CSMC 417

Computer Networks

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Set 5

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Chapter 4

The Medium Access Control Sublayer

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MAC
Medium Access Control Sublayer

- Local Area Networks
  - Broadcast Channels
  - Multi-access Channels
  - Random Access Channels

What is it all about?

- Consider an audioconference where
  - if one person speaks, all can hear
  - if more than one person speaks at the same time, both voices are garbled
- How should participants coordinate actions so that
  - the number of messages exchanged per second is maximized
  - time spent waiting for a chance to speak is minimized
- This is the *multiple access* problem

Some simple solutions

- Use a moderator
  - a speaker must wait for moderator to call on him or her, even if no one else wants to speak
  - what if the moderator's connection breaks?
- Distributed solution
  - speak if no one else is speaking
  - but if two speakers are waiting for a third to finish, guarantee collision
- Designing good schemes is surprisingly hard!

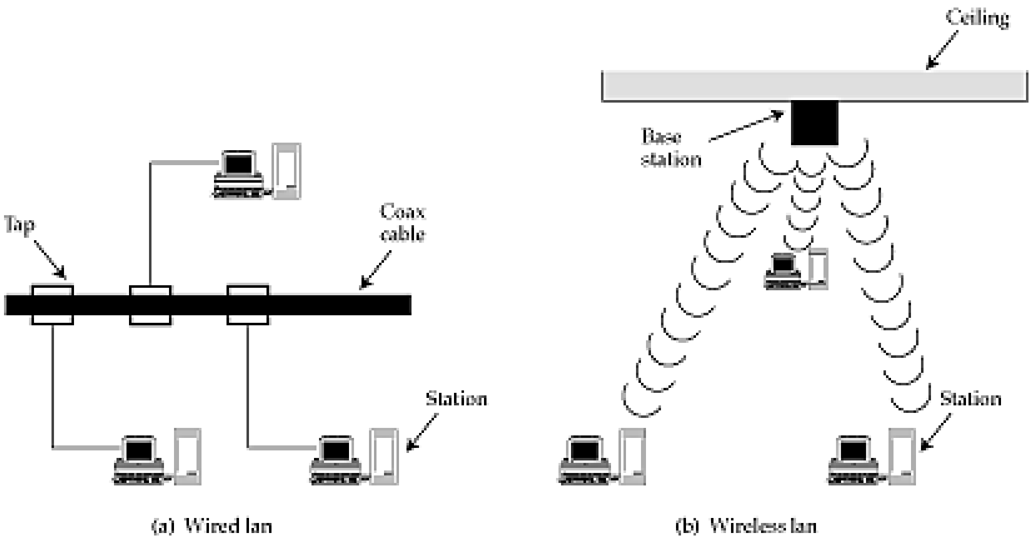
Outline

- Contexts for the problem
- Choices and constraints
- Performance metrics
- Base technologies
- Centralized schemes
- Distributed schemes

Contexts for the multiple access problem

- Broadcast transmission medium
  - message from any transmitter is received by all receivers
- Colliding messages are garbled
- Goal
  - maximize message throughput
  - minimize mean waiting time
- Shows up in five main contexts

Contexts


Tap
Coax cable
Station
Ceiling
Base station
Station

(a) Wired lan

(b) Wireless lan

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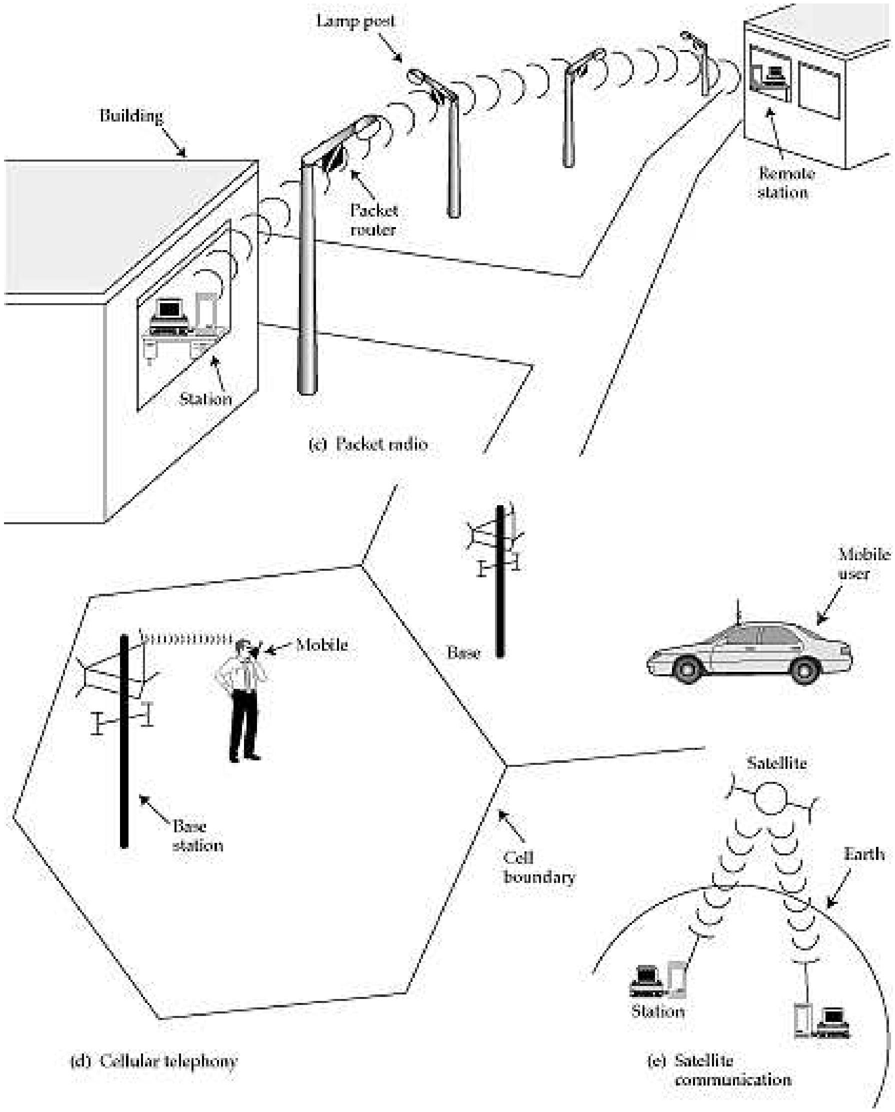
Contexts


Lamp post
Building
Packet router
Remote station
Station
(c) Packet radio
Mobile user
Mobile
Base
Base station
Cell boundary
Satellite
Earth
Station
(d) Cellular telephony
(e) Satellite communication

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Solving the problem

- First, choose a base technology
  - to isolate traffic from different stations
  - can be in time domain or frequency domain
- Then, choose how to allocate a limited number of transmission resources to a larger set of contending users

Choices

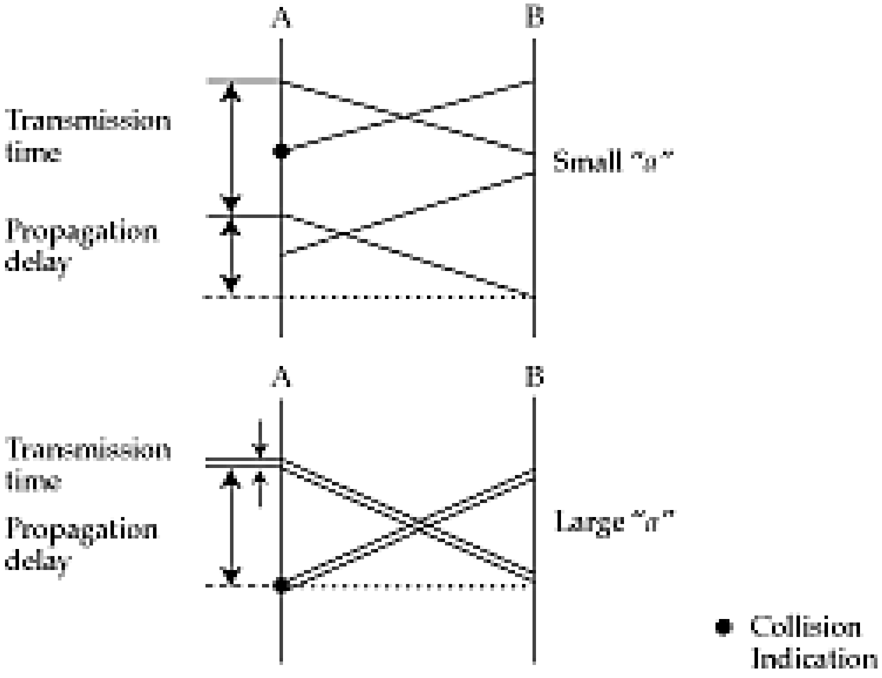
- Centralized vs. distributed design
  - is there a moderator or not?
  - in a centralized solution one of the stations is a master and the others are slaves
    - master->slave = downlink
    - slave->master = uplink
  - in a distributed solution, all stations are peers
- Circuit-mode vs. packet-mode
  - do stations send steady streams or bursts of packets?
  - with streams, doesn't make sense to contend for every packet
  - allocate resources to streams
  - with packets, makes sense to contend for every packet to avoid wasting bandwidth

Constraints

- Spectrum scarcity
  - radio spectrum is hard to come by
  - only a few frequencies available for long-distance communication
  - multiple access schemes must be careful not to waste bandwidth
- Radio link properties
  - radio links are error prone
    - fading
    - multipath interference
  - hidden terminals
    - transmitter heard only by a subset of receivers
  - capture
    - on collision, station with higher power overpowers the other
    - lower powered station may never get a chance to be heard

The parameter ‘a’

- The number of packets sent by a source before the farthest station receives the first bit


A
B
Transmission time
Propagation delay
Small “a”
A
B
Transmission time
Propagation delay
Large “a”
● Collision Indication

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Performance metrics

- Normalized throughput
  - fraction of link capacity used to carry non-retransmitted packets
  - example
    - with no collisions, 1000 packets/sec
    - with a particular scheme and workload, 250 packets/sec
    - => *goodput = 0.25*
- Mean delay
  - amount of time a station has to wait before it successfully transmits a packet
    - depends on the load and the characteristics of the medium

Performance metrics

- Stability
  - with heavy load, is all the time spent on resolving contentions?
  - => unstable
  - with a stable algorithm, throughput does not decrease with offered load
  - if infinite number of uncontrolled stations share a link, then instability is guaranteed
  - but if sources reduce load when overload is detected, can achieve stability
- Fairness
  - no single definition
  - ‘no-starvation’: source eventually gets a chance to send
  - max-min fair share: will study later

Base technologies

- Isolates data from different sources
- Three basic choices
  - Frequency division multiple access (FDMA)
  - Time division multiple access (TDMA)
  - Code division multiple access (CDMA)

FDMA

- Simplest
- Best suited for analog links
- Each station has its own frequency band, separated by guard bands
- Receivers tune to the right frequency
- Number of frequencies is limited
  - reduce transmitter power; reuse frequencies in non-adjacent cells
  - example: voice channel = 30 KHz
  - 833 channels in 25 MHz band
  - with hexagonal cells, partition into 118 channels each
  - but with N cells in a city, can get 118N calls => win if N > 7

TDMA

- All stations transmit data on same frequency, but at different times
- Needs time synchronization
- Pros
  - users can be given different amounts of bandwidth
  - mobiles can use idle times to determine best base station
  - can switch off power when not transmitting
- Cons
  - synchronization overhead
  - greater problems with multipath interference on wireless links

CDMA

- Users separated both by time and frequency
- Send at a different frequency at each time slot (frequency hopping)
- Or, convert a single bit to a code (direct sequence)
  - receiver can decipher bit by inverse process
- Pros
  - hard to spy
  - immune from narrowband noise
  - no need for all stations to synchronize
  - no hard limit on capacity of a cell
  - all cells can use all frequencies

CDMA

- Cons
  - implementation complexity
  - need for power control
    - to avoid capture
  - need for a large contiguous frequency band (for direct sequence)
  - problems installing in the field

FDD and TDD

- Two ways of converting a wireless medium to a duplex channel
- In Frequency Division Duplex, uplink and downlink use different frequencies
- In Time Division Duplex, uplink and downlink use different time slots
- Can combine with FDMA/TDMA
- Examples
  - TDD/FDMA in second-generation cordless phones
  - FDD/TDMA/FDMA in digital cellular phones

Centralized access schemes

- One station is master, and the other are slaves
  - slave can transmit only when master allows
- Natural fit in some situations
  - wireless LAN, where base station is the only station that can see everyone
  - cellular telephony, where base station is the only one capable of high transmit power

Centralized access schemes

- Pros
  - simple
  - master provides single point of coordination
- Cons
  - master is a single point of failure
    - need a re-election protocol
    - master is involved in every single transfer => added delay

Circuit mode

- When station wants to transmit, it sends a message to master using packet mode
- Master allocates transmission resources to slave
- Slave uses the resources until it is done
- No contention during data transfer
- Used primarily in cellular phone systems
  - EAMPS: FDMA
  - GSM/IS-54: TDMA
  - IS-95: CDMA

Polling and probing

- Centralized packet-mode multiple access schemes
- Polling
  - master asks each station in turn if it wants to send (roll-call polling)
  - inefficient if only a few stations are active, overhead for polling messages is high, or system has many terminals
- Probing
  - stations are numbered with consecutive logical addresses
  - assume station can listen both to its own address and to a set of multicast addresses
  - master does a binary search to locate next active station

Reservation-based schemes

- When ‘a’ is large, can’t use a distributed scheme for packet mode (too many collisions)
  - mainly for satellite links
- Instead master coordinates access to link using reservations
- Some time slots devoted to reservation messages
  - can be smaller than data slots => minislots
- Stations contend for a minislot (or own one)
- Master decides winners and grants them access to link
- Packet collisions are only for minislots, so overhead on contention is reduced

Distributed schemes

- Compared to a centralized scheme
  - more reliable
  - have lower message delays
  - often allow higher network utilization
  - but are more complicated
- Almost all distributed schemes are packet mode (why?)

Decentralized polling

- Just like centralized polling, except there is no master
- Each station is assigned a slot that it uses
  - if nothing to send, slot is wasted
- Also, all stations must share a time base

Decentralized probing

- Also called tree based multiple access
- All stations in left subtree of root place packet on medium
- If a collision, root <- root ->left_son, and try again
- On success, everyone in root->right_son places a packet etc.
- (If two nodes with successive logical addresses have a packet to send, how many collisions will it take for one of them to win access?)
- Works poorly with many active stations, or when all active stations are in the same subtree

Channel Allocation Problem

- Static Channel Allocation
  - FDM
  - TDM
- Dynamic Channel Allocation
  - Station model
    - N Independent Stations
  - Single Channel
  - Collision
  - Time
    - Continuous
    - Slotted
  - Carrier Sense
    - Available
    - Not available

The Channel Allocation Problem

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

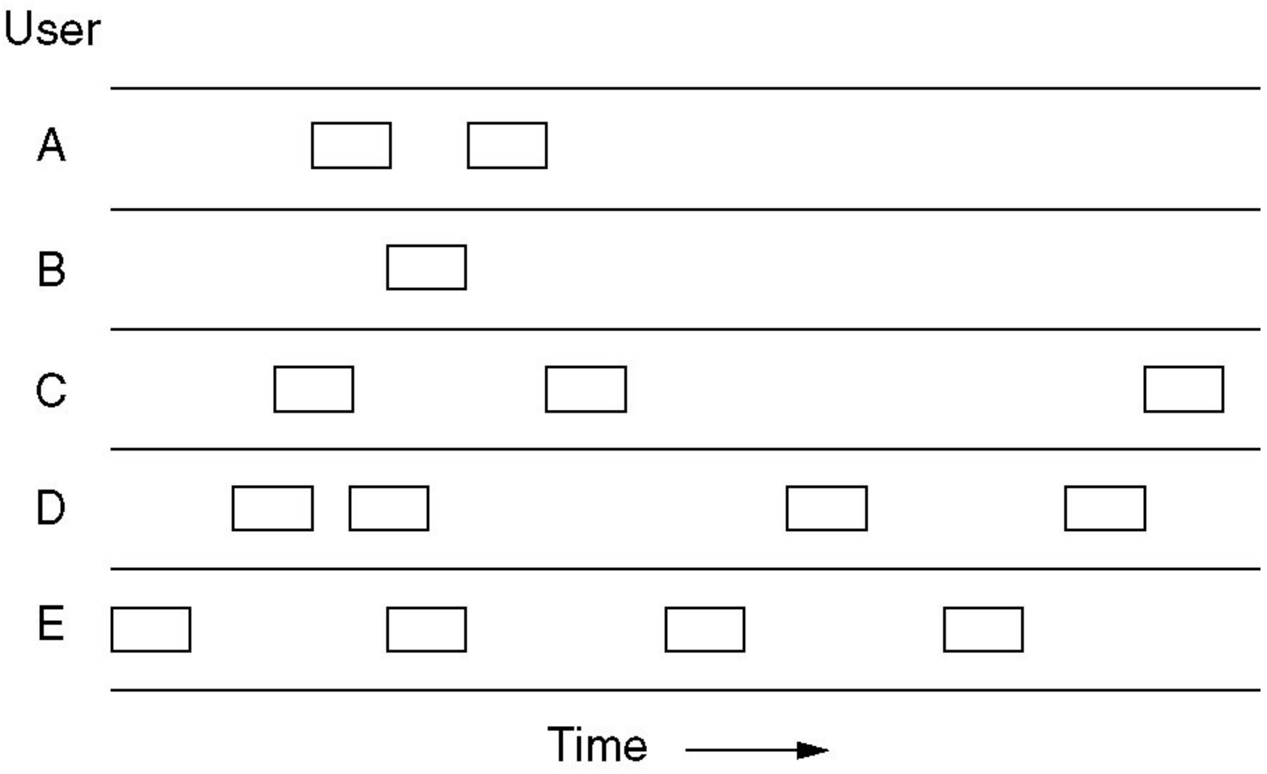
Dynamic Channel Allocation in LANs and MANs

- Station Model.
- Single Channel Assumption.
- Collision Assumption.
- (a) Continuous Time.
  (b) Slotted Time.
- (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

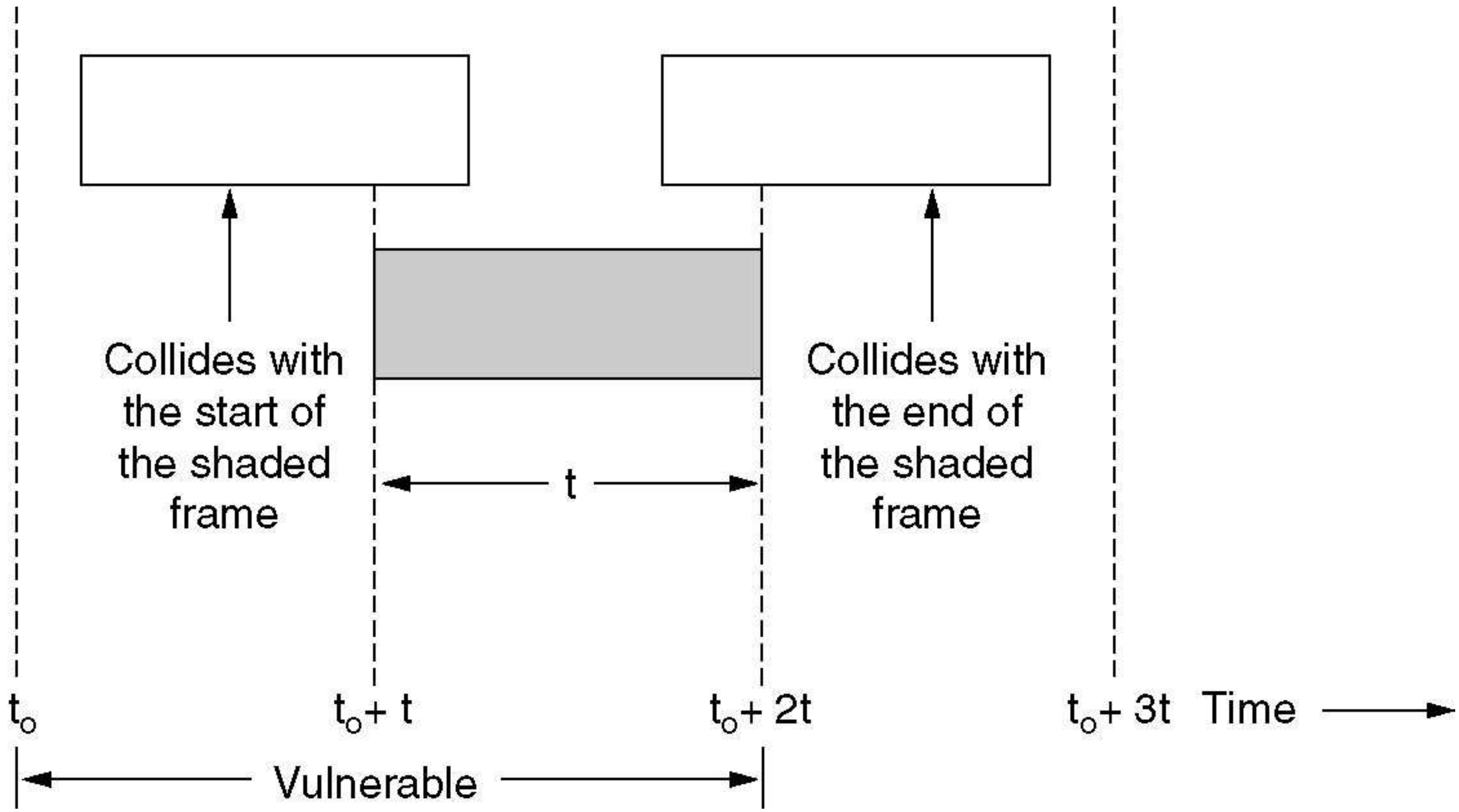


In pure ALOHA, frames are transmitted at completely arbitrary times.

ALOHA

- Constant frame time
- N frames per frame time
  - $0 < N < 1$
- G frames attempted per frame time
  - $G > N$
- Throughput $S = G P_0$, where P_0 is the prob of success of a frame

Pure ALOHA


Collides with the start of the shaded frame
Collides with the end of the shaded frame
t
t_o
$t_o + t$
$t_o + 2t$
$t_o + 3t$
Time
Vulnerable

Vulnerable period for the shaded frame.

