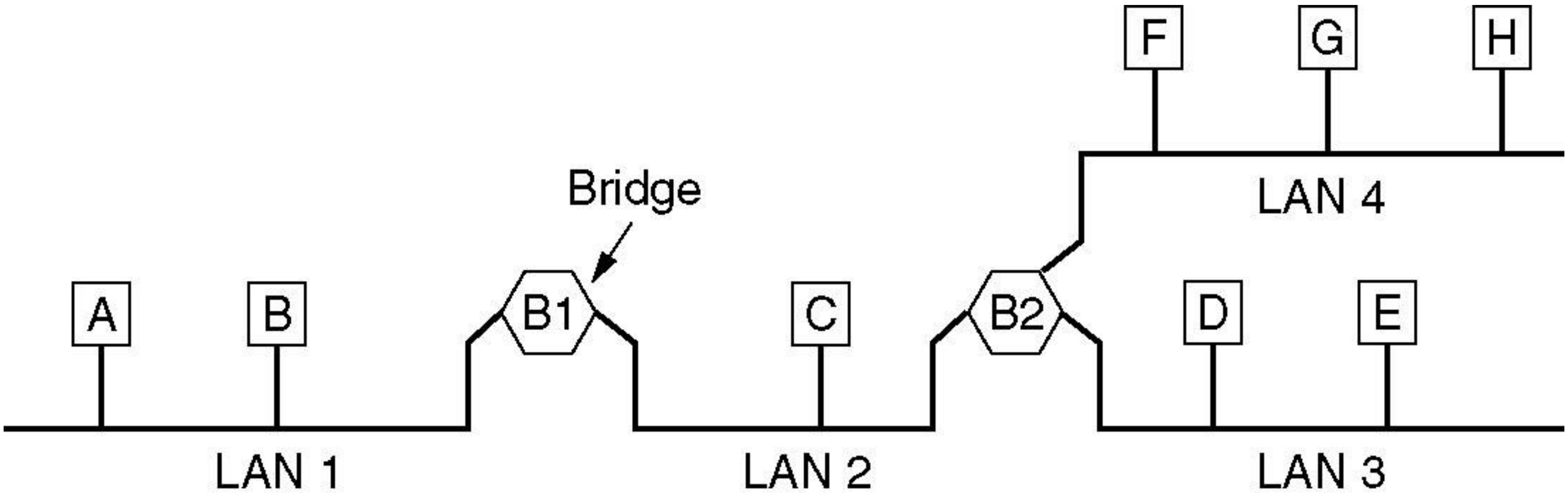
Operation of a LAN bridge from 802.11 to 802.3.

Bridges from 802.x to 802.y (2)



