CSMC 417

Computer Networks

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Set 5

The Medium Access Control Sublayer

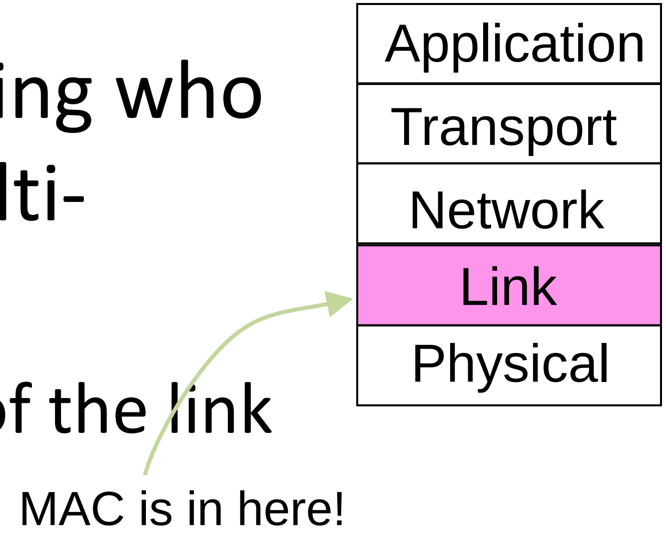
Medium Access Control Sublayer

- Channel Allocation Problem
- Multiple Access Protocols
- Ethernet
- Wireless LANs
- Broadband Wireless
- Bluetooth
- RFID
- Data Link Layer Switching

The MAC Sublayer

Responsible for deciding who sends next on a multi-access link

- An important part of the link layer, especially for LANs



The Channel Allocation Problem

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

Channel Allocation Problem (1)

For fixed channel and traffic from N users

- Divide up bandwidth using FTM, TDM, CDMA, etc.
- This is a static allocation, e.g., FM radio

This static allocation performs poorly for bursty traffic

- Allocation to a user will sometimes go unused

Channel Allocation Problem (2)

Dynamic allocation gives the channel to a user when they need it. Potentially N times as efficient for N users.

Schemes vary with assumptions:

Assumption	**Implication**
Independent traffic	Often not a good model, but permits analysis
Single channel	No external way to coordinate senders
Observable collisions	Needed for reliability; mechanisms vary
Continuous or slotted time	Slotting may improve performance
Carrier sense	Can improve performance if available

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

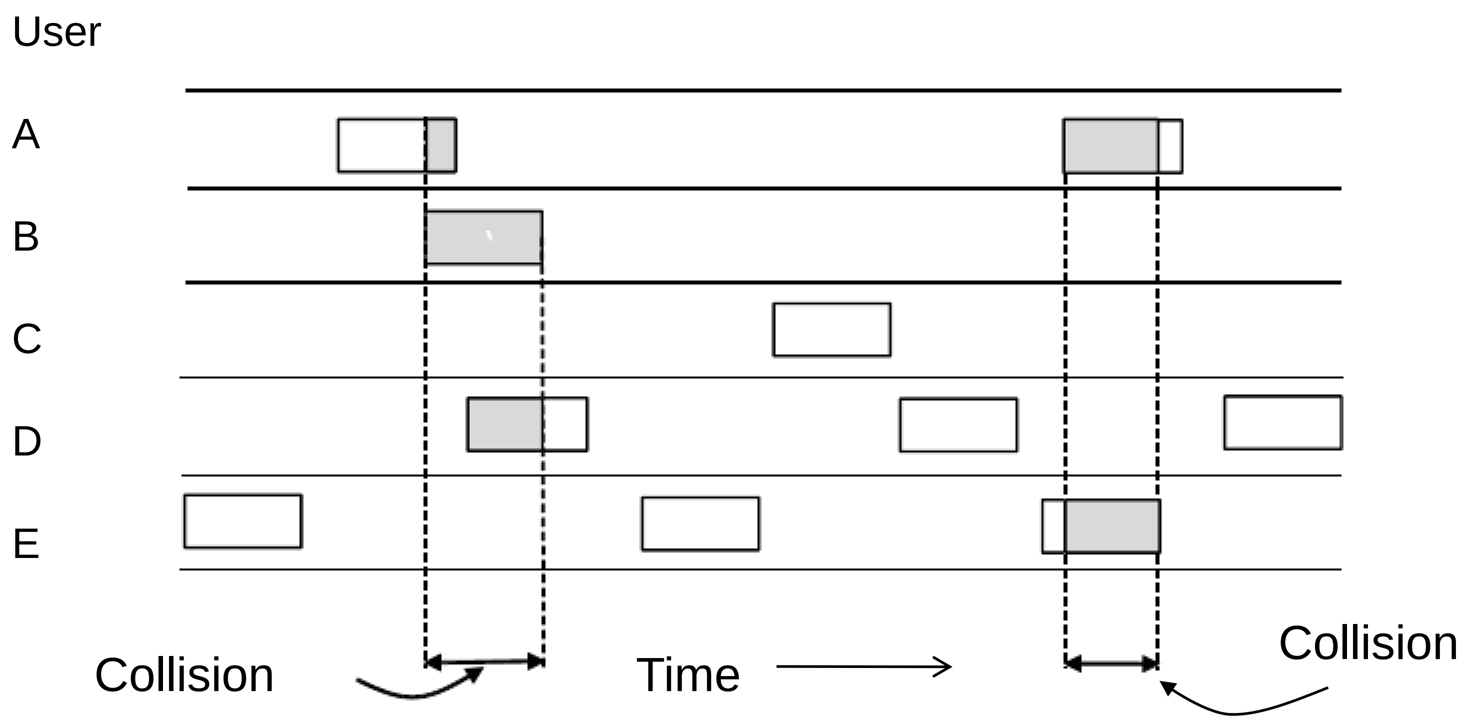
Random Access Protocols

- When node has packet to send
  - Transmit at full channel data rate R.
  - No a priori coordination among nodes
- Two or more transmitting nodes ➜ “collision”,
- Random access MAC protocol specifies:
  - How to detect collisions
  - How to recover from collisions
- Examples
  - ALOHA and Slotted ALOHA
  - CSMA, CSMA/CD, CSMA/CA

Key Ideas of Random Access

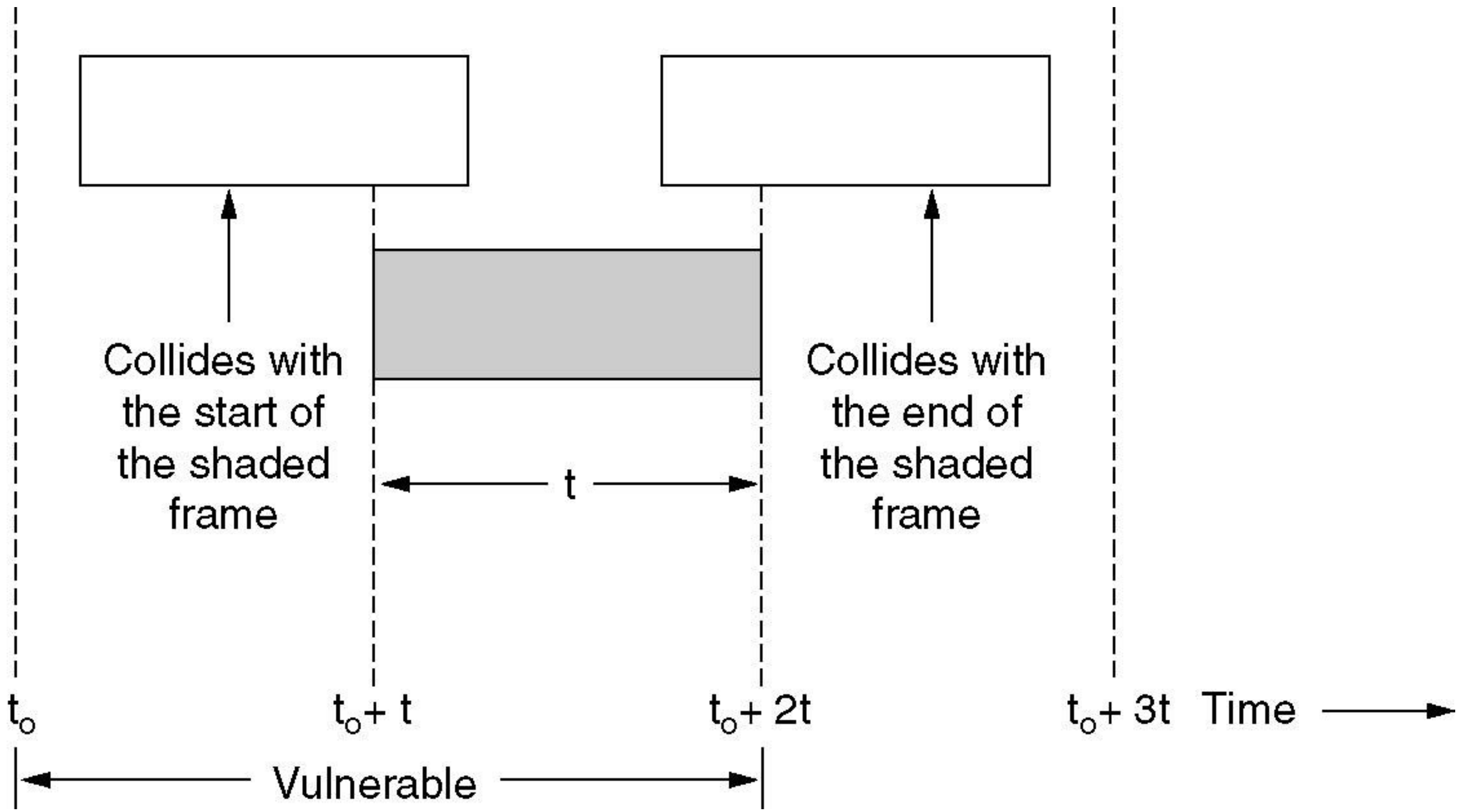
- Carrier sense
  - *Listen before speaking, and don't interrupt*
  - Checking if someone else is already sending data
  - … and waiting till the other node is done
- Collision detection
  - *If someone else starts talking at the same time, stop*
  - Realizing when two nodes are transmitting at once
  - …by detecting that the data on the wire is garbled
- Randomness
  - *Don't start talking again right away*
  - Waiting for a random time before trying again

ALOHA (1)



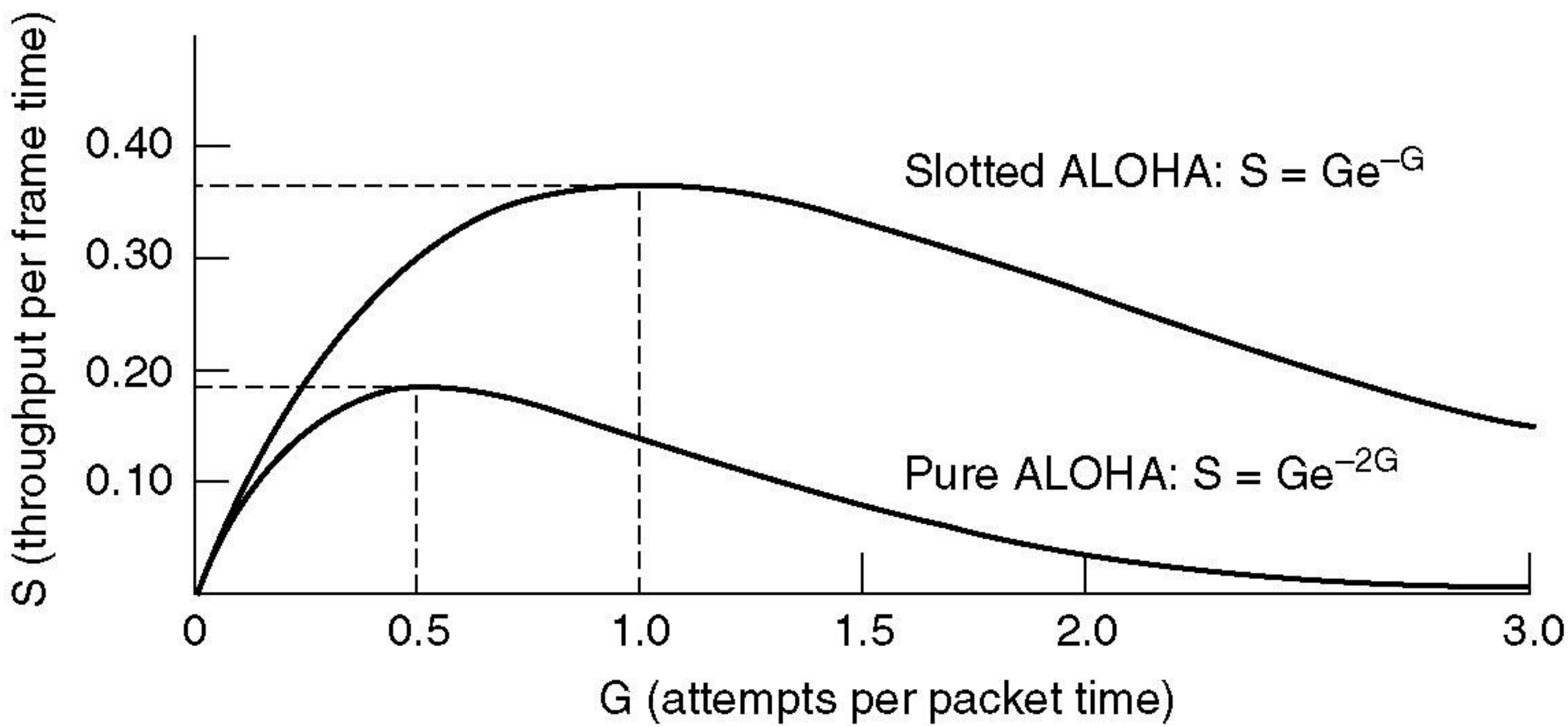
In pure ALOHA, frames are transmitted at completely arbitrary times

Pure ALOHA (2)



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

Pure ALOHA (3)



S (throughput per frame time)
0.40
0.30
0.20
0.10
Slotted ALOHA: S = Ge^{–G}
Pure ALOHA: S = Ge^{–2G}
0
0.5
1.0
1.5
2.0
3.0
G (attempts per packet time)

Slotted ALOHA

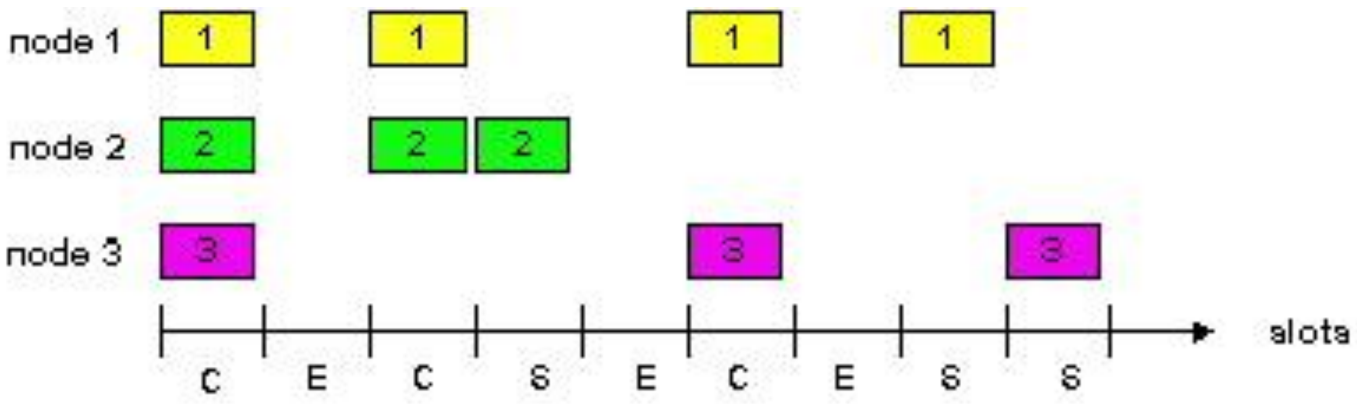
Assumptions

- All frames same size
- Time divided into equal slots (time to transmit a frame)
- Nodes start to transmit frames only at start of slots
- Nodes are synchronized
- If two or more nodes transmit, all nodes detect collision

Operation

- When node obtains fresh frame, transmits in next slot
- No collision: node can send new frame in next slot
- Collision: node retransmits frame in each subsequent slot with probability p until success

Slotted ALOHA



Pros

- Single active node can continuously transmit at full rate of channel
- Highly decentralized: only slots in nodes need to be in sync
- Simple

Cons

- Collisions, wasting slots
- Idle slots
- Nodes may be able to detect collision in less than time to transmit packet
- Clock synchronization

CSMA (Carrier Sense Multiple Access)

- Collisions hurt the efficiency of ALOHA protocol
  - At best, channel is useful 37% of the time
- CSMA: listen before transmit
  - If channel sensed idle: transmit entire frame
  - If channel sensed busy, defer transmission
- Human analogy: don’t interrupt others!

CSMA (1)

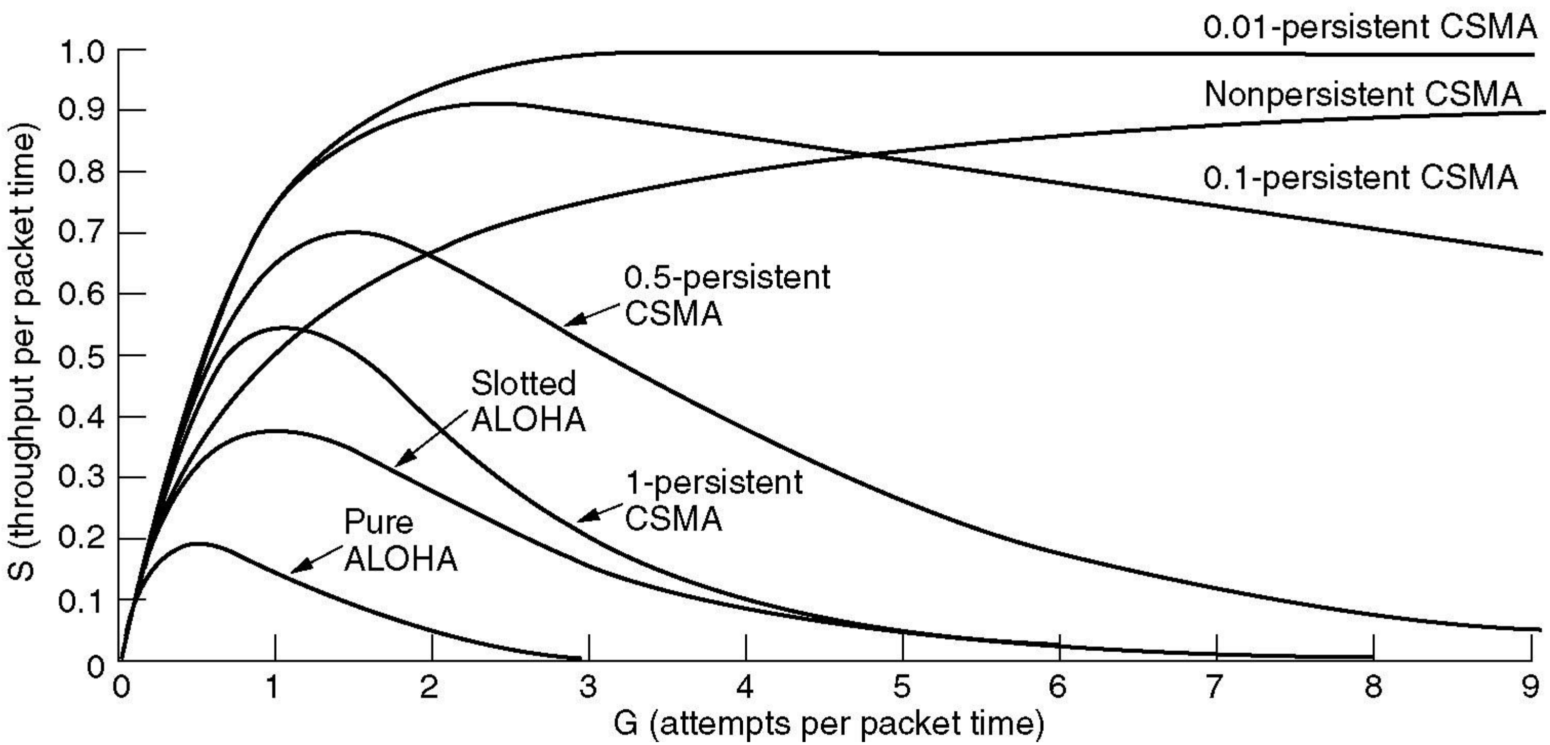
CSMA improves on ALOHA by sensing the channel!

- User doesn't send if it senses someone else

Variations on what to do if the channel is busy:

- 1-persistent (greedy) sends as soon as idle
- Nonpersistent waits a random time then tries again
- p-persistent sends with probability p when idle

Persistent and Nonpersistent CSMA



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

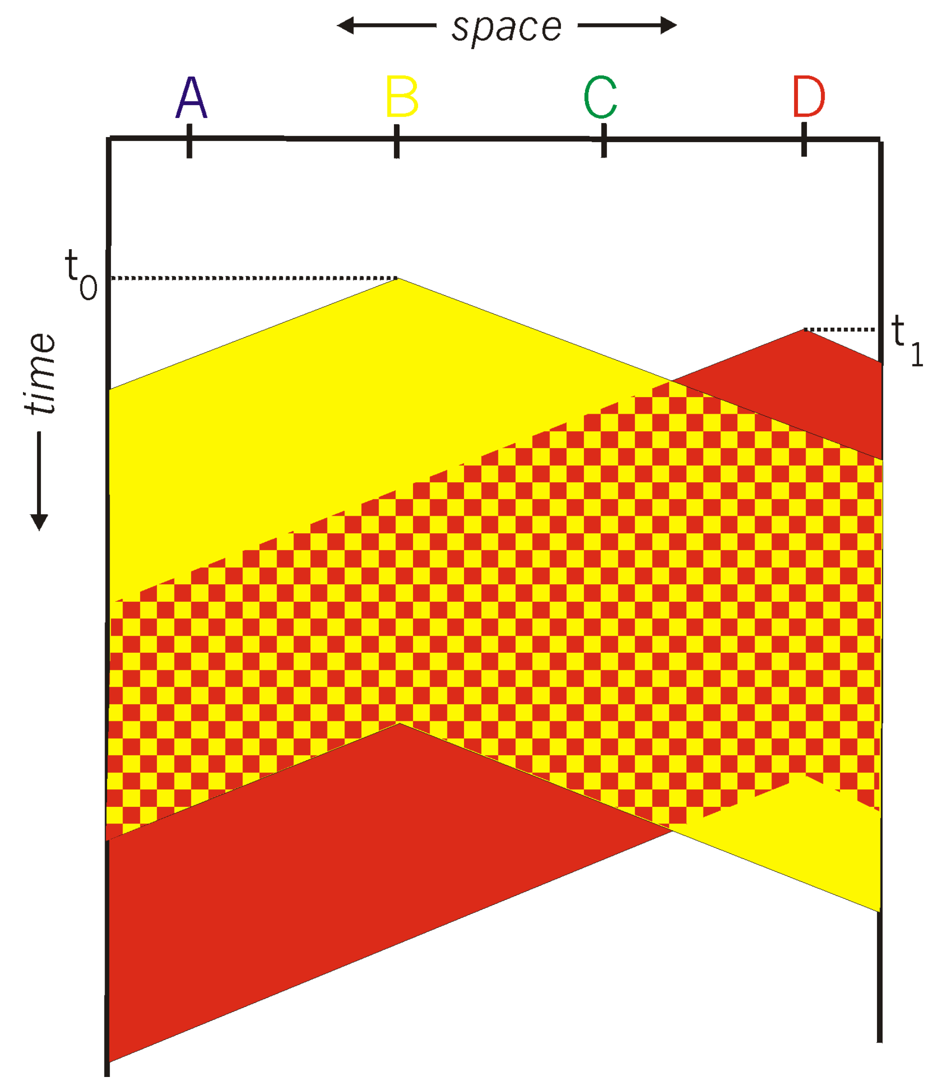
CSMA Collisions

Collisions *can* still occur:

propagation delay means two nodes may not hear each other's transmission

Collision:

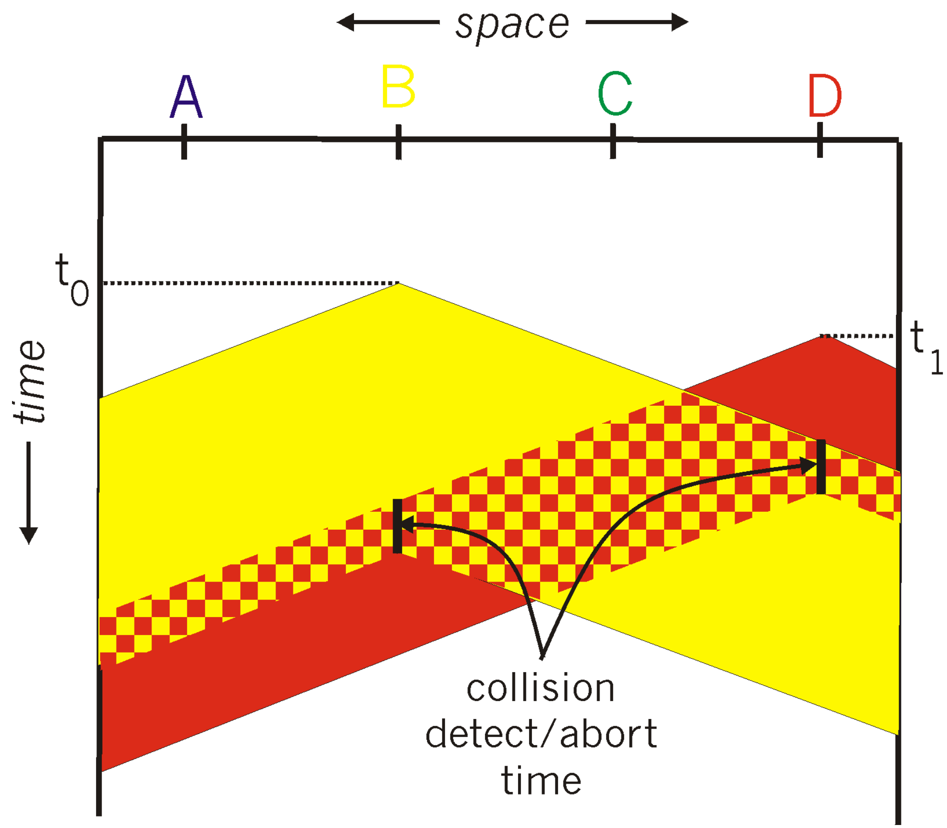
entire packet transmission time wasted



CSMA/CD (Collision Detection)