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Pure ALOHA

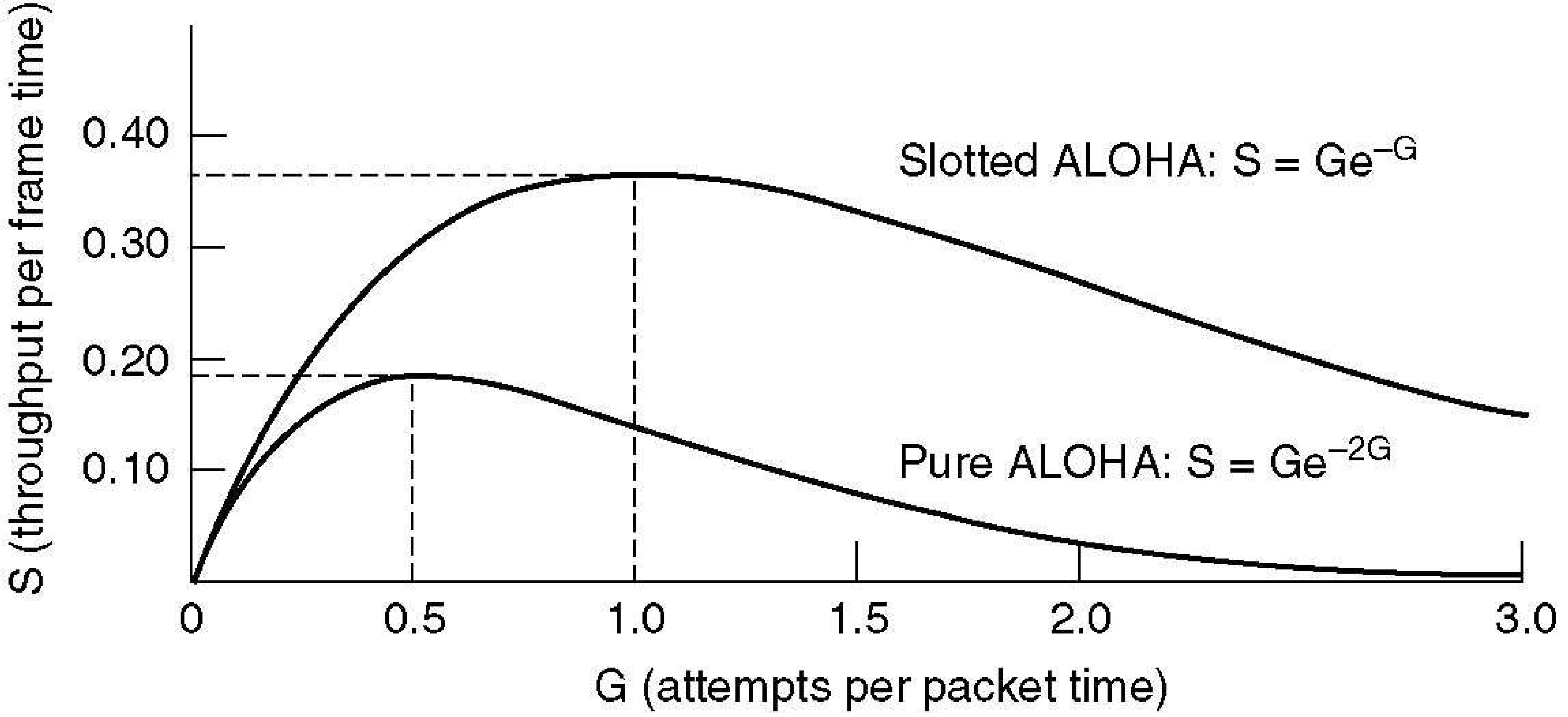
- Probability that k frames are generated during a given frame time is given by the Poisson Distribution

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

$$S = Ge^{-2G}$$

When G = 0.5 S = 1/2e
0.184

Pure ALOHA (3)



Throughput versus offered traffic for ALOHA systems.

Carrier Sense Multiple Access (CSMA)

- A fundamental advance: check whether the medium is active before sending a packet (i.e carrier sensing)
- Unlike polling/probing a node with something to send doesn’t have to wait for a master, or for its turn in a schedule
- If medium idle, then can send
- If collision happens, detect and resolve
- Works when ‘a’ is small

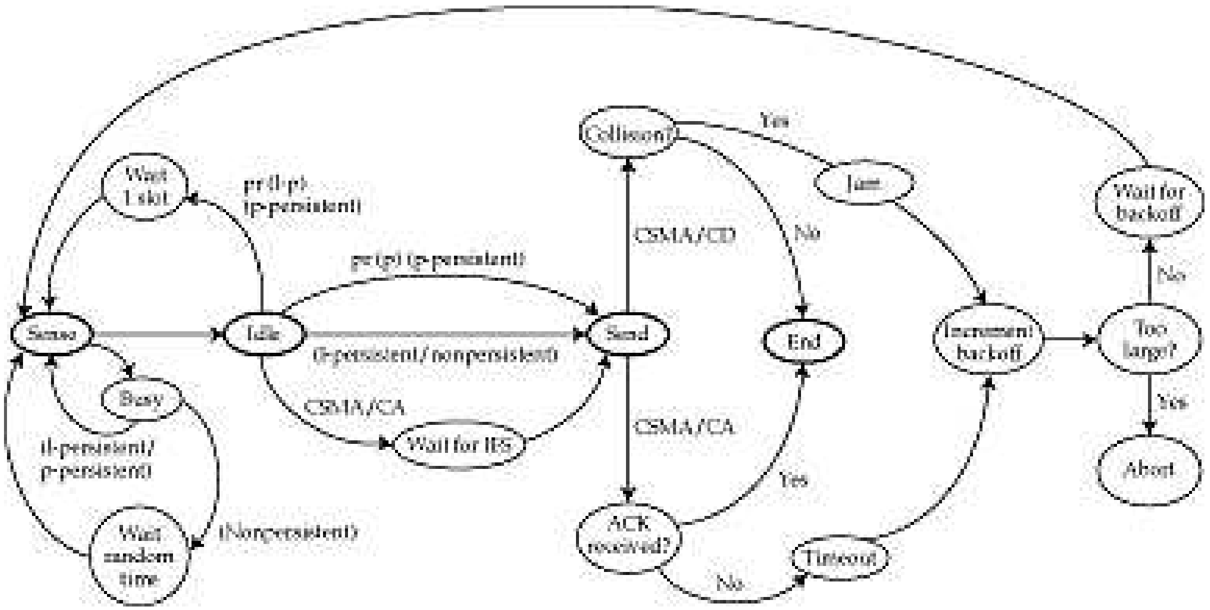
Simplest CSMA scheme

- Send a packet as soon as medium becomes idle
- If, on sensing busy, wait for idle -> persistent
- If, on sensing busy, set a timer and try later -> non-persistent
- Problem with persistent: two stations waiting to speak will collide

How to solve the collision problem

- Two solutions
- p-persistent: on idle, transmit with probability p:
  - hard to choose p
  - if p small, then wasted time
  - if p large, more collisions
- exponential backoff
  - on collision, choose timeout randomly from doubled range
  - backoff range adapts to number of contending stations
  - no need to choose p
  - need to detect collisions: collision detect circuit => CSMA/CD

Summary of CSMA schemes


Wait 1 slot
pr (1-p) (p-persistent)
pr (p) (p-persistent)
Sense
Idle
Send
(1-persistent / nonpersistent)
Busy
(1-persistent/ p-persistent)
CSMA/CA
Wait for IFS
Wait random time
(Nonpersistent)
Collision?
Yes
Jam
CSMA/CD
No
End
CSMA/CA
Yes
ACK received?
No
Timeout
Increment backoff
Too large?
No
Wait for backoff
Yes
Abort

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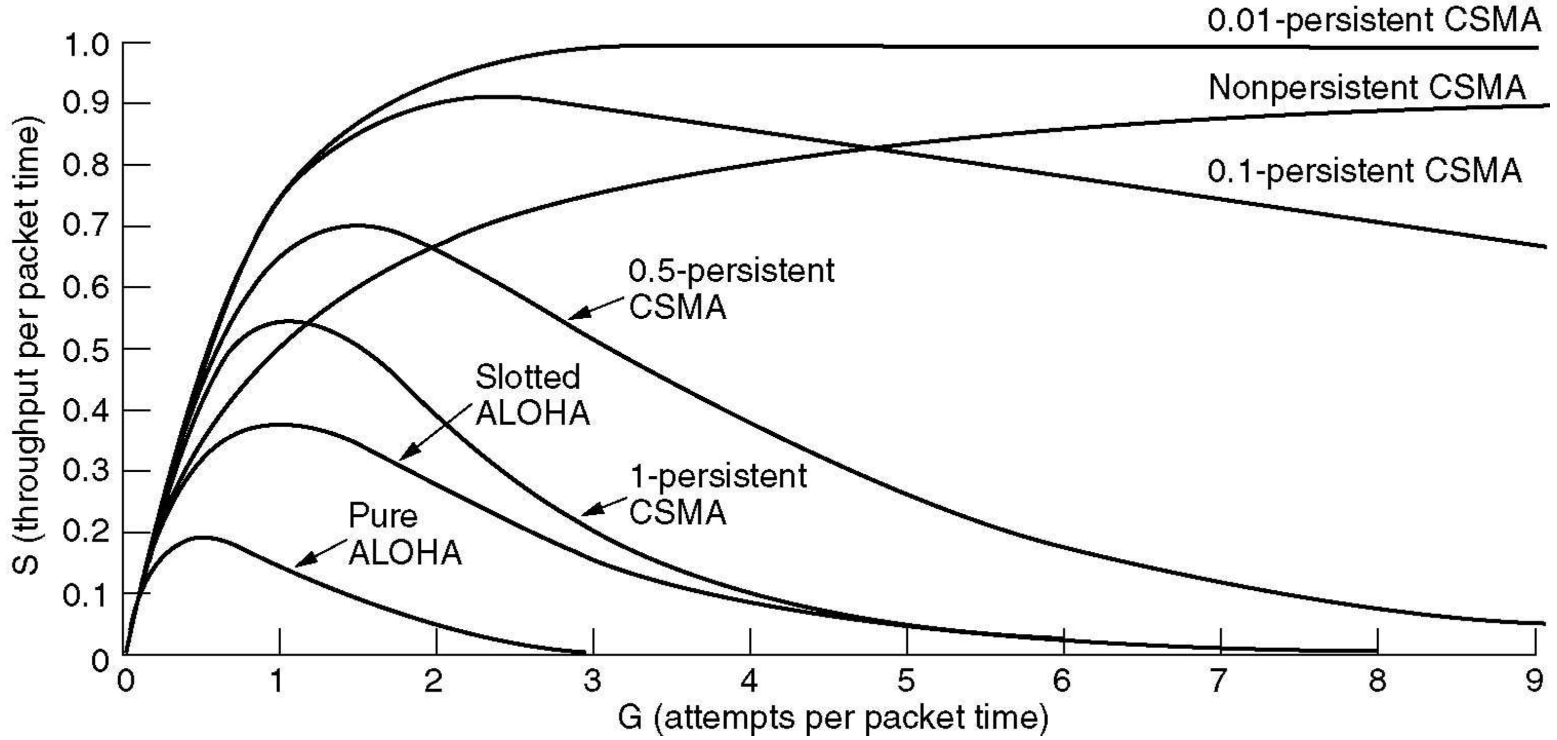
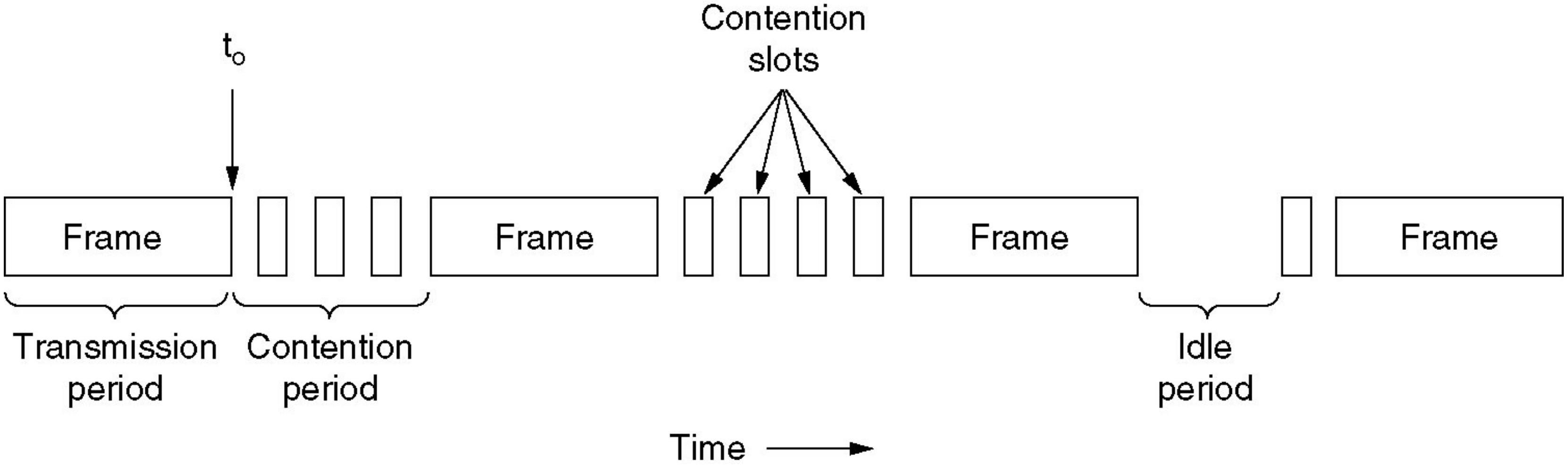
Persistent and Nonpersistent CSMA



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

CSMA with Collision Detection


Contention
slots
t_o
Frame
Frame
Frame
Frame
Transmission
period
Contention
period
Idle
period
Time →

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

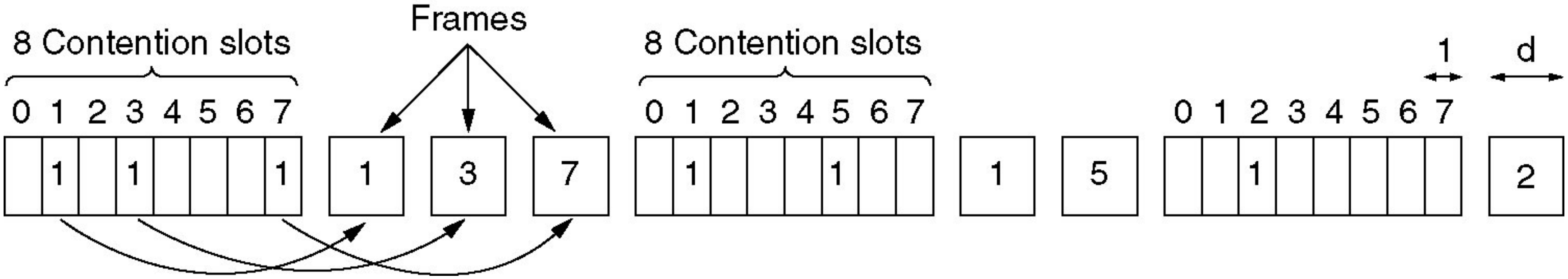
Ethernet

- The most widely used LAN
- Standard is called IEEE 802.3
- Uses CSMA/CD with exponential backoff
- Also, on collision, place a jam signal on wire, so that all stations are aware of collision and can increment timeout range
- ‘a’ small =>time wasted in collision is around 50 microseconds
- Ethernet requires packet to be long enough that a collision is detected before packet transmission completes (a <= 1)
  - packet should be at least 64 bytes long for longest allowed segment
- Max packet size is 1500 bytes
  - prevents hogging by a single station

More on Ethernet

- First version ran at 3 Mbps and used ‘thick’ coax
- These days, runs at 10 Mbps, and uses ‘thin’ coax, or twisted pair (Category 3 and Category 5)
- Ethernet types are coded as <Speed><Baseband or broadband><physical medium>
  - Speed = 3, 10, 100 Mbps
  - Baseband = within building, broadband = on cable TV
  - Physical medium:
    - “2” is cheap 50 Ohm cable, upto 185 meters
    - “T” is unshielded twisted pair (also used for telephone wiring)
    - “36” is 75 Ohm cable TV cable, upto 3600 meters

Collision-Free Protocols


8 Contention slots
Frames
8 Contention slots
1
d
0 1 2 3 4 5 6 7
1 1 1
1
3
7
0 1 2 3 4 5 6 7
1 1
1
5
0 1 2 3 4 5 6 7
1
2

The basic bit-map protocol.

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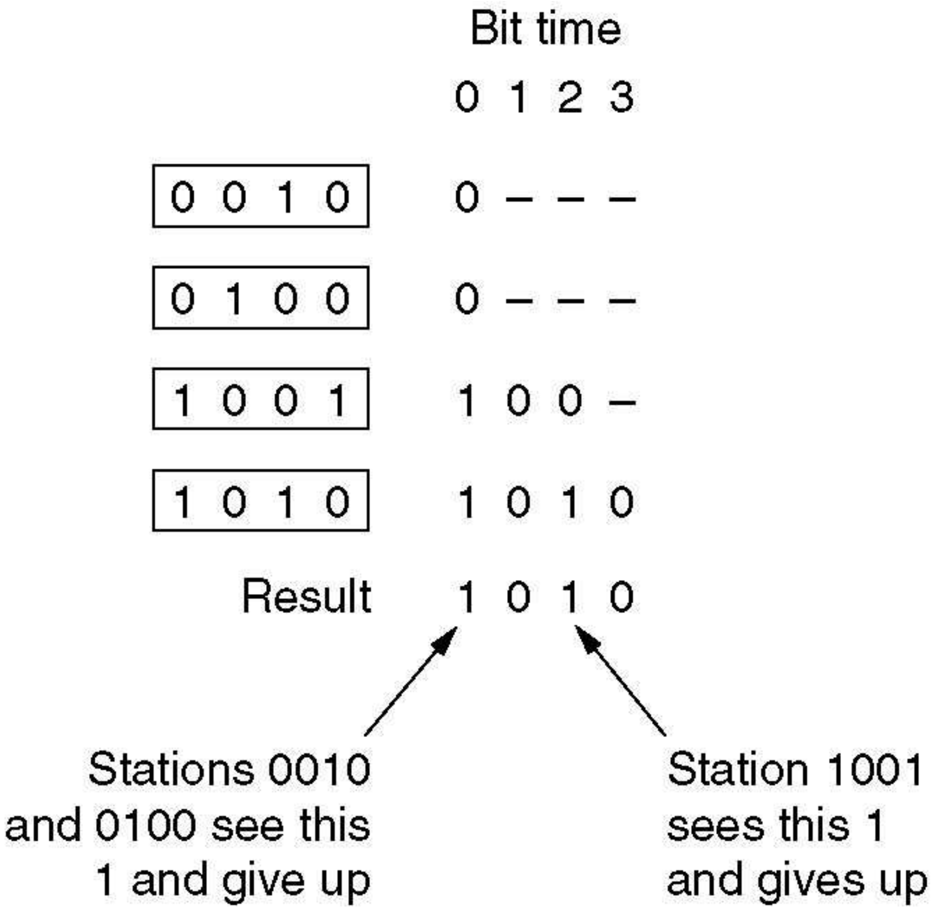
Collision-Free Protocols (2)



	Bit time 0	1	2	3
0 0 1 0	0	–	–	–
0 1 0 0	0	–	–	–
1 0 0 1	1	0	0	–
1 0 1 0	1	0	1	0
Result	1	0	1	0

Stations 0010
and 0100 see this
1 and give up

Station 1001
sees this 1
and gives up

The binary countdown protocol. A dash indicates silence.

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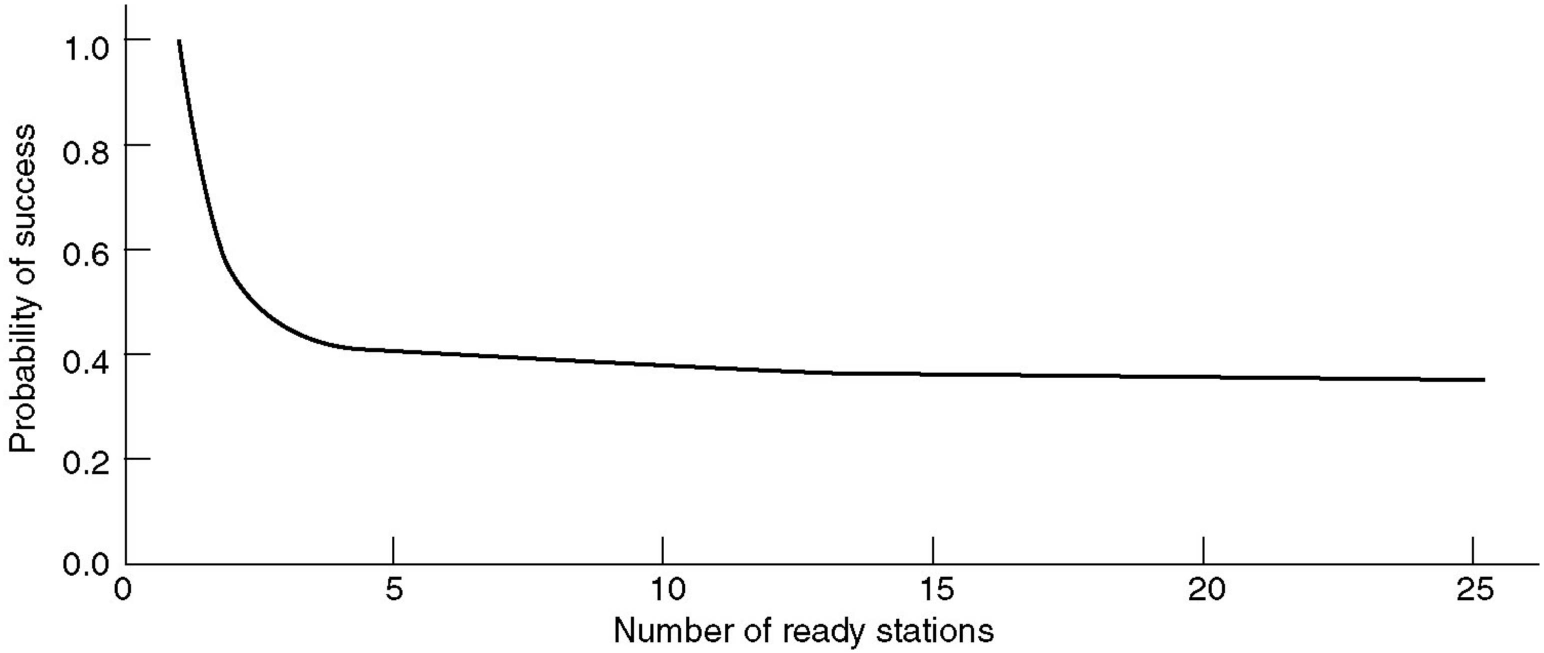
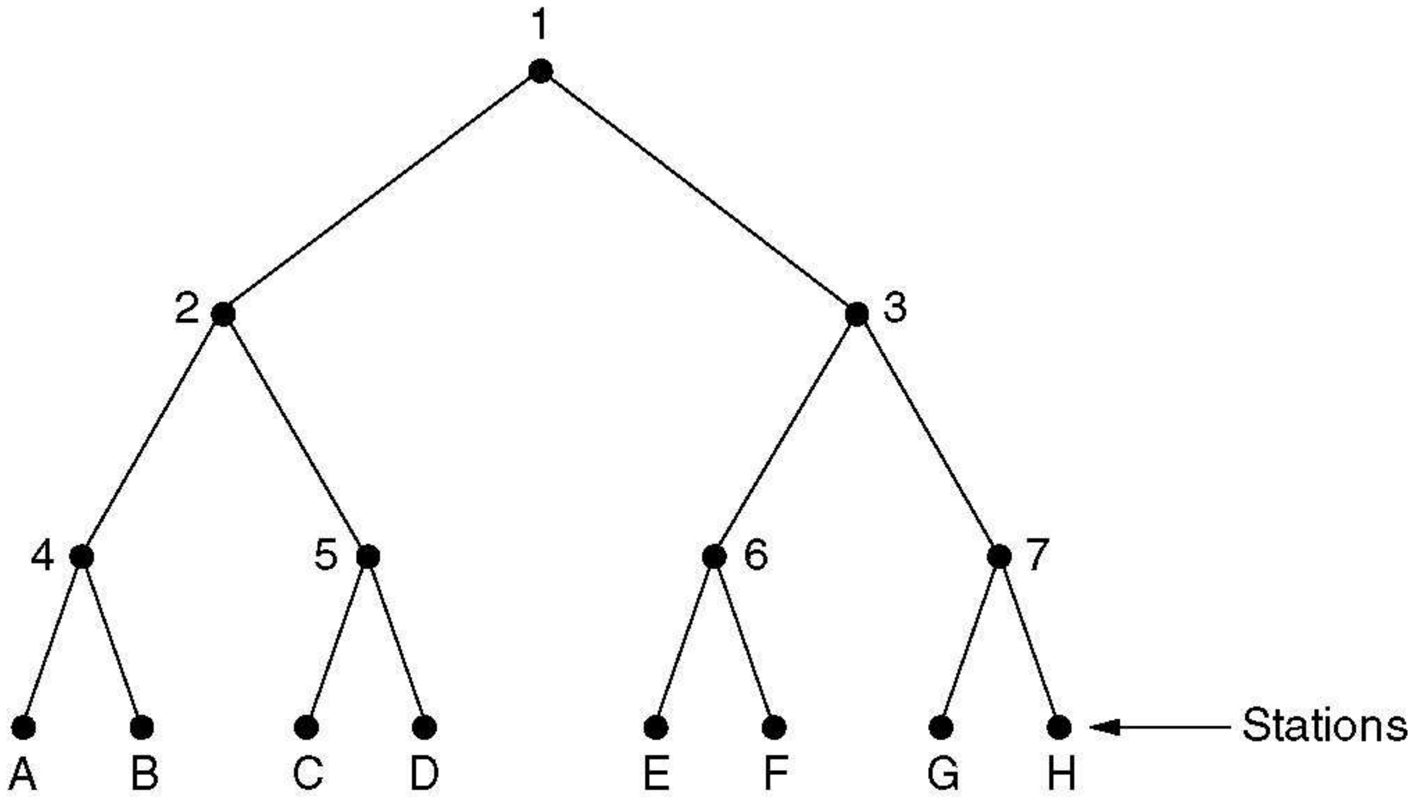
Limited-Contention Protocols



Acquisition probability for a symmetric contention channel.