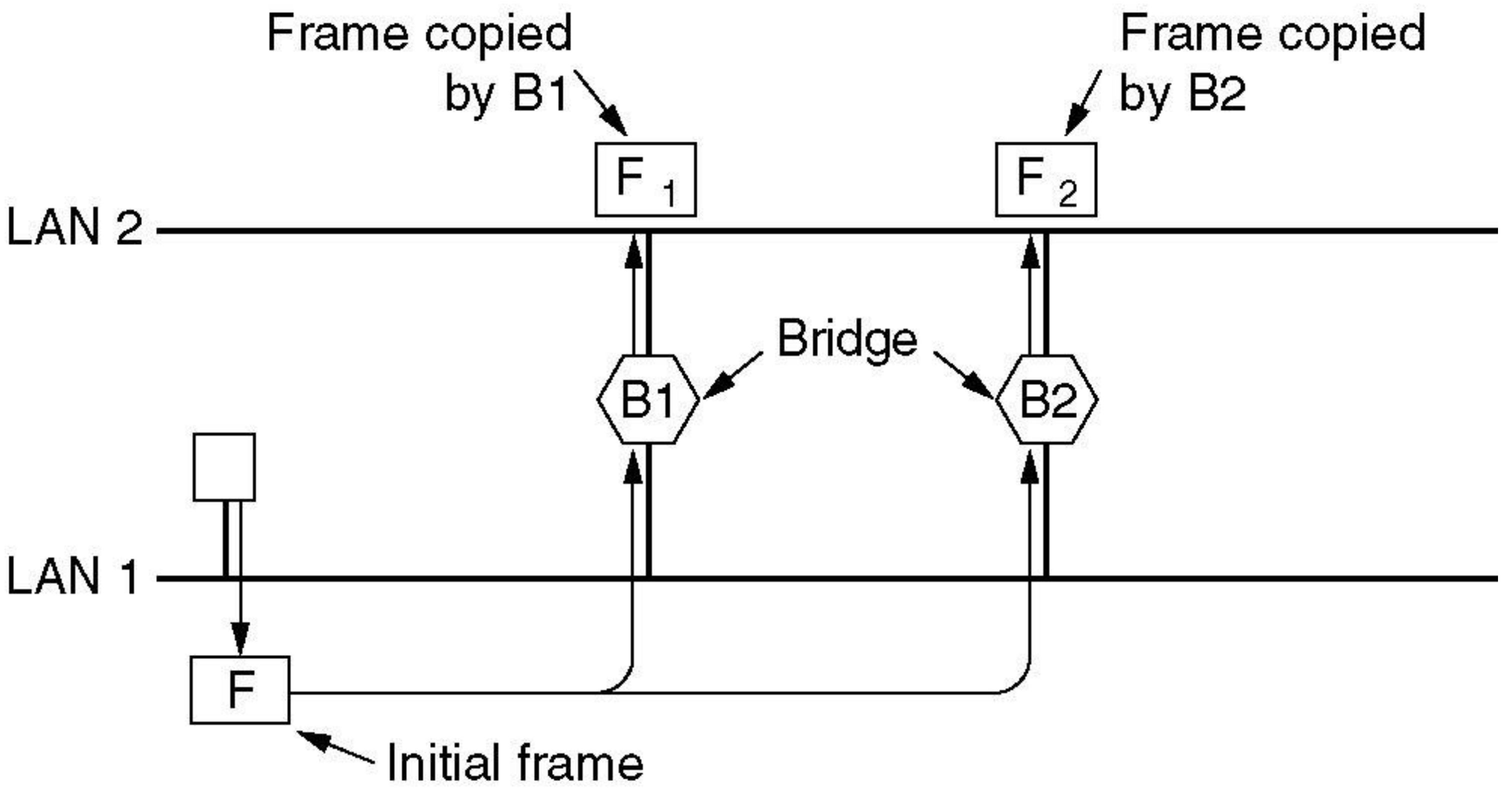
The IEEE 802 frame formats. The drawing is not to scale.