- CSMA/CD: carrier sensing, deferral as in CSMA
  - Collisions detected within short time
  - Colliding transmissions aborted, reducing wastage
- Collision detection
  - Easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - Difficult in wireless LANs: receiver shut off while transmitting
- Human analogy: the polite conversationalist

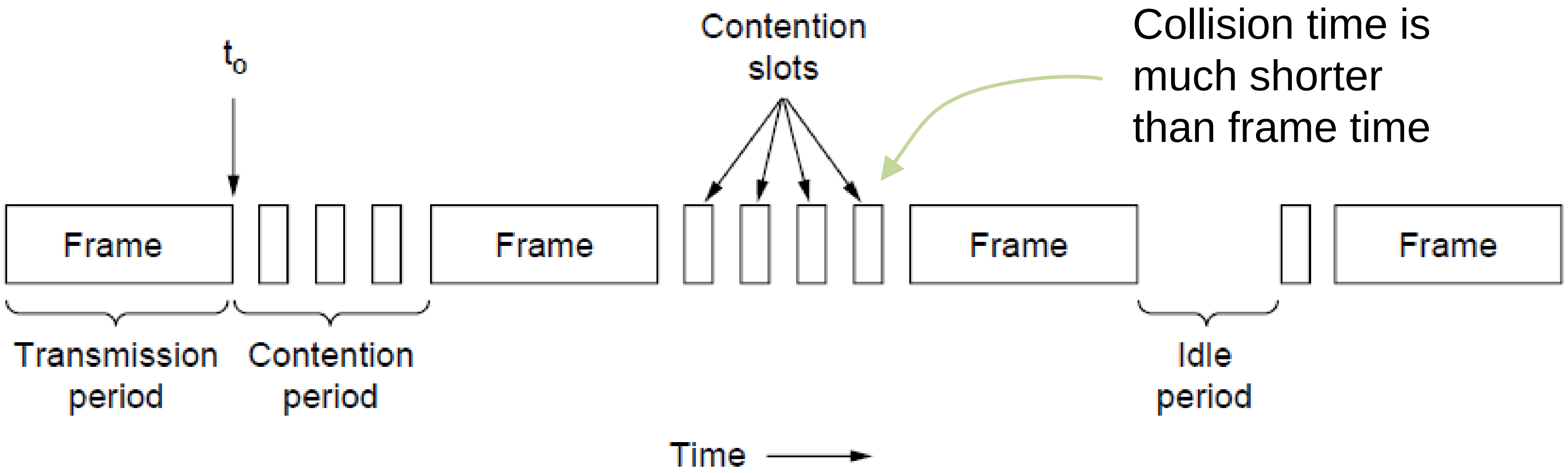
CSMA/CD Collision Detection



CSMA (3) – Collision Detection

CSMA/CD improvement is to detect/abort collisions

– Reduced contention times improve

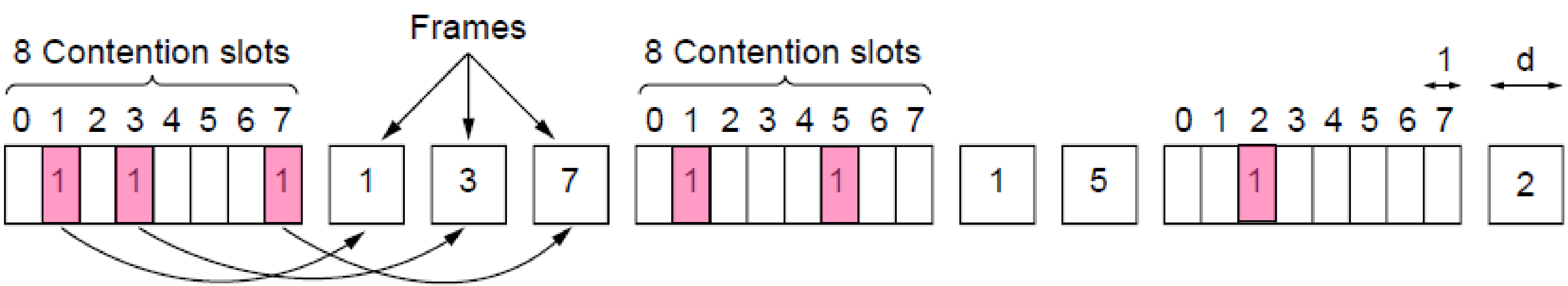


Collision-Free Protocols (1) – Bitmap

Collision-free protocols avoid collisions entirely

- Senders must know when it is their turn to send

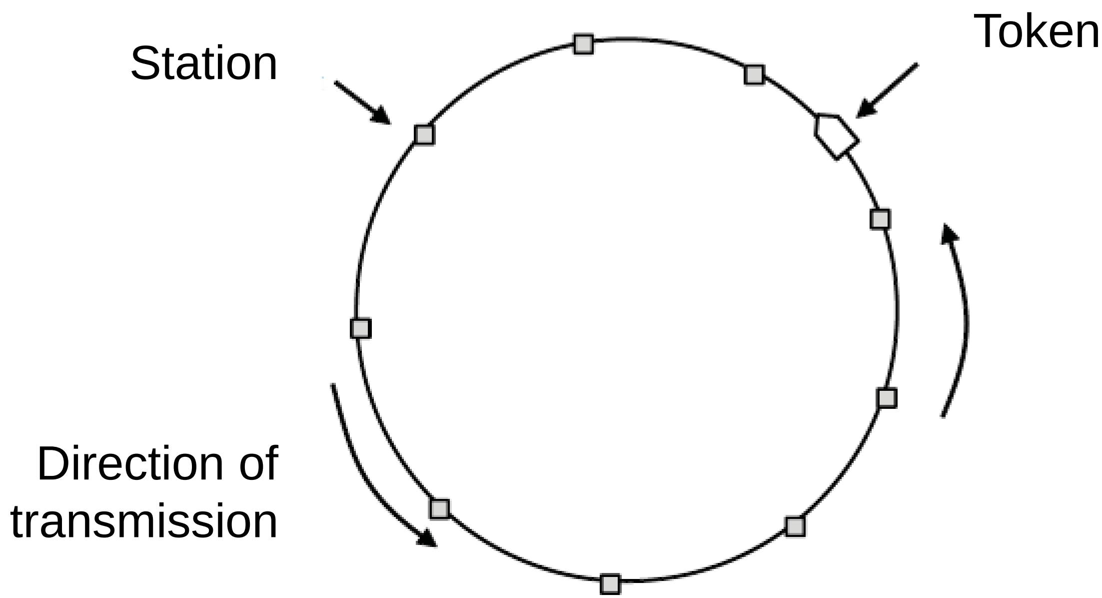
The basic bit-map protocol:



Collision-Free Protocols– Token Ring

Token sent round ring defines the sending order

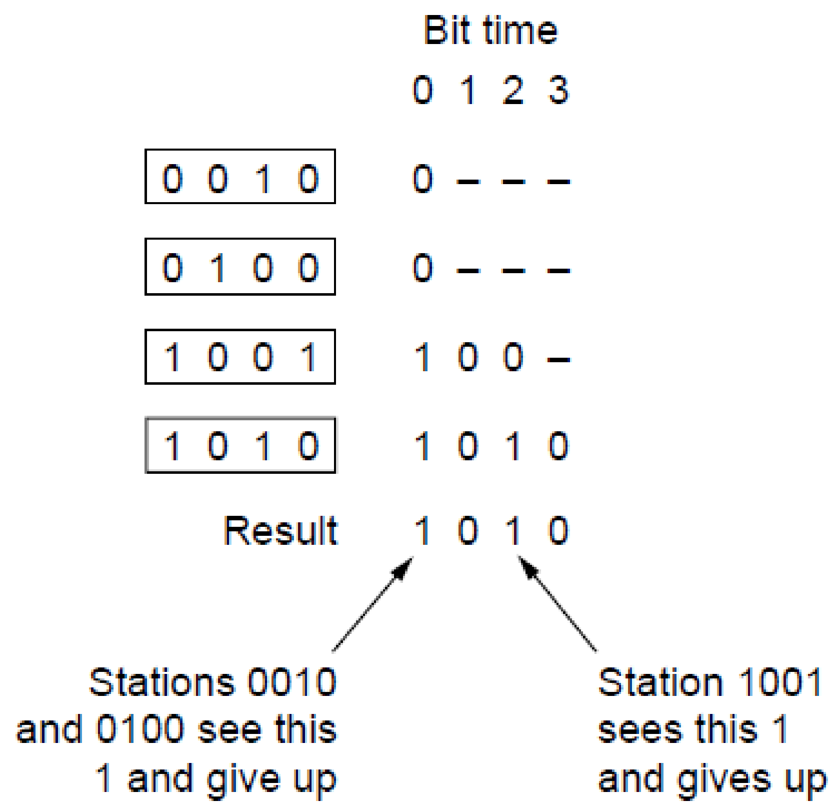
- Station with token may send a frame before passing
- Idea can be used without ring too, e.g., token bus



Collision-Free Protocols– Countdown

Binary countdown improves on the bitmap protocol

- Stations send their address in contention slot (log N bits instead of N bits)
- Medium ORs bits; stations give up when they send a "0" but see a "1"
- Station that sees its full address is next to send

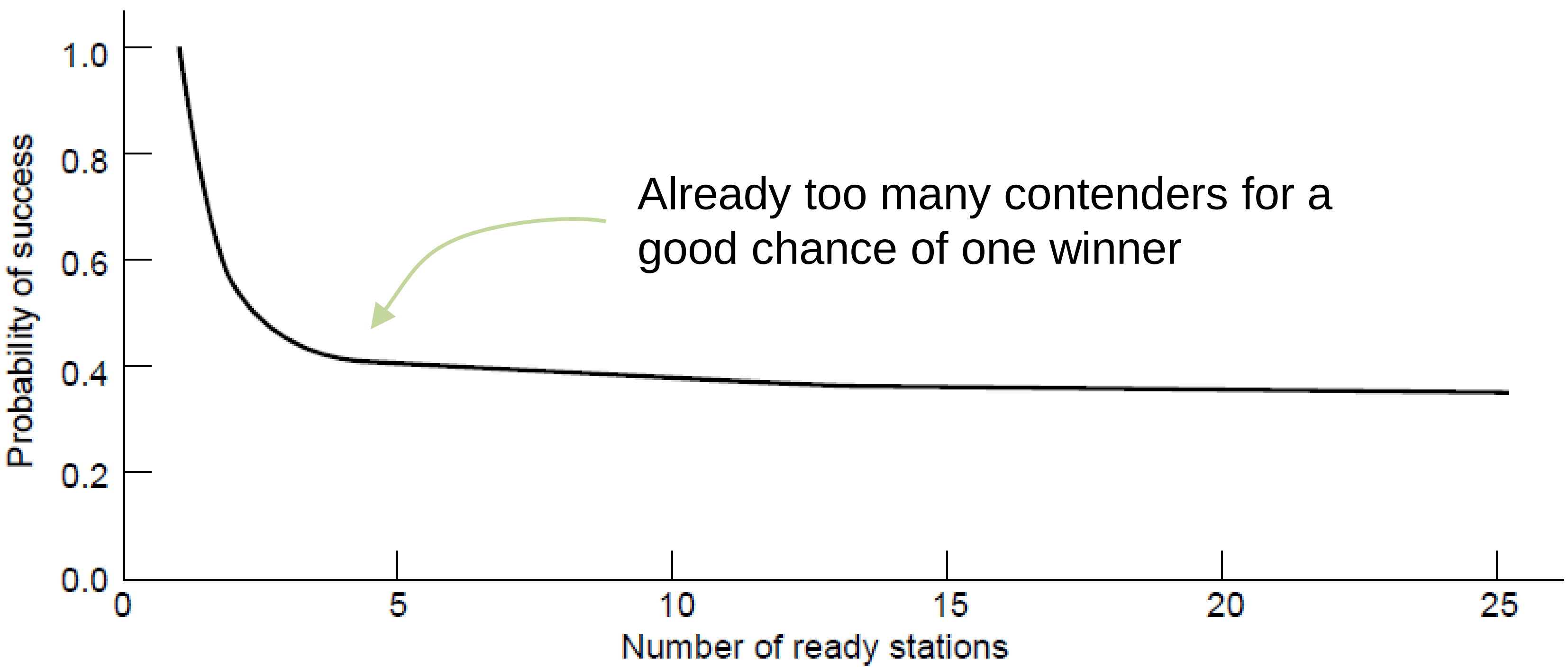


Analysis of Contention

- k stations, always ready to transmit
- Assume constant retransmission probability p
- Probability, A that some station acquires channel during a given slot
- $A = kp(1-p)^{k-1}$
- Optimal value of p – differentiate w.r.t. p and equate to 0
  - $p = \frac{1}{k}$ then optimal $A = [\frac{k-1}{k}]^{k-1}$
  - As k → ∞ $p \rightarrow \frac{1}{e}$

Limited-Contention Protocols (1)

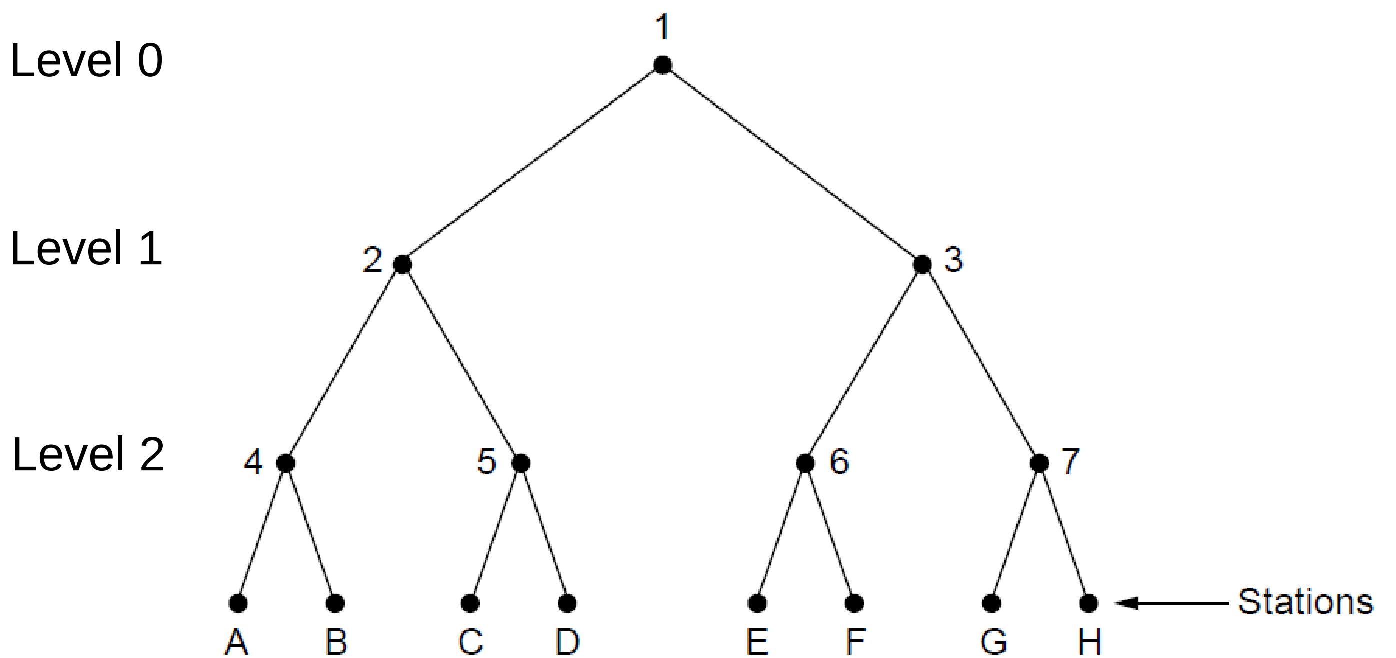
Idea is to divide stations into groups within which only a very small number are likely to want to send



Limited Contention Adaptive Tree Walk

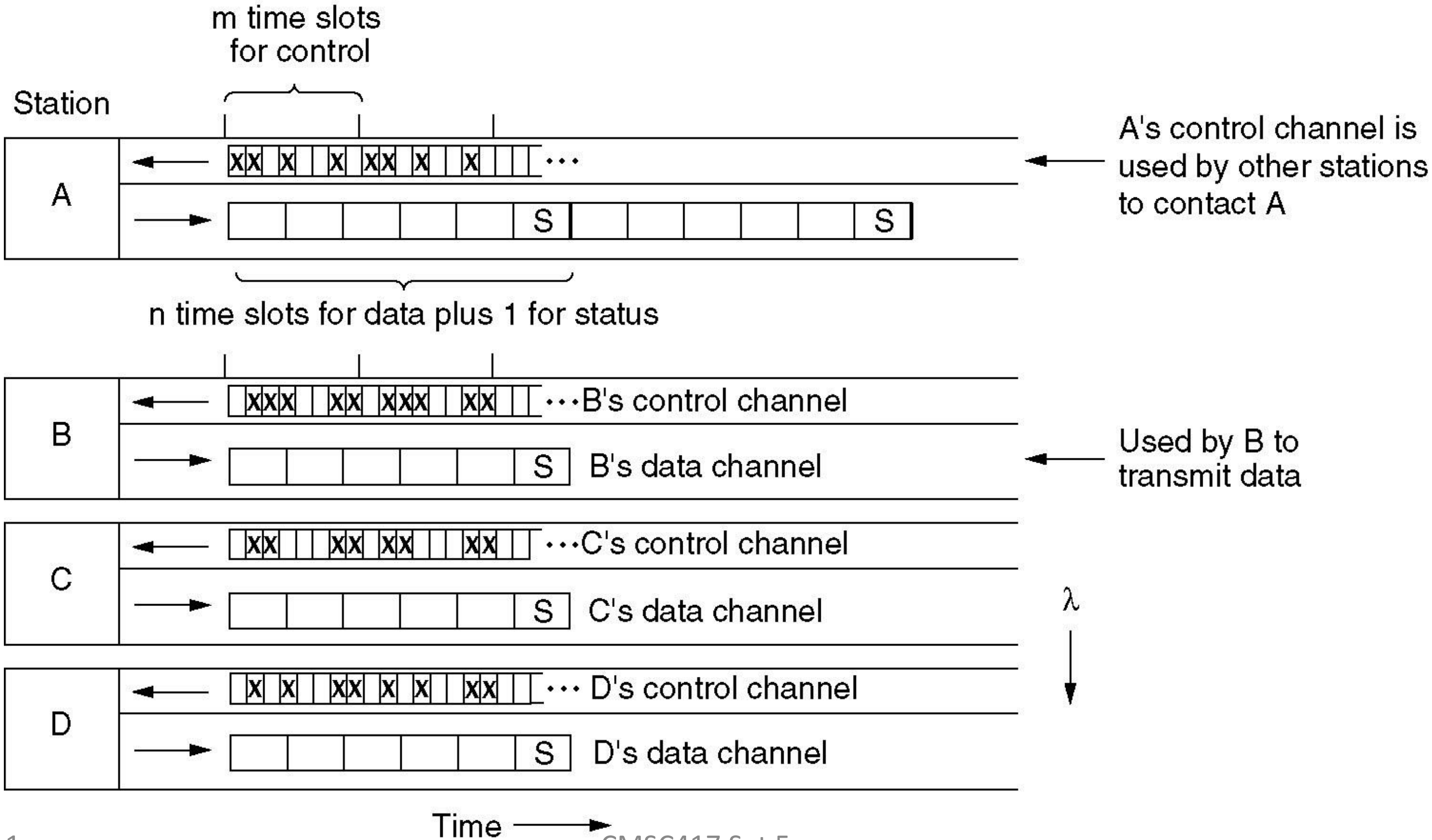
Tree divides stations into groups (nodes) to poll

- Depth first search under nodes with poll collisions
- Start search at lower levels if >1 station expected



Wavelength Division Multiple Access Protocols

Wavelength division multiple access.

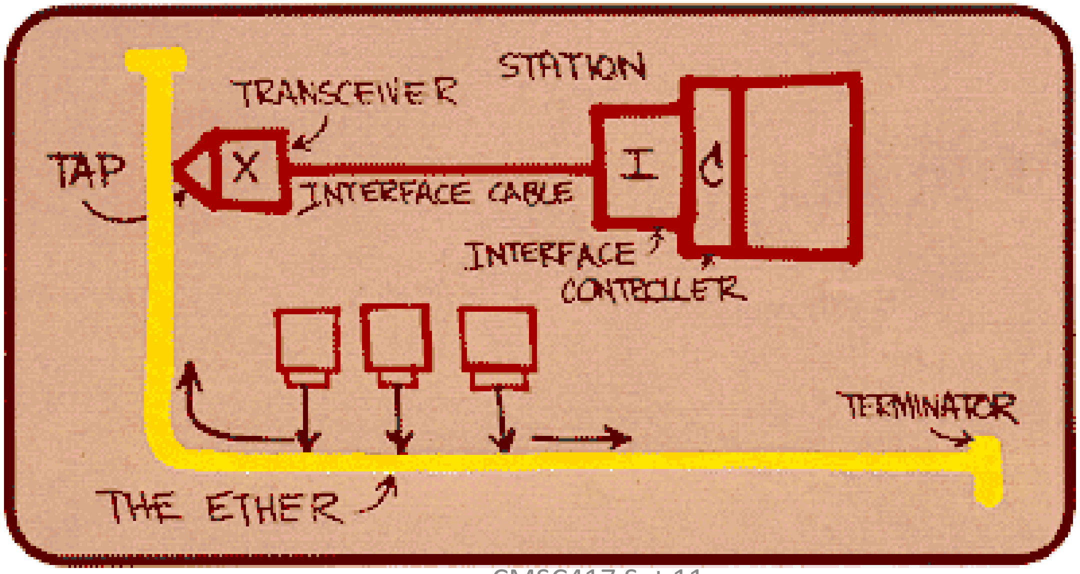


Ethernet

- 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

- Dominant wired LAN technology:
- First widely used LAN technology
- Simpler, cheaper than token LANs and ATM
- Kept up with speed race: 10 Mbps – 10 Gbps

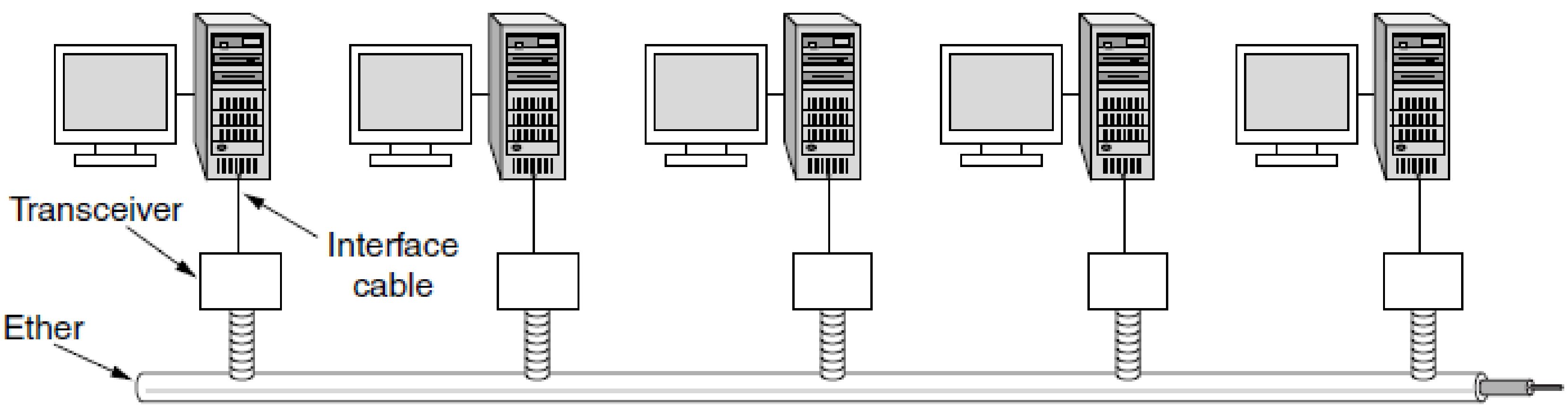


Metcalfe's Ethernet sketch

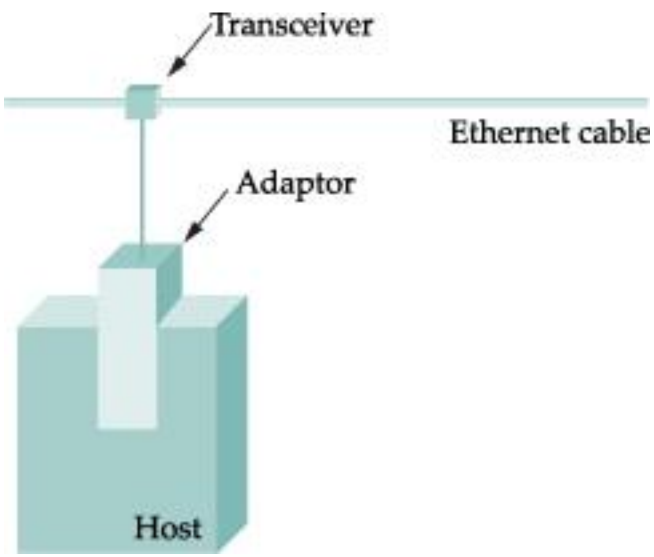
Classic Ethernet– Physical Layer

One shared coaxial cable to which all hosts attached

– Up to 10 Mbps, with Manchester encoding



Ethernet Transceiver and Adapter



- Medium – 50 ohm cable
- Taps 2.5 m apart
- Transceiver – can send and receive
- Multiple segments can be joined by repeaters – no more than 4
- Max end-to-end distance – 2500 m