Adaptive Tree Walk Protocol


1
2
3
4
5
6
7
A
B
C
D
E
F
G
H
Stations

The tree for eight stations.

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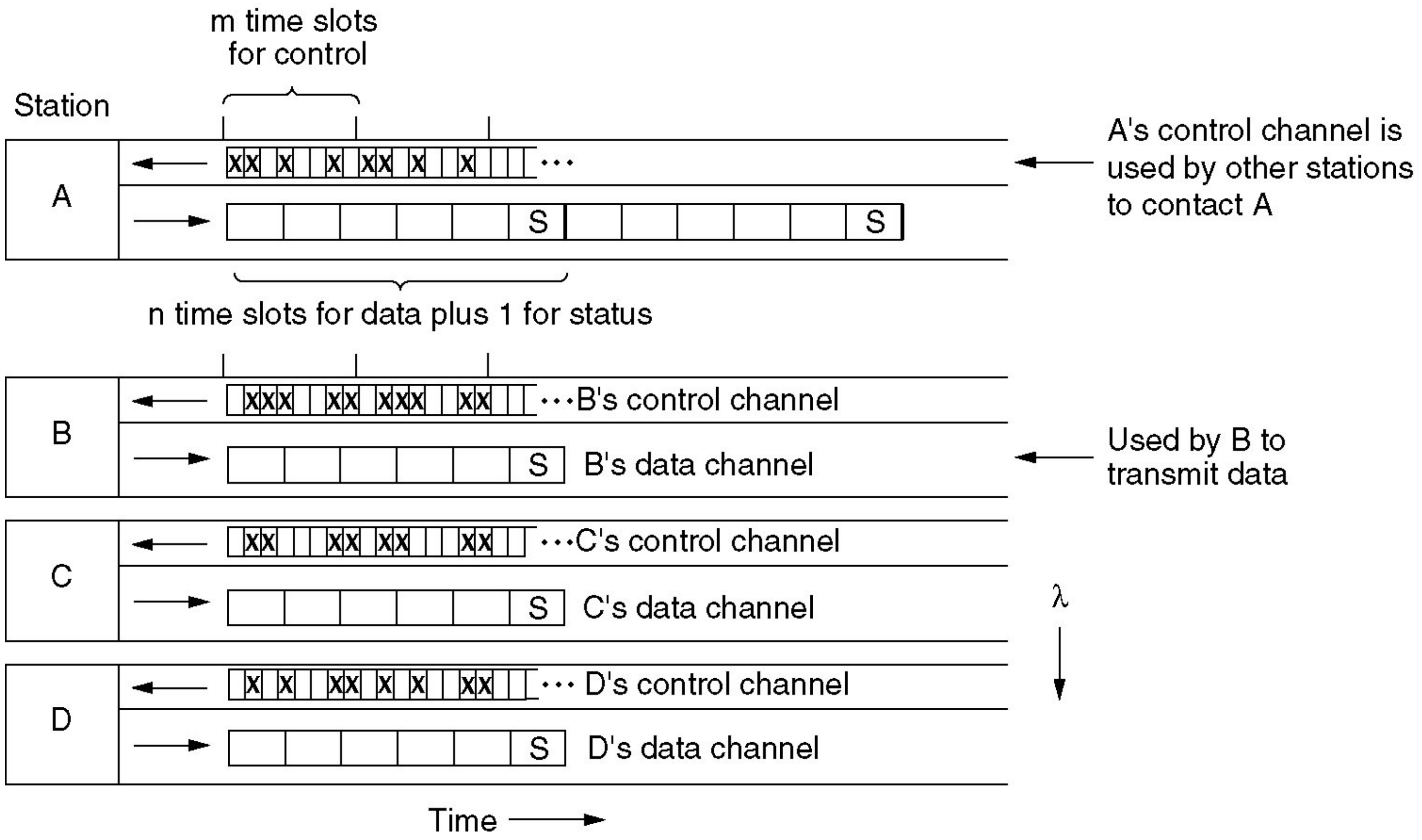
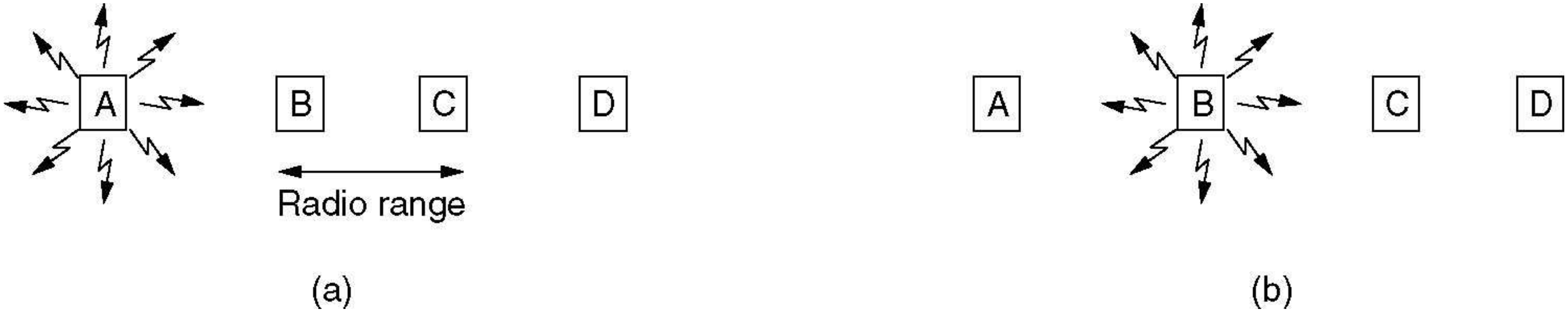
Wavelength Division Multiple Access Protocols


m time slots
for control
Station
A
A's control channel is
used by other stations
to contact A
n time slots for data plus 1 for status
B
B's control channel
B's data channel
Used by B to
transmit data
C
C's control channel
C's data channel
λ
D
D's control channel
D's data channel
Time

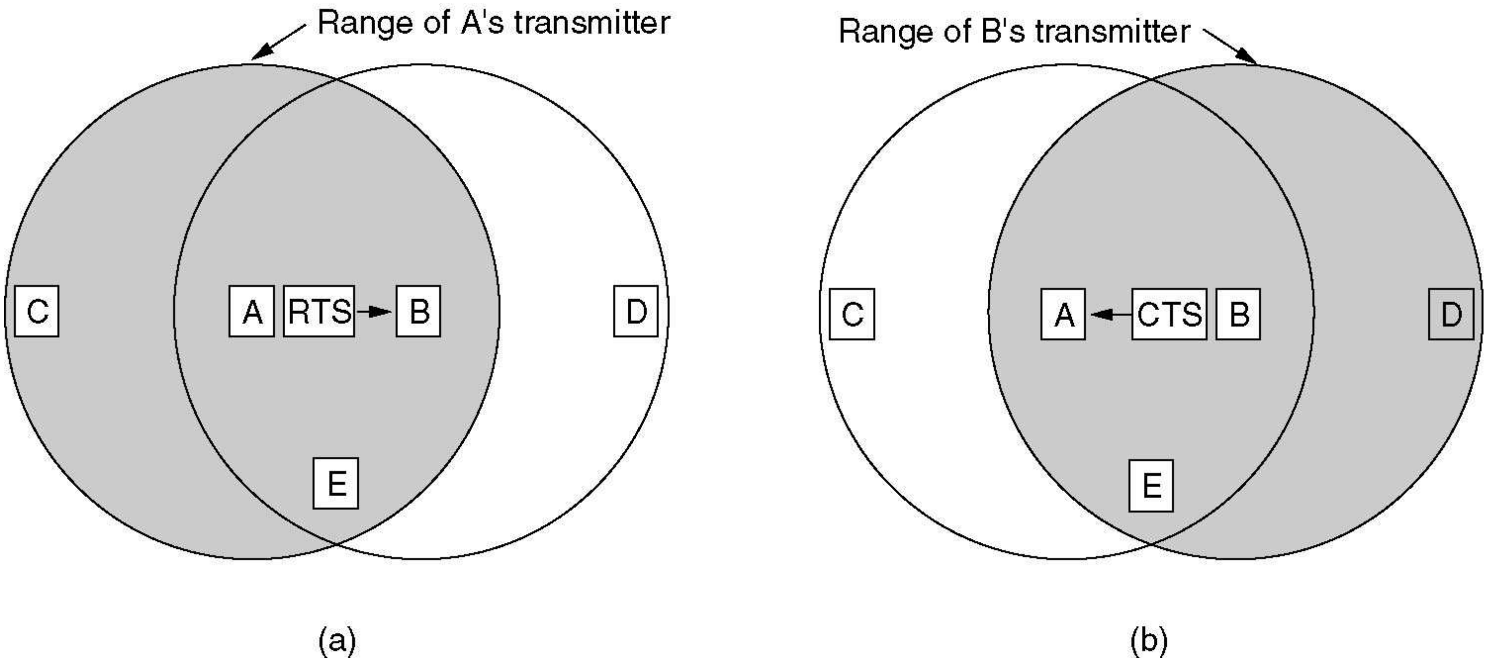
Wavelength division multiple access.

Wireless LAN Protocols


A
B
C
D
Radio range
(a)
A
B
C
D
(b)

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

Wireless LAN Protocols (2)


Range of A's transmitter
C
A
RTS
B
D
E
(a)
Range of B's transmitter
C
A
CTS
B
D
E
(b)

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

Dealing with hidden terminals

- CSMA/CA works when every station can receive transmissions from every other station
- Not always true
- Hidden terminal
  - some stations in an area cannot hear transmissions from others, though base can hear both
- Exposed terminal
  - some (but not all) stations can hear transmissions from stations not in the local area

Dealing with hidden and exposed terminals

- In both cases, CSMA/CA doesn’t work
  - with hidden terminal, collision because carrier not detected
  - with exposed terminal, idle station because carrier incorrectly detected
- Two solutions
- Busy Tone Multiple Access (BTMA)
  - uses a separate “busy-tone” channel
  - when station is receiving a message, it places a tone on this channel
  - everyone who might want to talk to a station knows that it is busy
    - even if they cannot hear transmission that that station hears
  - this avoids both problems (why?)

Ethernet

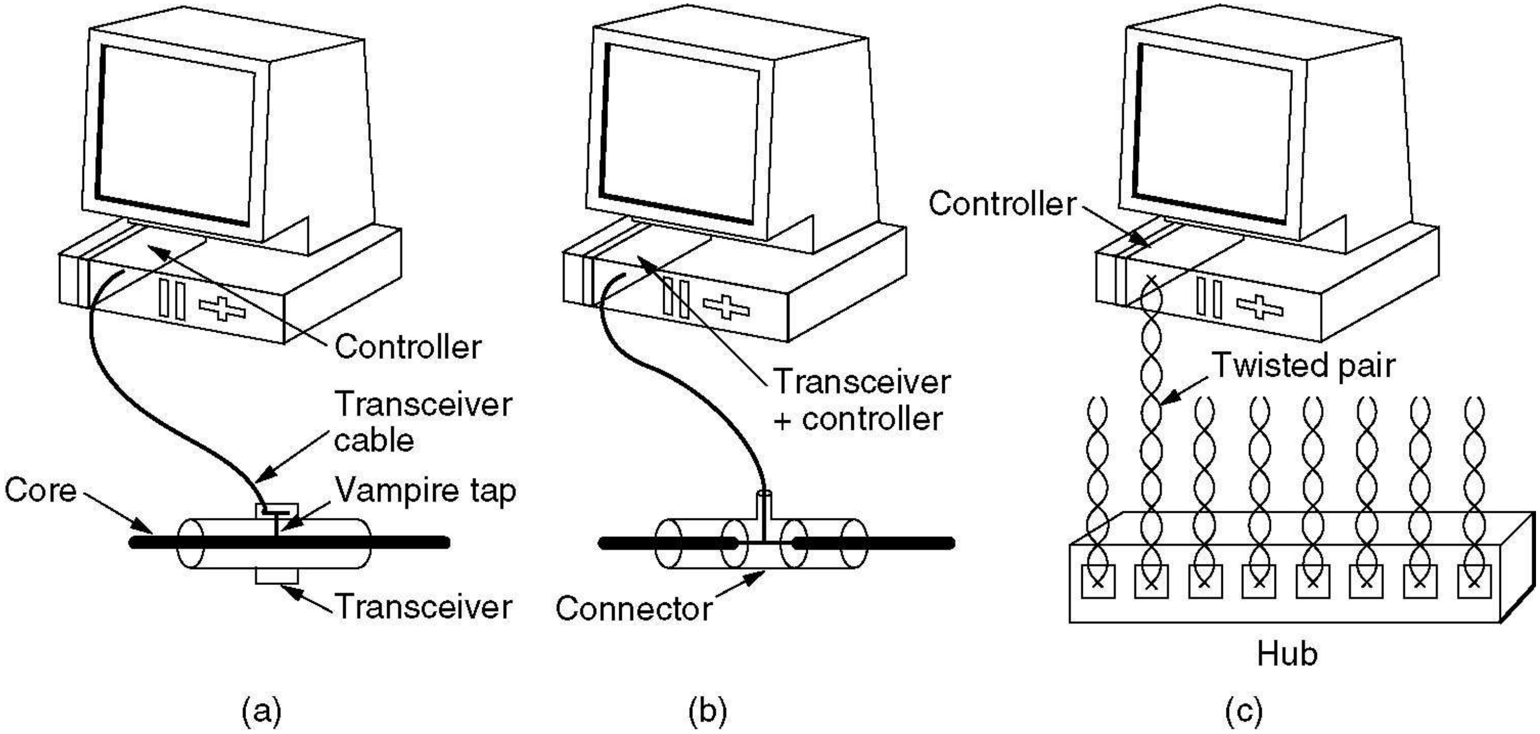
- Ethernet Cabling
- Manchester Encoding
- The Ethernet MAC Sublayer Protocol
- The Binary Exponential Backoff Algorithm
- Ethernet Performance
- Switched Ethernet
- Fast Ethernet
- Gigabit Ethernet
- IEEE 802.2: Logical Link Control
- Retrospective on Ethernet

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.

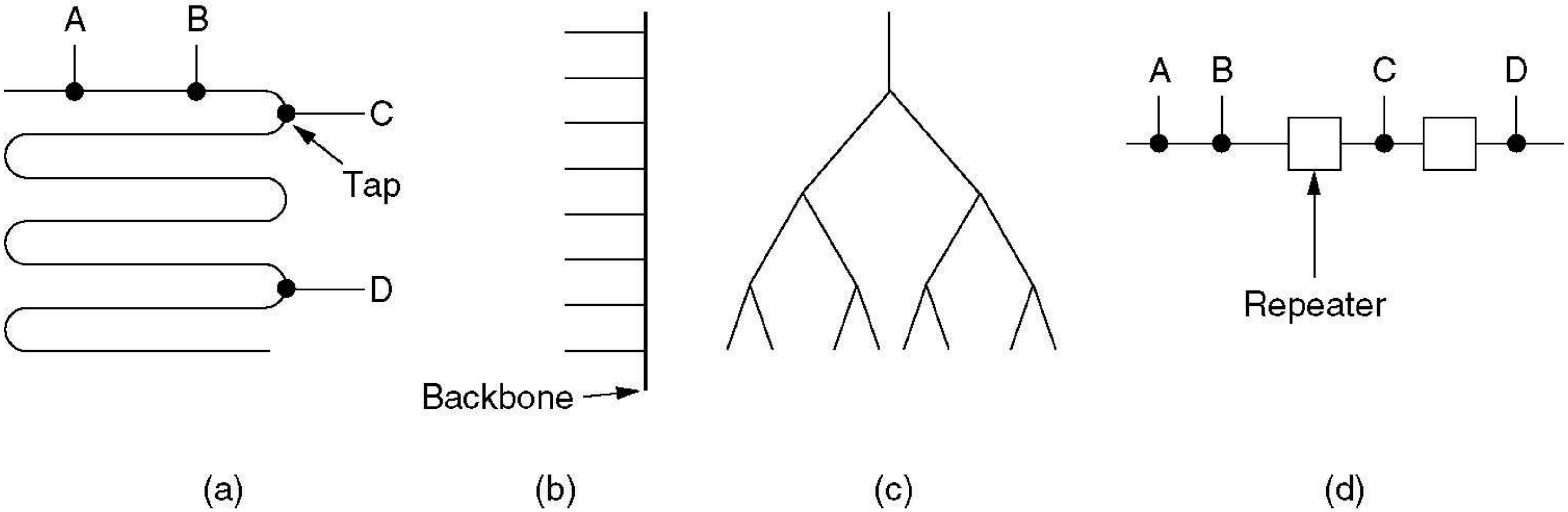
Ethernet Cabling (2)


Controller
Transceiver cable
Core
Vampire tap
Transceiver
(a)
Transceiver + controller
Connector
(b)
Controller
Twisted pair
Hub
(c)

Three kinds of Ethernet cabling.

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

Ethernet Cabling (3)


A
B
C
Tap
D
Backbone
A
B
C
D
Repeater
(a)
(b)
(c)
(d)

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

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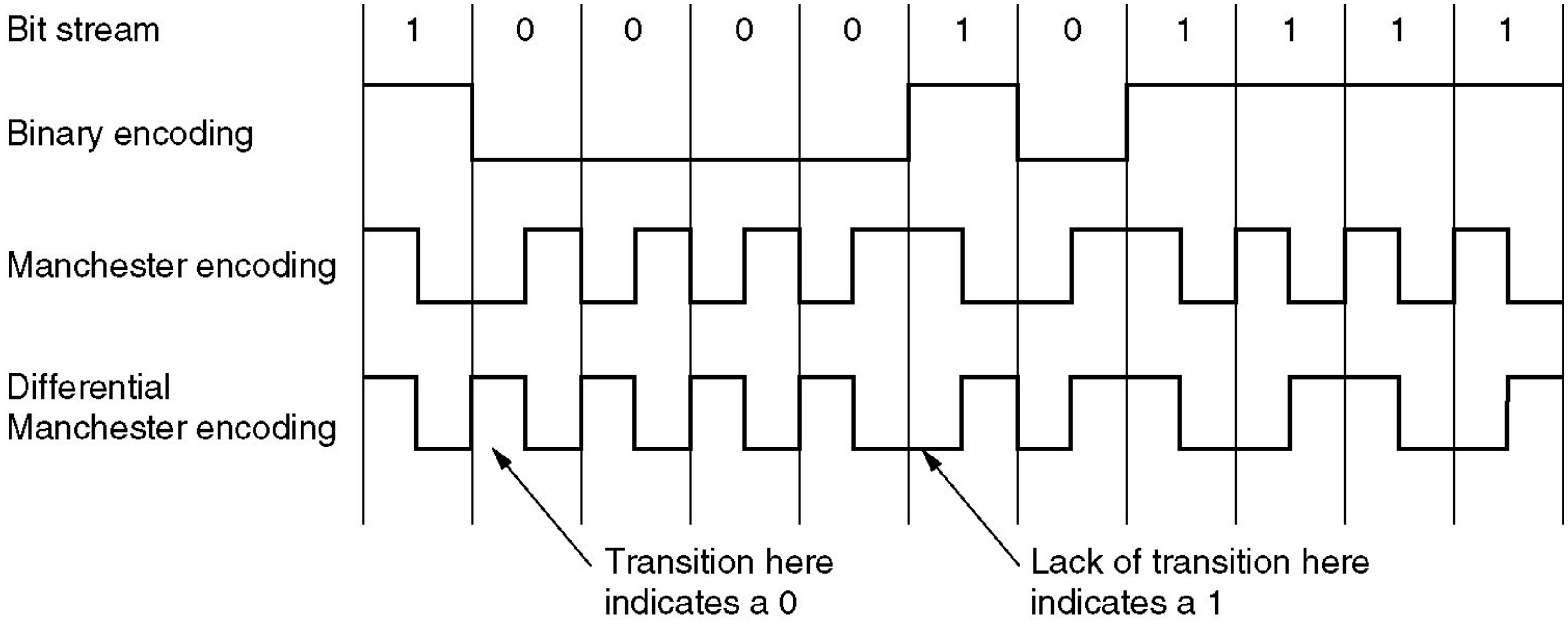
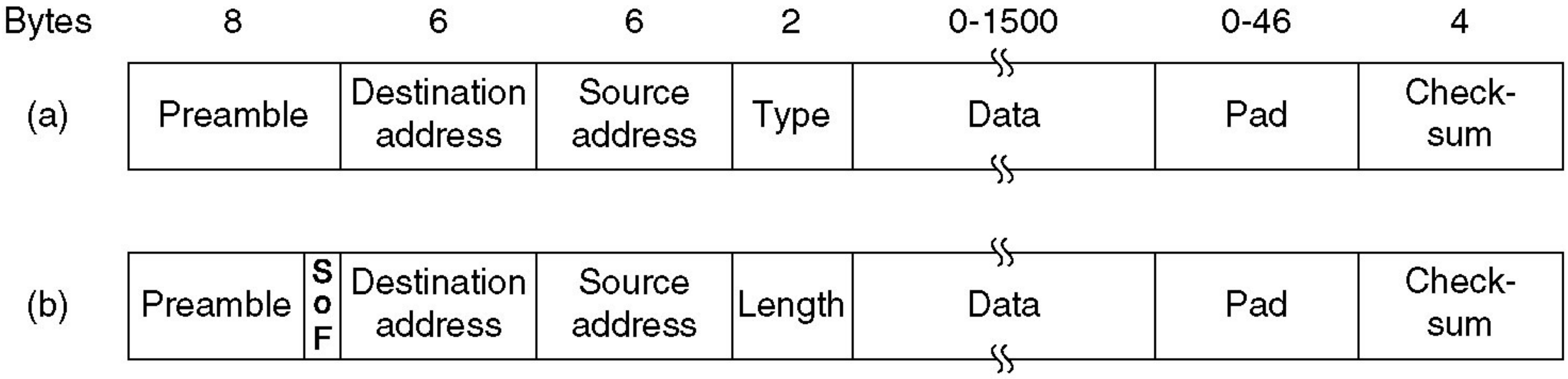
Ethernet Cabling (4)


Bit stream
1
0
0
0
0
1
0
1
1
1
1
Binary encoding
Manchester encoding
Differential Manchester encoding
Transition here indicates a 0
Lack of transition here indicates a 1

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

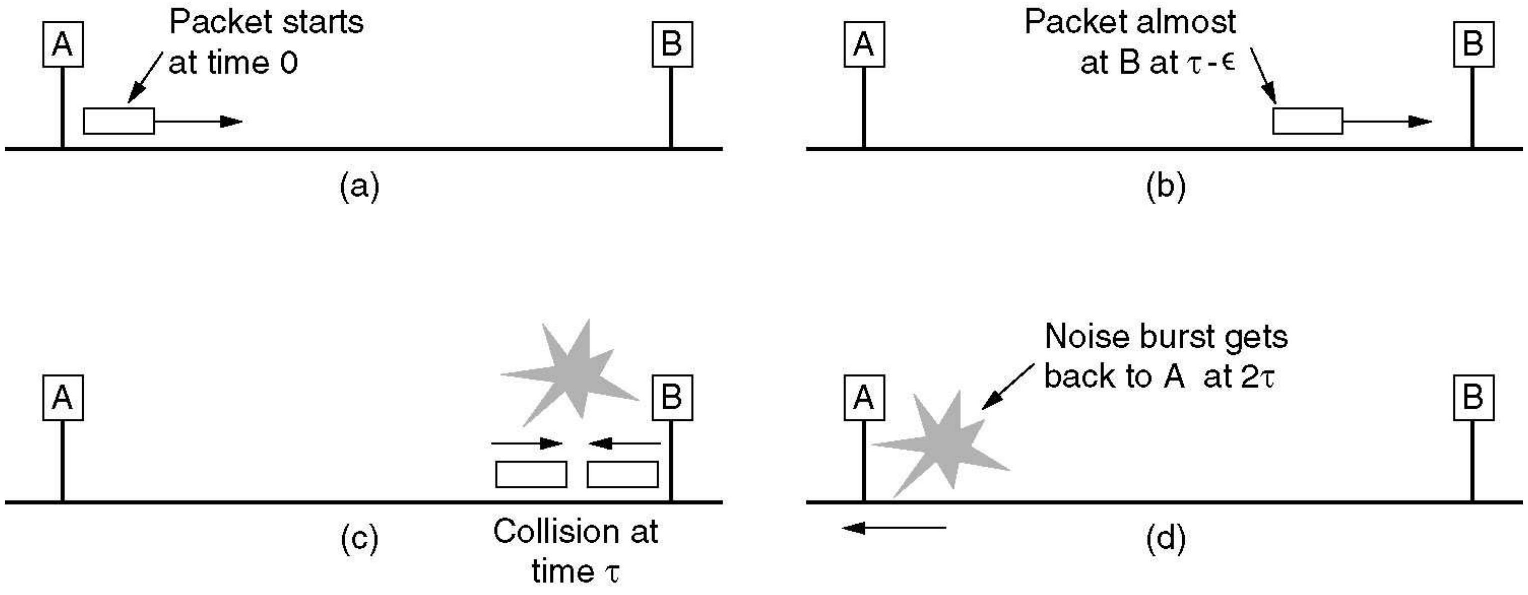
Ethernet MAC Sublayer Protocol



Bytes	8	6	6	2	0-1500	0-46	4
(a)	Preamble	Destination address	Source address	Type	Data	Pad	Checksum
(b)	Preamble SOF	Destination address	Source address	Length	Data	Pad	Checksum

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

Ethernet MAC Sublayer Protocol (2)


Packet starts
at time 0
A
B
(a)
Packet almost
at B at τ - ϵ
A
B
(b)
A
B
(c)
Collision at
time τ
Noise burst gets
back to A at 2τ
A
B
(d)

Collision detection can take as long as 2τ.