Local Internetworking



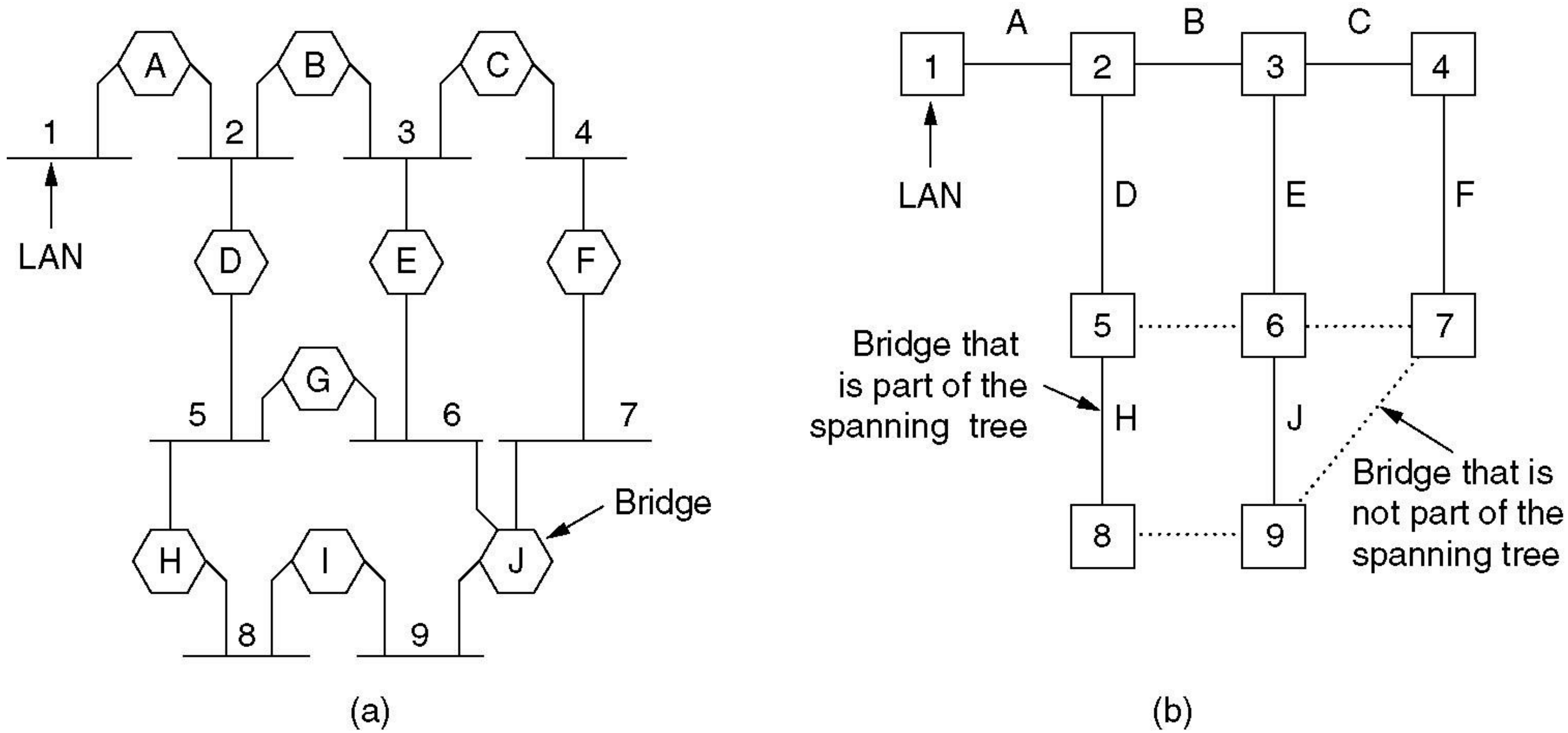
A configuration with four LANs and two bridges.

Spanning Tree Bridges



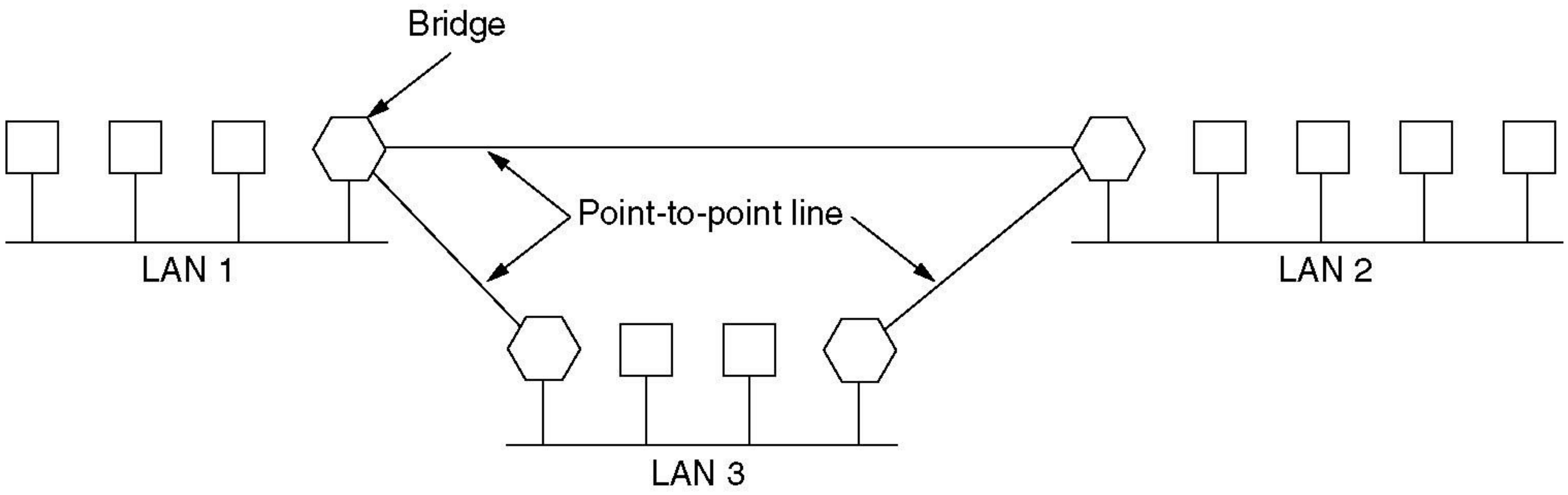
Two parallel transparent bridges.