Ethernet Uses CSMA/CD

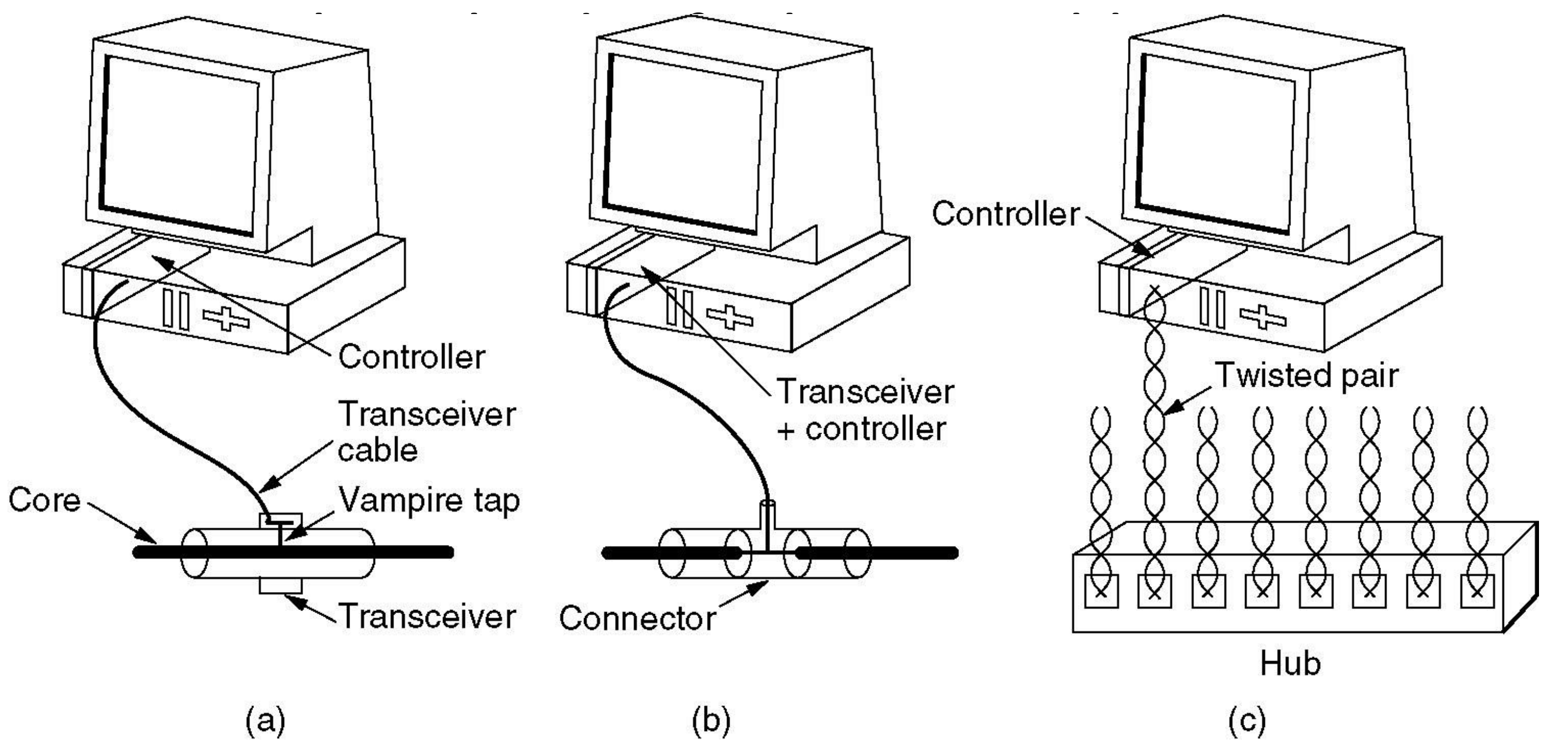
- Carrier sense: wait for link to be idle
  - Channel idle: start transmitting
  - Channel busy: wait until idle
- Collision detection: listen while transmitting
  - No collision: transmission is complete
  - Collision: abort transmission, and send jam signal
- Random access: exponential back-off
  - After collision, wait a random time before trying again
  - After m^{th} collision, choose K randomly from $\{0, \ldots, 2^m-1\}$
  - … and wait for K*512 bit times before trying again

Ethernet Cabling

The most common kinds of Ethernet cabling.

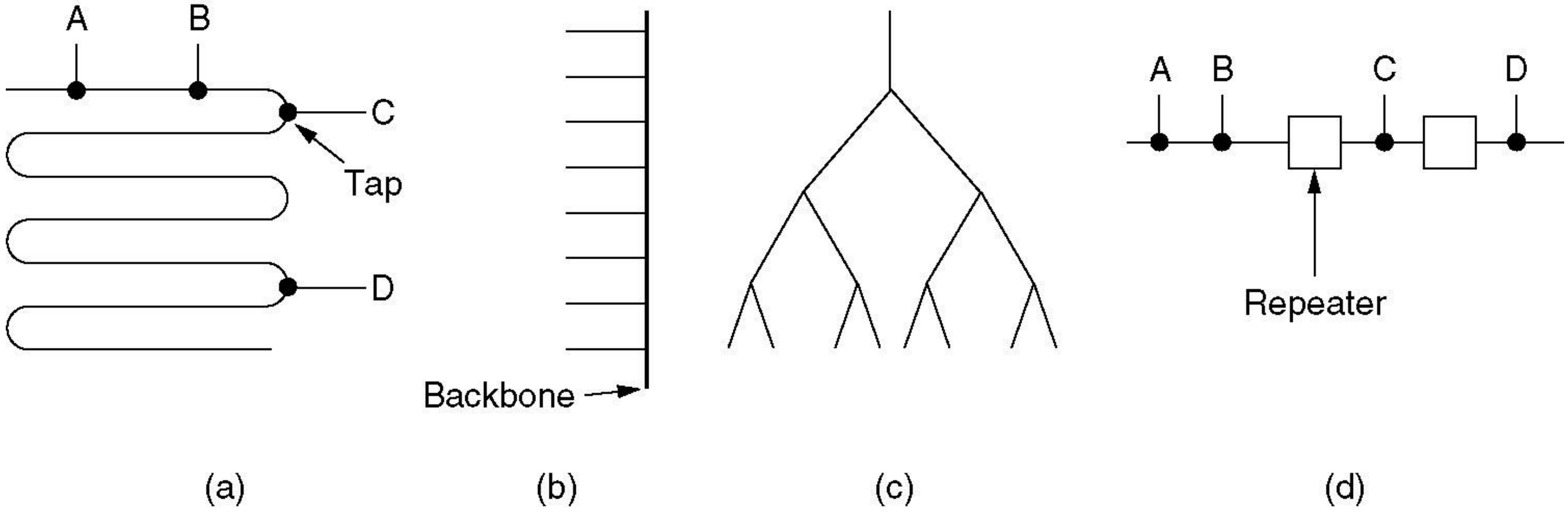
Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings

Ethernet Cabling (2)

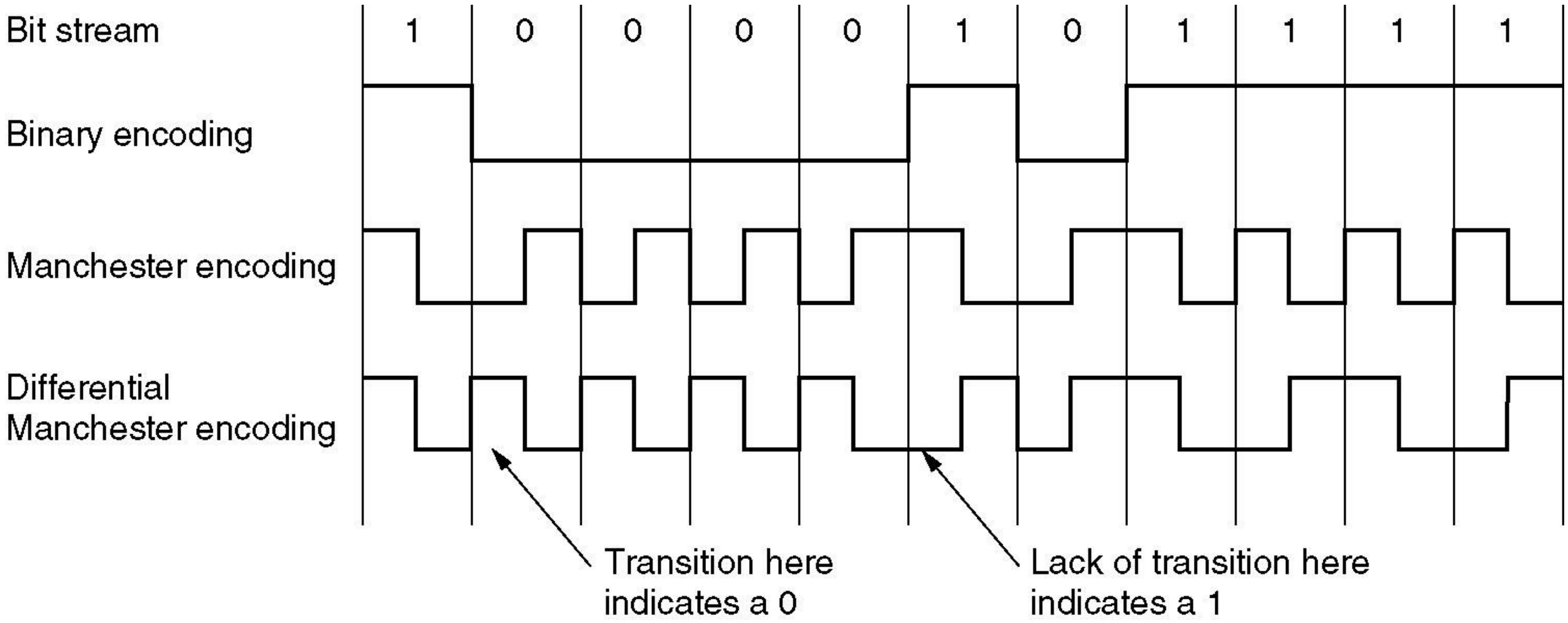


Ethernet Cabling (3)

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

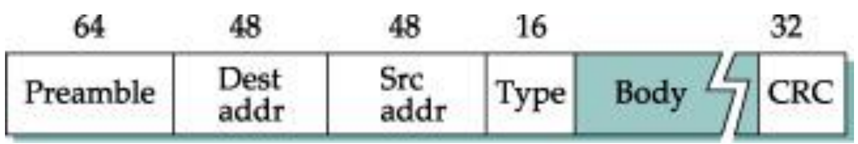


Ethernet Signalling



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

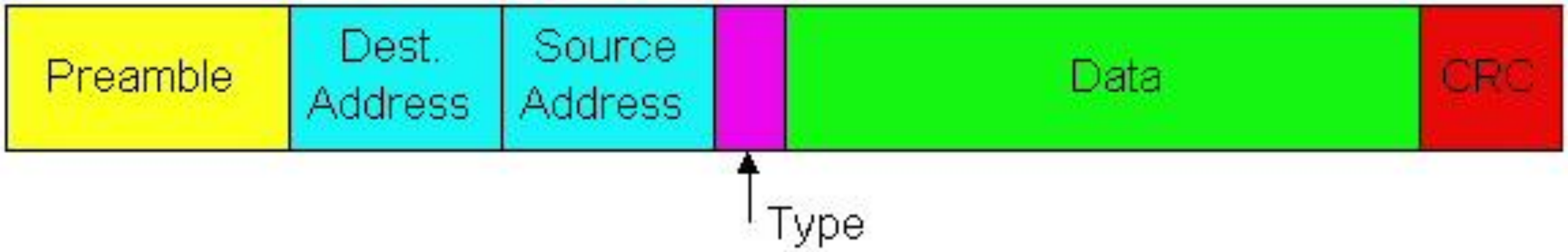
Ethernet Frame Format



- Preamble –
  - For synchronizing
  - Alternate 0 and 1
- Address – 48 bit MAC
- Type – Id for higher level protocol
- Length – up to 1500 bytes, with minimum of 46 bytes, of data
- 802.3 – Length for Type field.

Ethernet Frame Structure

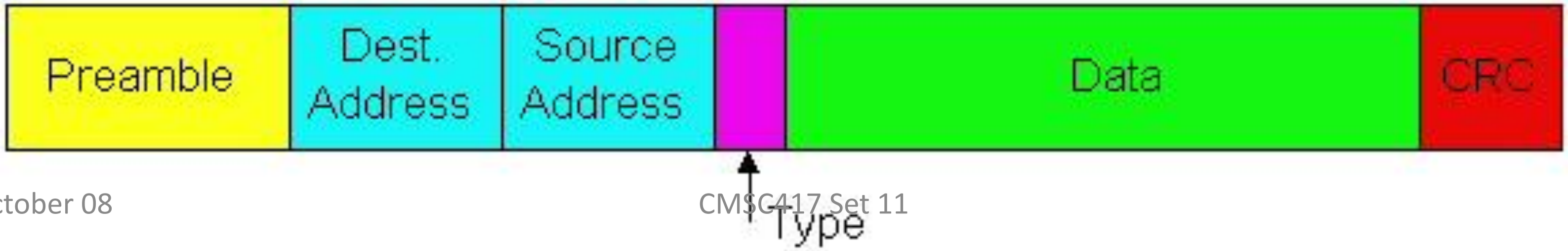
- Sending adapter encapsulates packet in frame



- Preamble: synchronization
  - Seven bytes with pattern 10101010, followed by one byte with pattern 10101011
  - Used to synchronize receiver, sender clock rates

Ethernet Frame Structure (Continued)

- Addresses: source and destination MAC addresses
  - Adaptor passes frame to network-level protocol
    - If destination address matches the adaptor
    - Or the destination address is the broadcast address
  - Otherwise, adapter discards frame
- Type: indicates the higher layer protocol
  - Usually IP
  - But also Novell IPX, AppleTalk, …
- CRC: cyclic redundancy check
  - Checked at receiver
  - If error is detected, the frame is simply dropped



Classic Ethernet (2) – MAC

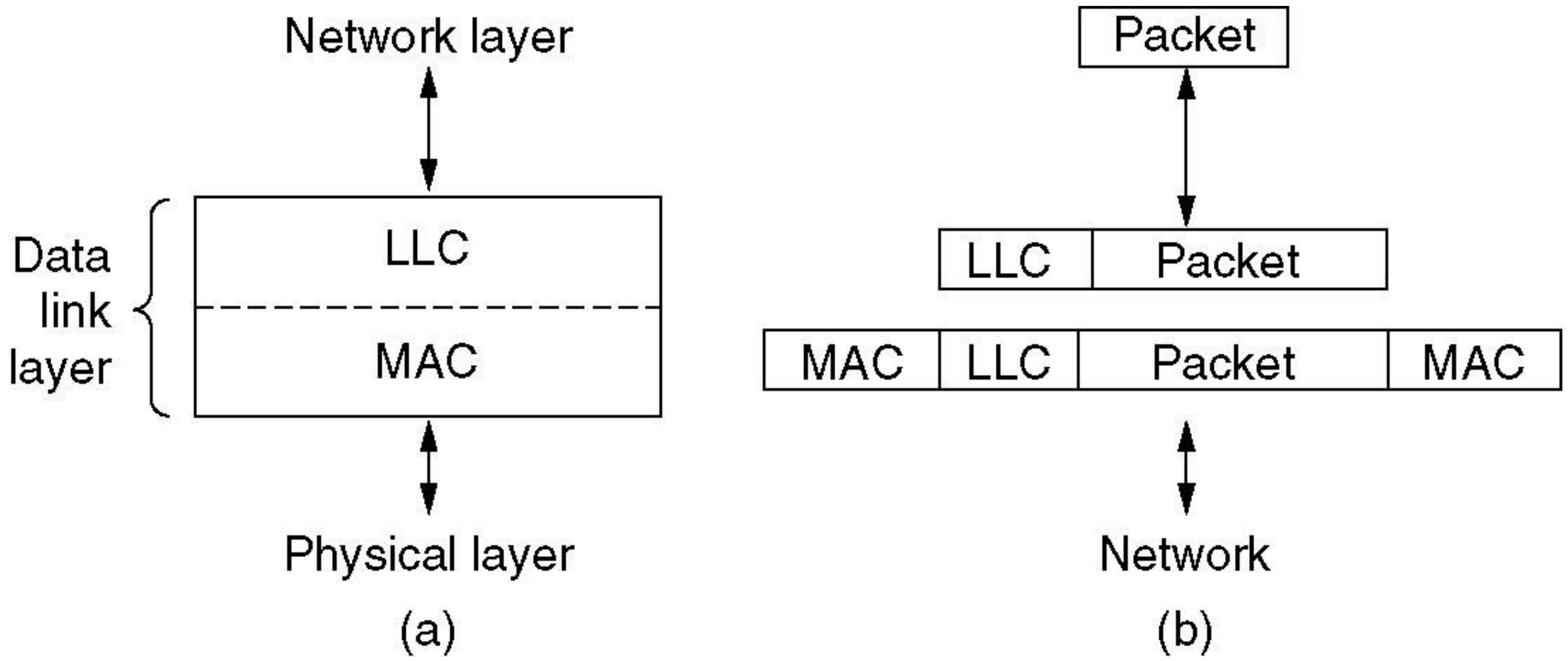
MAC protocol is 1-persistent CSMA/CD
- Random delay (backoff) after collision is computed with BEB (Binary Exponential Backoff)

Bytes	8		6	6	2	0-1500	0-46	4
Ethernet (DIX)	Preamble		Destination address	Source address	Type	Data	Pad	Check-sum
IEEE 802.3	Preamble	SoF	Destination address	Source address	Length	Data	Pad	Check-sum

Ethernet Transmitter Algorithm

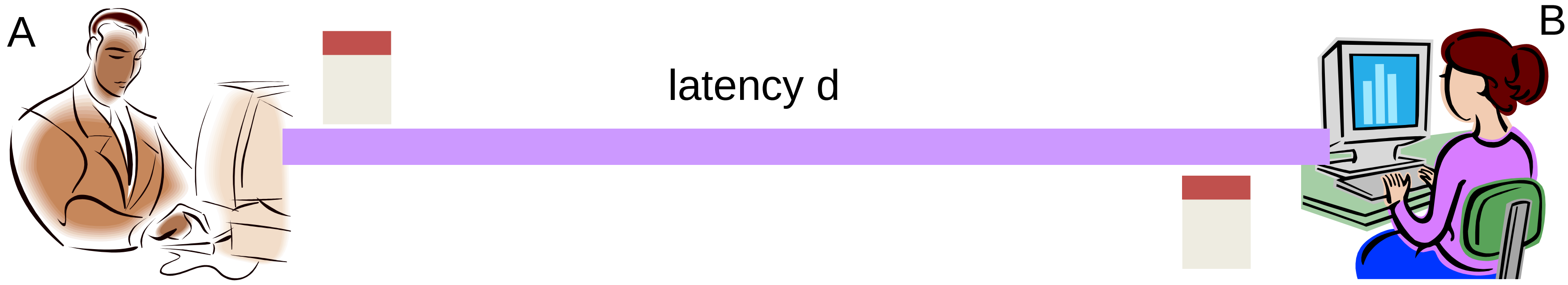
- P-persistent
  - Transmit with prob p when line goes idle
- Ethernet uses 1-persistent algorithm
- On Collision-
  - 32 bit jamming sequence
  - Stops transmitting
  - Runt frame – 64 synch + 32 bit jamming sequence
- Min frame size – 64 bytes – 46 + 14 + 4
- For 2500 m line with up to 4 repeaters max round trip delay – 51.2μs
- Exponential Backoff
  - In steps of 51.2μs
  - Wait k* rand (0,.. 2^k-1)

IEEE 802.2: Logical Link Control



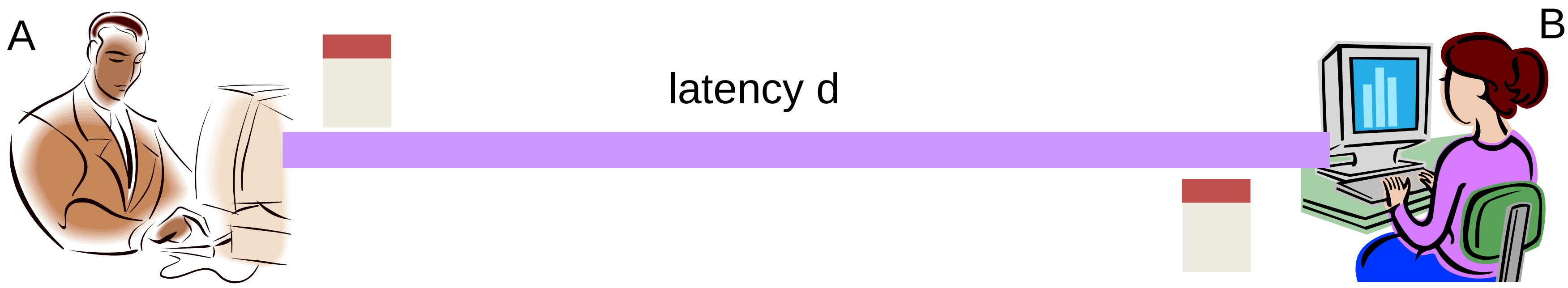
(a) Position of LLC. (b) Protocol formats.

Limitations on Ethernet Length



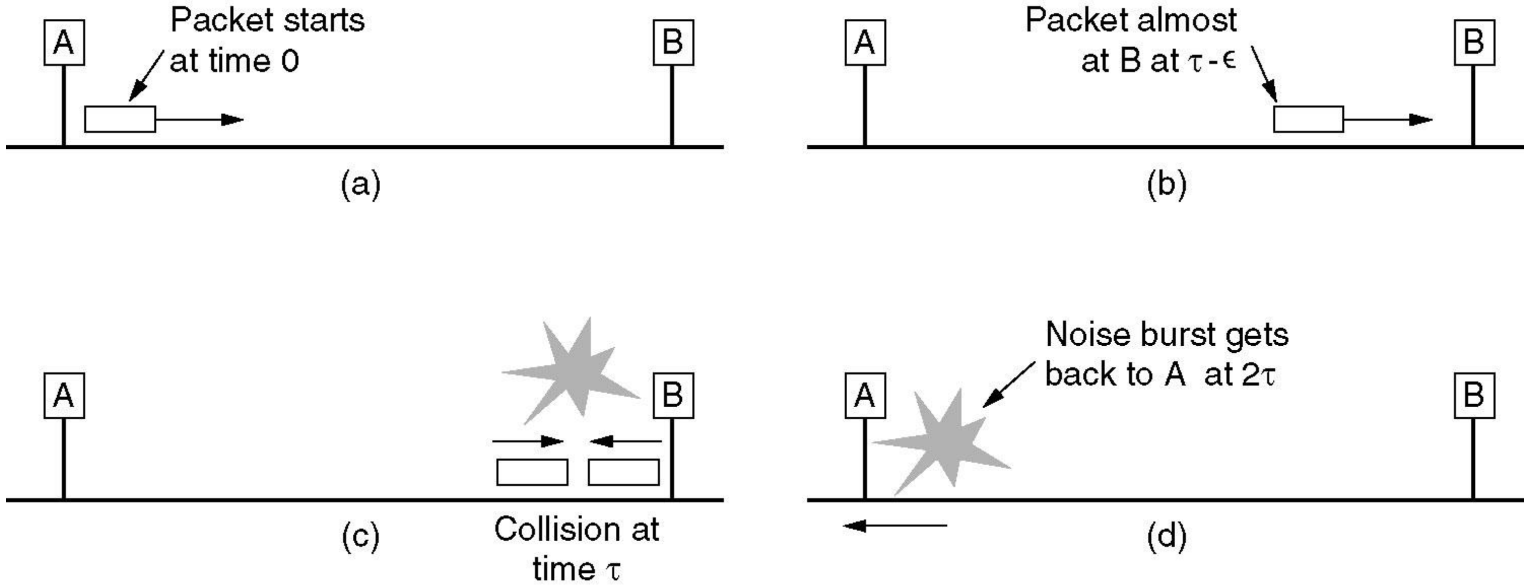
- Latency depends on physical length of link
  - Time to propagate a packet from one end to the other
- Suppose A sends a packet at time t
  - And B sees an idle line at a time just before t+d
  - … so B happily starts transmitting a packet
- B detects a collision, and sends jamming signal
  - But A doesn't see collision till t+2d

Limitations on Ethernet Length



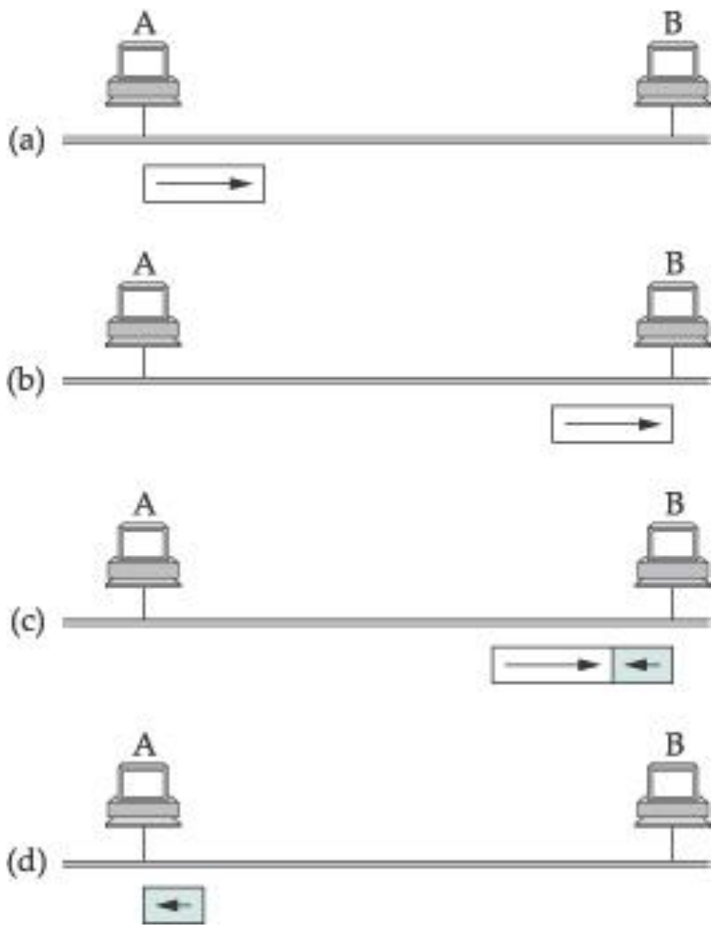
- A needs to wait for time 2d to detect collision
  - So, A should keep transmitting during this period
  - … and keep an eye out for a possible collision
- Imposes restrictions on Ethernet
  - Maximum length of the wire: 2500 meters
  - Minimum length of the packet: 512 bits (64 bytes)

Ethernet MAC Sublayer Protocol (2)



Collision detection can take as long as 2τ.