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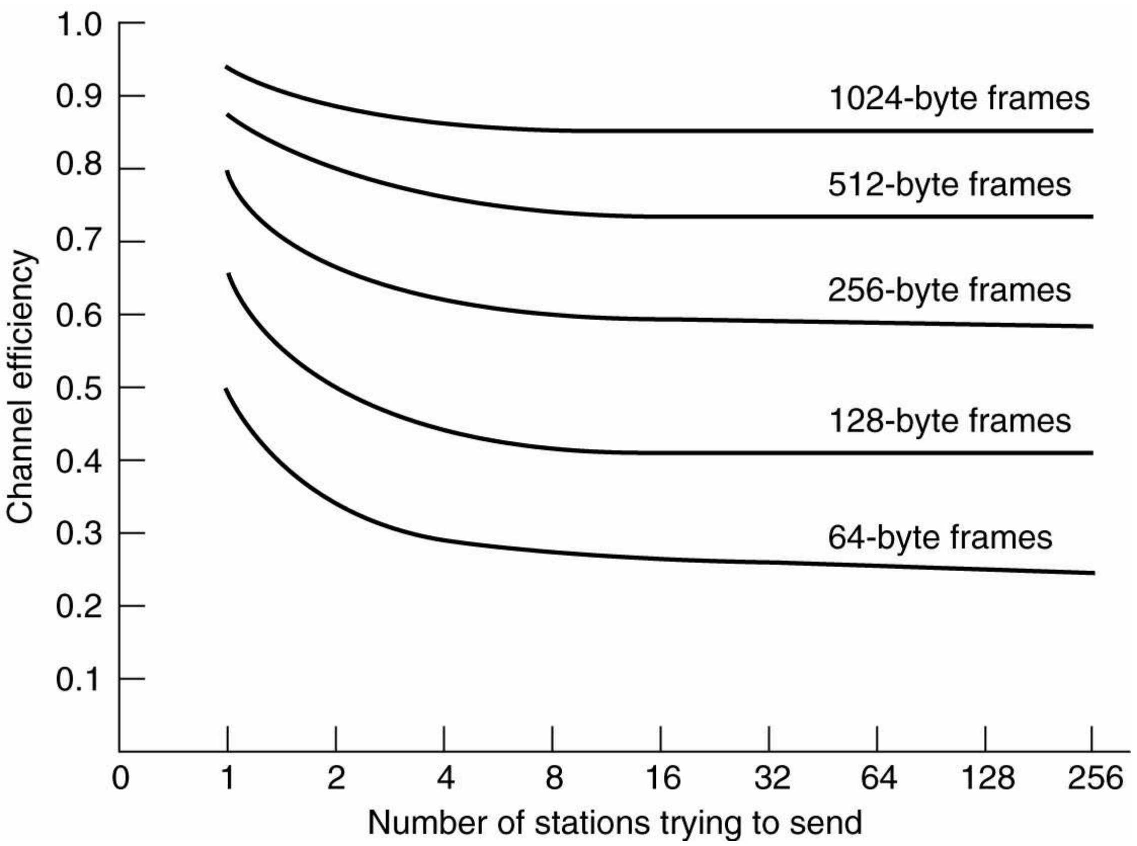
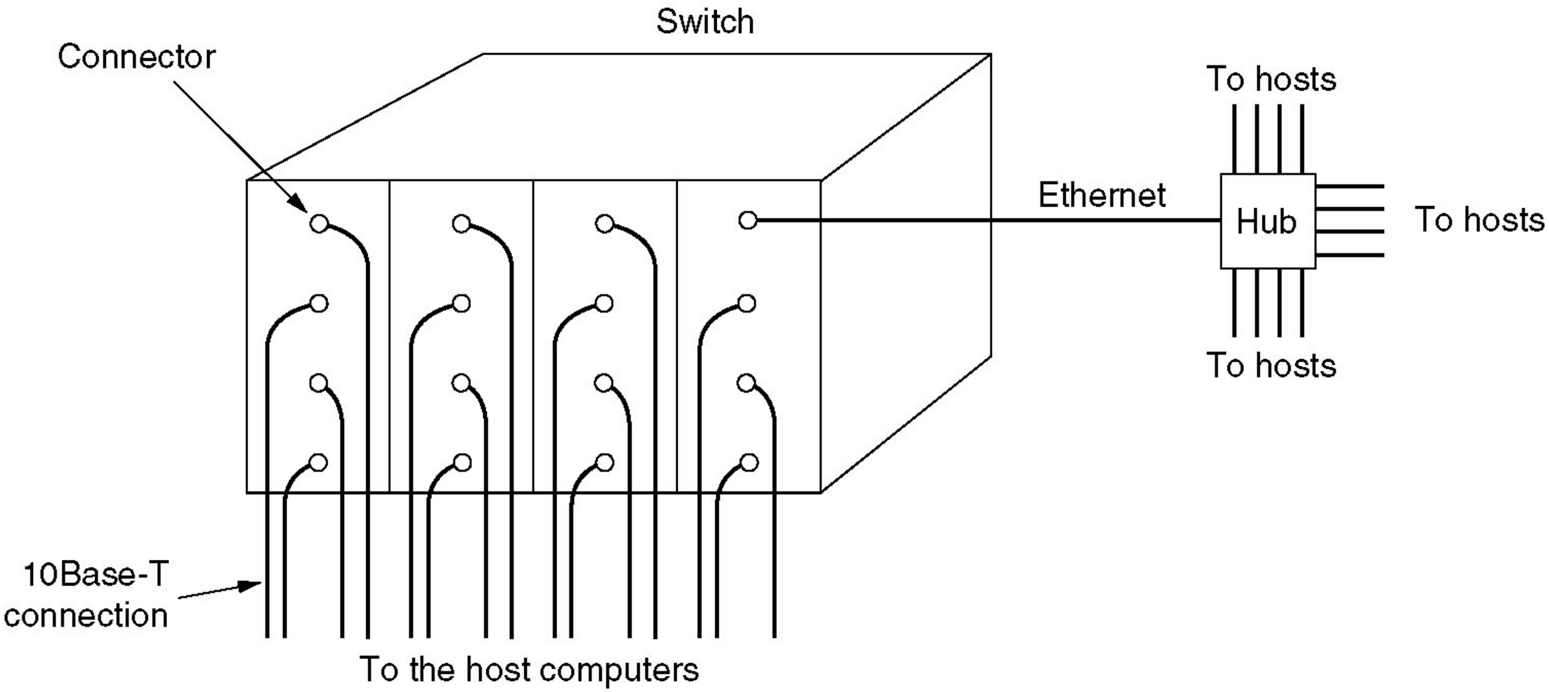
Ethernet Performance



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

Switched Ethernet


Switch
Connector
To hosts
Ethernet
Hub
To hosts
To hosts
10Base-T connection
To the host computers

A simple example of switched Ethernet.

Recent developments

- Switched Ethernet
  - each station is connected to switch by a separate UTP wire
  - line card of switch has a buffer to hold incoming packets
  - fast backplane switches packet from one line card to others
  - simultaneously arriving packets do not collide (until buffers overflow)
  - higher intrinsic capacity than 10BaseT (and more expensive)

Fast Ethernet variants

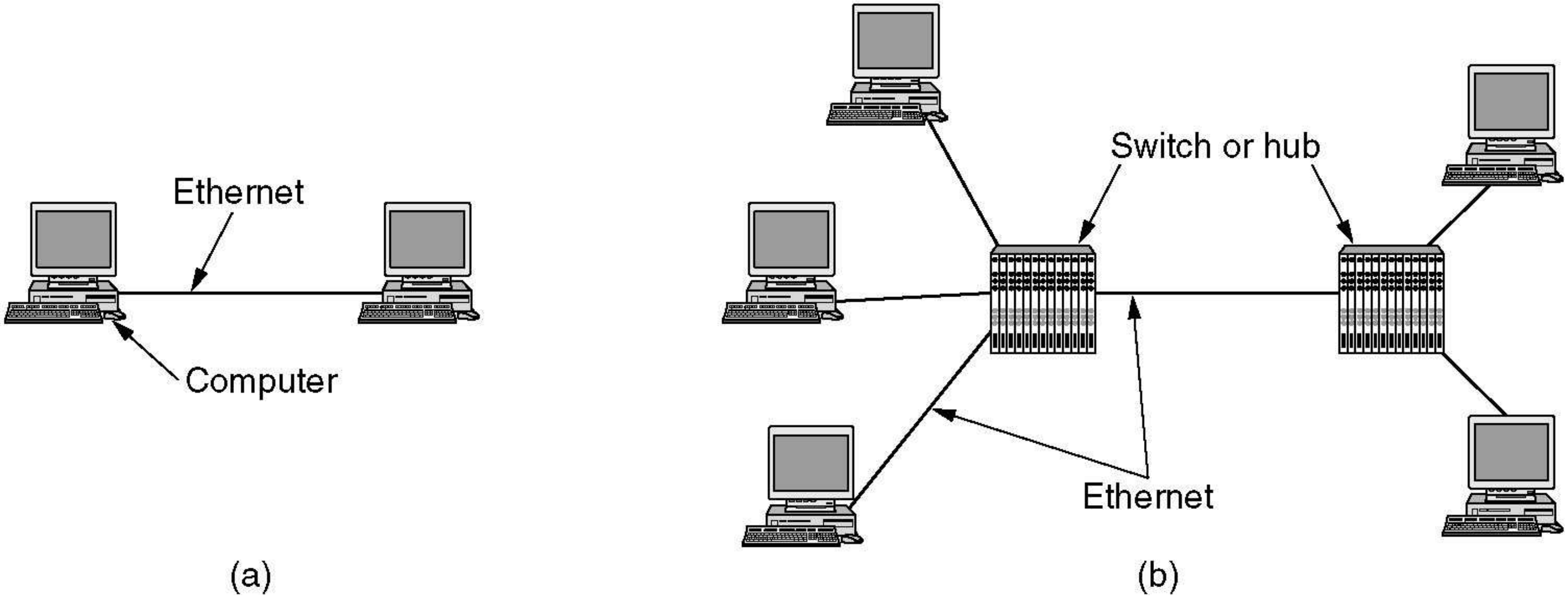
- Fast Ethernet (IEEE 802.3u)
  - same as 10BaseT, except that line speed is 100 Mbps
  - spans only 205 m
  - big winner
  - most current cards support both 10 and 100 Mbps cards (10/100 cards) for about $80
- 100VG Anylan (IEEE 802.12)
  - station makes explicit service requests to master
  - master schedules requests, eliminating collisions
  - not a success in the market
- Gigabit Ethernet
  - aims to continue the trend
  - still undefined, but first implementation will be based on fiber links

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


Ethernet
Computer
(a)
Switch or hub
Ethernet
(b)

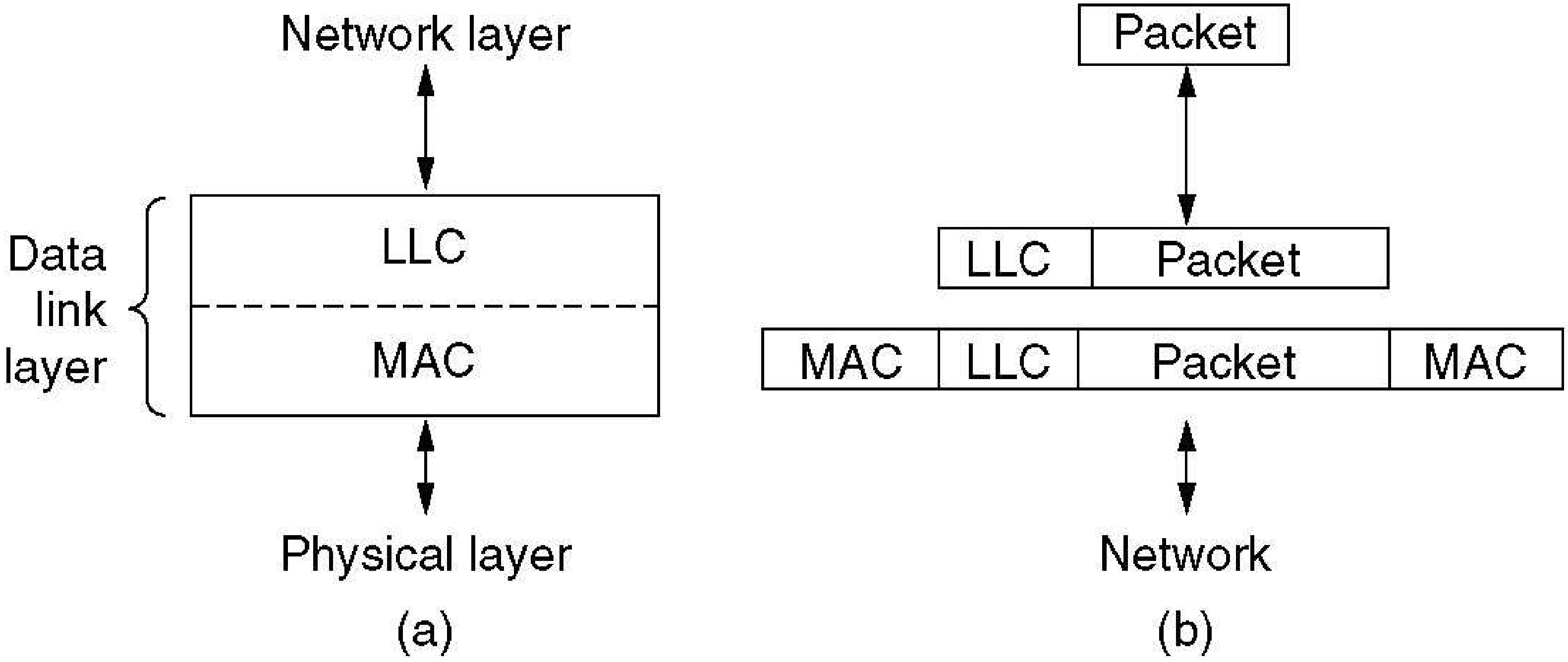
(a) A two-station Ethernet. (b) A multistation Ethernet.

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

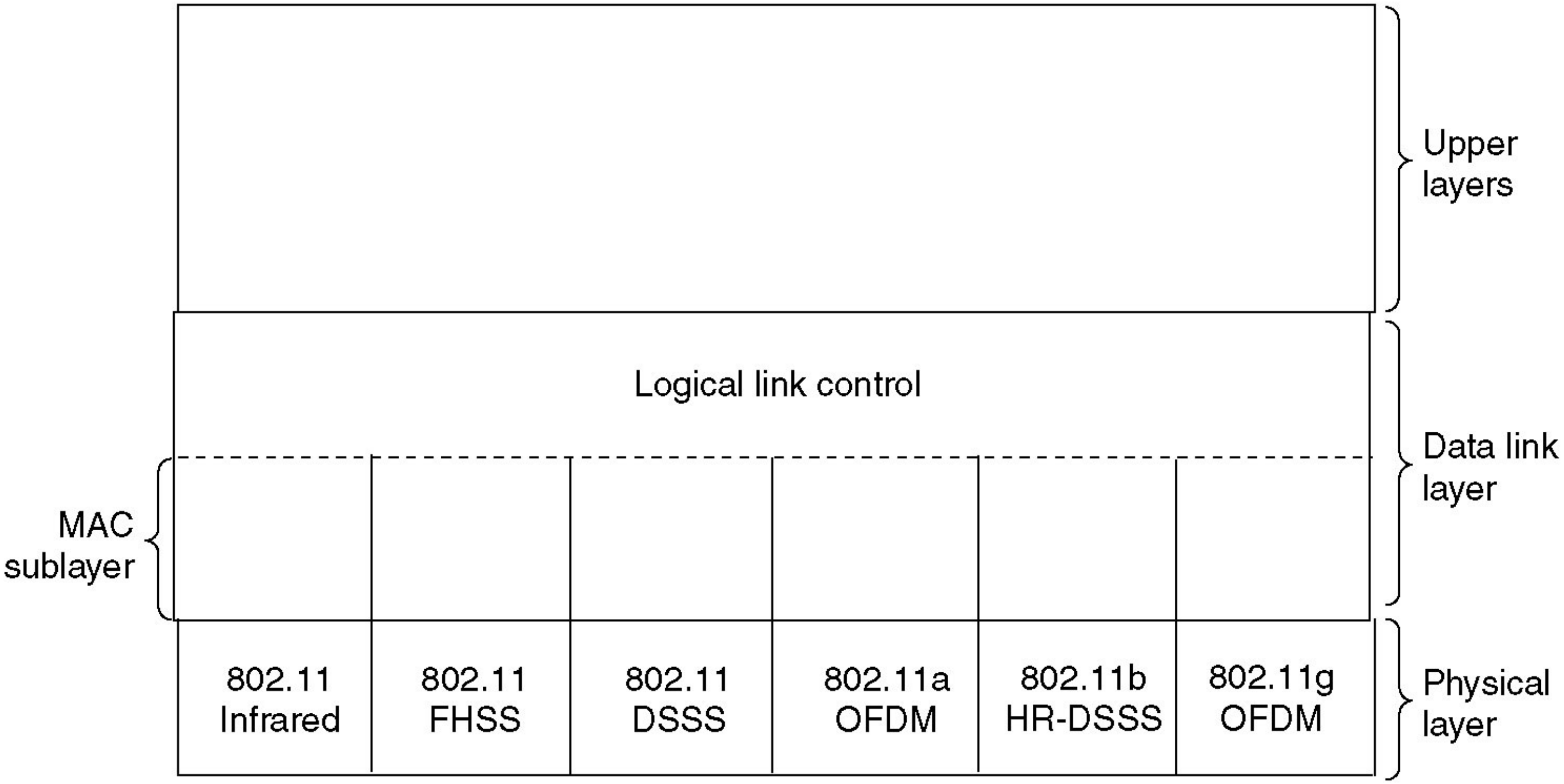

Network layer
Data link layer
LLC
MAC
Physical layer
(a)
Packet
LLC
Packet
MAC
LLC
Packet
MAC
Network
(b)

(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


Upper layers
Logical link control
Data link layer
MAC sublayer
802.11 Infrared
802.11 FHSS
802.11 DSSS
802.11a OFDM
802.11b HR-DSSS
802.11g OFDM
Physical layer

Part of the 802.11 protocol stack.

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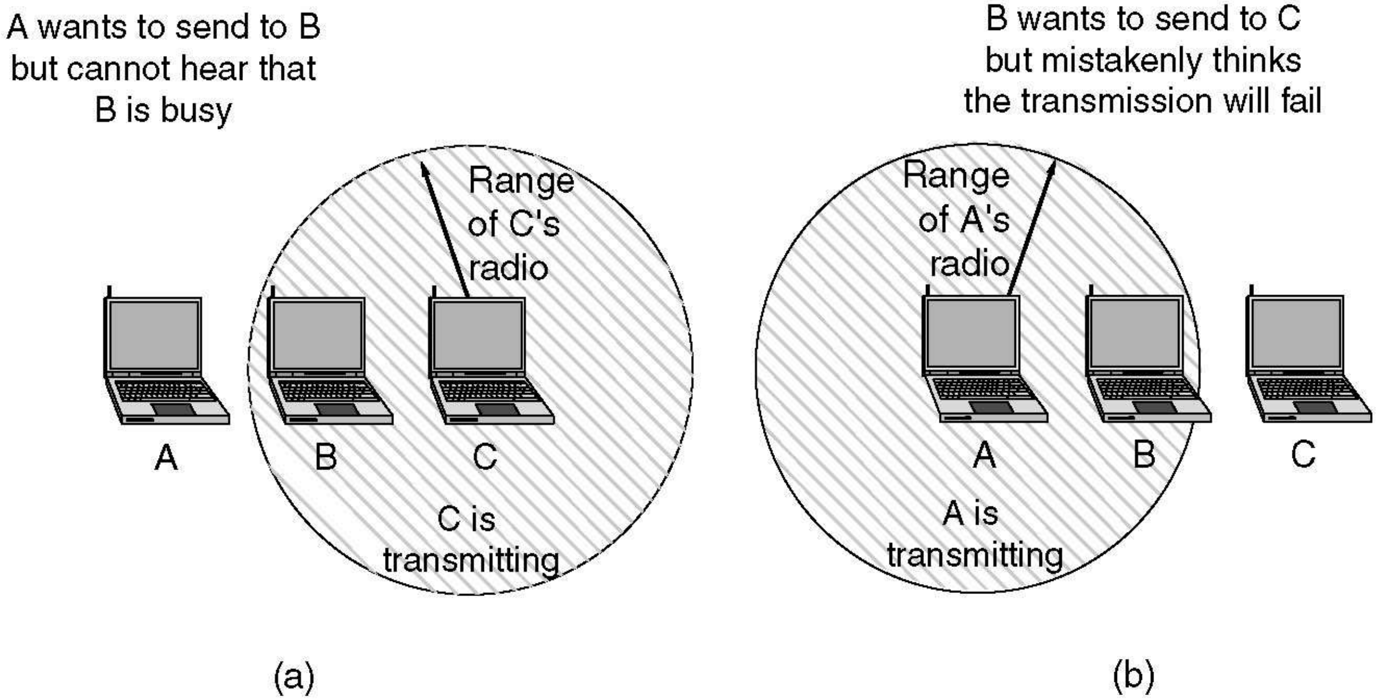
The 802.11 MAC Sublayer Protocol


A wants to send to B but cannot hear that B is busy
Range of C's radio
A
B
C
C is transmitting
(a)
B wants to send to C but mistakenly thinks the transmission will fail
Range of A's radio
A
B
C
A is transmitting
(b)

(a) The hidden station problem.

(b) The exposed station problem.