Spanning Tree Bridges (2)



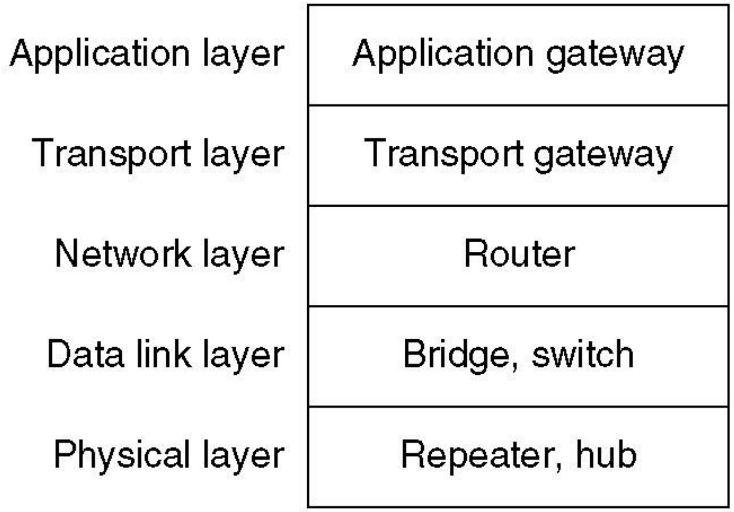
(a) Interconnected LANs. (b) A spanning tree covering the LANs. The dotted lines are not part of the spanning tree.

Remote Bridges

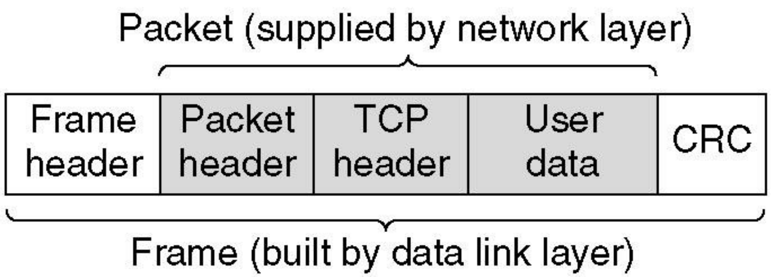


Remote bridges can be used to interconnect distant LANs.

Repeaters, Hubs, Bridges, Switches, Routers and Gateways



(a)