Worst Case Secnario



A sends a frame at time t

Frame arrives at B at t+d

B begins transmitting at t+d and collides with A's Frame

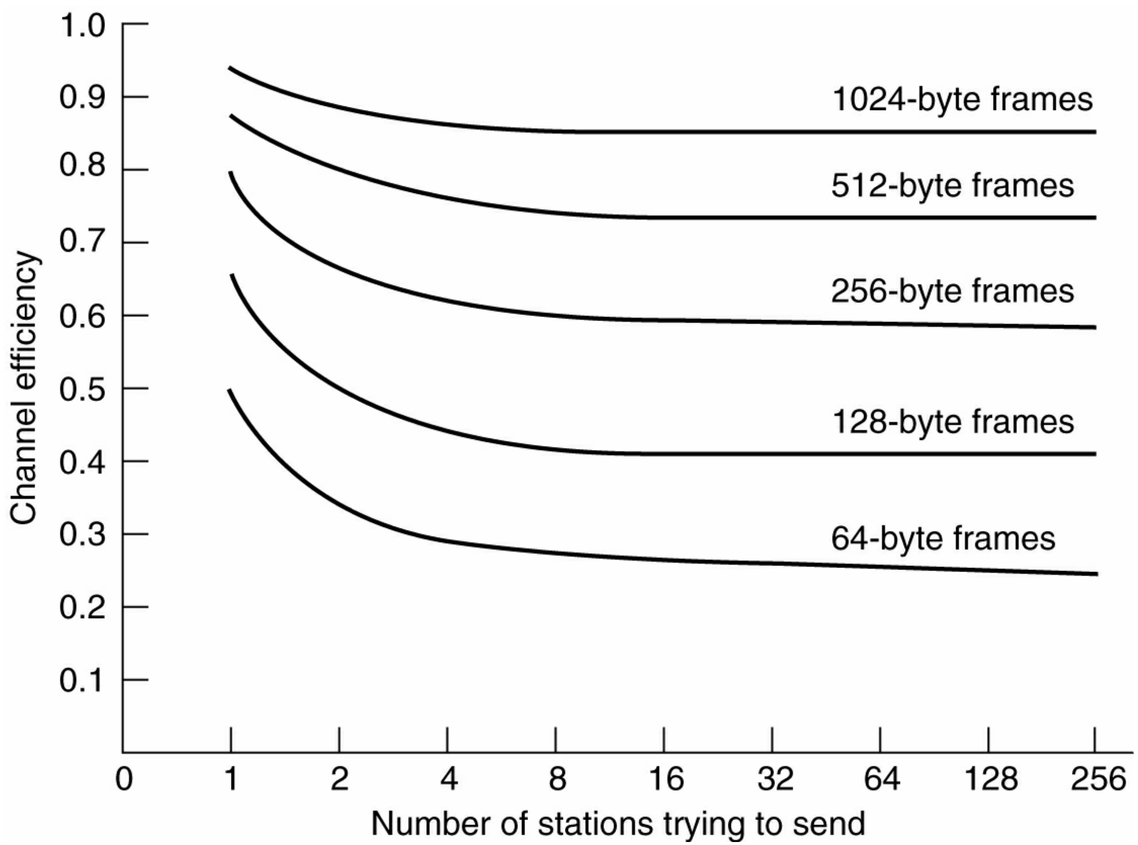
B's 32 bit frame arrives at A at t+2d

Ethernet Performance

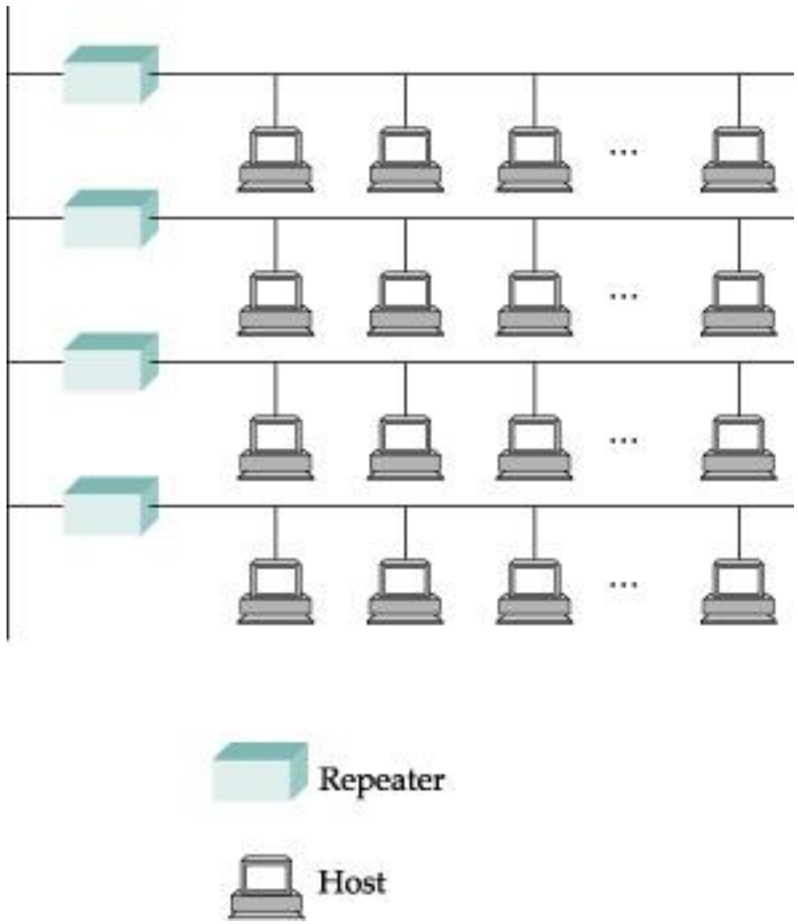
- k stations, always ready to transmit
- Assume constant retransmission probability p
- Probability, A that some station acquires channel during a given slot
- $A = \ kp(1-p)^{k-1}$
- Optimal value of p – differentiate w.r.t. p and equate to 0
  - $p = \frac{1}{k}$ then optimal $A = \ [\frac{k-1}{k}]^{k-1}$
  - As k → ∞ $p \ \rightarrow \ \frac{1}{e}$
- Probability that Contention Interval is exactly j slots is $A(1-A)^{j-1}$
- So, the mean number of slots per contention
  - $\sum_{j=0}^{\infty} jA(1-A)^{j-1} = \frac{1}{A}$
- Slot duration = 2τ
- Mean contention interval $w = \frac{2\tau}{A}$ …. Mean number of cont. slots = e
- If frame transmission time = P
- Channel efficiency $= \frac{P}{P+2\tau/A}$ = $\frac{1}{1+2BLe/cF}$
  - Where F=Frame length, B=network Bandwidth, L = cable length

Ethernet Performance

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



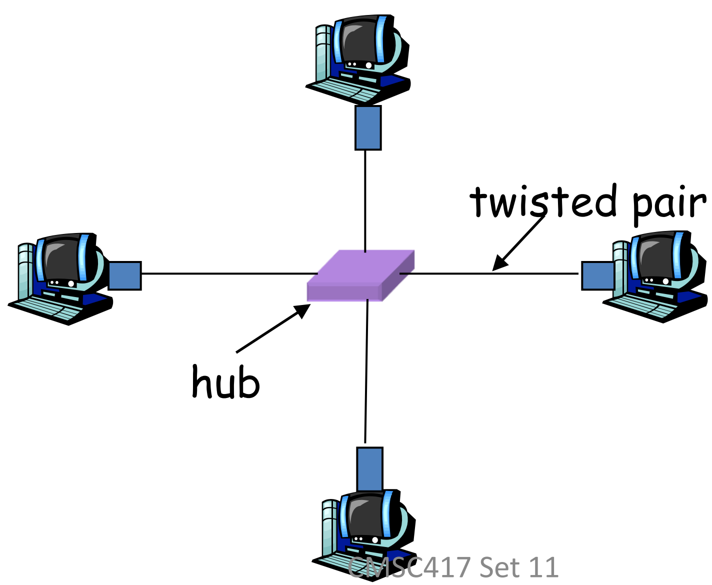
Ethernet Repeaters



- Up to 4 Repeaters
- Cables
  - 10Base 5
    - 10Mbps
    - Baseband
    - 500 Meters
  - 10Base2
  - 10BaseT
    - Twisted Pair 100 M
  - Category 5 (Cat 5)
    - 10 M and 100 M
    - Twisted Pair

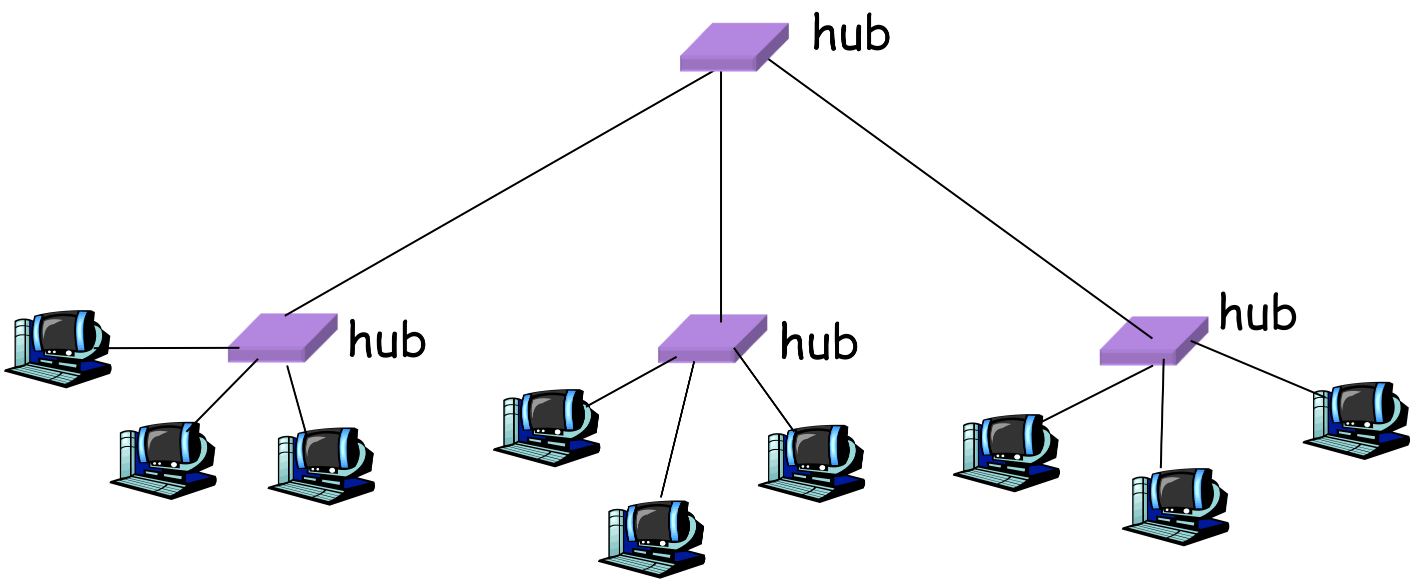
Hubs: Physical-Layer Repeaters

- Hubs are physical-layer repeaters
  - Bits coming from one link go out all other links
  - At the same rate, with no frame buffering
  - No CSMA/CD at hub: adapters detect collisions



Interconnecting with Hubs

- Backbone hub interconnects LAN segments
- All packets seen everywhere, forming one large collision domain
- Can’t interconnect Ethernets of different speeds

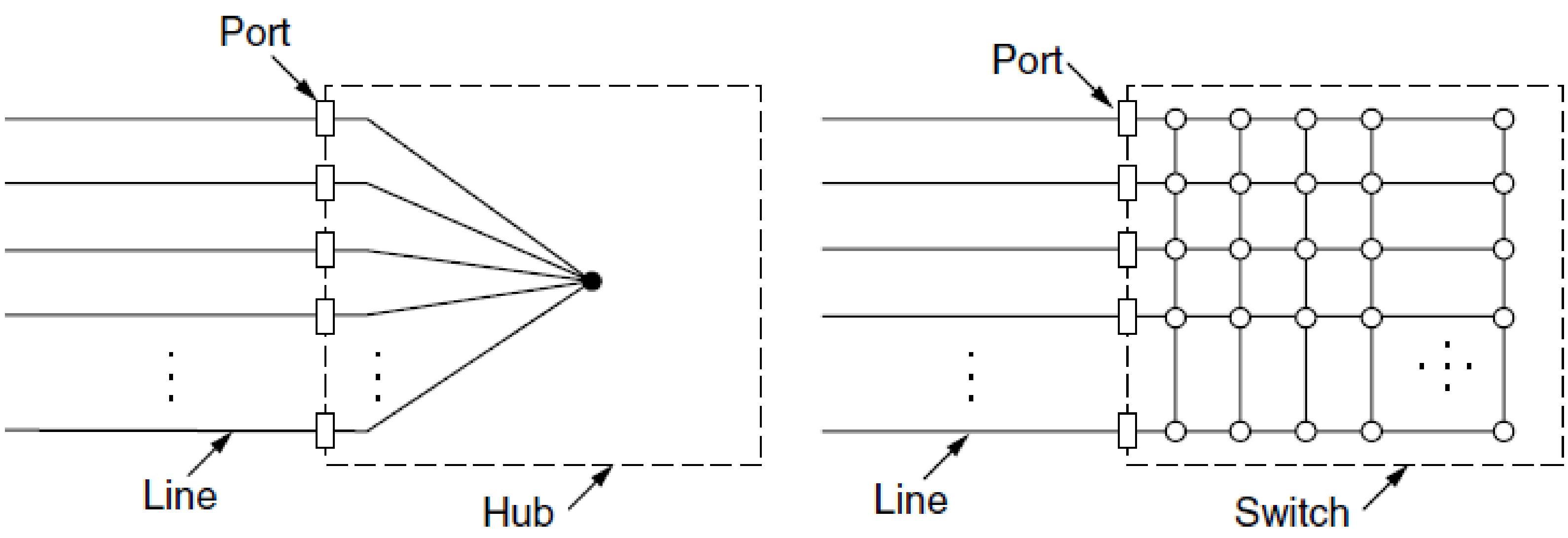


Switch

- Link layer device
  - Stores and forwards Ethernet frames
  - Examines frame header and selectively forwards frame based on MAC dest address
  - When frame is to be forwarded on segment, uses CSMA/CD to access segment
- Transparent
  - Hosts are unaware of presence of switches
- Plug-and-play, self-learning
  - Switches do not need to be configured

Switched/Fast Ethernet (1)

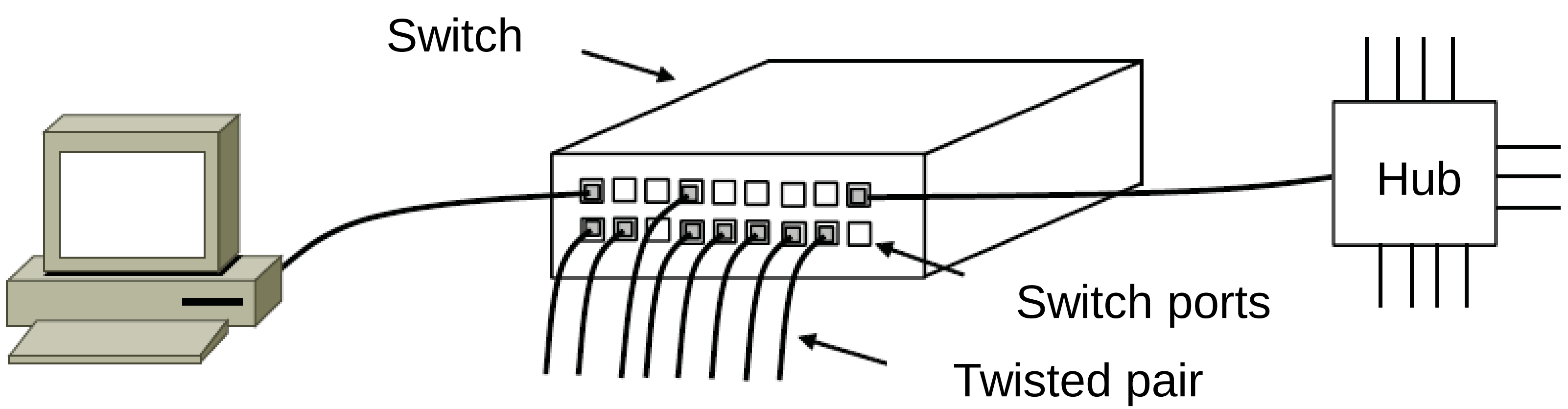
- Hubs wire all lines into a single CSMA/CD domain
- Switches isolate each port to a separate domain
  - Much greater throughput for multiple ports
  - No need for CSMA/CD with full-duplex lines



Switched/Fast Ethernet (2)

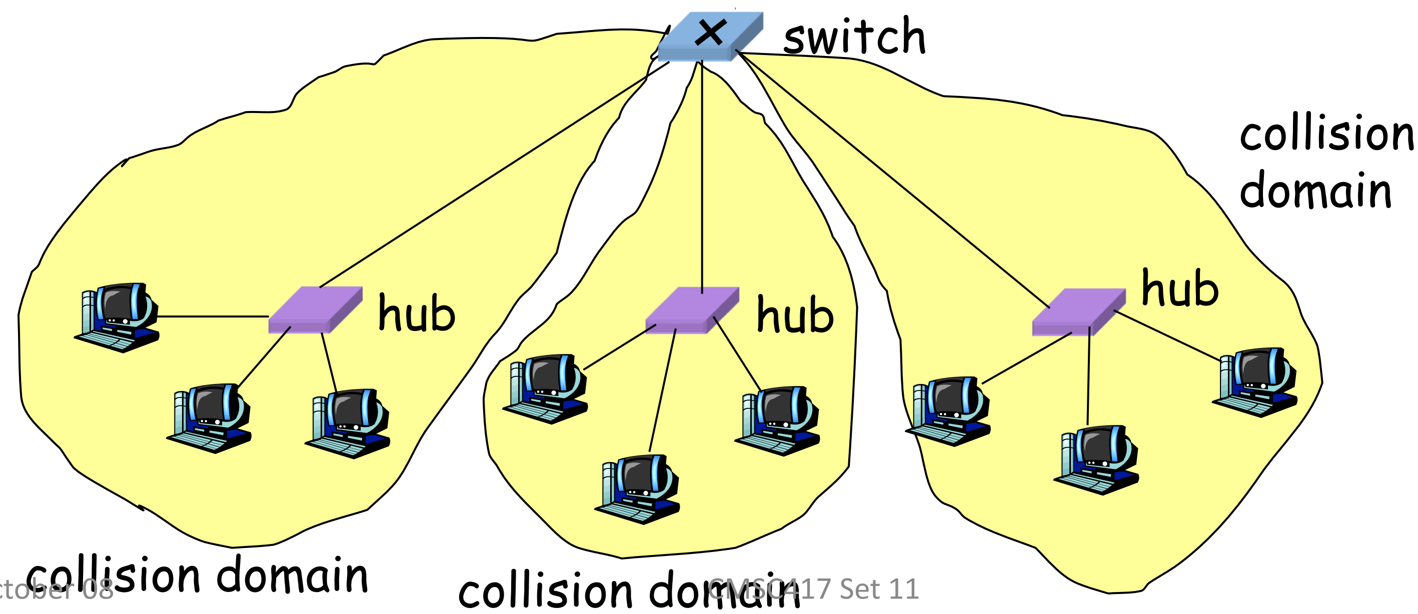
Switches can be wired to computers, hubs and switches

- Hubs concentrate traffic from computers
- More on how to switch frames the in 4.8



Switch: Traffic Isolation

- Switch breaks subnet into LAN segments
- Switch filters packets
  - Same-LAN-segment frames not usually forwarded onto other LAN segments
  - Segments become separate collision domains



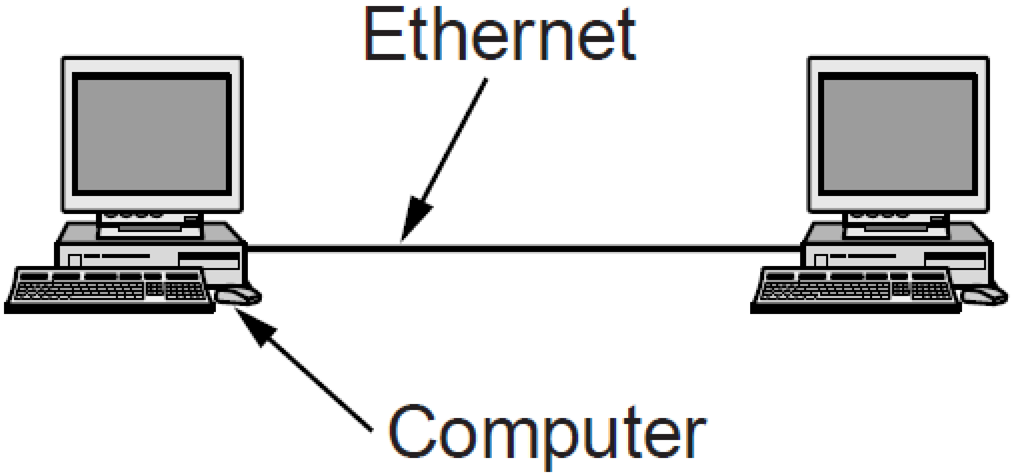
Switched/Fast Ethernet (3)

Fast Ethernet extended Ethernet from 10 to 100 Mbps

- Twisted pair (with Cat 5) dominated the market

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

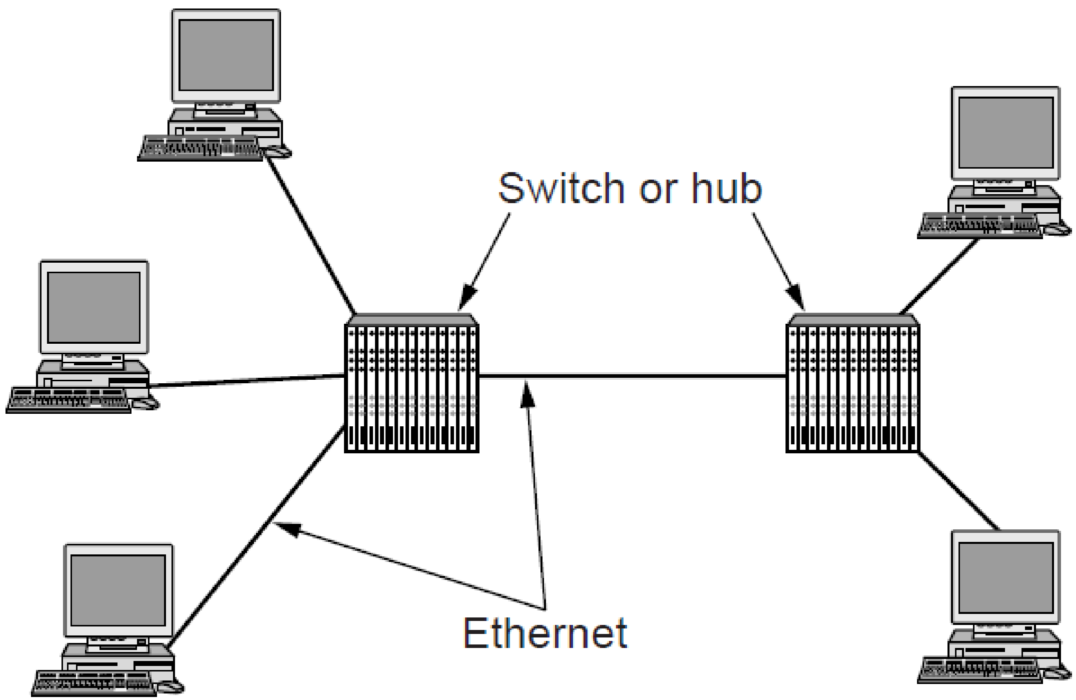
Gigabit Ethernet (1)



A two-station Ethernet

Gigabit / 10 Gigabit Ethernet (1)