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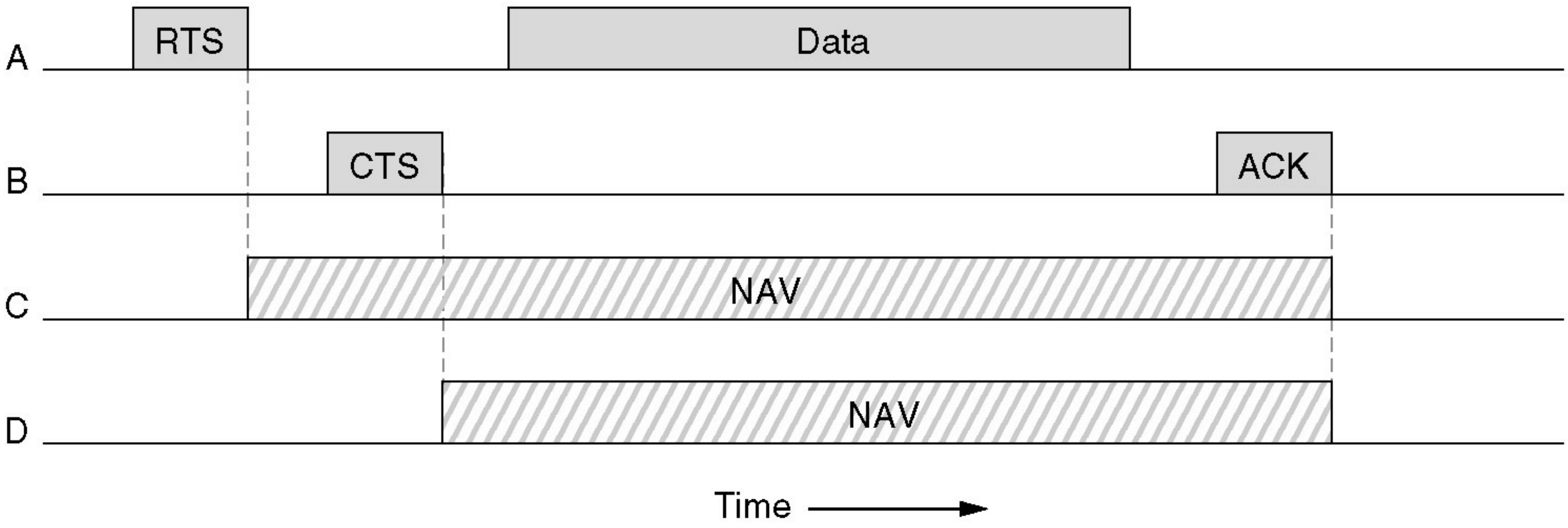
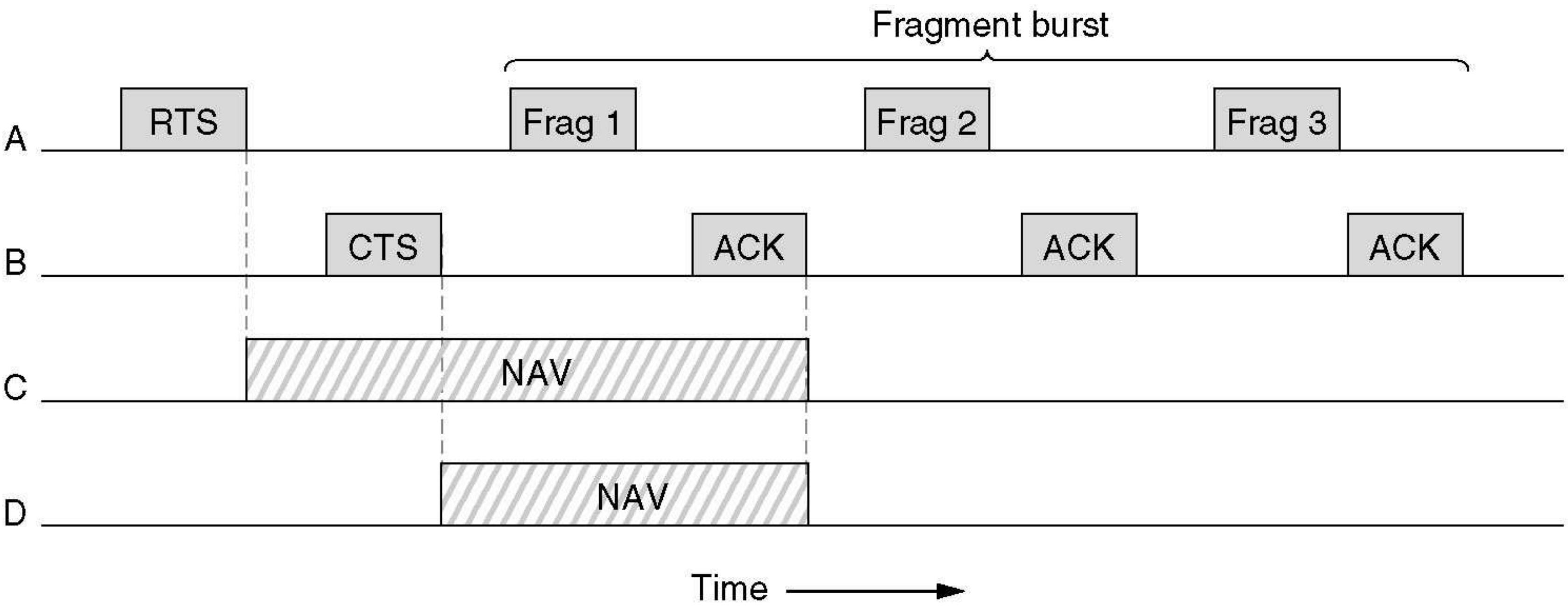
The 802.11 MAC Sublayer Protocol (2)


RTS
Data
A
CTS
ACK
B
NAV
C
NAV
D
Time

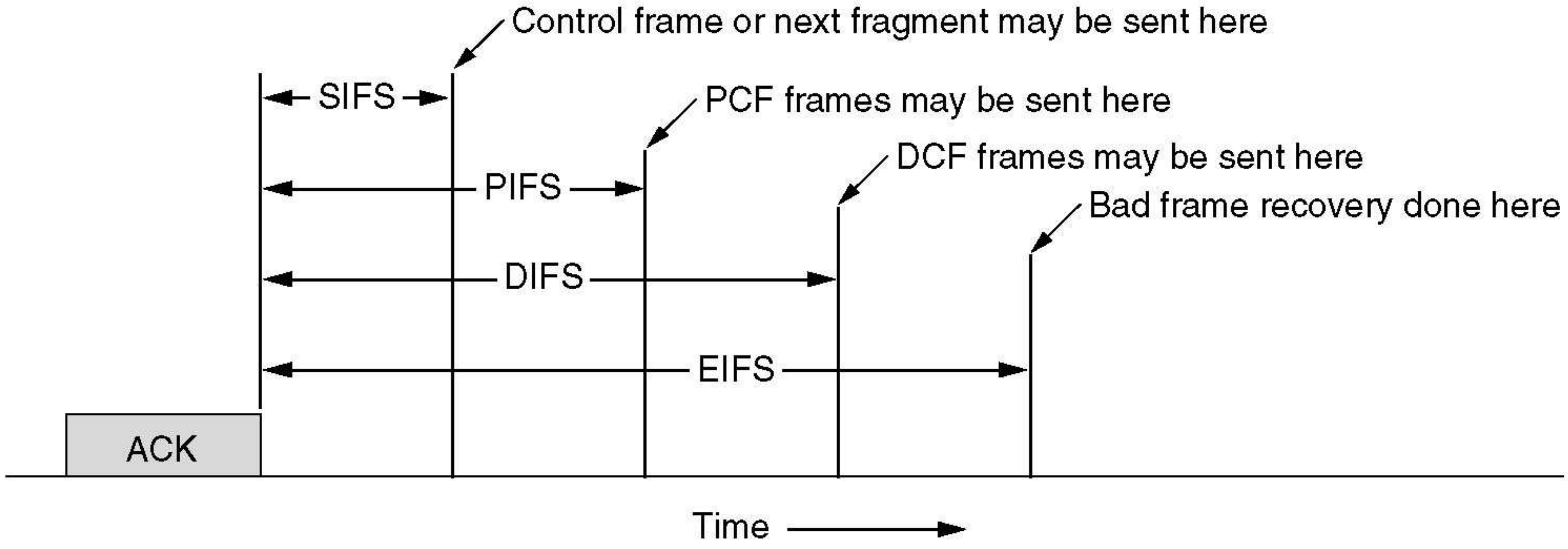
The use of virtual channel sensing using CSMA/CA.

The 802.11 MAC Sublayer Protocol (3)


Fragment burst
A
RTS
Frag 1
Frag 2
Frag 3
B
CTS
ACK
ACK
ACK
C
NAV
D
NAV
Time

A fragment burst.

The 802.11 MAC Sublayer Protocol (4)


Control frame or next fragment may be sent here
SIFS
PCF frames may be sent here
PIFS
DCF frames may be sent here
Bad frame recovery done here
DIFS
EIFS
ACK
Time

Interframe spacing in 802.11.

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The 802.11 Frame Structure

Bytes	2	2	6	6	6	2	6	0-2312	4
	Frame control	Duration	Address 1	Address 2	Address 3	Seq.	Address 4	Data	Checksum

Bits	2	2	4	1	1	1	1	1	1	1	1	
	Version	Type	Subtype	To DS	From DS	MF	Retry	Pwr	More	W	O	Frame control

The 802.11 data frame.

802.11 Services

Distribution Services

- Association
- Disassociation
- Reassociation
- Distribution
- Integration

802.11 Services

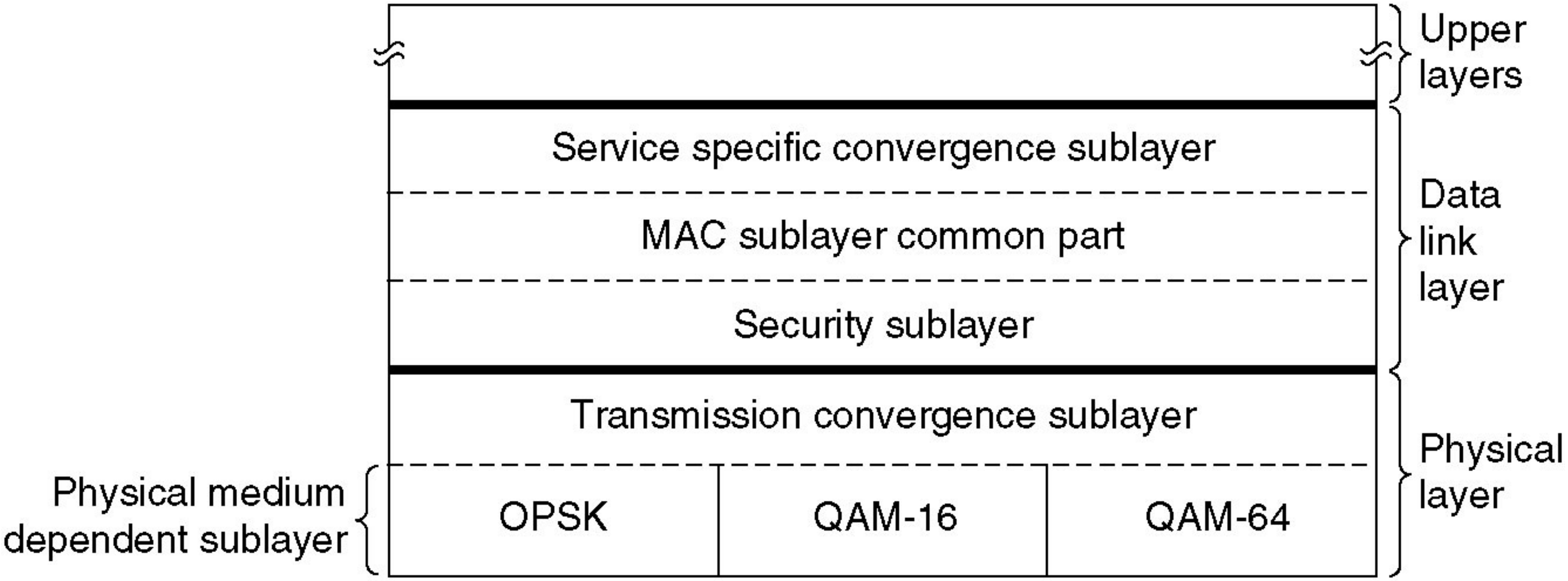
Intracell Services

- Authentication
- Deauthentication
- Privacy
- Data Delivery

Broadband Wireless

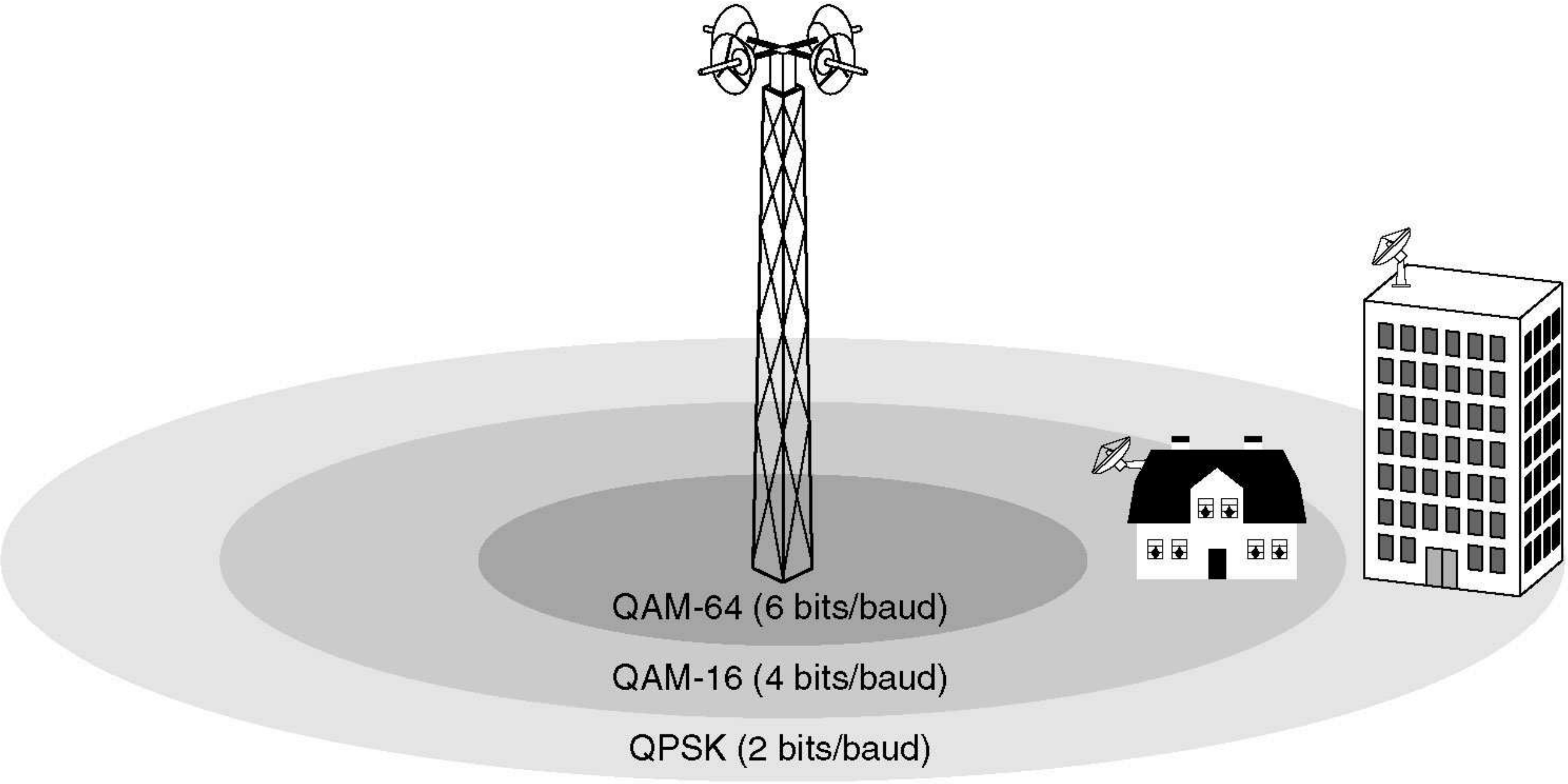
- Comparison of 802.11 and 802.16
- The 802.16 Protocol Stack
- The 802.16 Physical Layer
- The 802.16 MAC Sublayer Protocol
- The 802.16 Frame Structure

The 802.16 Protocol Stack


Upper layers
Service specific convergence sublayer
MAC sublayer common part
Security sublayer
Data link layer
Transmission convergence sublayer
Physical medium dependent sublayer
OPSK
QAM-16
QAM-64
Physical layer

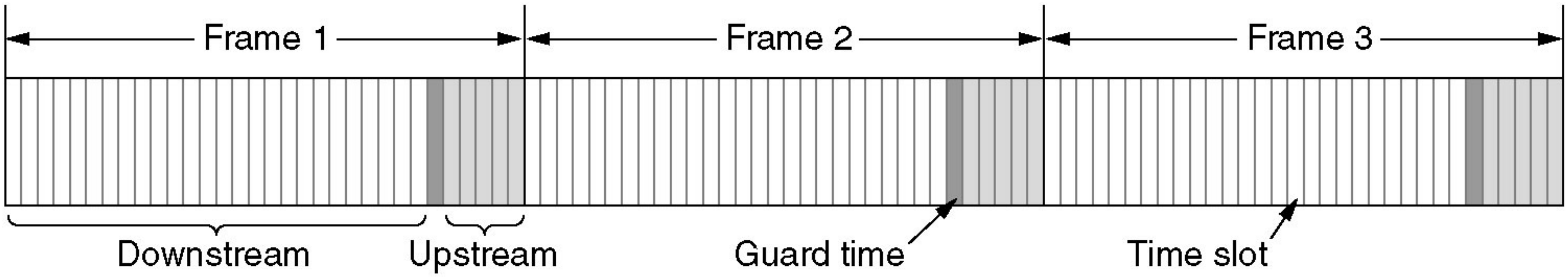
The 802.16 Protocol Stack.

The 802.16 Physical Layer


QAM-64 (6 bits/baud)
QAM-16 (4 bits/baud)
QPSK (2 bits/baud)

The 802.16 transmission environment.

The 802.16 Physical Layer (2)


Frame 1
Frame 2
Frame 3
Downstream
Upstream
Guard time
Time slot

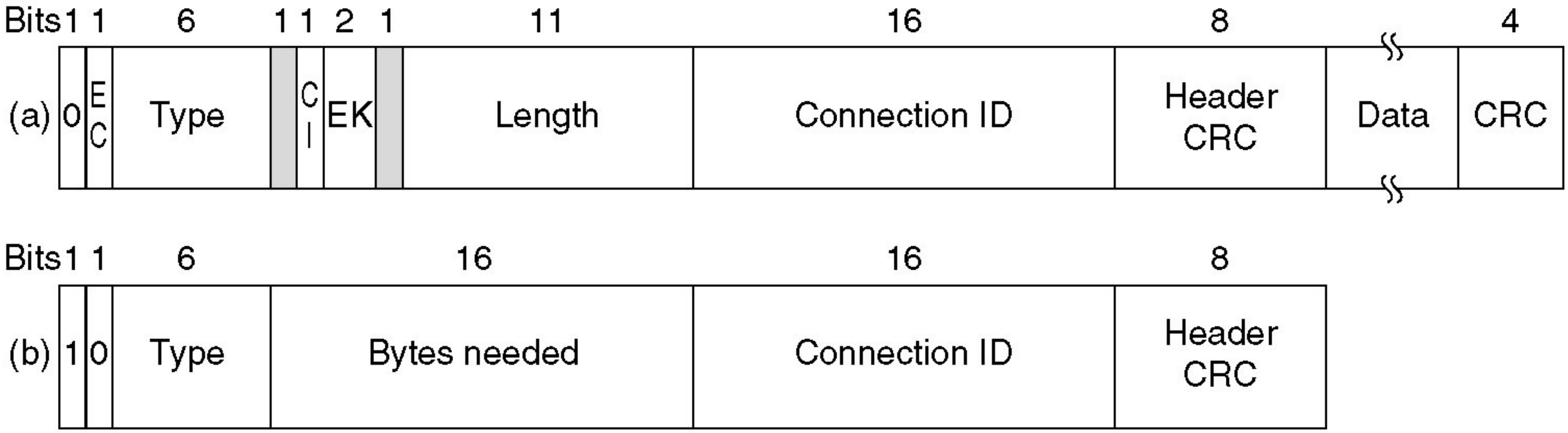
Frames and time slots for time division duplexing.

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



Bits	1	1	6	1	1	2	1	11	16	8		4
(a)	0	EC	Type		CI	EK		Length	Connection ID	Header CRC	Data	CRC

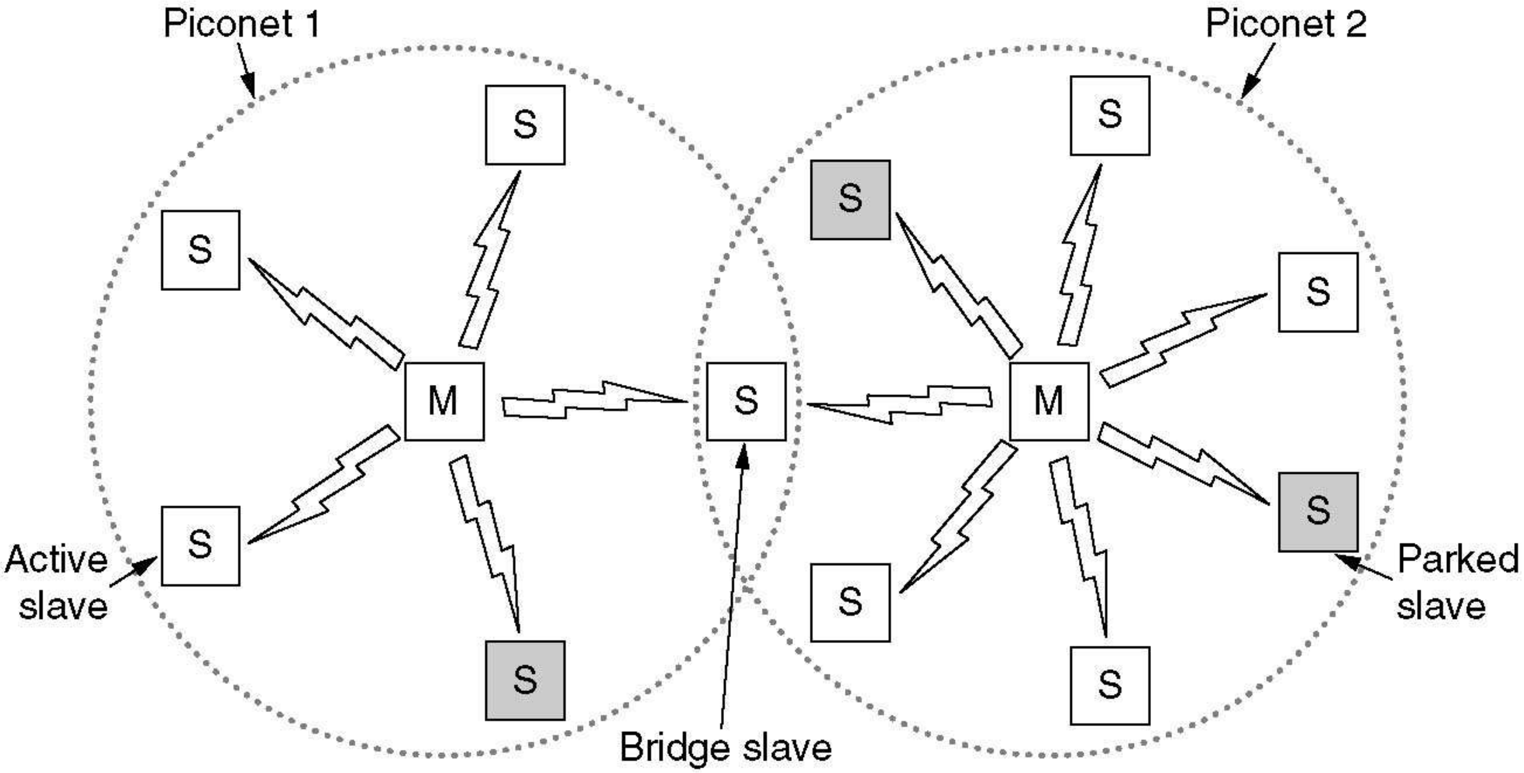
Bits	1	1	6	16	16	8
(b)	1	0	Type	Bytes needed	Connection ID	Header CRC

(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

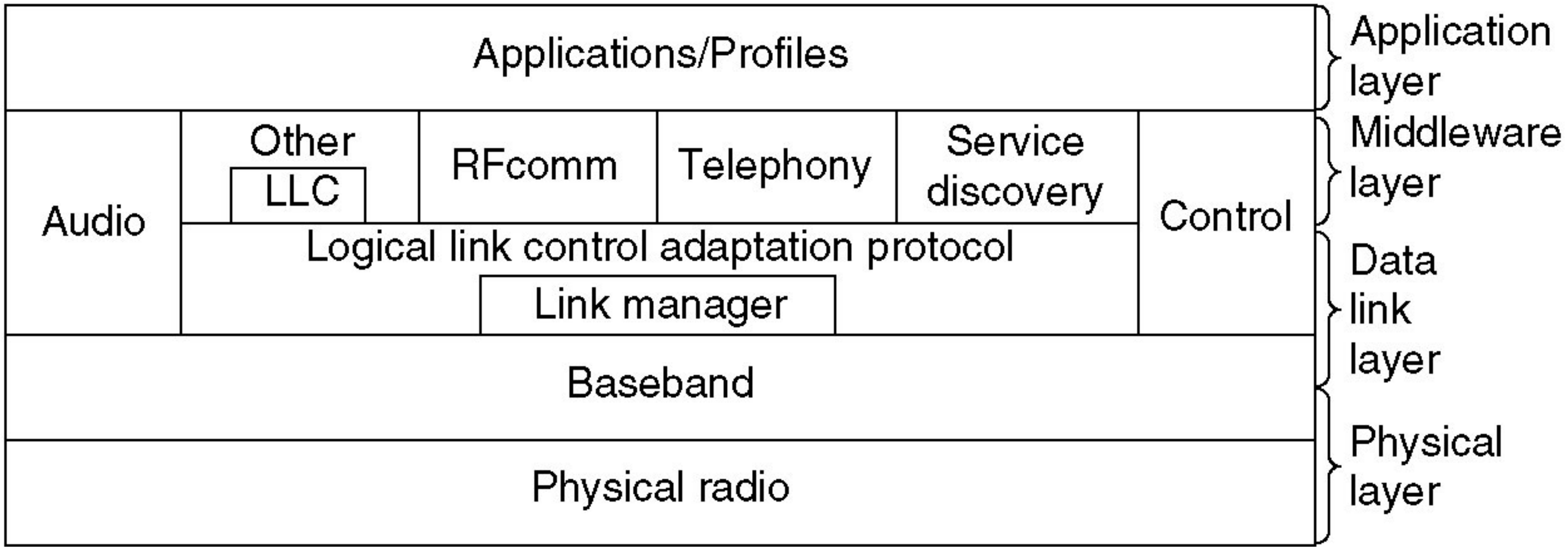

Piconet 1
Piconet 2
S
S
S
S
M
S
M
S
S
S
S
S
S
S
Active slave
Parked slave
Bridge slave

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 Protocol Stack


Applications/Profiles
Audio
Other
LLC
RFcomm
Telephony
Service discovery
Control
Logical link control adaptation protocol
Link manager
Baseband
Physical radio
Application layer
Middleware layer
Data link layer
Physical layer

The 802.15 version of the Bluetooth protocol architecture.