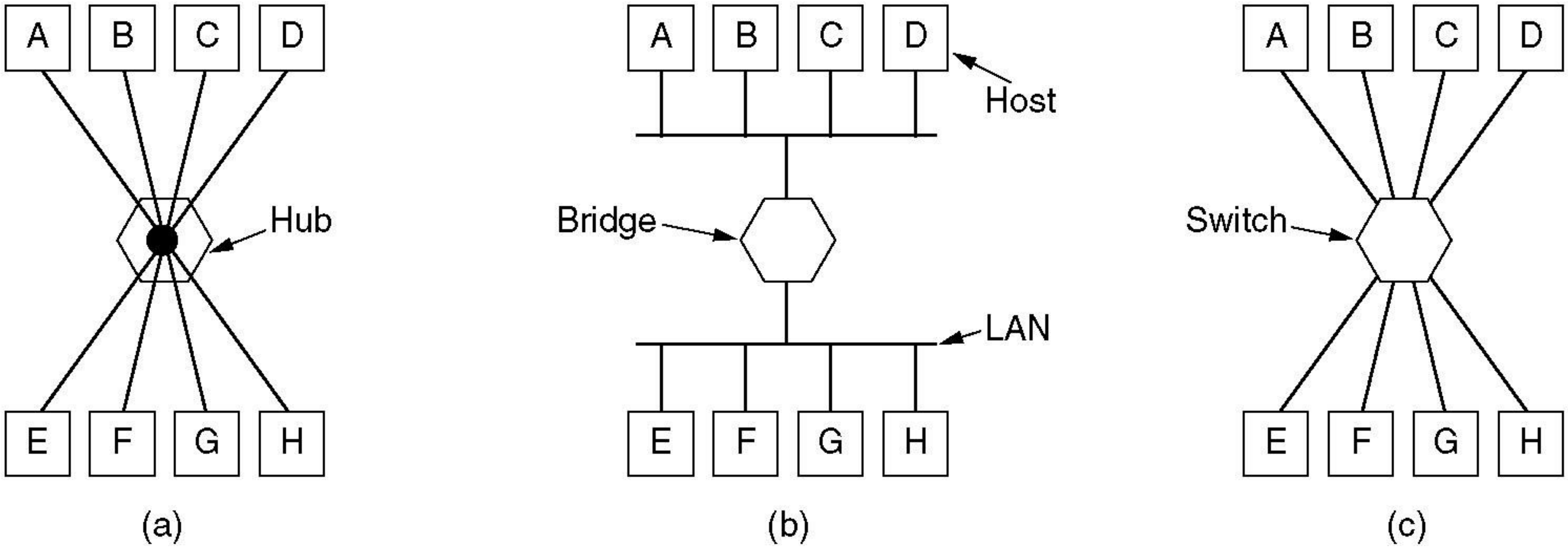


(b)

(a) Which device is in which layer.

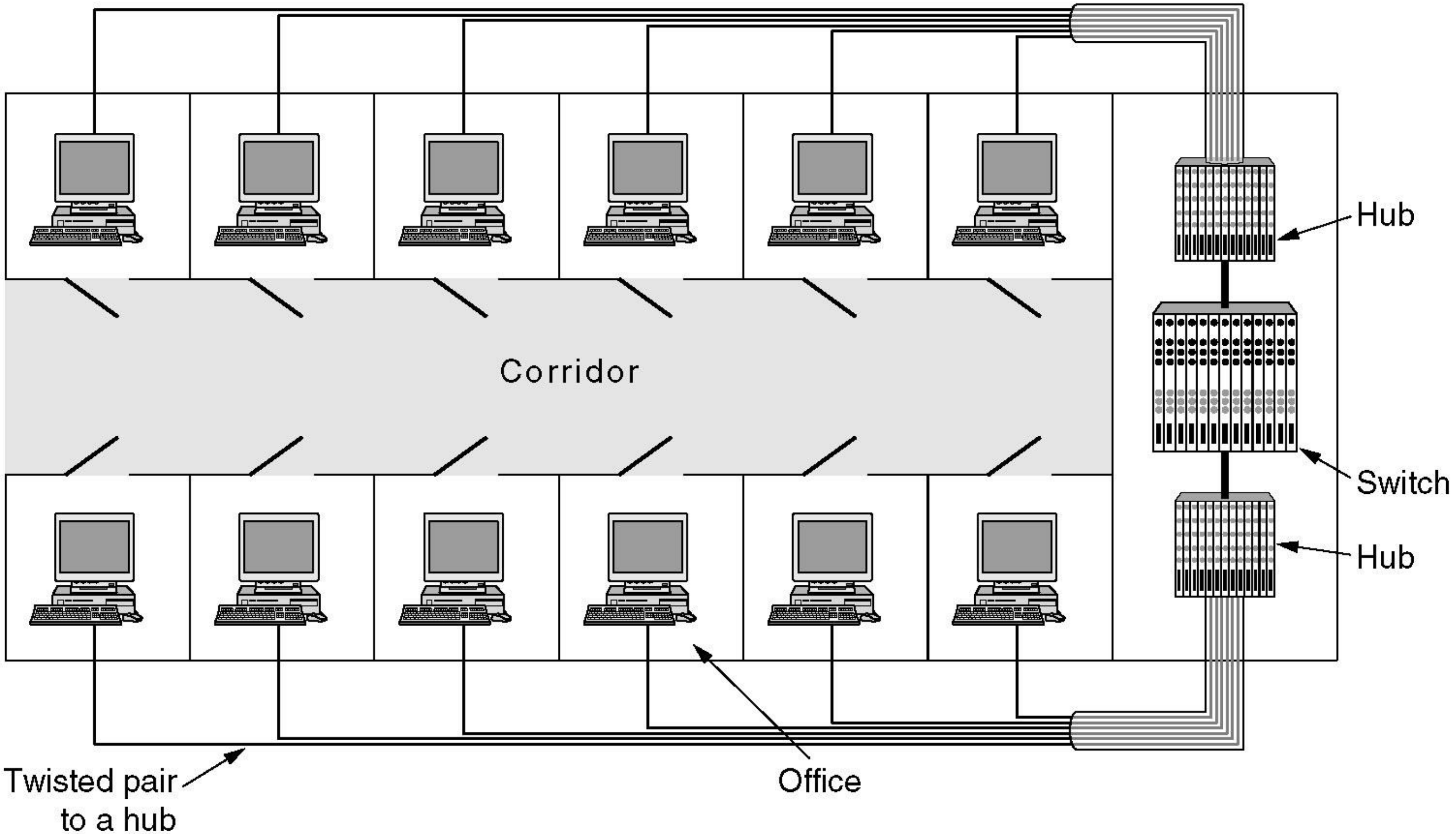
(b) Frames, packets, and headers.