Switched Gigabit Ethernet is now the garden variety



Gigabit / 10 Gigabit Ethernet (1)

- Gigabit Ethernet is commonly run over twisted pair

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

- 10 Gigabit Ethernet is being deployed where needed

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

- 40/100 Gigabit Ethernet is under development

Benefits of Ethernet

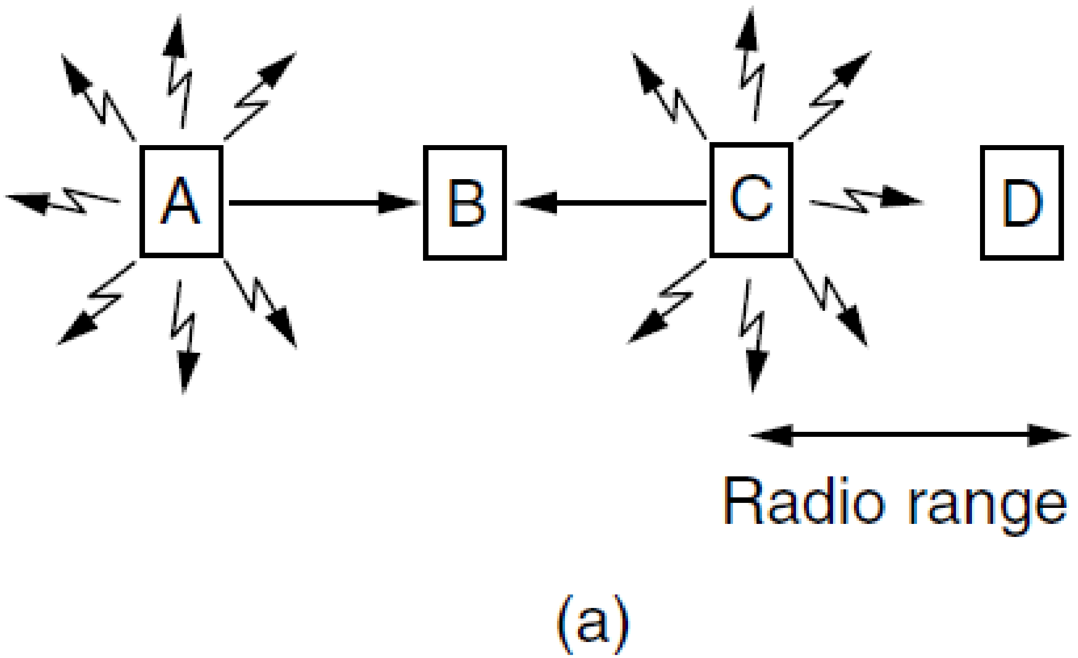
- Easy to administer and maintain
- Inexpensive
- Increasingly higher speed

- Moved from shared media to switches
  - Change everything except the frame format
  - A good general lesson for evolving the Internet

Unreliable, Connectionless Service

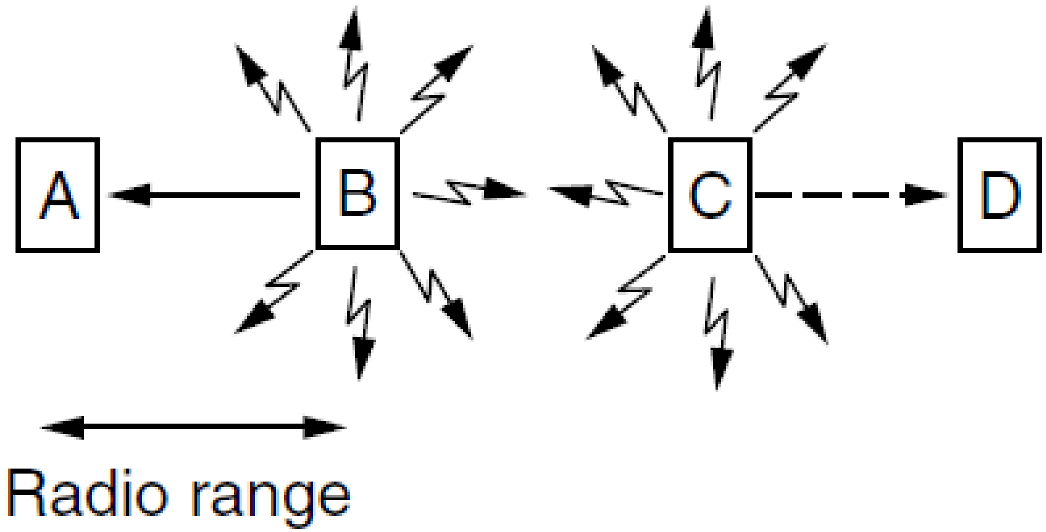
- Connectionless
  - No handshaking between sending and receiving adapter.
- Unreliable
  - Receiving adapter doesn't send ACKs or NACKs
  - Packets passed to network layer can have gaps
  - Gaps will be filled if application is using TCP
  - Otherwise, the application will see the gaps

Wireless LAN Protocols (1)



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

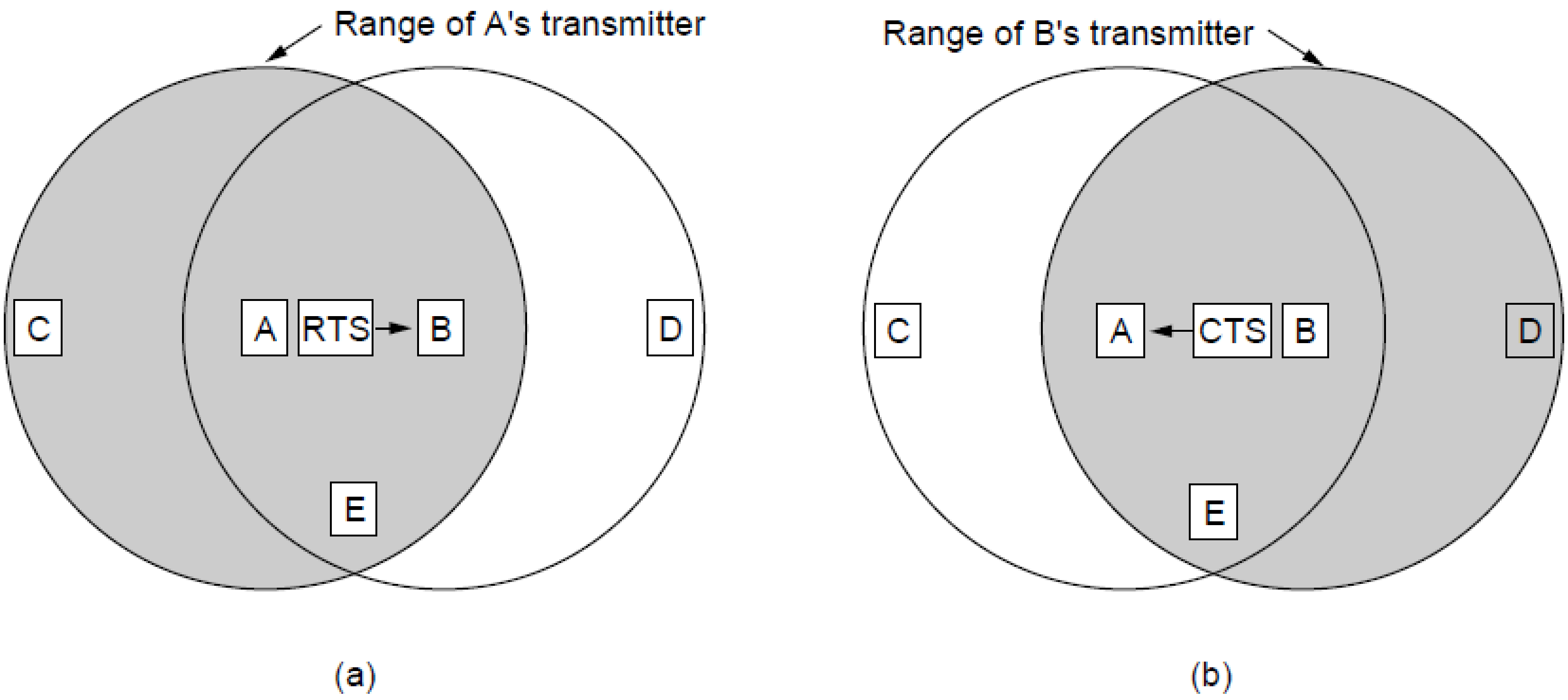
Wireless LAN Protocols (2)



(b)

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

Wireless LAN Protocols (3)

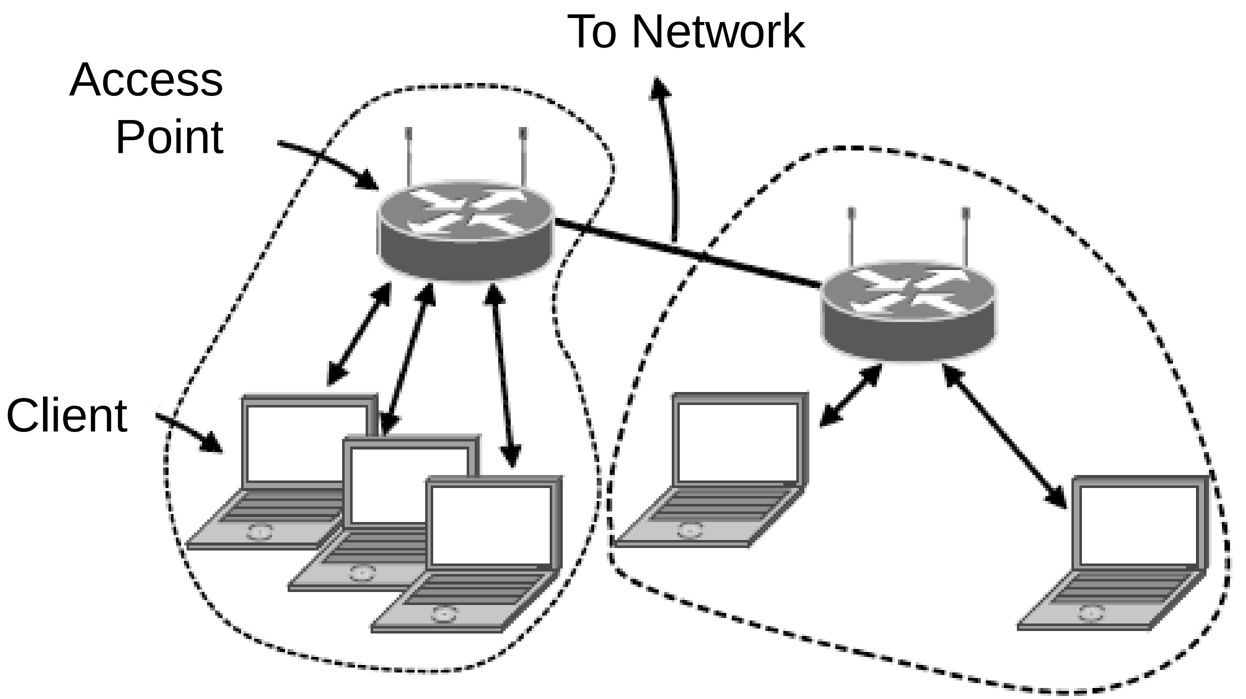


The MACA protocol. (a) *A sending an RTS to B. (b) B responding* with a CTS to *A.*

Wireless LANs

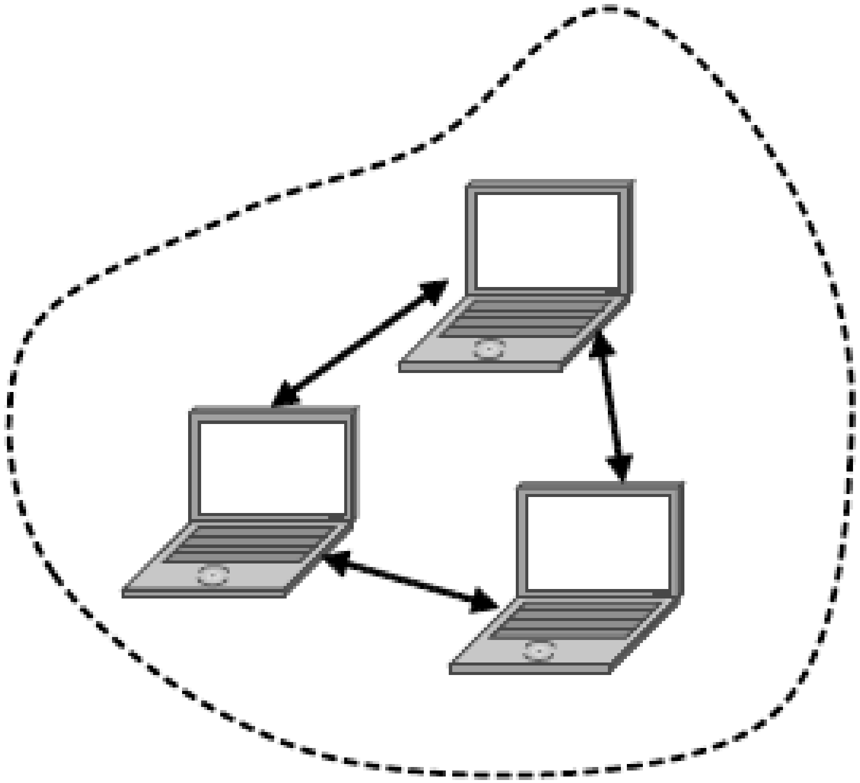
- The 802.11 Protocol Stack
- The 802.11 Physical Layer
- The 802.11 MAC Sublayer Protocol
- The 802.11 Frame Structure
- Services

802.11 Architecture and Protocol Stack (1)



802.11 architecture – infrastructure mode

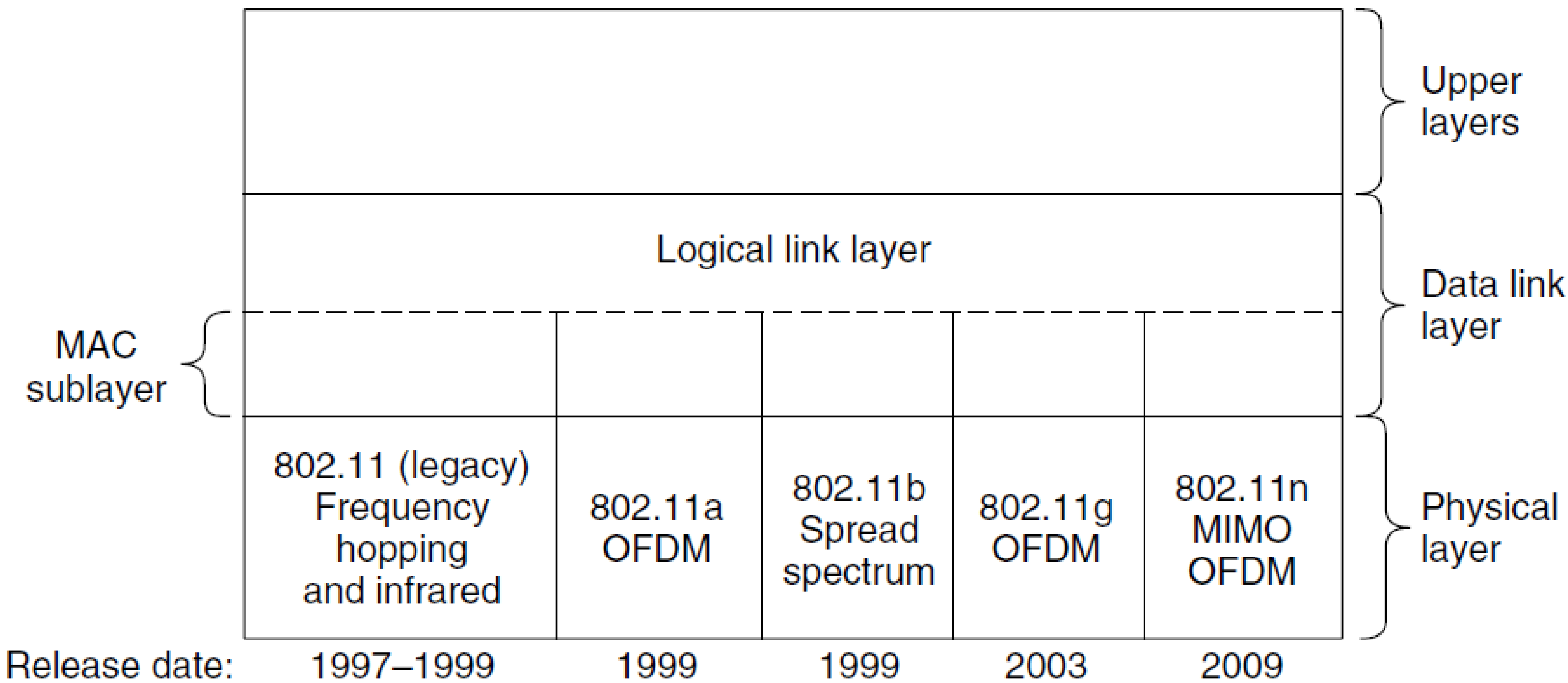
802.11 Architecture and Protocol Stack



802.11 architecture – ad-hoc mode

802.11 Architecture/Protocol Stack

MAC is used across different physical



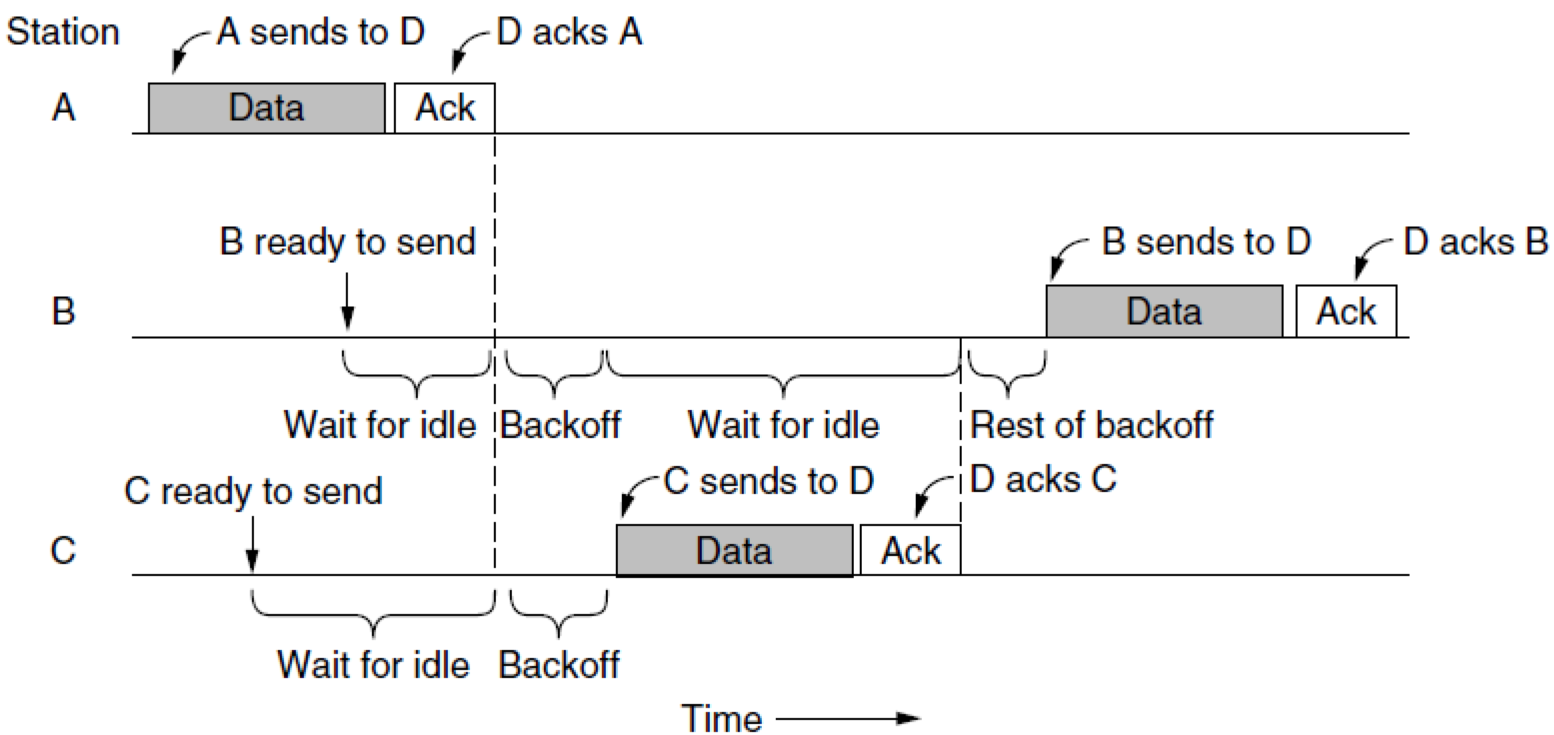
802.11 physical layer

– NICs are compatible with multiple physical layers
    - E.g., 802.11 a/b/g

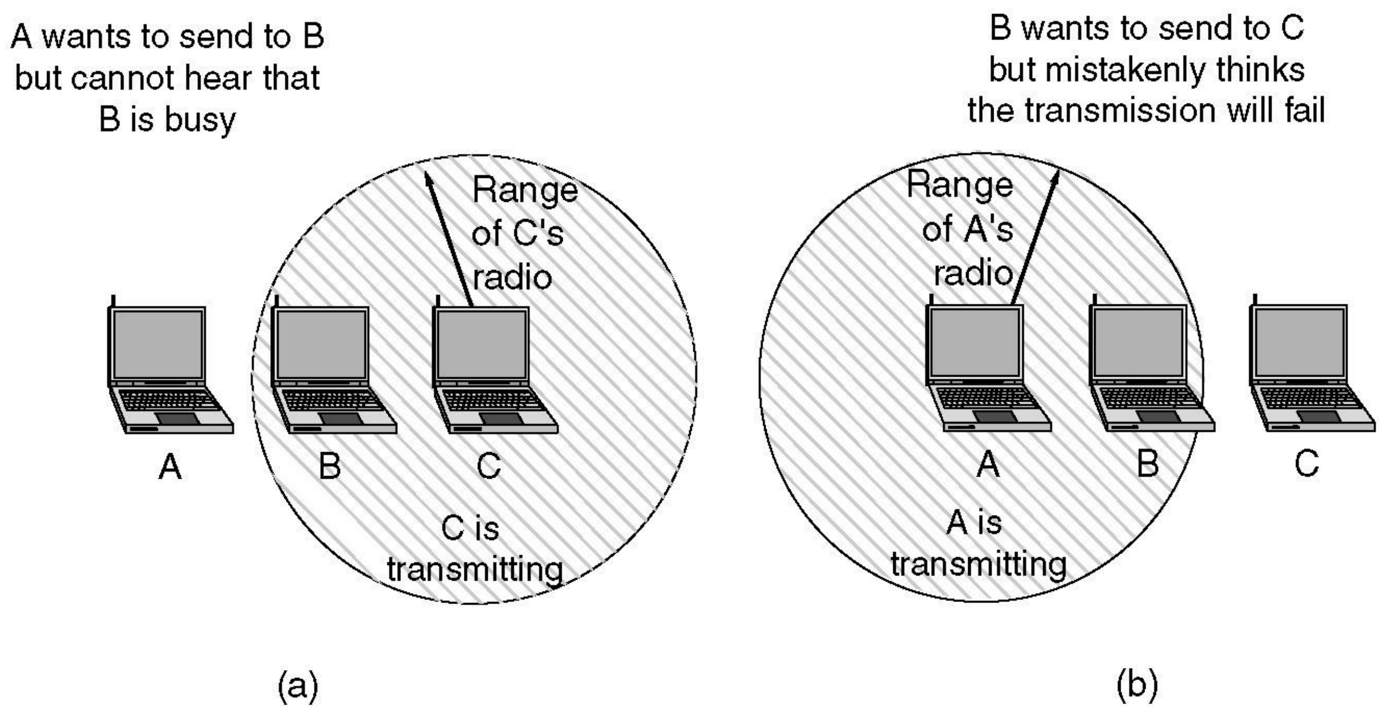
Name	Technique	Max. Bit Rate
802.11b	Spread spectrum, 2.4 GHz	11 Mbps
802.11g	OFDM, 2.4 GHz	54 Mbps
802.11a	OFDM, 5 GHz	54 Mbps
802.11n	OFDM with MIMO, 2.4/5 GHz	600 Mbps

802.11 MAC (1)

- CSMA/CA inserts backoff slots to avoid collisions
- MAC uses ACKs/retransmissions for wireless errors