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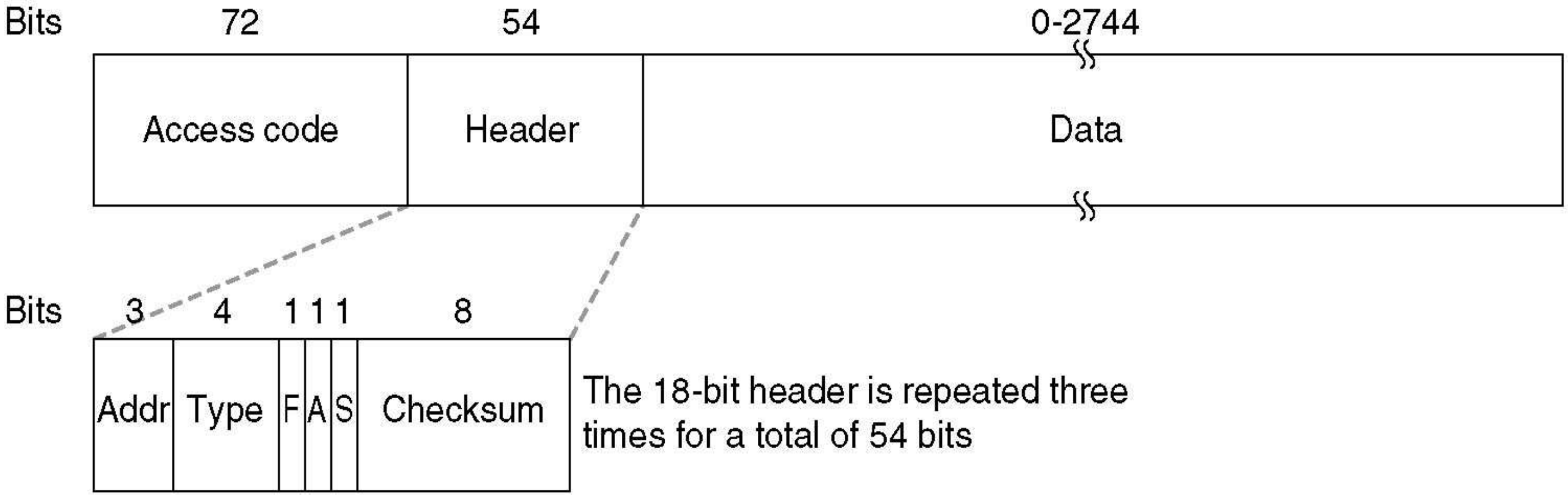
The Bluetooth Frame Structure

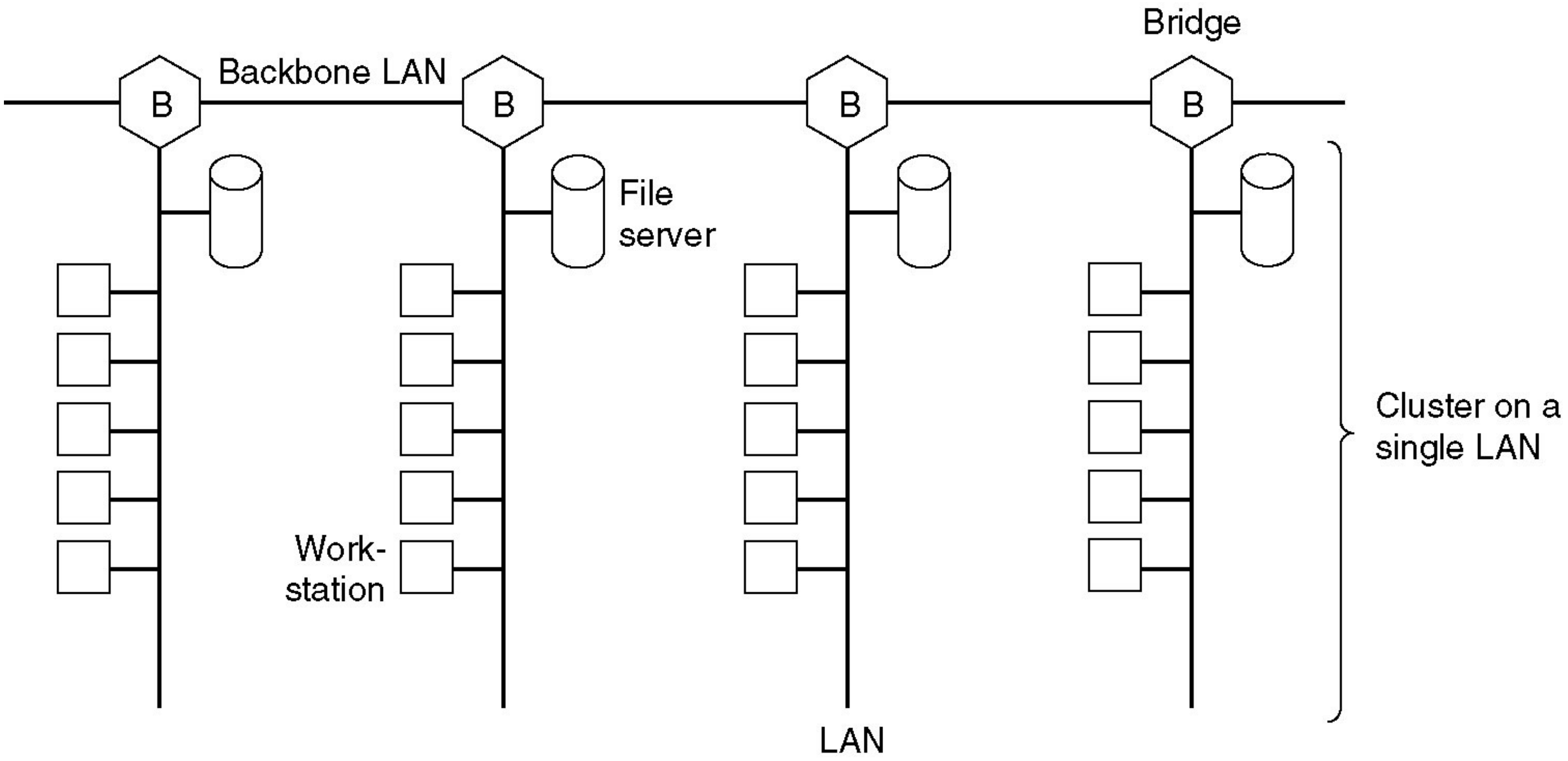

Bits
72
54
0-2744
Access code
Header
Data
Bits
3
4
1 1 1
8
Addr
Type
F
A
S
Checksum
The 18-bit header is repeated three times for a total of 54 bits

A typical Bluetooth data frame.

Data Link Layer Switching

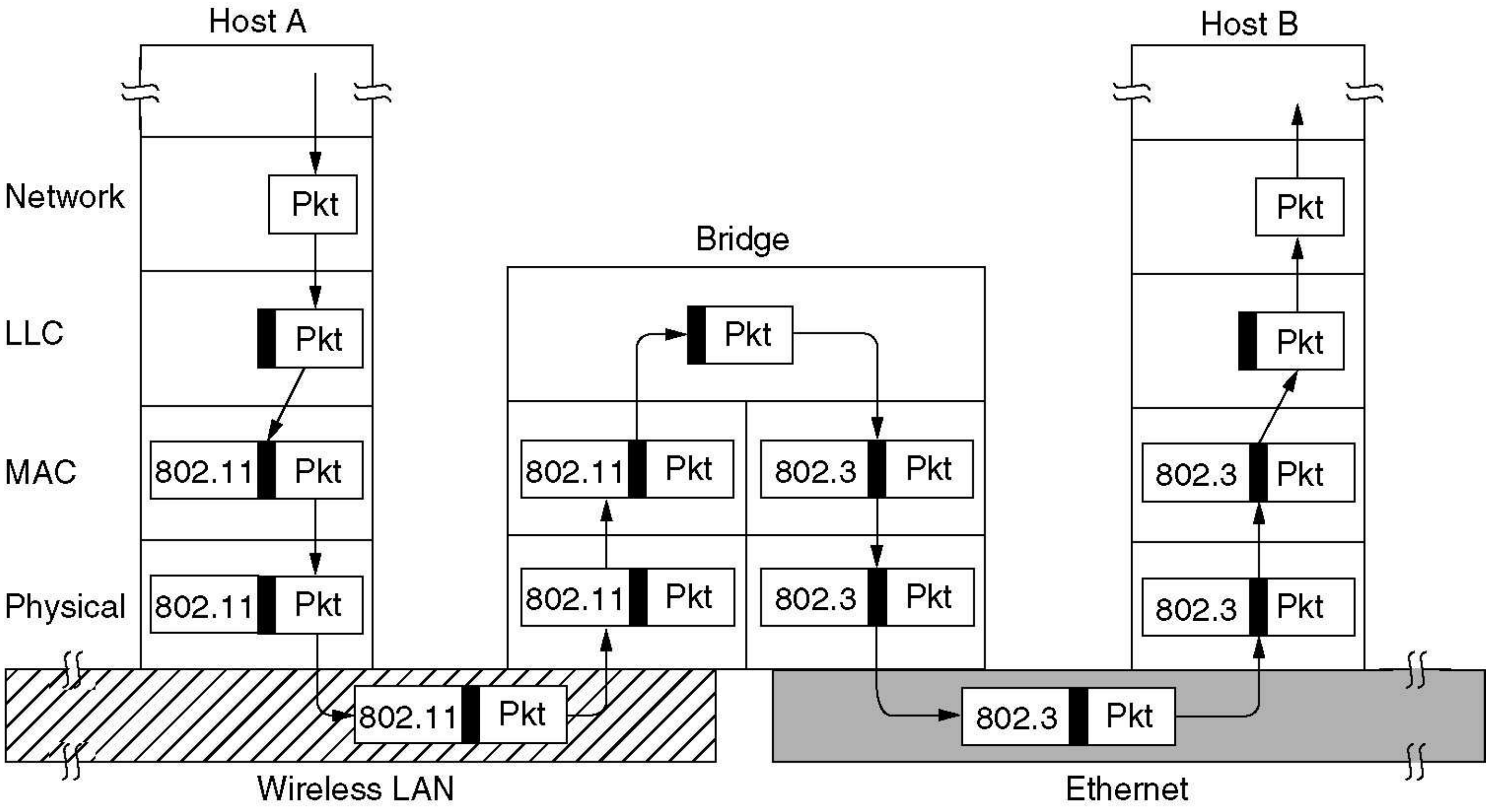
- Bridges from 802.x to 802.y
- Local Internetworking
- Spanning Tree Bridges
- Remote Bridges
- Repeaters, Hubs, Bridges, Switches, Routers, Gateways
- Virtual LANs

Data Link Layer Switching


Bridge
Backbone LAN
B
B
B
B
File server
Work-station
Cluster on a single LAN
LAN

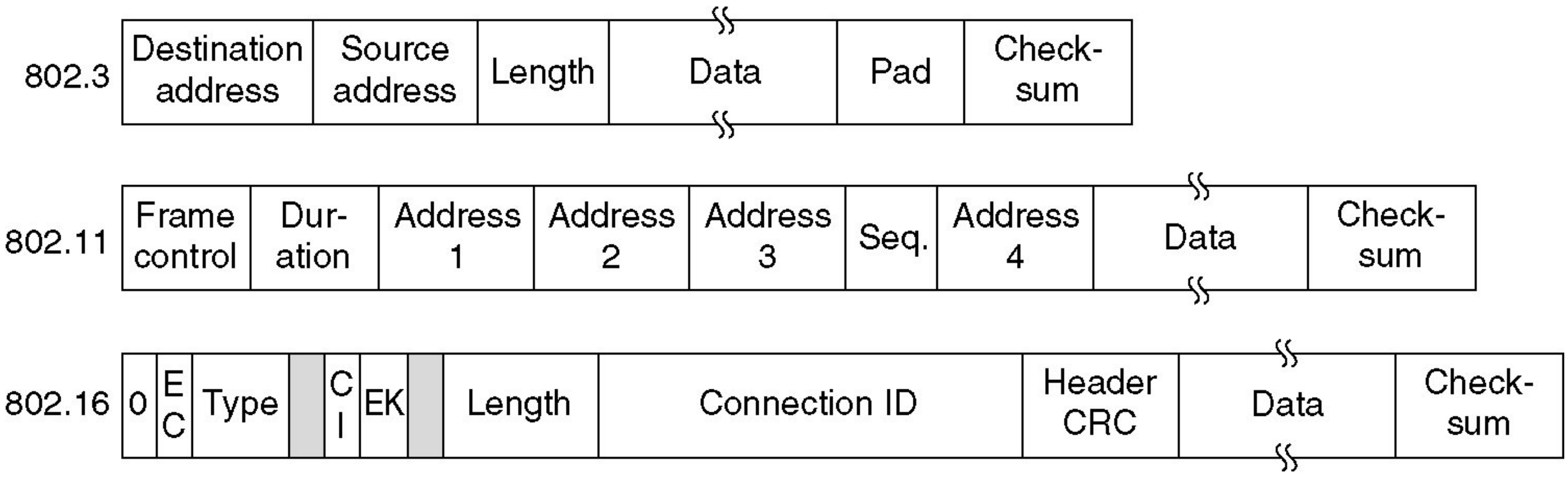
Multiple LANs connected by a backbone to handle a total load higher than the capacity of a single LAN.

Bridges from 802.x to 802.y


Host A
Host B
Bridge
Network
LLC
MAC
Physical
Pkt
802.11
802.3
Wireless LAN
Ethernet

Operation of a LAN bridge from 802.11 to 802.3.

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



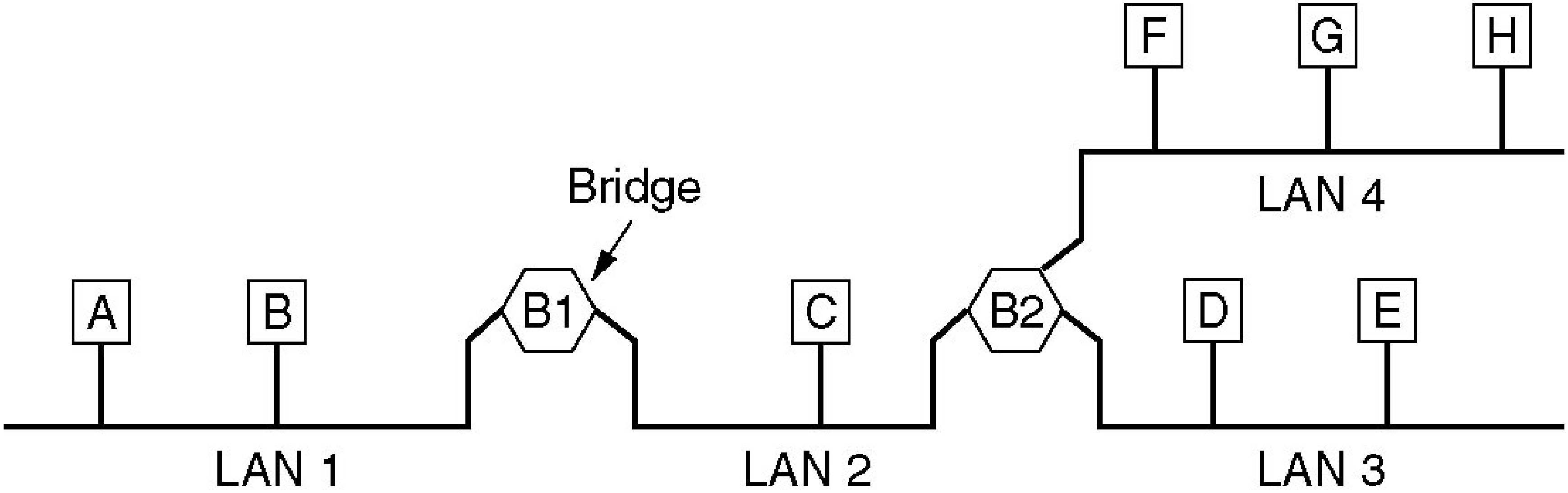
802.3	Destination address	Source address	Length	Data	Pad	Check-sum

802.11	Frame control	Dur-ation	Address 1	Address 2	Address 3	Seq.	Address 4	Data	Check-sum

802.16	0	EC	Type	▨	CI	EK	▨	Length	Connection ID	Header CRC	Data	Check-sum

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

Local Internetworking


F
G
H
Bridge
LAN 4
A
B
B1
C
B2
D
E
LAN 1
LAN 2
LAN 3

A configuration with four LANs and two bridges.

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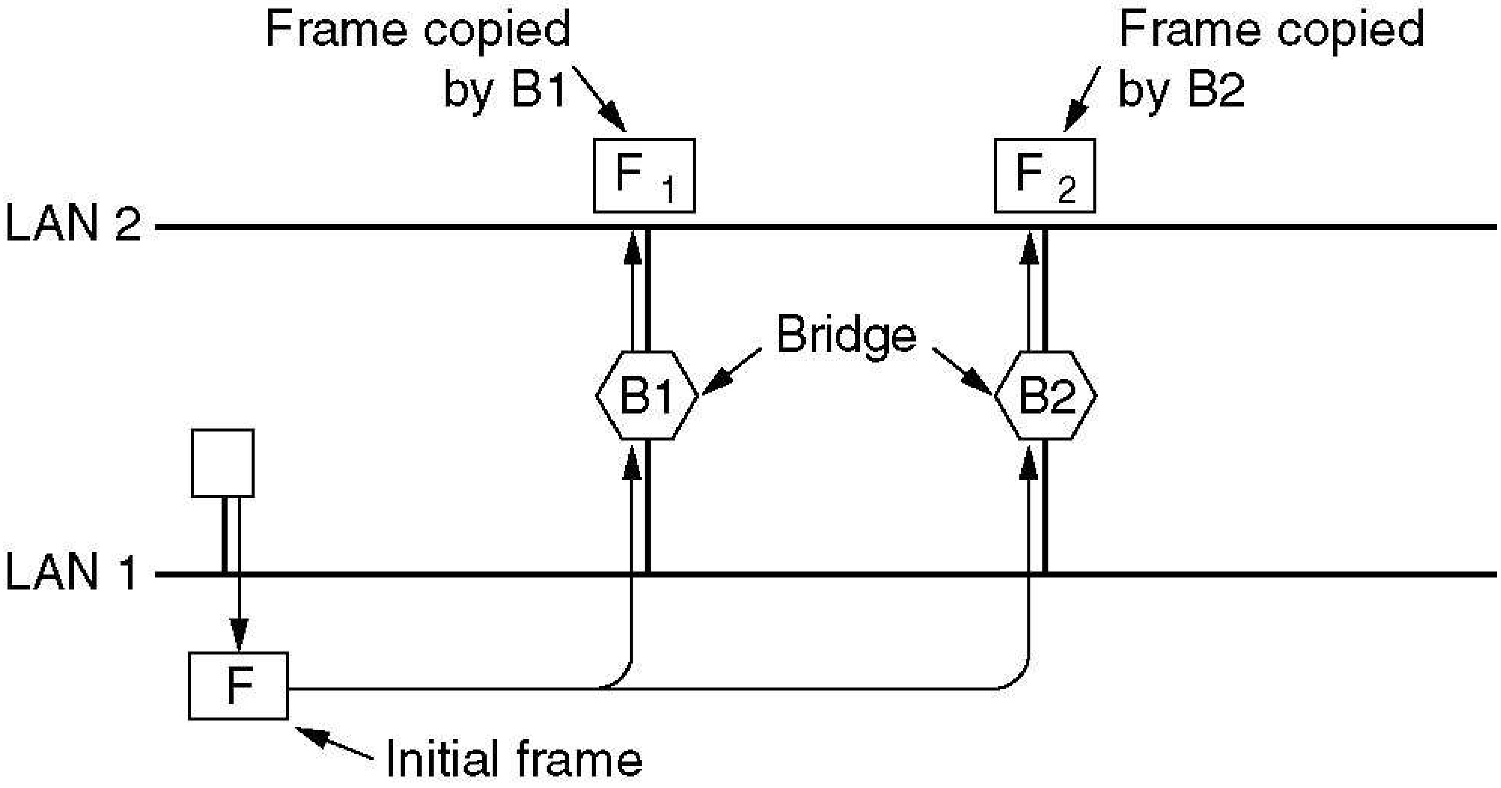
Spanning Tree Bridges


Frame copied by B1
Frame copied by B2
F1
F2
LAN 2
Bridge
B1
B2
LAN 1
F
Initial frame

Two parallel transparent bridges.