Repeaters, Hubs, Bridges, Switches, Routers and Gateways (2)



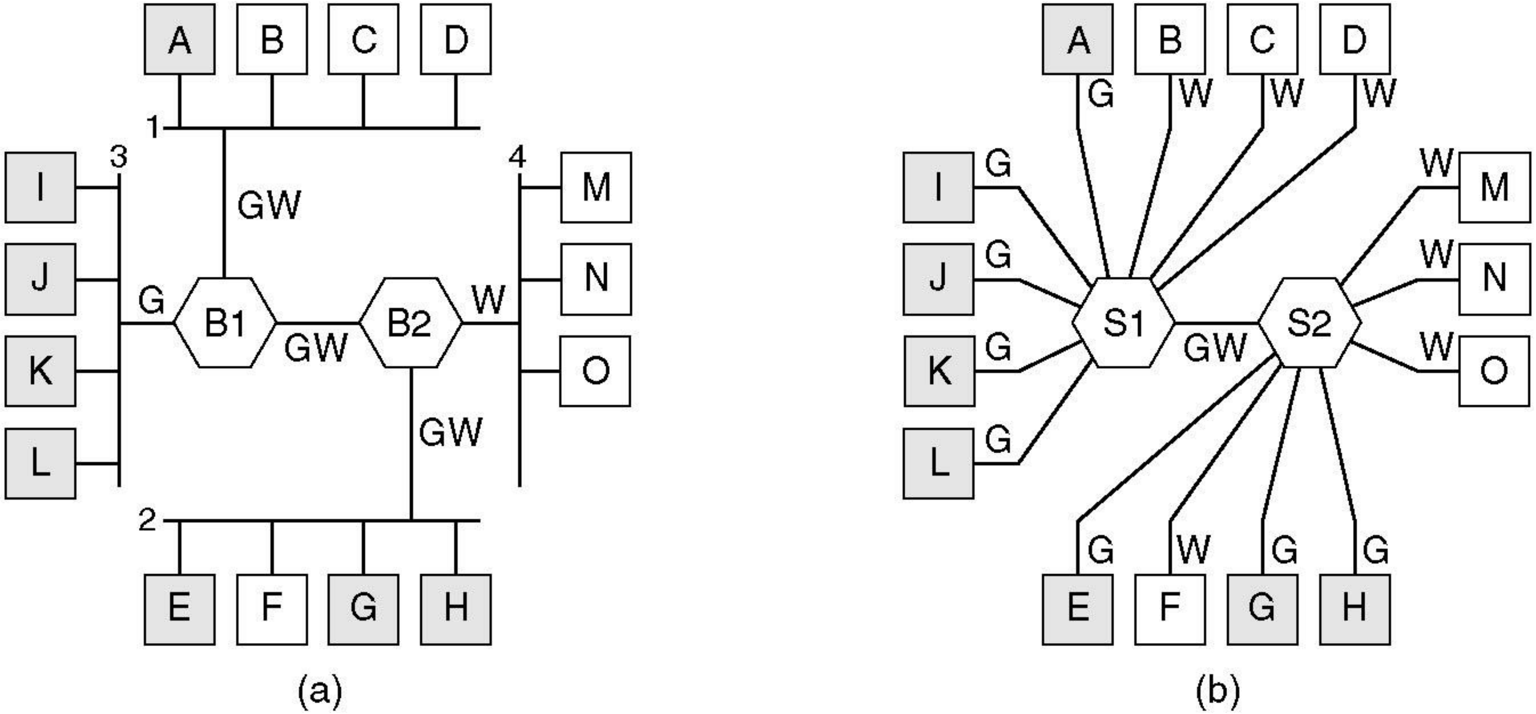
(a) A hub. (b) A bridge. (c) a switch.