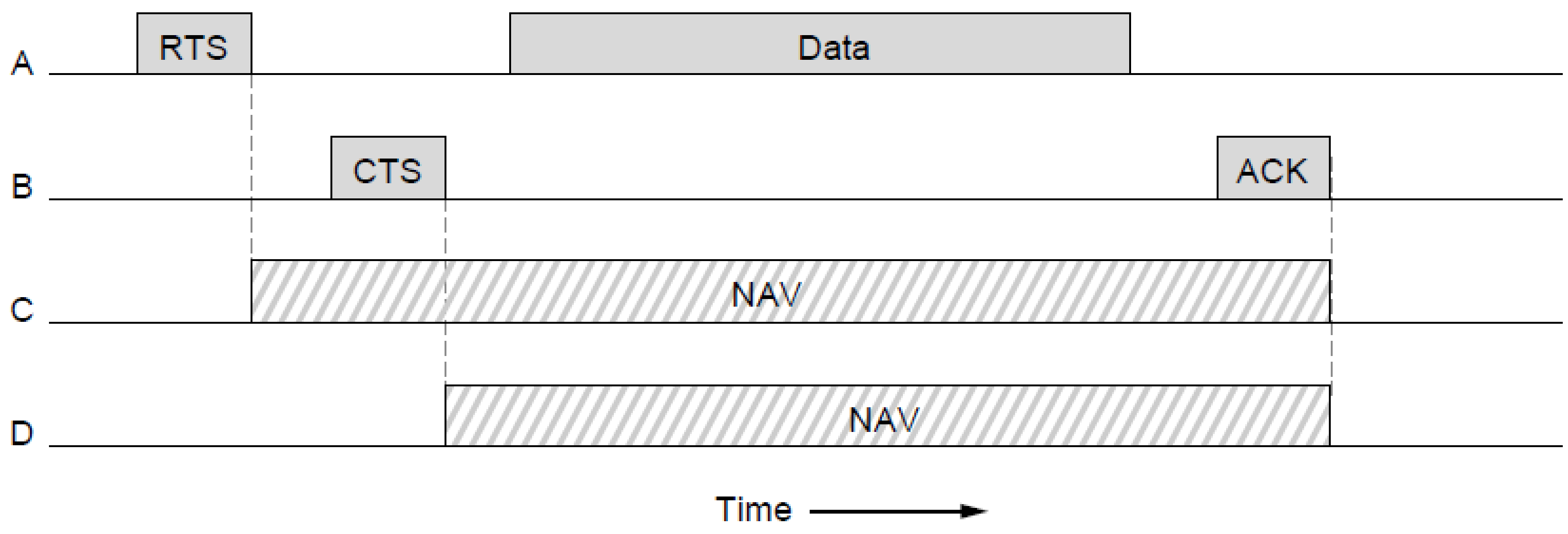
The 802.11 MAC Sublayer Protocol



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

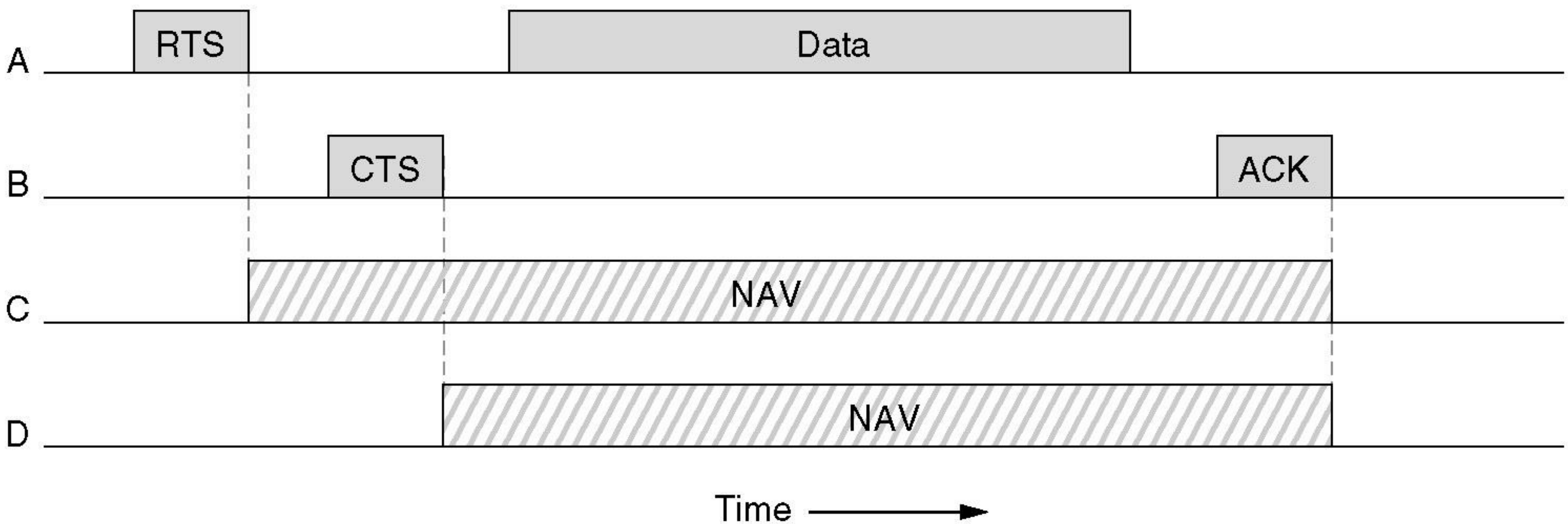
802.11 MAC (2)

Virtual channel sensing with the NAV and optional RTS/CTS (often not used) avoids hidden terminals



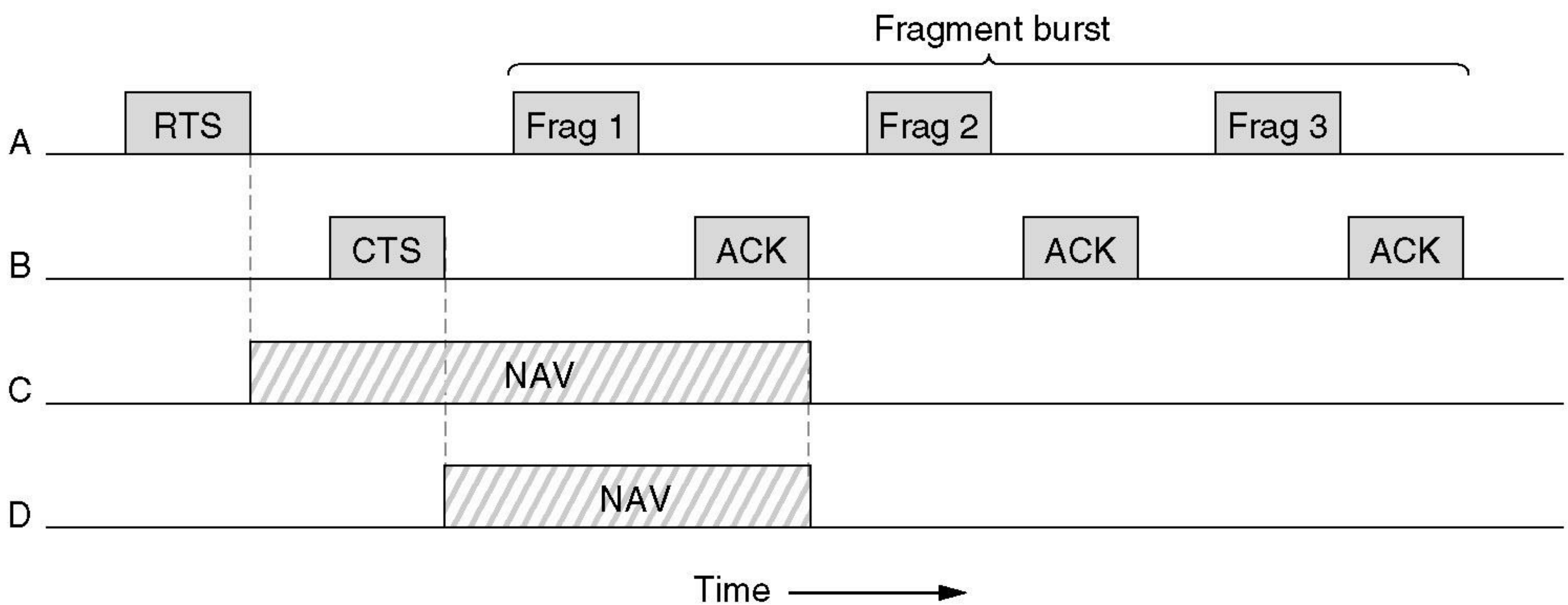
The 802.11 MAC Sublayer Protocol (2)

The use of virtual channel sensing using CSMA/CA.



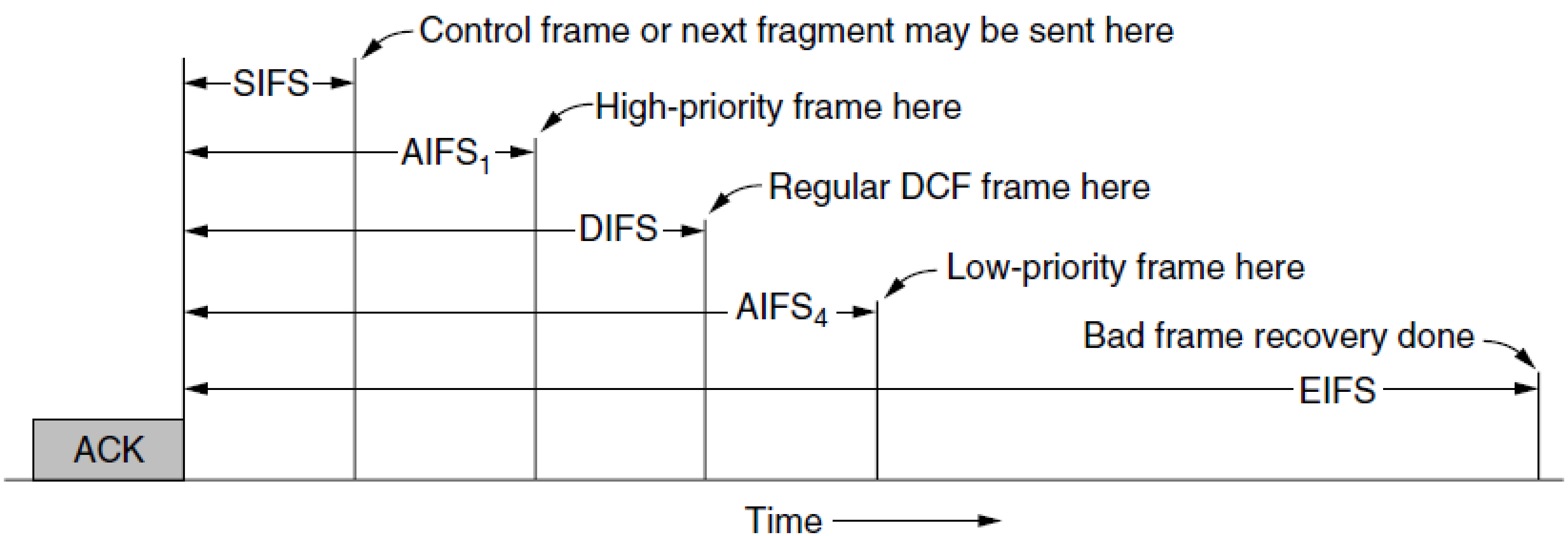
The 802.11 MAC Sublayer Protocol (3)

A fragment burst.



802.11 MAC (3)

- Different backoff slot times add quality of service
  - Short intervals give preferred access, e.g., control, VoIP
- MAC has other mechanisms too, e.g., power save



802.11 Frames

– Frames vary depending on their type (Frame control)
– Data frames have 3 addresses to pass via APs

Bytes	2	2	6	6	6	2	0–2312	4
	Frame control	Duration	Address 1 (recipient)	Address 2 (transmitter)	Address 3	Sequence	Data	Check sequence

	Version = 00	Type = 10	Subtype = 0000	To DS	From DS	More frag.	Retry	Pwr. mgt.	More data	Protected	Order
Bits	2	2	4	1	1	1	1	1	1	1	1

802.11 Services

Distribution Services

- Association
- Disassociation
- Reassociation
- Distribution
- Integration

802.11 Services

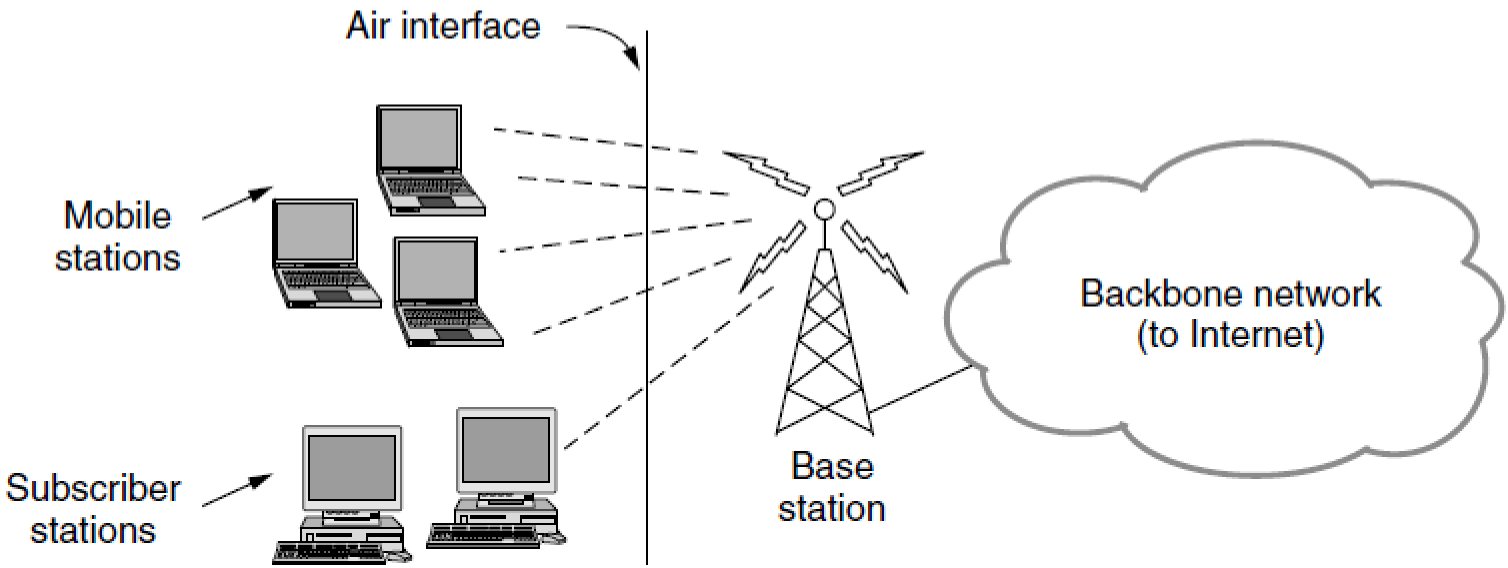
Intracell Services

- 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

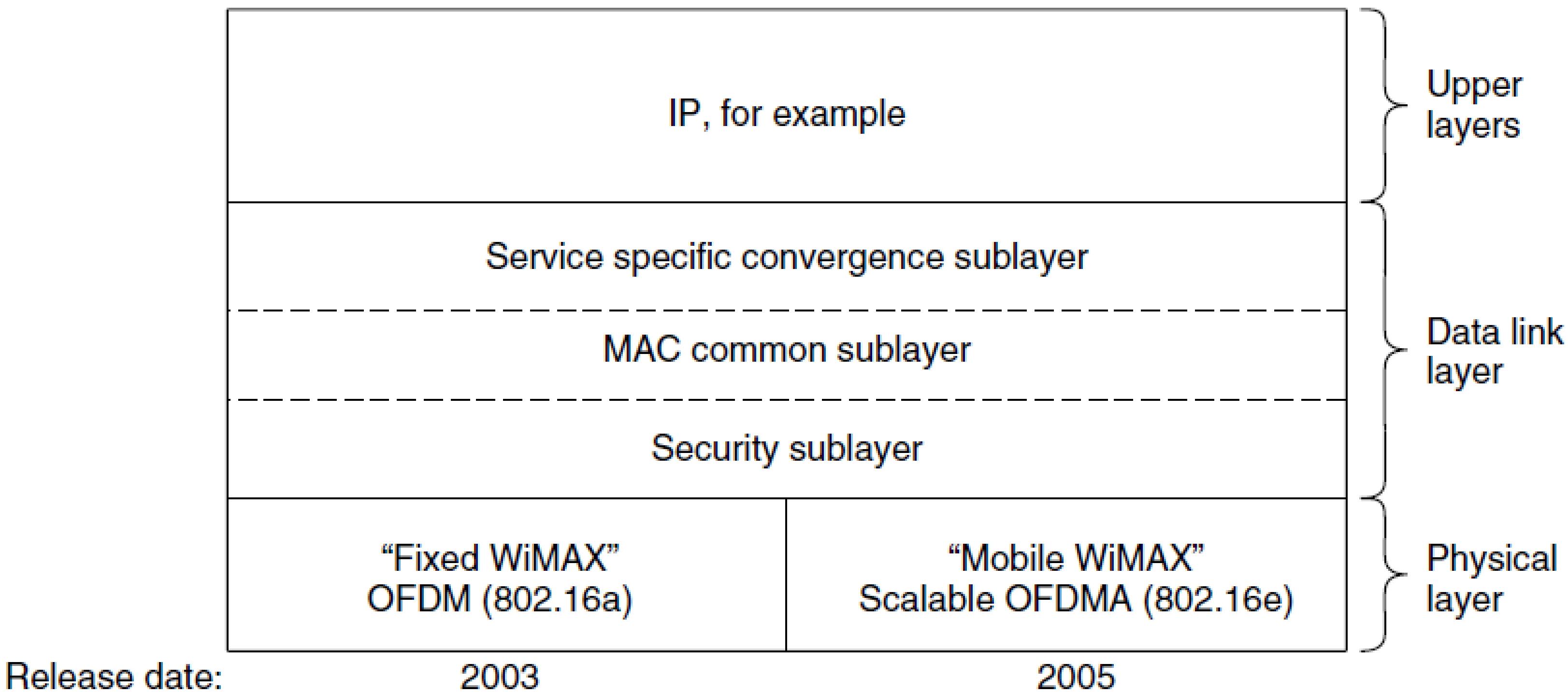
Comparison of 802.16 with 802.11 and 3G



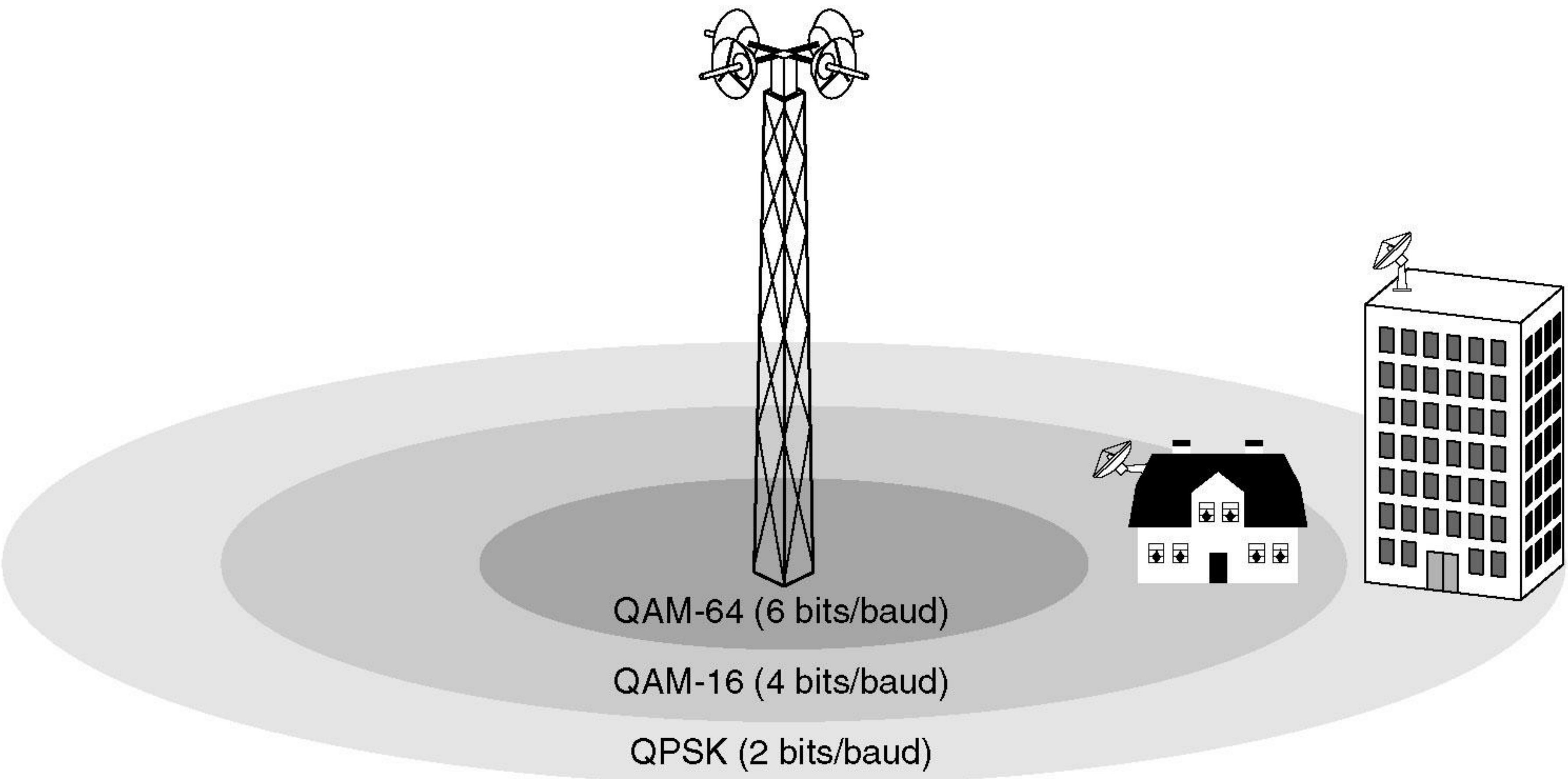
The 802.16 architecture

802.16 Architecture/Protocol Stack (2)

- MAC is connection-oriented; IP is connectionless
  - Convergence sublayer maps between the two

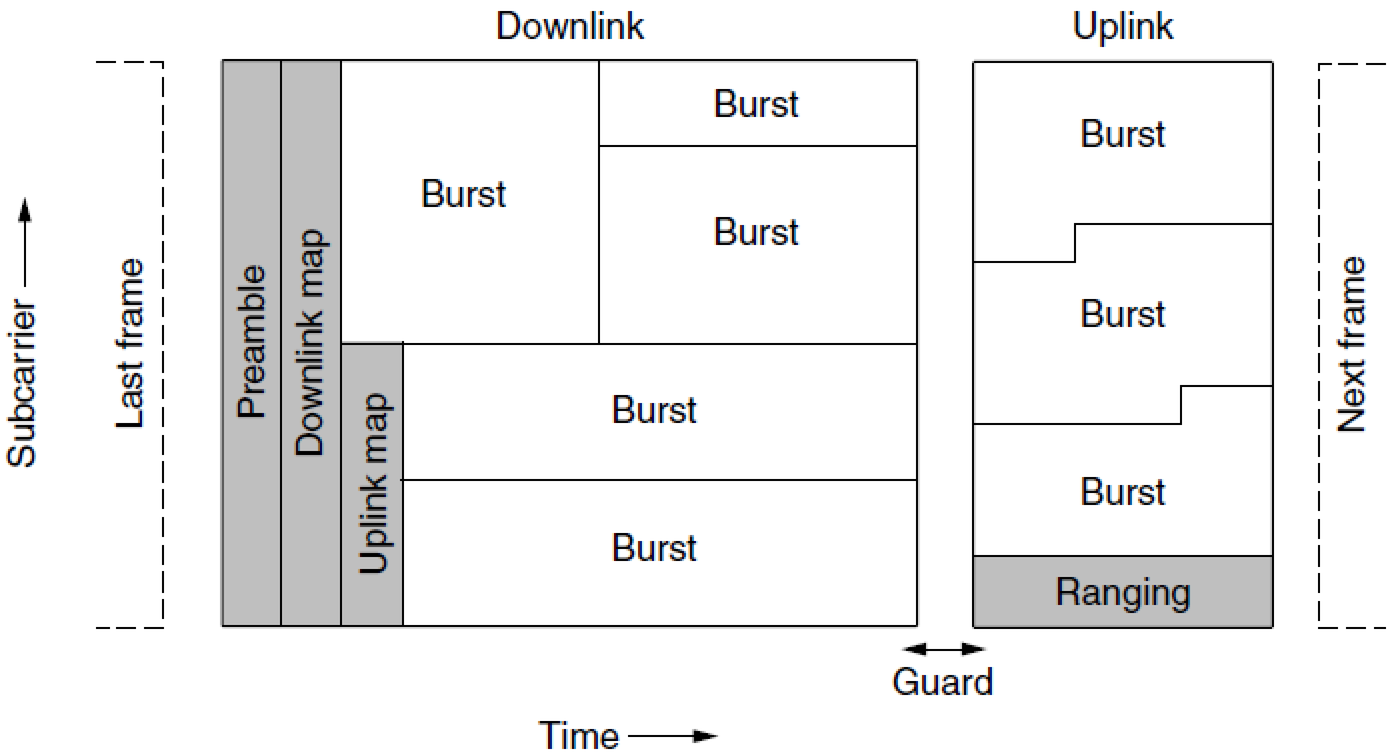


The 802.16 Physical Layer



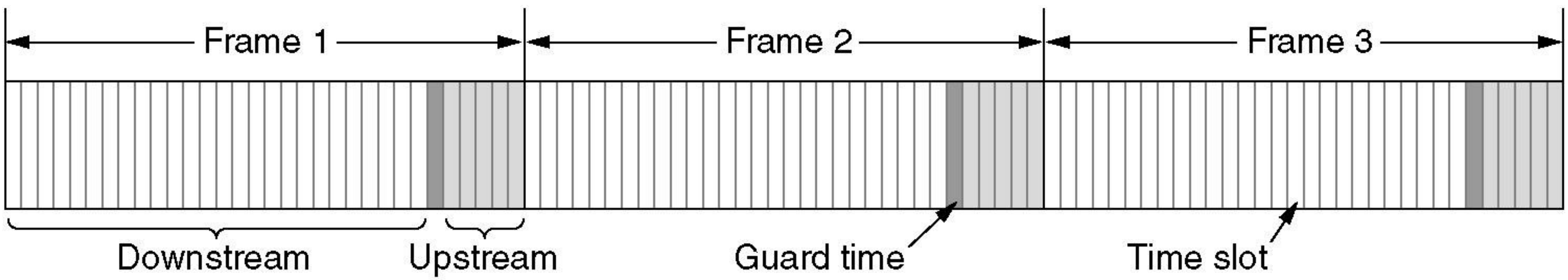
The 802.16 transmission environment.