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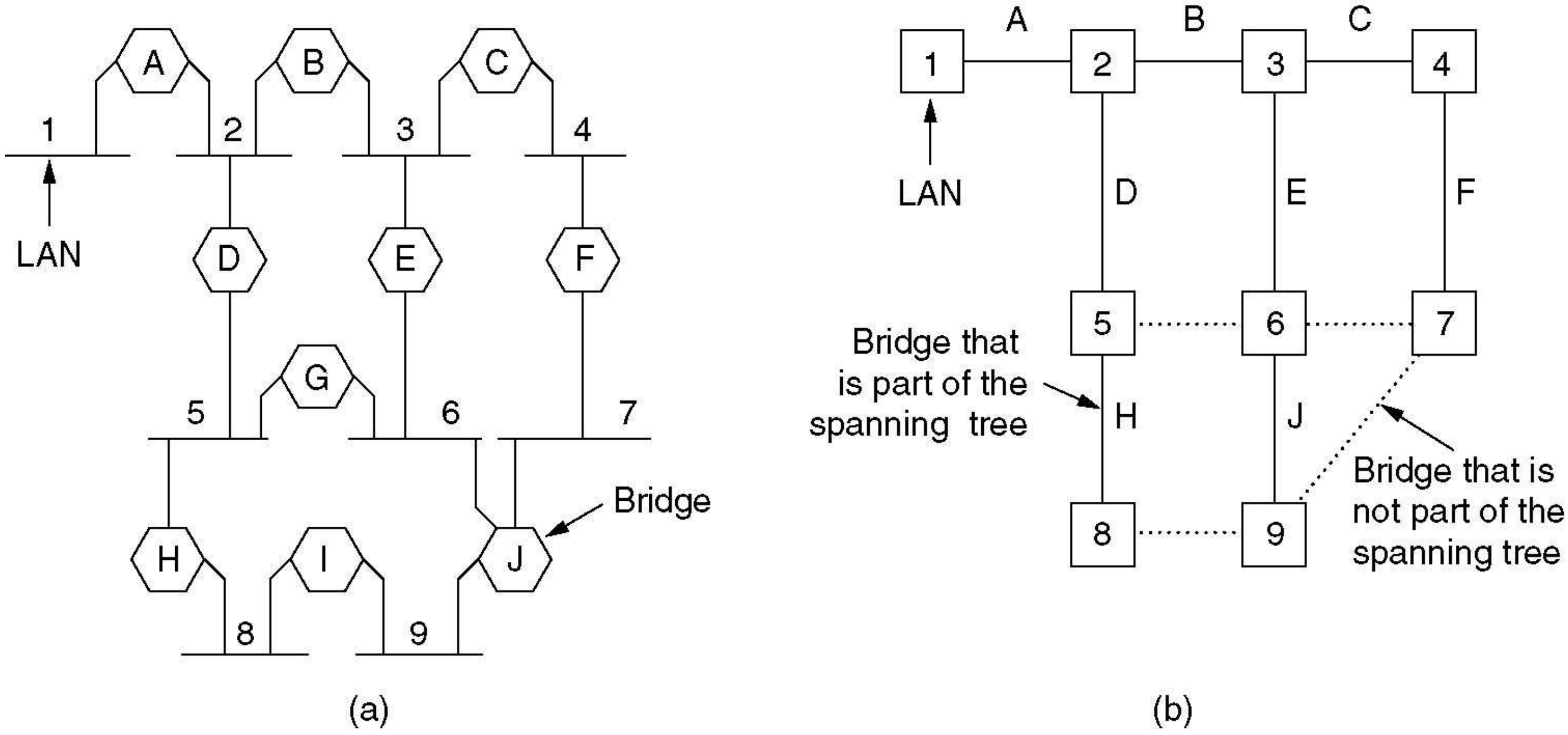
Spanning Tree Bridges (2)


A
B
C
1
2
3
4
LAN
D
E
F
G
5
6
7
Bridge
H
I
J
8
9
(a)
A
B
C
1
2
3
4
LAN
D
E
F
5
6
7
Bridge that is part of the spanning tree
H
J
Bridge that is not part of the spanning tree
8
9
(b)

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

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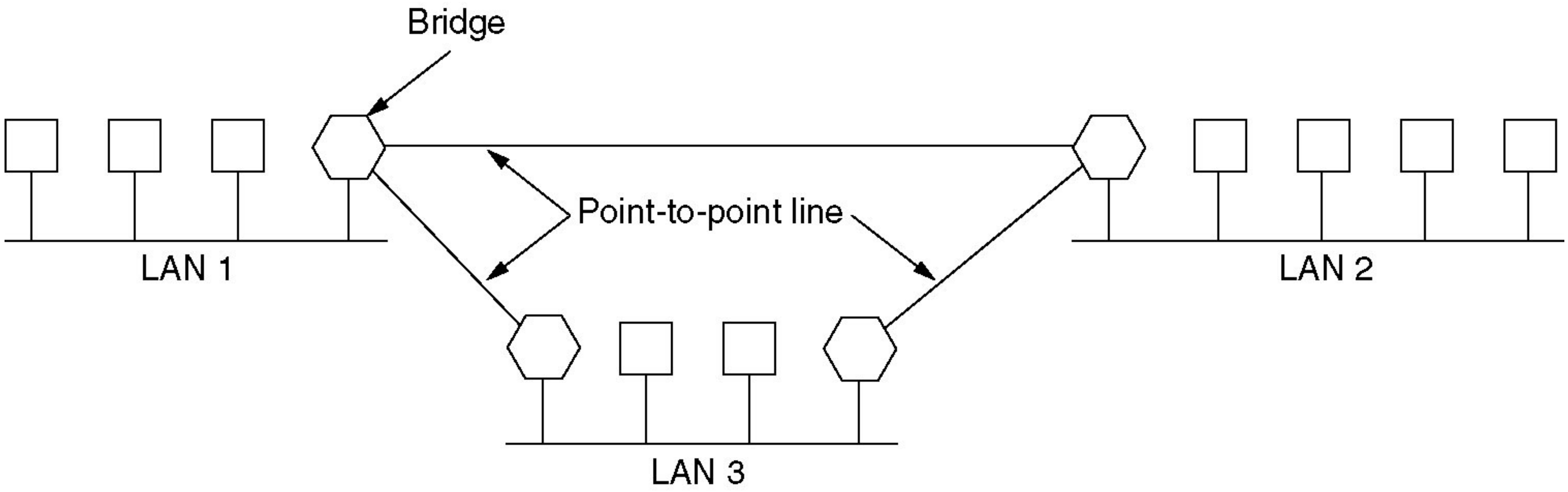
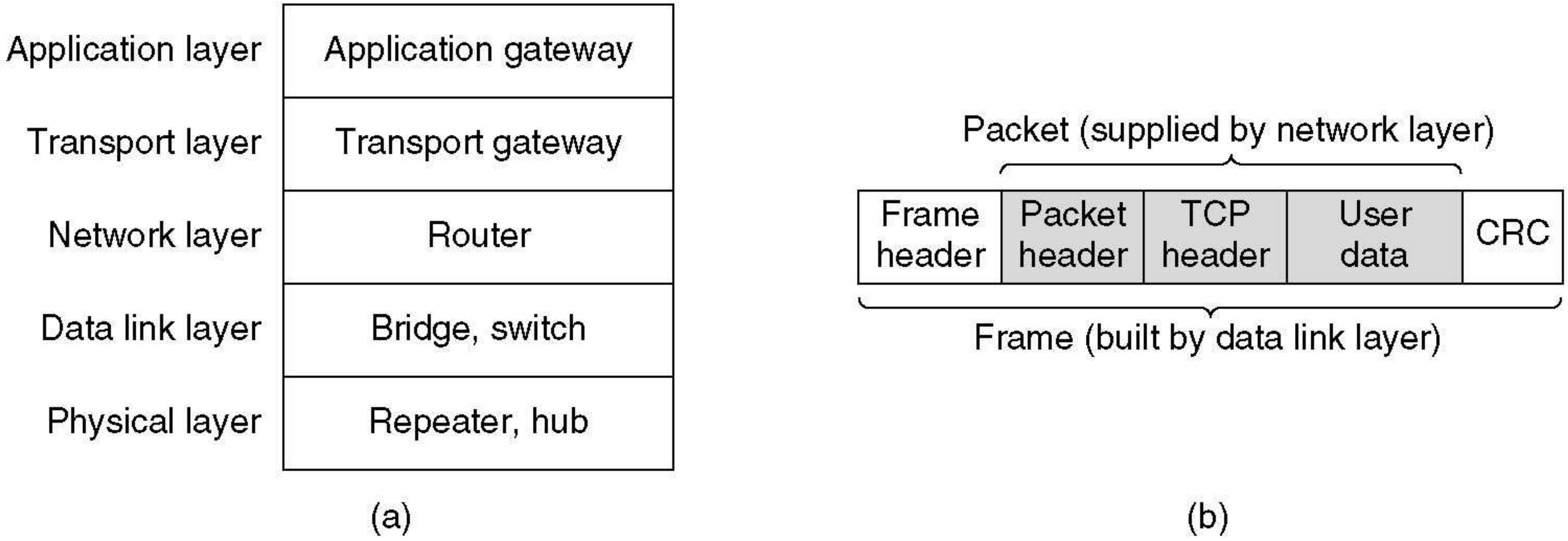
Remote Bridges


Bridge
Point-to-point line
LAN 1
LAN 2
LAN 3

Remote bridges can be used to interconnect distant LANs.

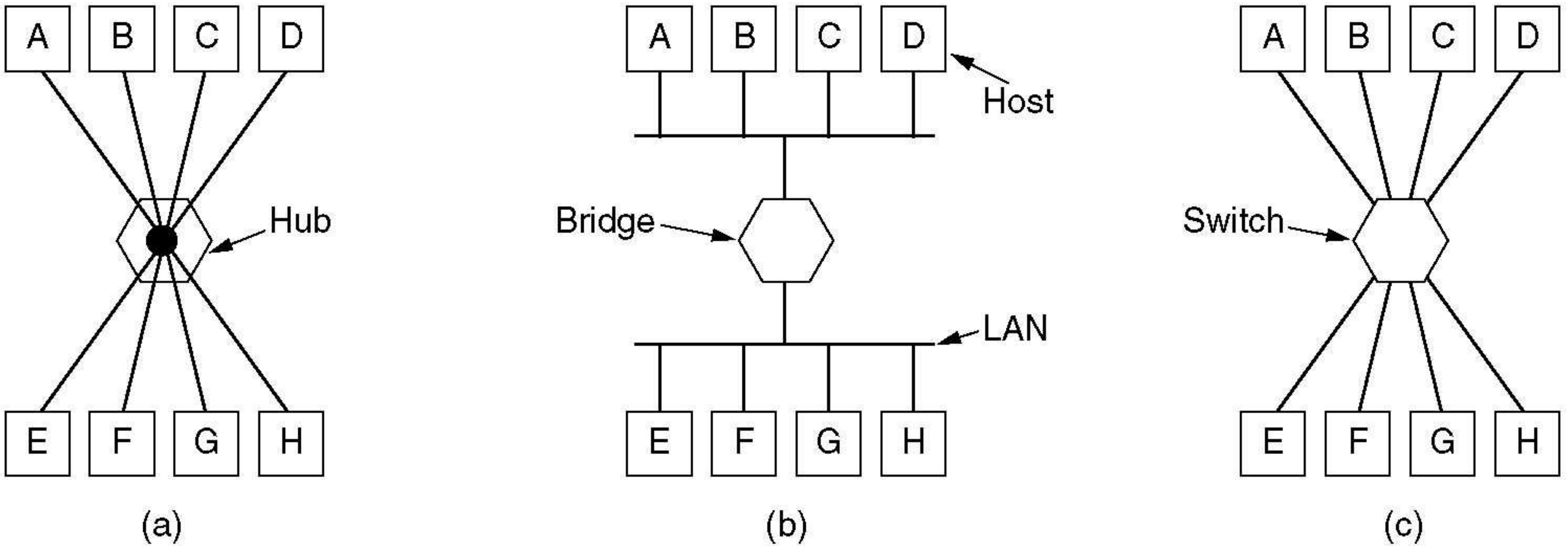
Repeaters, Hubs, Bridges, Switches, Routers and Gateways


Application layer
Application gateway
Transport layer
Transport gateway
Network layer
Router
Data link layer
Bridge, switch
Physical layer
Repeater, hub
Packet (supplied by network layer)
Frame header
Packet header
TCP header
User data
CRC
Frame (built by data link layer)
(a)
(b)

(a) Which device is in which layer.

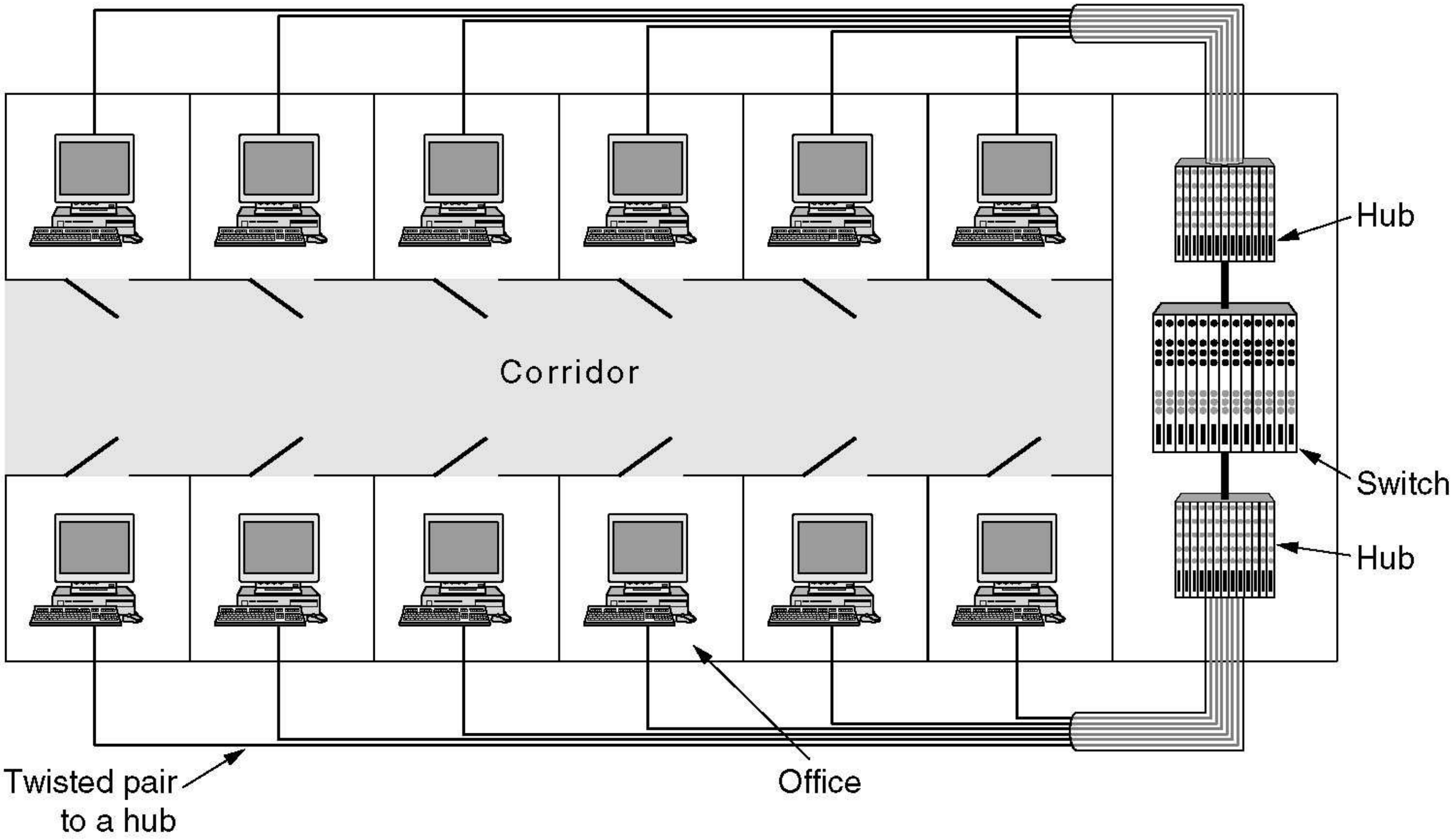
(b) Frames, packets, and headers.

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


A
B
C
D
Hub
E
F
G
H
(a)
A
B
C
D
Host
Bridge
LAN
E
F
G
H
(b)
A
B
C
D
Switch
E
F
G
H
(c)

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

Virtual LANs


Hub
Corridor
Switch
Hub
Twisted pair to a hub
Office

A building with centralized wiring using hubs and a switch.

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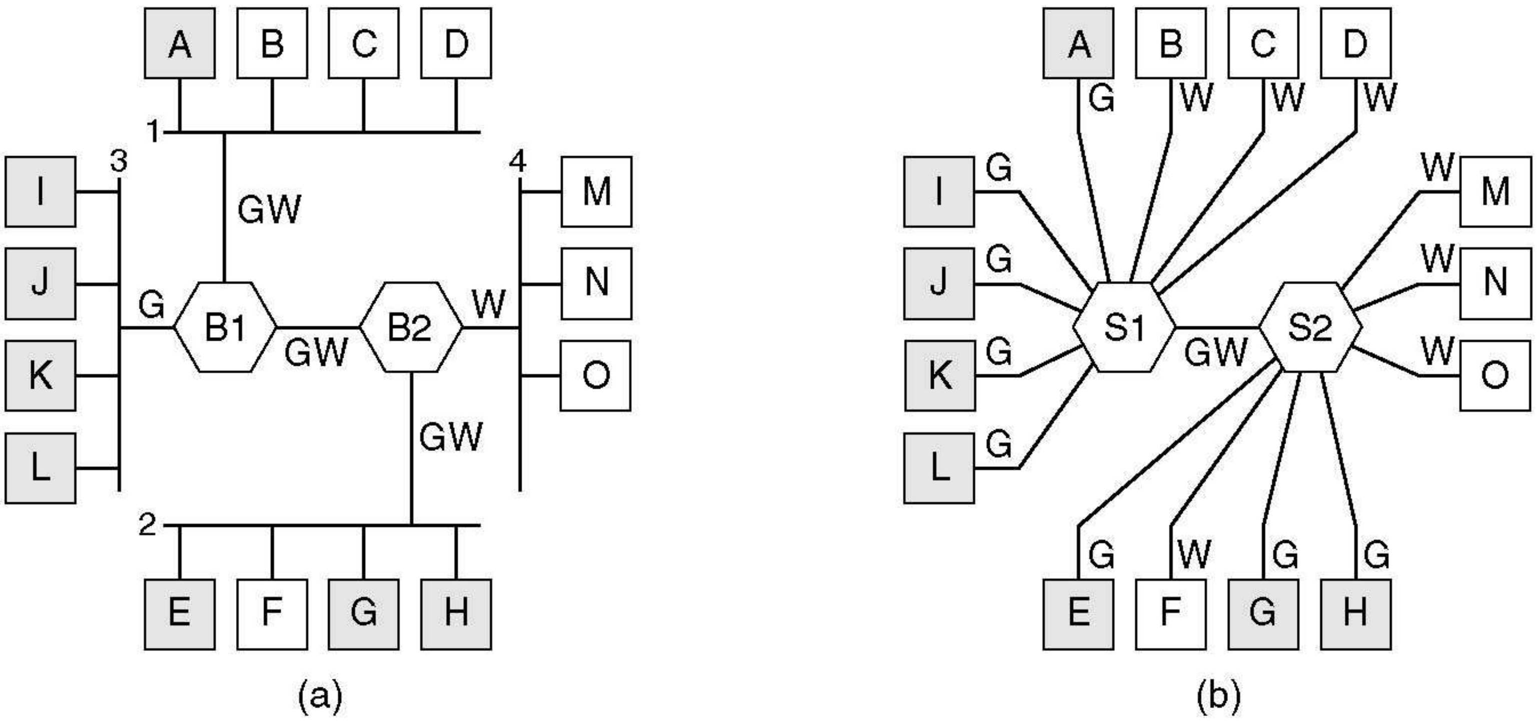
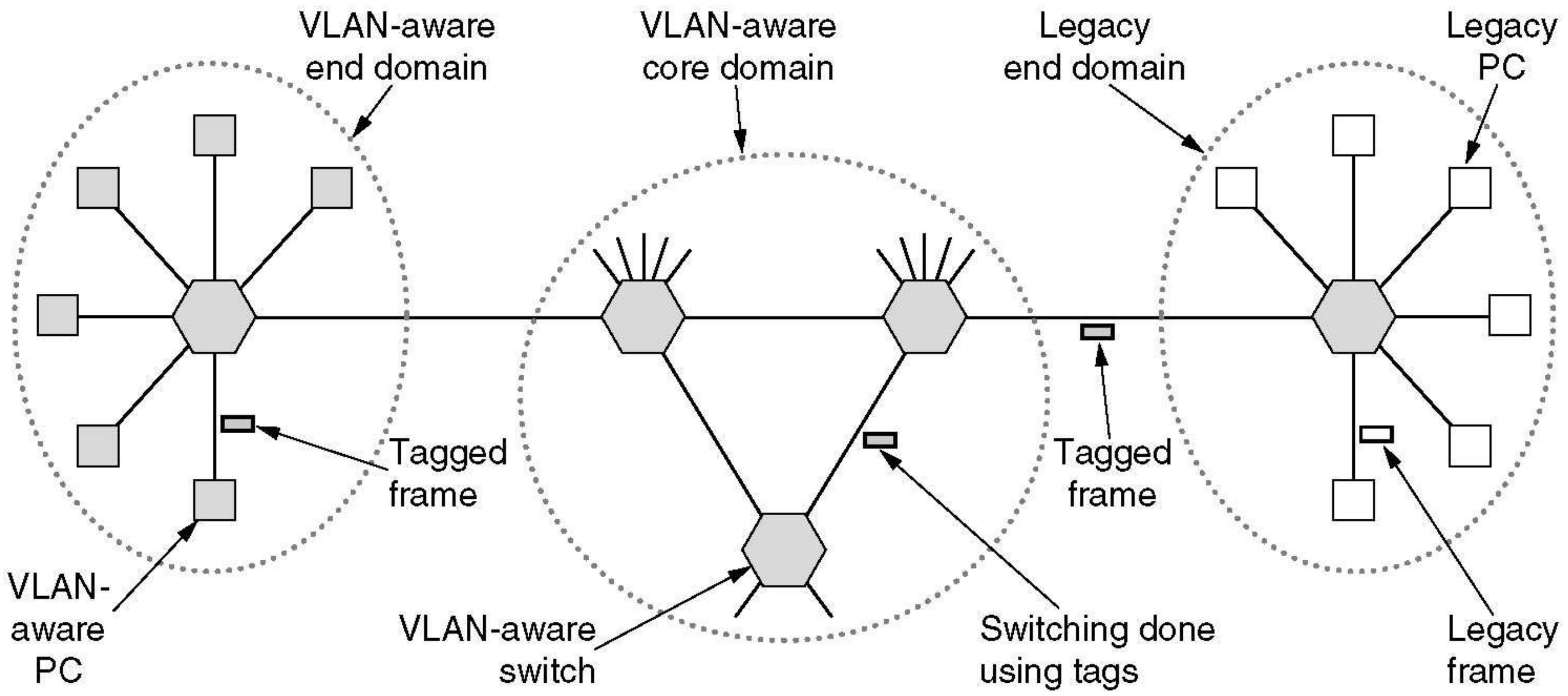
Virtual LANs (2)


A
B
C
D
1
3
4
I
J
K
L
M
N
O
GW
G
W
B1
B2
GW
GW
2
E
F
G
H
(a)
A
B
C
D
G
W
W
W
G
G
G
G
W
W
W
S1
S2
GW
G
W
G
G
E
F
G
H
(b)

(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


VLAN-aware
end domain
VLAN-aware
core domain
Legacy
end domain
Legacy
PC
Tagged
frame
Tagged
frame
VLAN-
aware
PC
VLAN-aware
switch
Switching done
using tags
Legacy
frame

Transition from legacy Ethernet to VLAN-aware Ethernet. The shaded symbols are VLAN aware. The empty ones are not.