Virtual LANs



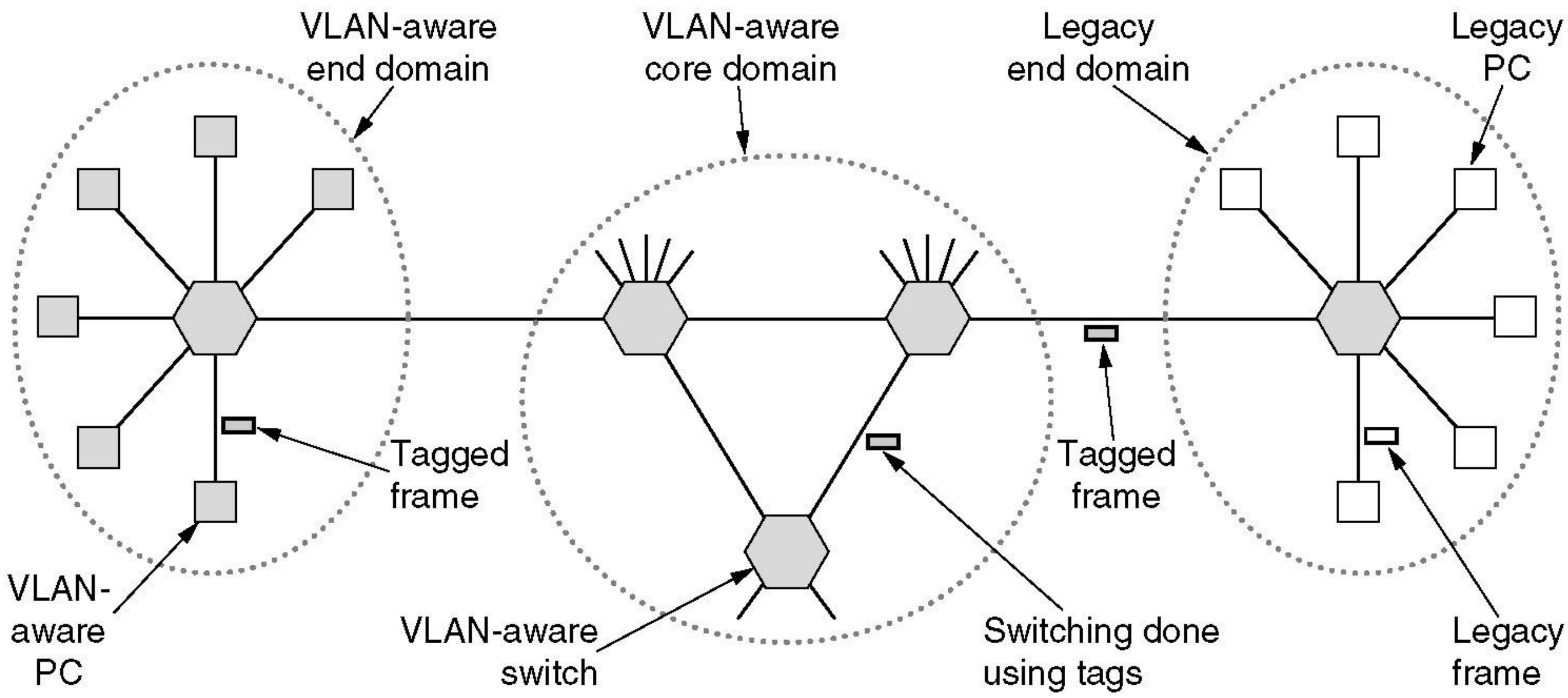
A building with centralized wiring using hubs and a switch.