802.16 Physical Layer



The 802.16 Physical Layer (2)

Frames and time slots for time division duplexing.



802.16 MAC

- Connection-oriented with base station in control
  - Clients request the bandwidth they need
- Different kinds of service can be requested:
  - Constant bit rate, e.g., uncompressed voice
  - Real-time variable bit rate, e.g., video, Web
  - Non-real-time variable bit rate, e.g., file download
  - Best-effort for everything else

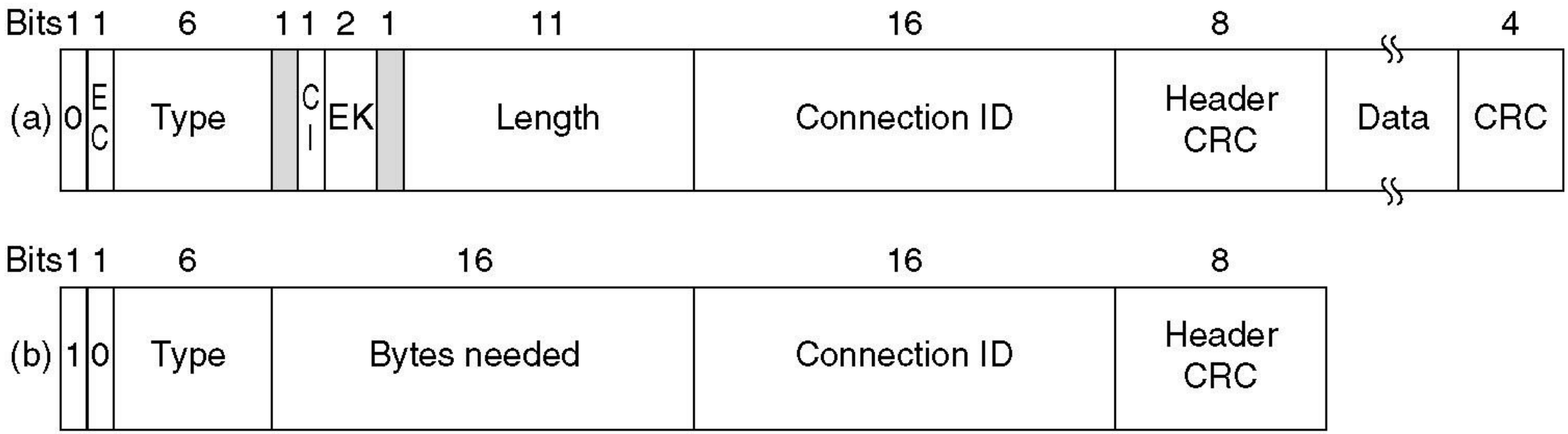
802.16 MAC Sublayer Protocol

Classes of service

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

The 802.16 Frame Structure

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



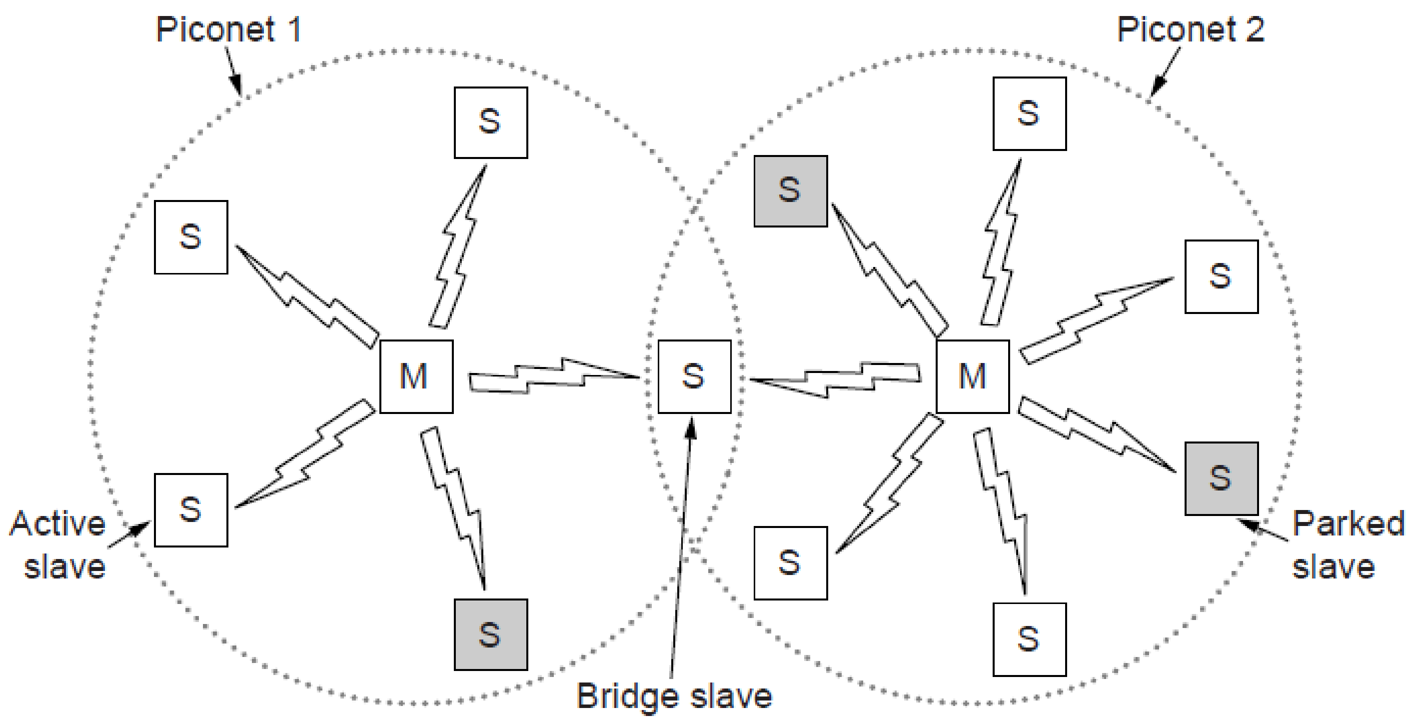
Bluetooth

- 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

Piconet master is connected to slave wireless devices

- Slaves may be asleep (parked) to save power



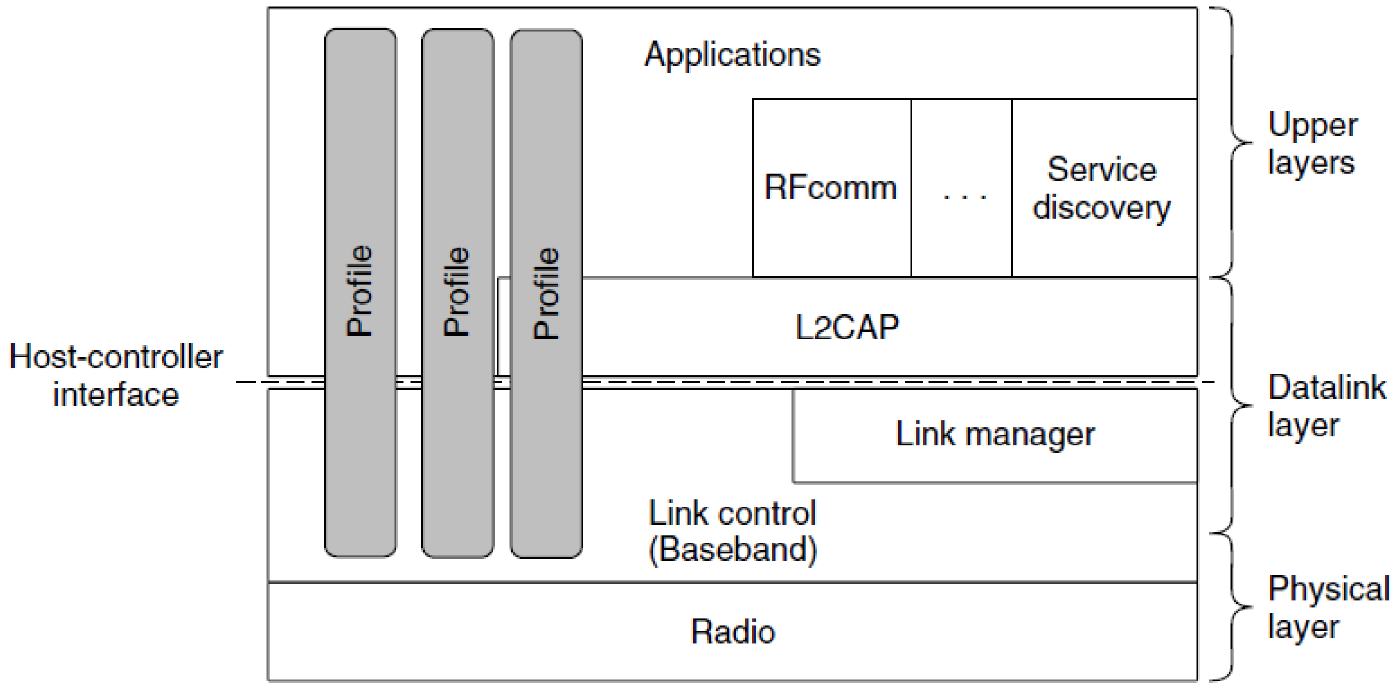
Bluetooth Applications

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

Bluetooth Applications / Protocol Stack

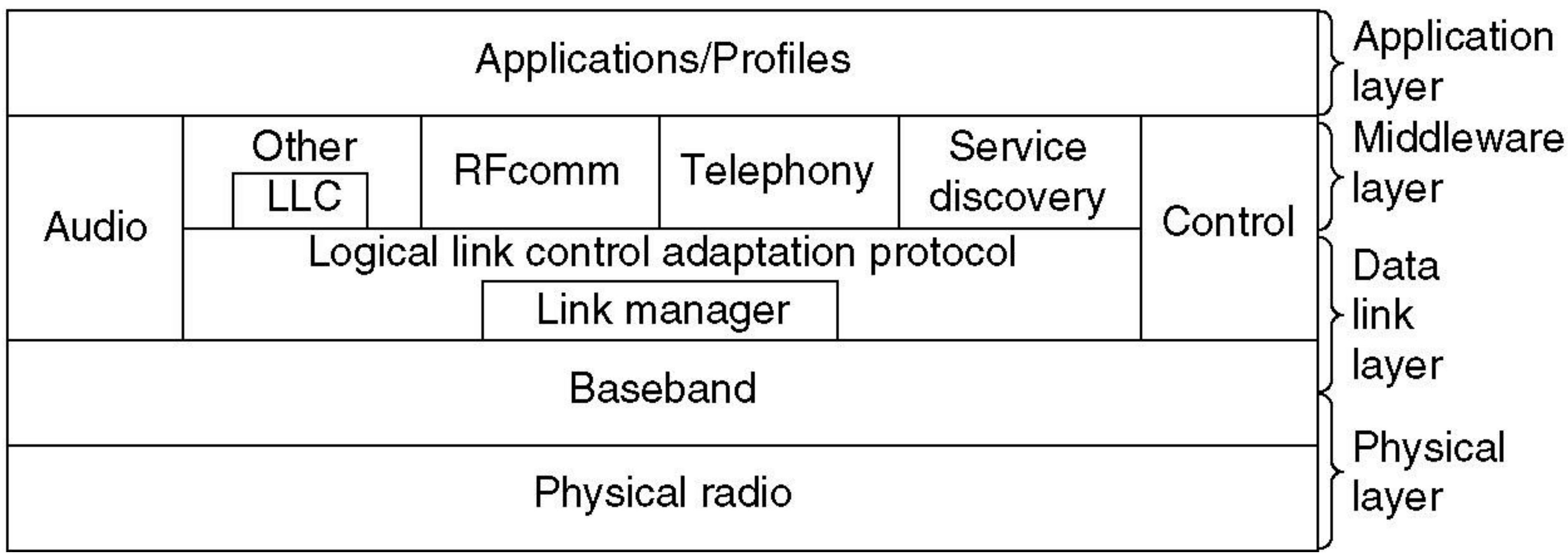
Profiles give the set of protocols for a given application

- 25 profiles, including headset, intercom, streaming audio, remote control, personal area network, …



The Bluetooth Protocol Stack

The 802.15 version of the Bluetooth protocol architecture.



Bluetooth Radio / Link Layers

Radio layer

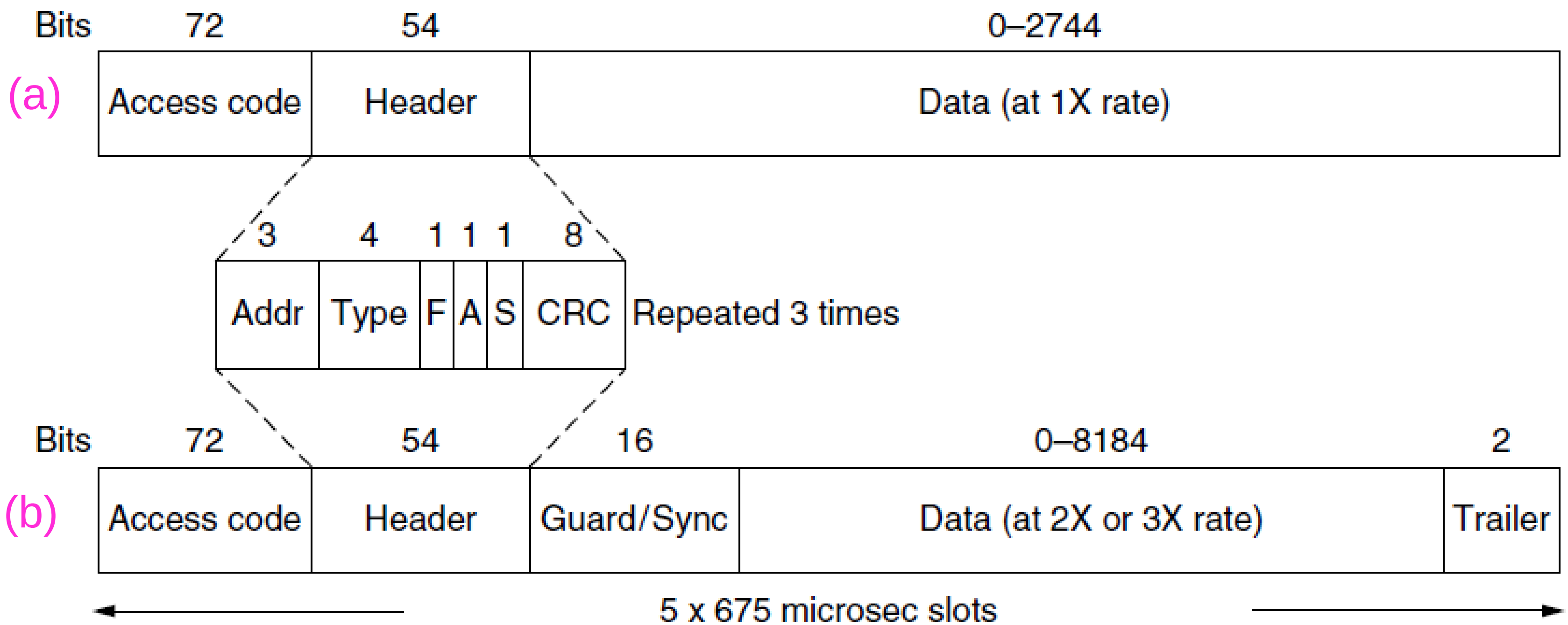
- Uses adaptive frequency hopping in 2.4 GHz band

Link layer

- TDM with timeslots for master and slaves
- Synchronous CO for periodic slots in each direction
- Asynchronous CL for packet-switched data
- Links undergo pairing (user confirms passkey/PIN) to authorize them before use

Bluetooth Frames

Time is slotted; enhanced data rates send faster but for the same time; addresses are only 3 bits for 8 devices

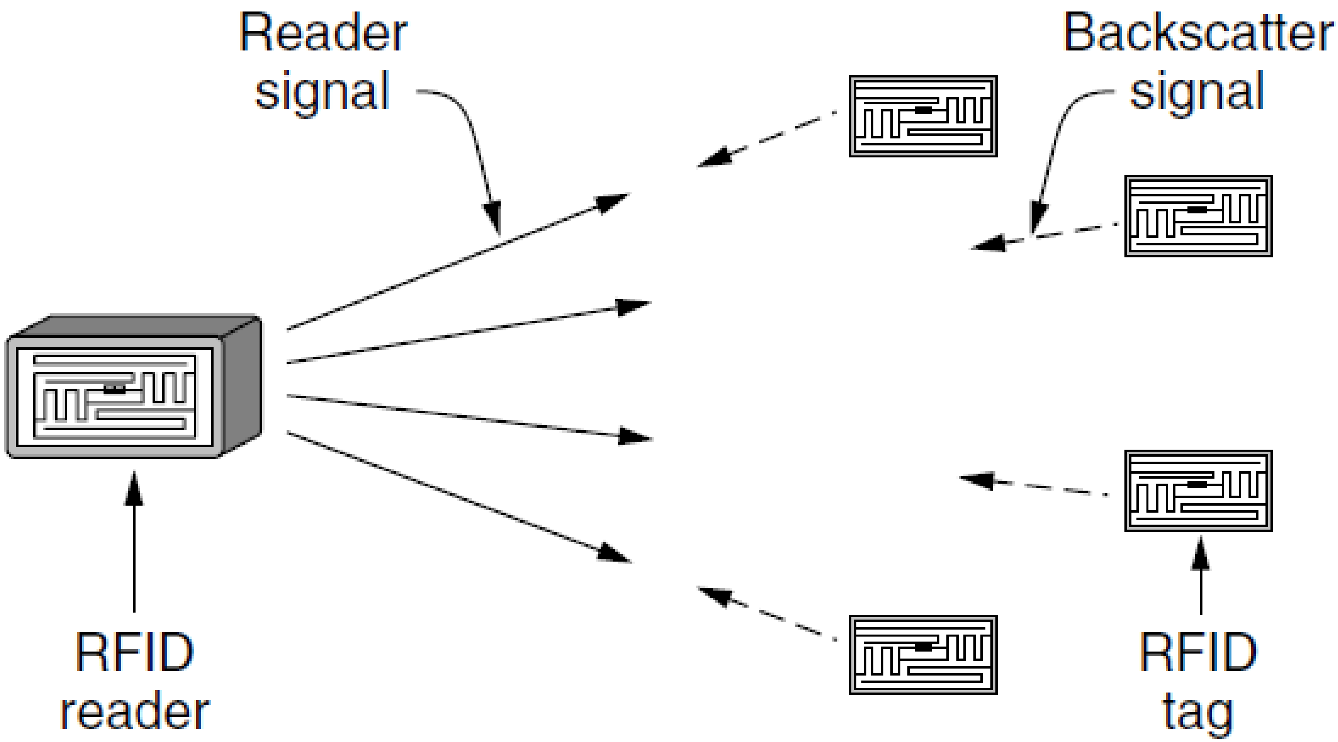


(a) Basic rate data frame (b) Enhanced rate data frame

RFID

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

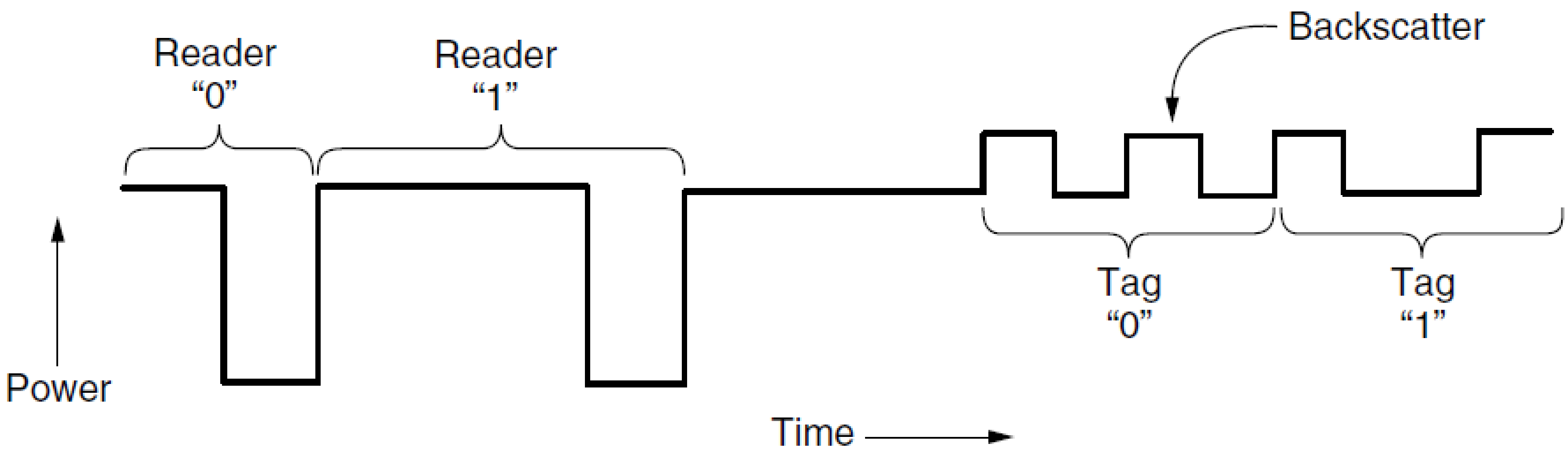
EPC Gen 2 Architecture



RFID architecture.

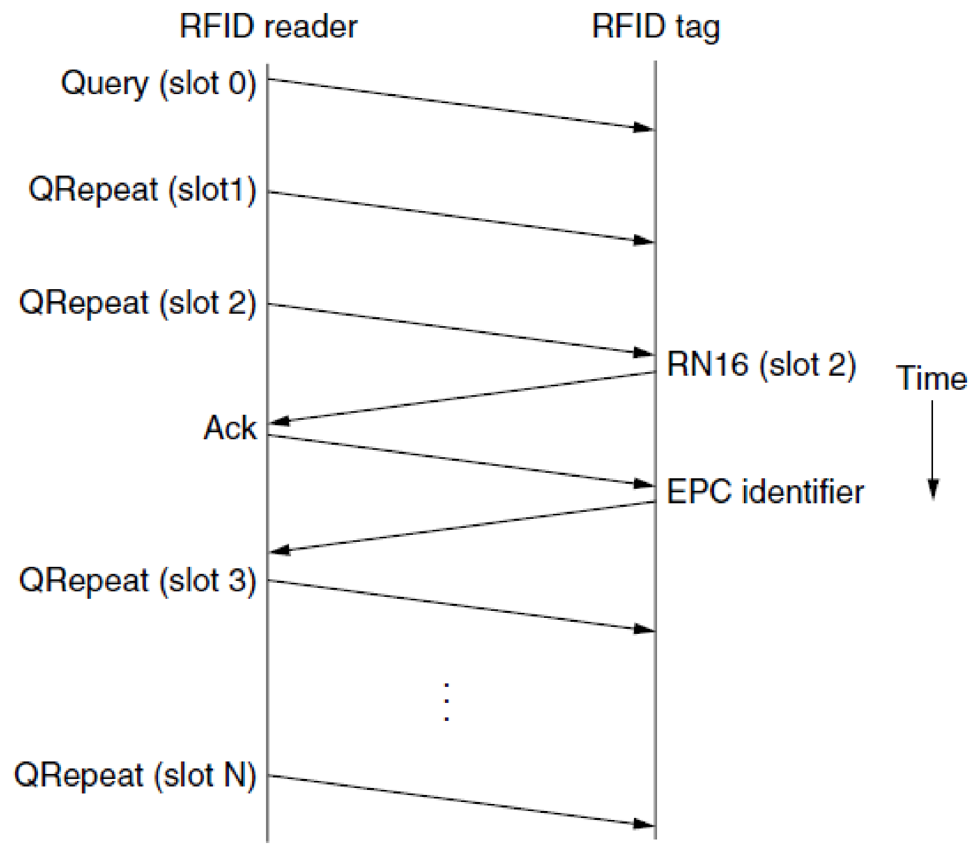
Gen 2 Physical Layer

- Reader uses duration of on period to send 0/1
- Tag backscatters reader signal in pulses to send 0/1



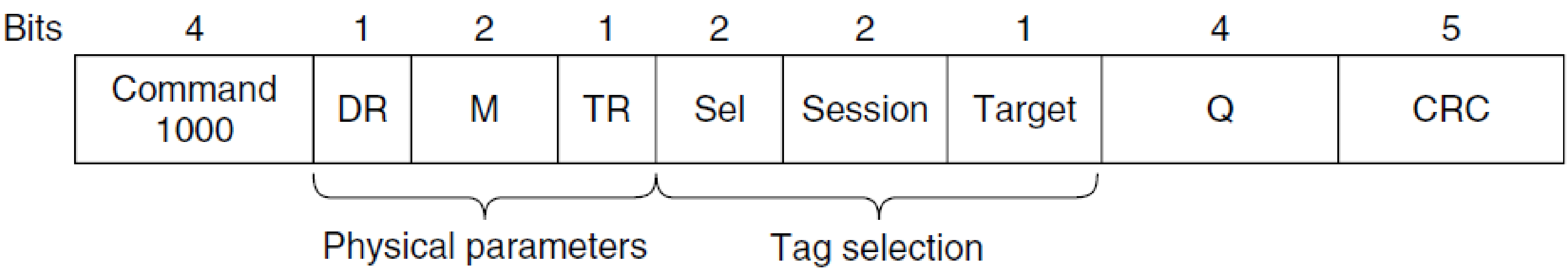
Gen 2 Tag Identification Layer

- Reader sends query and sets slot structure
- Tags reply (RN16) in a random slot; may collide
- Reader asks one tag for its identifier (ACK)
- Process continues until no tags are left



Gen 2 Frames

- Reader frames vary depending on type (Command)
  - Query shown below, has parameters and error detection
- Tag responses are simply data
  - Reader sets timing and knows the expected format