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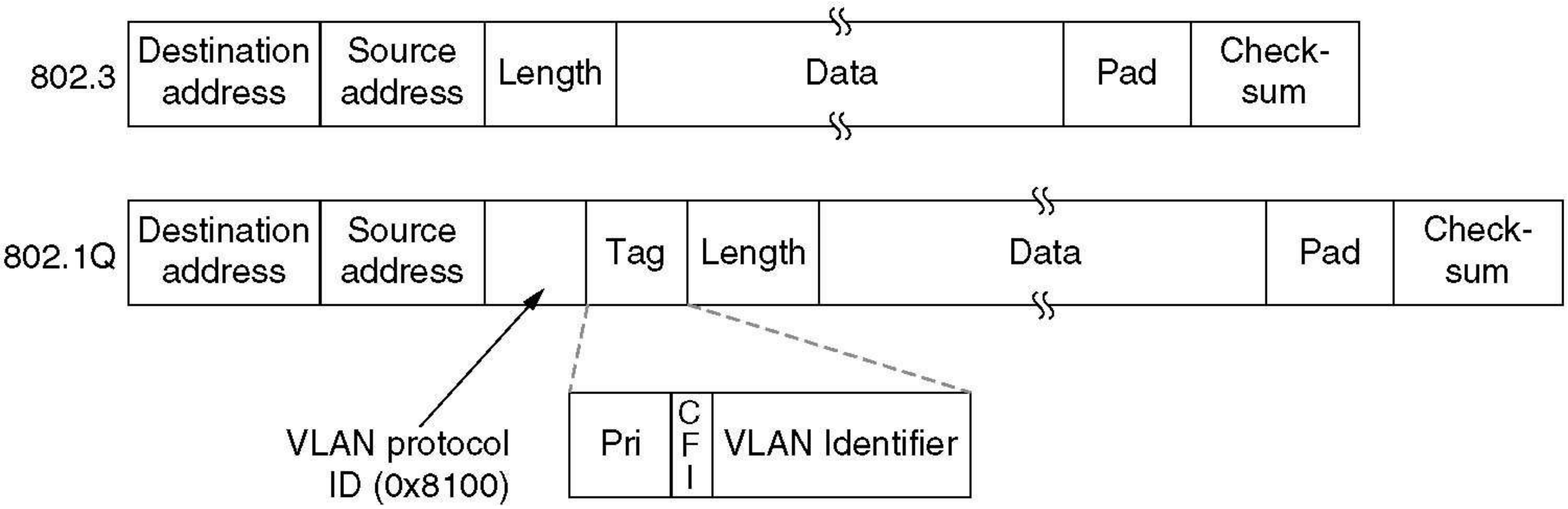
The IEEE 802.1Q Standard (2)


802.3
Destination address
Source address
Length
Data
Pad
Check-sum
802.1Q
Destination address
Source address
Tag
Length
Data
Pad
Check-sum
VLAN protocol ID (0x8100)
Pri
CFI
VLAN Identifier

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

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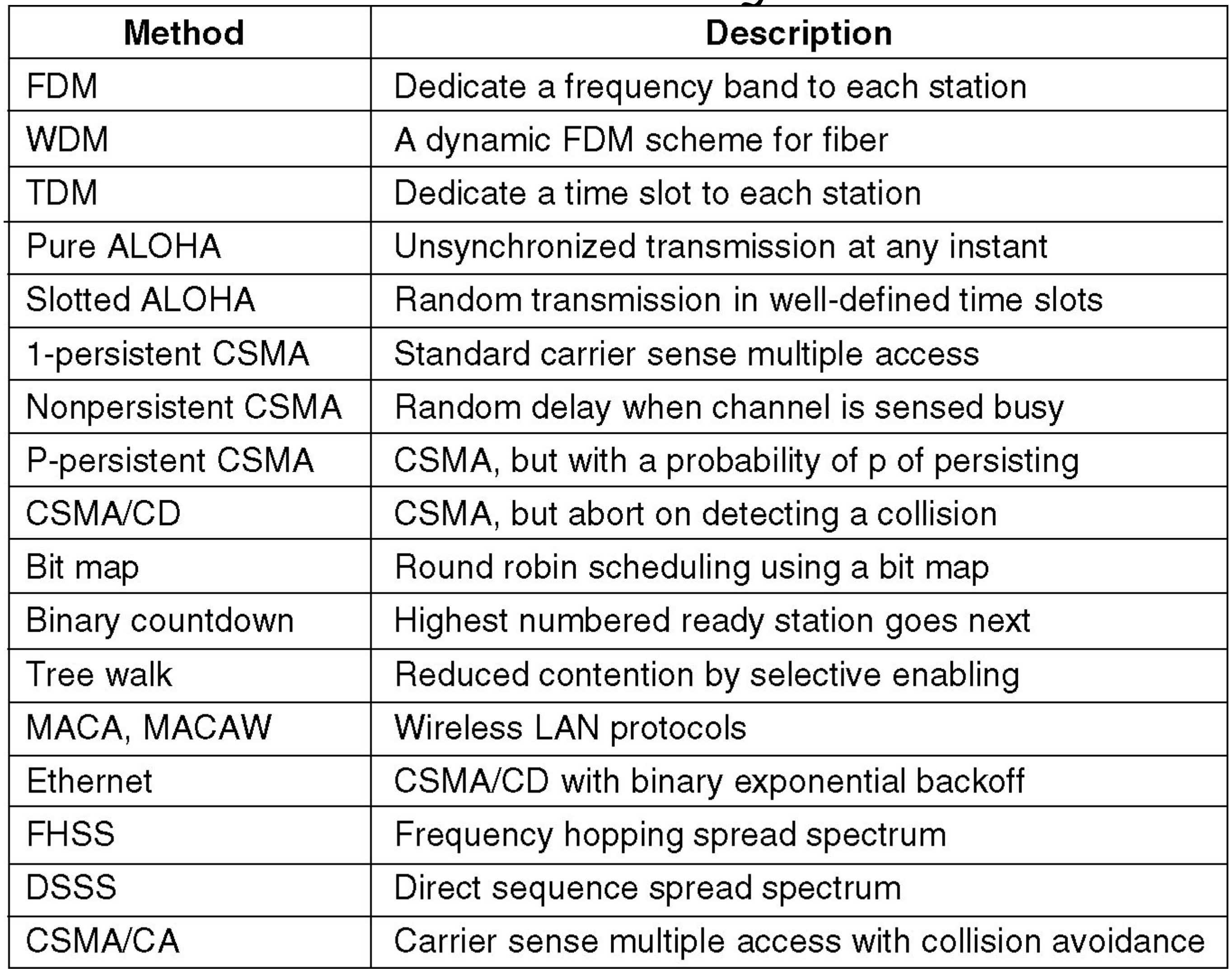
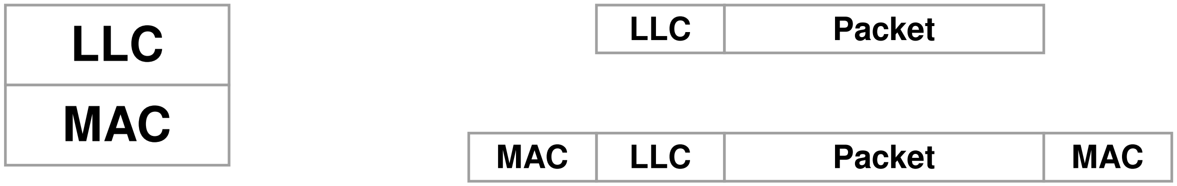
Summary



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.

802.2 Logical Link Control



LLC

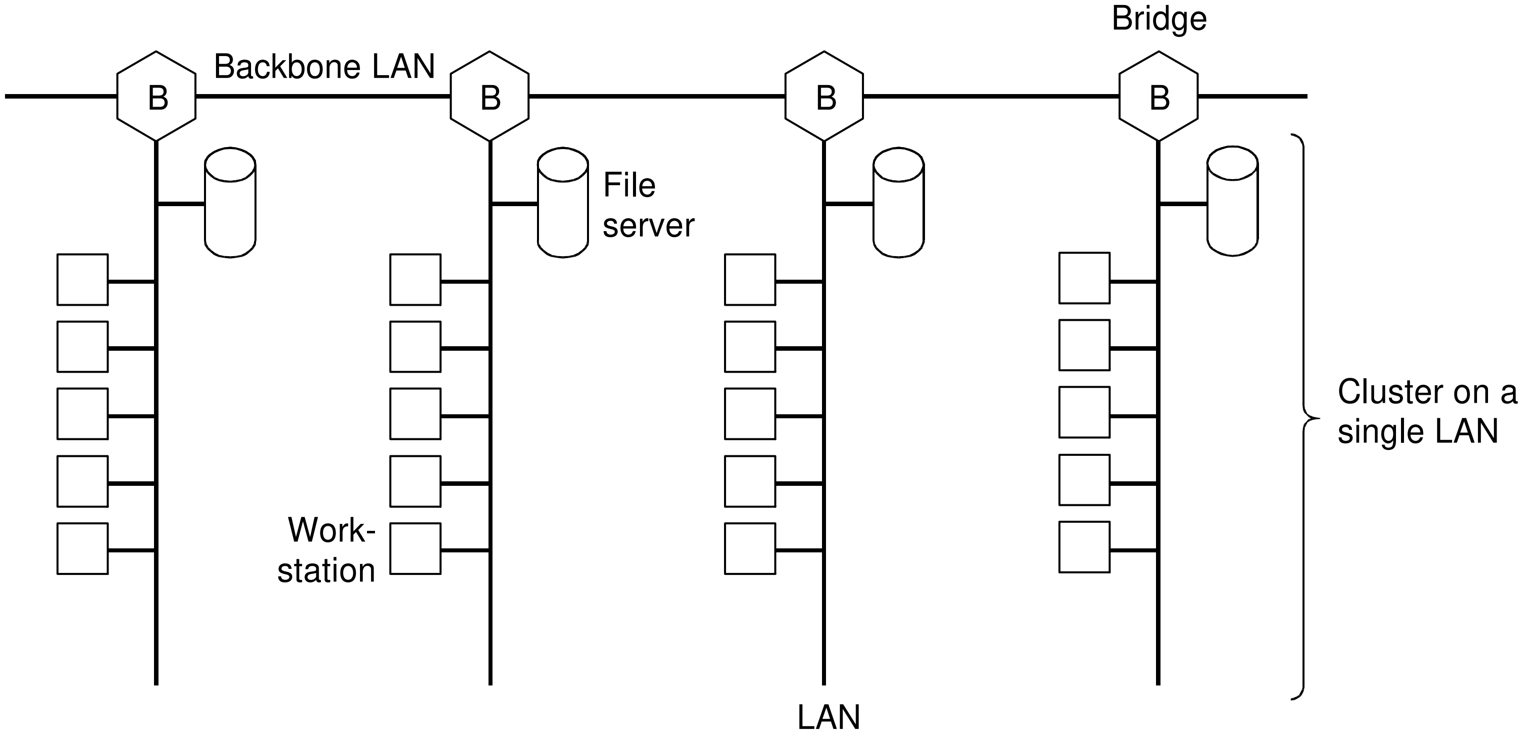
MAC

LLC | Packet

MAC | LLC | Packet | MAC

- Network layer sends packet using LLC primitives
- LLC adds its header containing sequence and acknowledgement numbers and passes it to MAC
- LLC Service Options
  - unreliable datagram service
  - acknowledged datagram service
  - reliable connection oriented service

Bridges

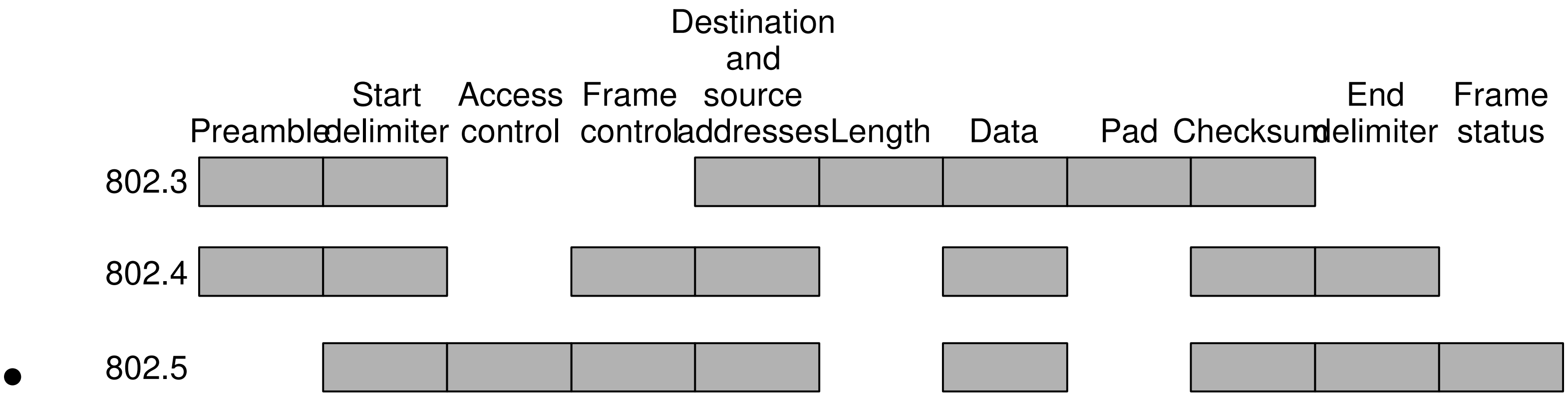

Bridge
Backbone LAN
B
B
B
B
File
server
Cluster on a
single LAN
Work-
station
LAN

Spring 2003

Bridges

- Used to connect multiple LANS
- Data Link Layer operation
  - Do not examine network layer headers
- Only forward frames if necessary
  - Security / Firewalls
- Format matching

Bridges



	Preamble	Start delimiter	Access control	Frame control	Destination and source addresses	Length	Data	Pad	Checksum	End delimiter	Frame status
802.3	▨	▨			▨	▨	▨	▨	▨		
802.4	▨	▨		▨	▨		▨		▨	▨	
• 802.5		▨	▨	▨	▨		▨		▨	▨	▨

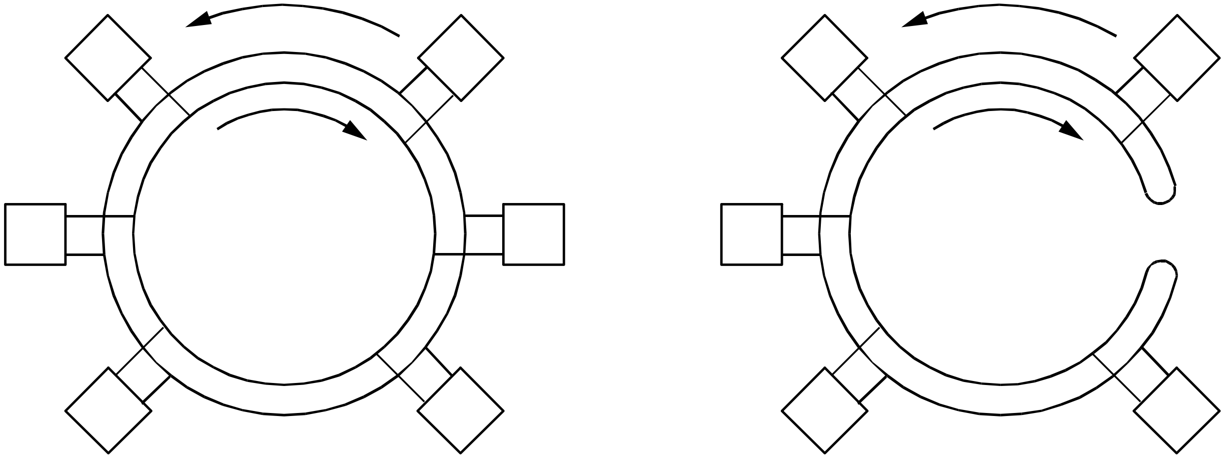
High Speed LANS

- FDDI - Fiber Distributed Data Interface
- Fast Ethernet
- HIPPI - High Performance Parallel Interface
- Fiber Channel

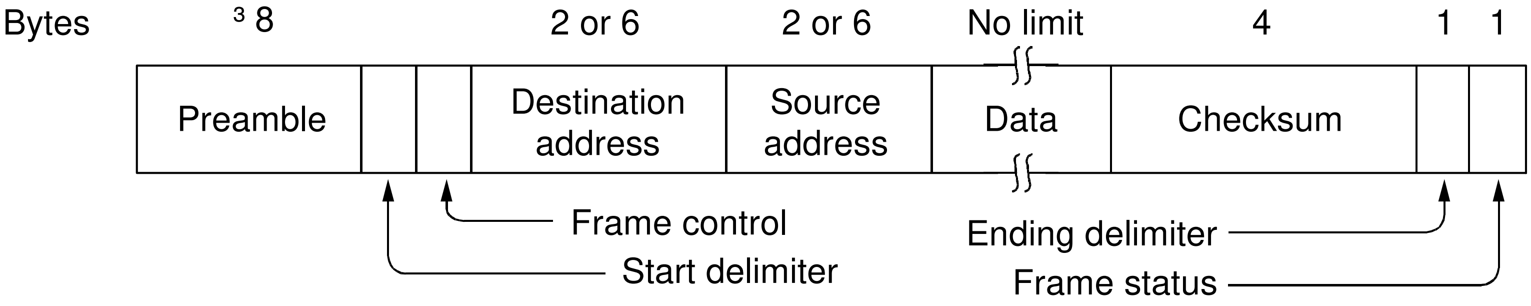
Fiber Distributed Data Interface

- FDDI is the most popular token-ring base LAN
- Dual counterrotating rings, each at 100 Mbps
- Uses both copper and fiber links
- Supports both non-realtime and realtime traffic
  - token is guaranteed to rotate once every Target Token Rotation Time (TTRT)
  - station is guaranteed a synchronous allocation within every TTRT
- Supports both single attached and dual attached stations
  - single attached (cheaper) stations are connected to only one of the rings

FDDI



(a) (b)



Bytes	^{3} 8			2 or 6	2 or 6	No limit	4	1	1
	Preamble			Destination address	Source address	Data	Checksum		

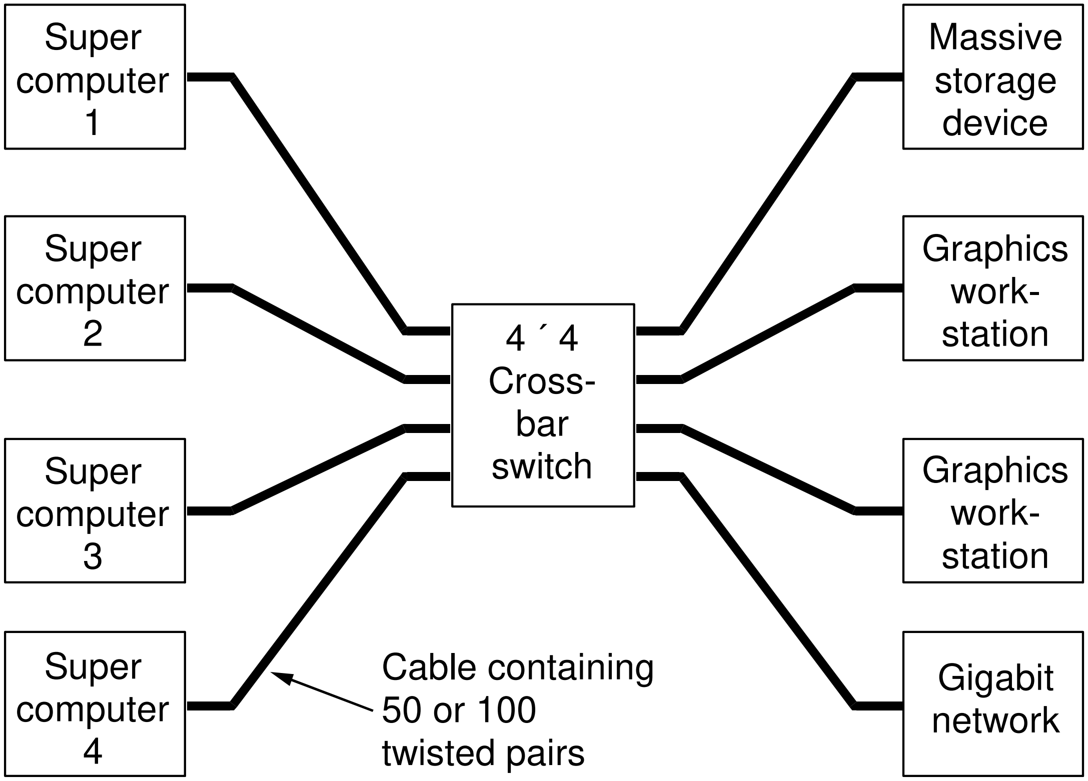
Frame control

Start delimiter

Ending delimiter

Frame status

HIPPI



Super computer 1

Super computer 2

Super computer 3

Super computer 4

4 ´ 4 Cross-bar switch

Massive storage device

Graphics work-station

Graphics work-station

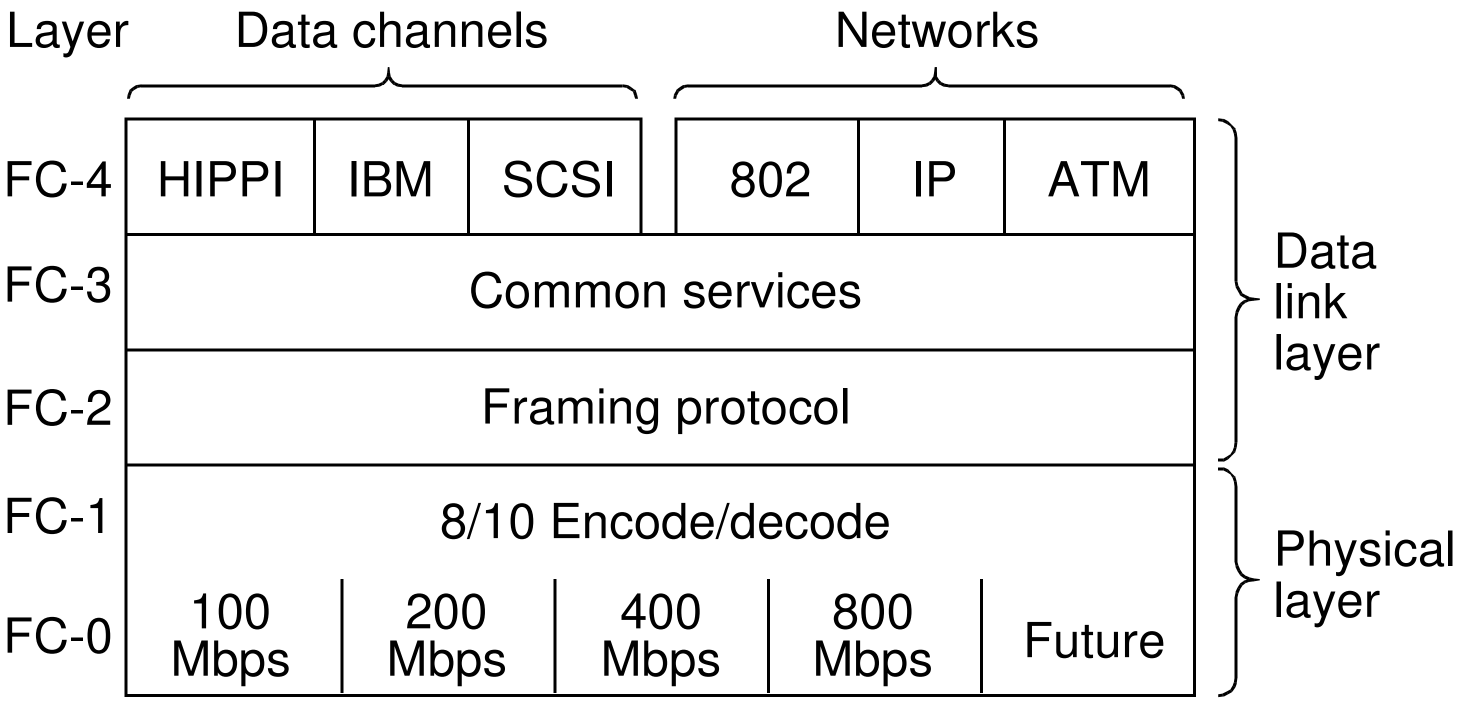
Gigabit network

Cable containing 50 or 100 twisted pairs

Fiber Channel

- Fiber based
- Handles
  - data channels
    - HIPPI, IBM, SCSI
  - Network
    - 802, IP, ATM
- Basic Structure is a crossbar switch
  - Connections established for one packet, or longer
- Services
  - Circuit switching
  - Packet switching
    - With guaranteed delivery
    - Without guaranteed delivery

Fiber Channel


Layer
Data channels
Networks
FC-4
HIPPI
IBM
SCSI
802
IP
ATM
FC-3
Common services
FC-2
Framing protocol
FC-1
8/10 Encode/decode
FC-0
100 Mbps
200 Mbps
400 Mbps
800 Mbps
Future
Data link layer
Physical layer