Virtual LANs (2)



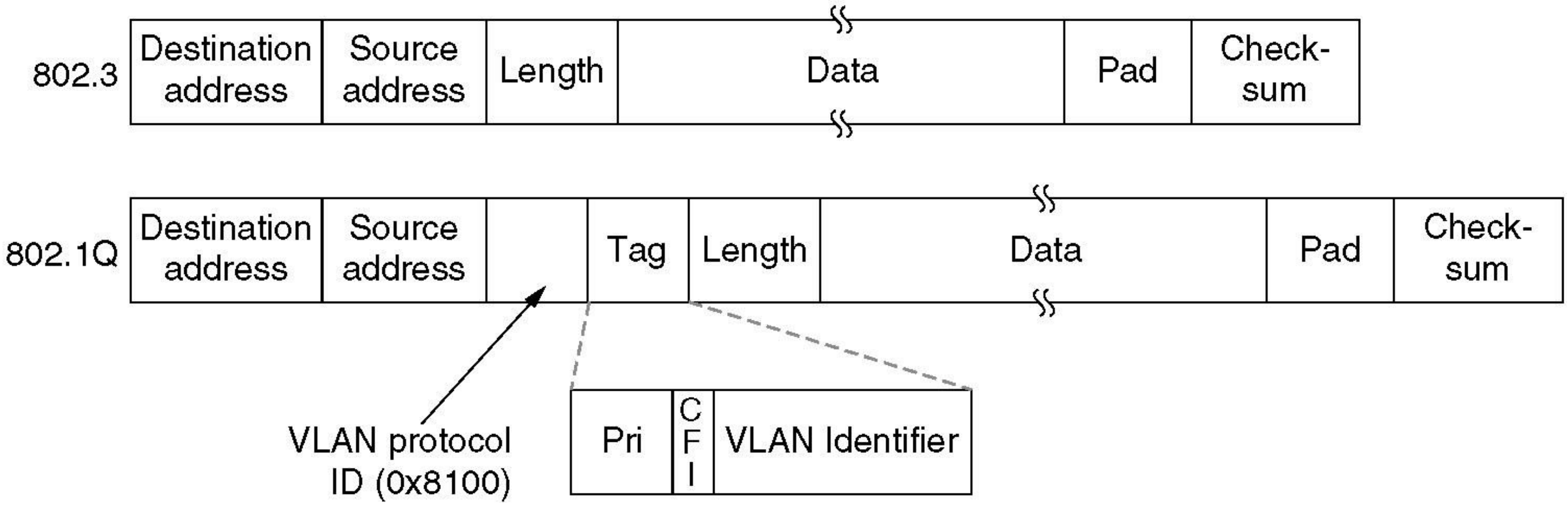
(a) Four physical LANs organized into two VLANs, gray and white, by two bridges. (b) The same 15 machines organized into two VLANs by switches.

The IEEE 802.1Q Standard



Transition from legacy Ethernet to VLAN-aware Ethernet. 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.

Summary

Method	Description
FDM	Dedicate a frequency band to each station
WDM	A dynamic FDM scheme for fiber
TDM	Dedicate a time slot to each station
Pure ALOHA	Unsynchronized transmission at any instant
Slotted ALOHA	Random transmission in well-defined time slots
1-persistent CSMA	Standard carrier sense multiple access
Nonpersistent CSMA	Random delay when channel is sensed busy
P-persistent CSMA	CSMA, but with a probability of p of persisting
CSMA/CD	CSMA, but abort on detecting a collision
Bit map	Round robin scheduling using a bit map
Binary countdown	Highest numbered ready station goes next
Tree walk	Reduced contention by selective enabling
MACA, MACAW	Wireless LAN protocols
Ethernet	CSMA/CD with binary exponential backoff
FHSS	Frequency hopping spread spectrum
DSSS	Direct sequence spread spectrum
CSMA/CA	Carrier sense multiple access with collision avoidance

Channel allocation methods and systems for a common channel.