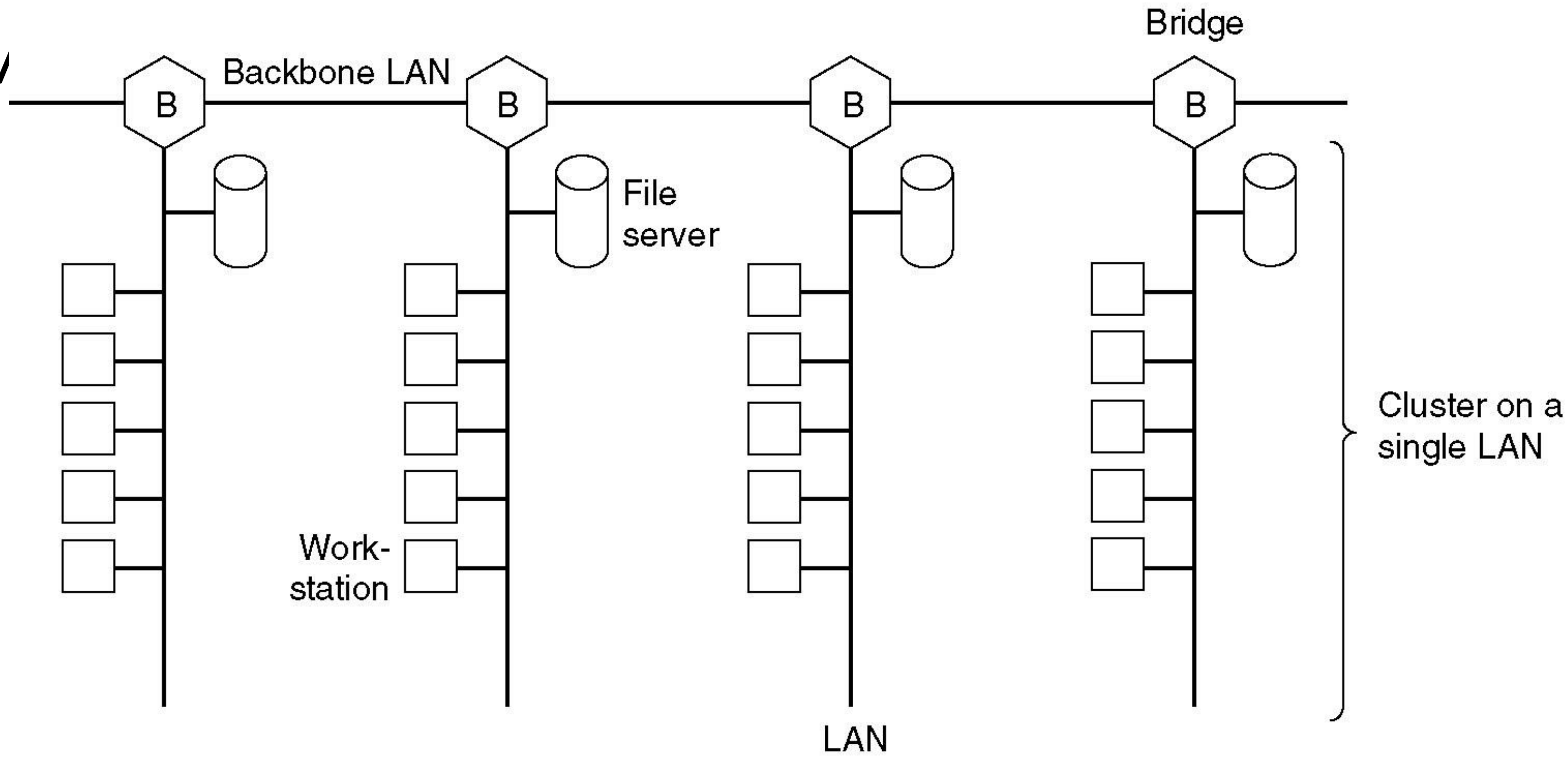


Query message

Data Link Layer Switching

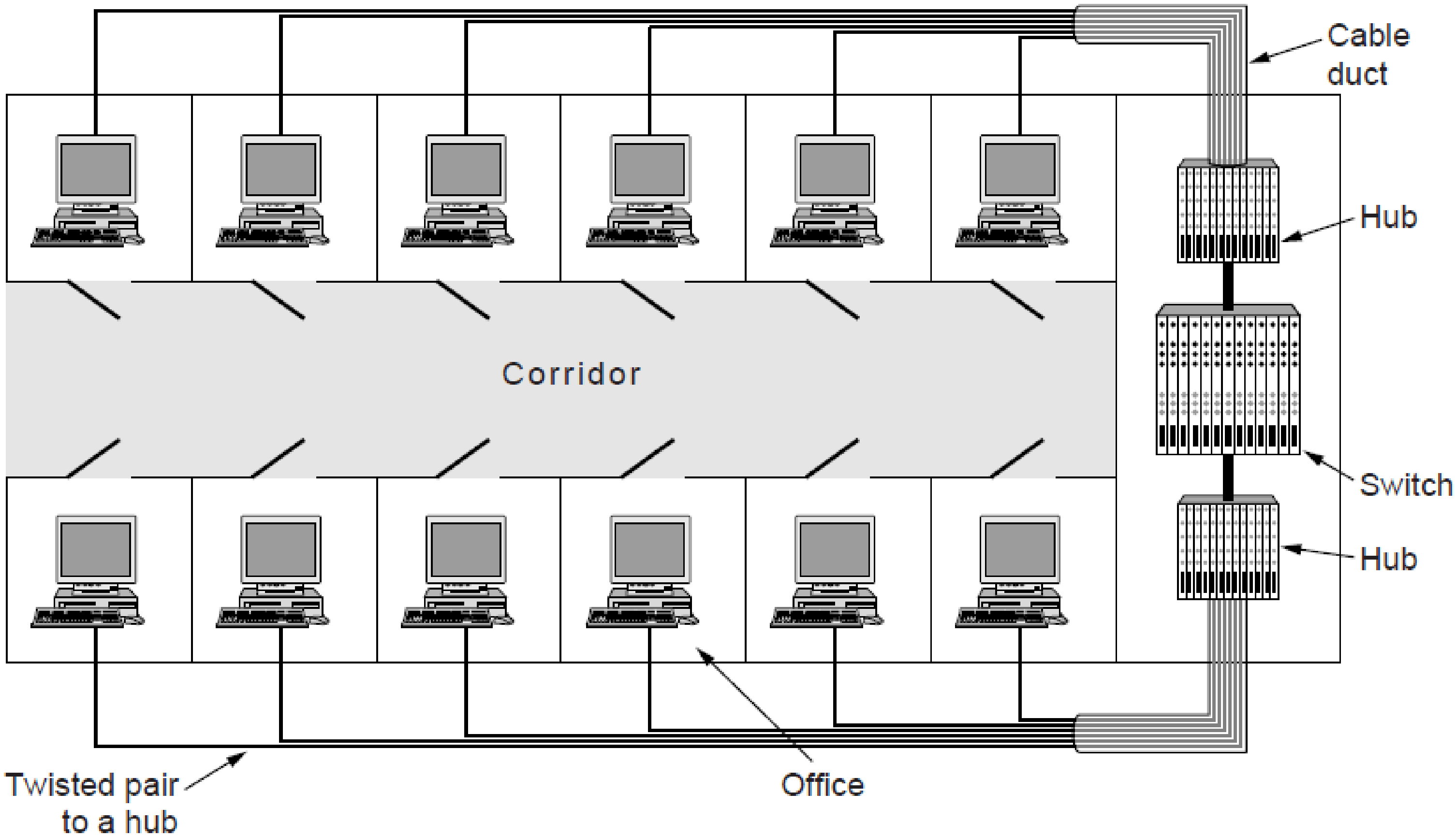
- Bridges from 802.x to 802.y
- Local Internetworking
- Spanning Tree Bridges
- Remote Bridges
- Repeaters, Hubs, Bridges, Switches, Routers, Gateways
- Virtual LANs

Data Link Layer Switching



Uses of Bridges

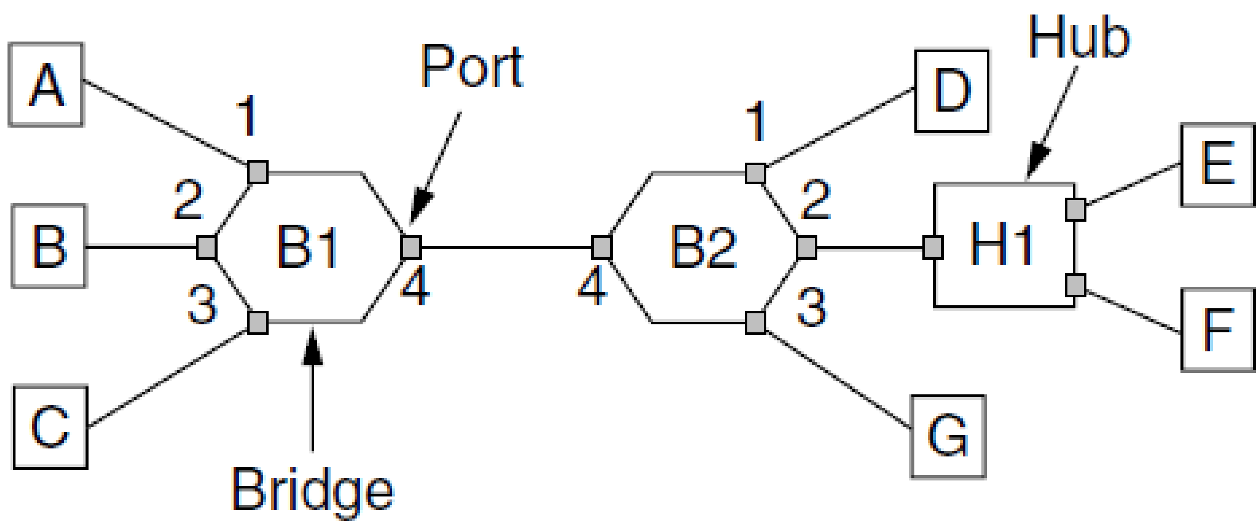
- Common setup is a building with centralized wiring
  - Bridges (switches) are placed in or near wiring closets



Learning Bridges

A bridge operates as a switched LAN (not a hub)

- Computers, bridges, and hubs connect to its ports



Learning Bridges

Backward learning algorithm picks the output port:

- Associates source address on frame with input port
- Frame with destination address sent to learned port
- Unlearned destinations are sent to all other ports

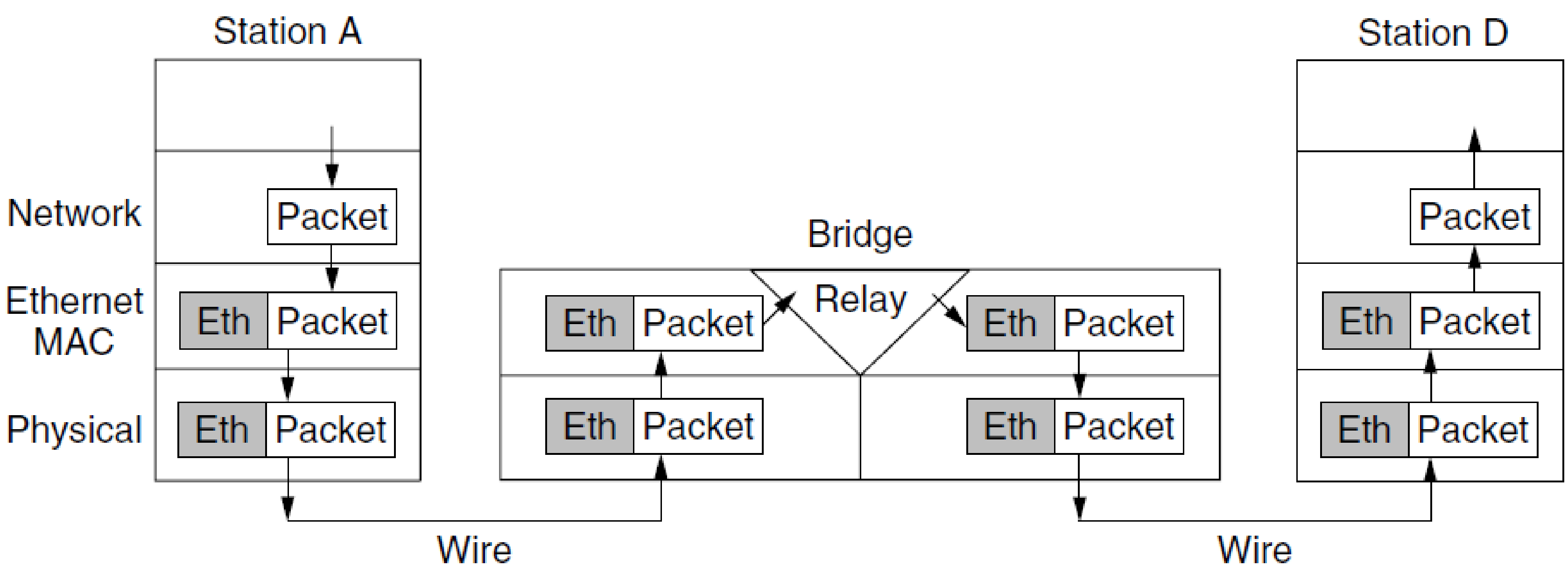
Needs no configuration

- Forget unused addresses to allow changes
- Bandwidth efficient for two-way traffic

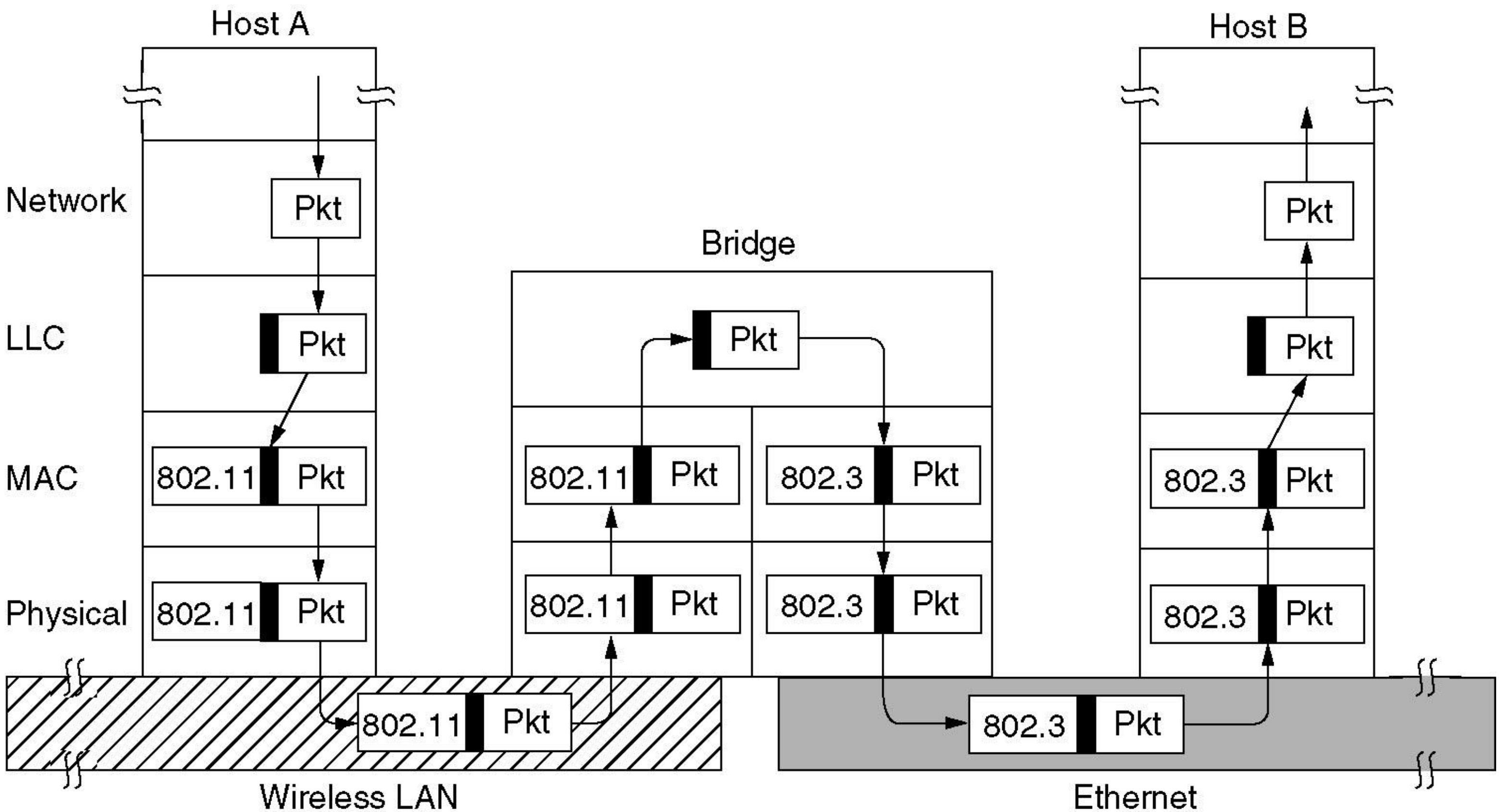
Learning Bridges

Bridges extend the Link layer:

- Use but don't remove Ethernet header/addresses
- Do not inspect Network header

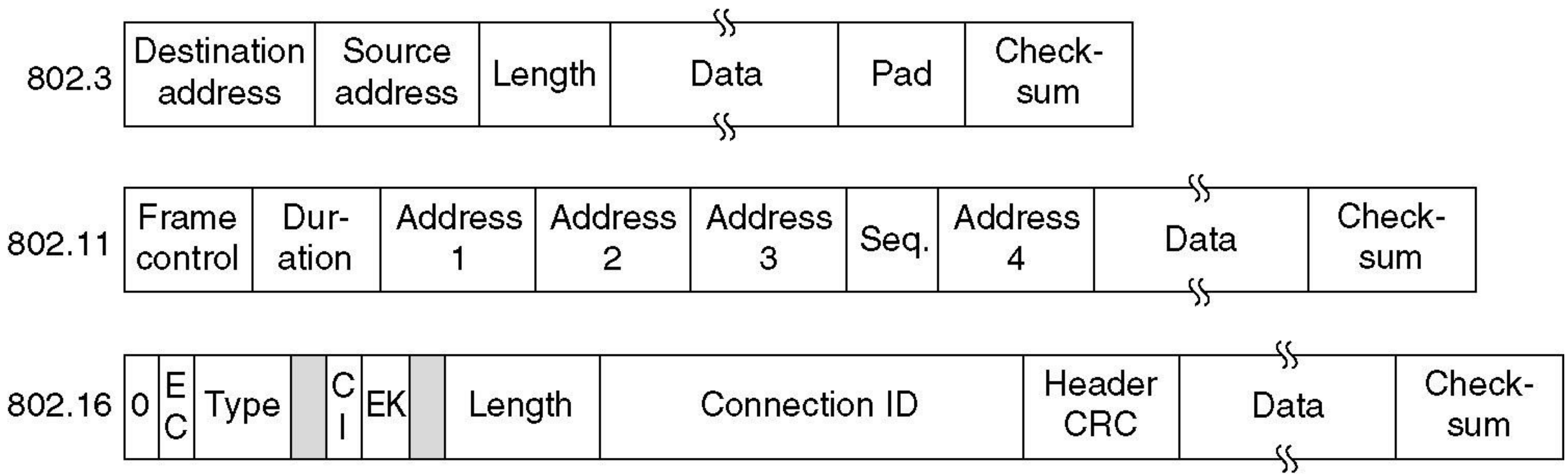


Bridges from 802.x to 802.y



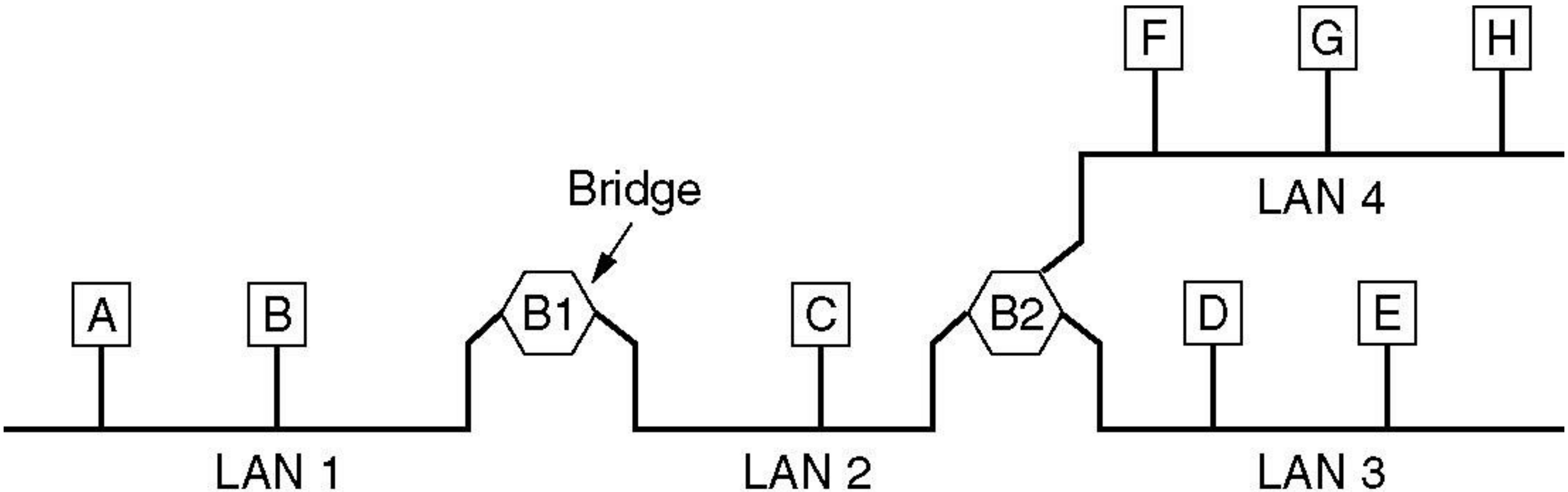
Bridges from 802.x to 802.y (2)

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

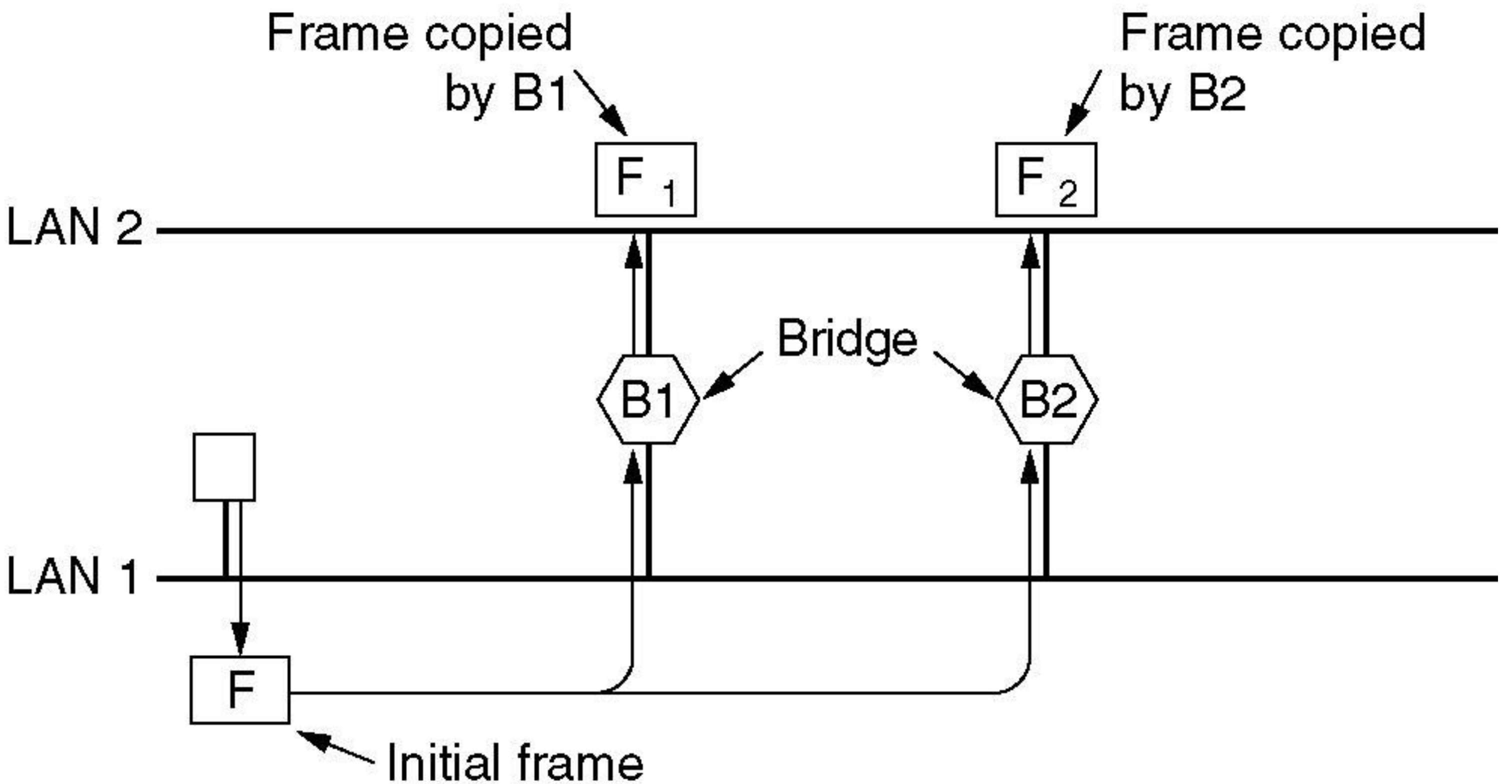


Local Internetworking

A configuration with four LANs and two bridges.



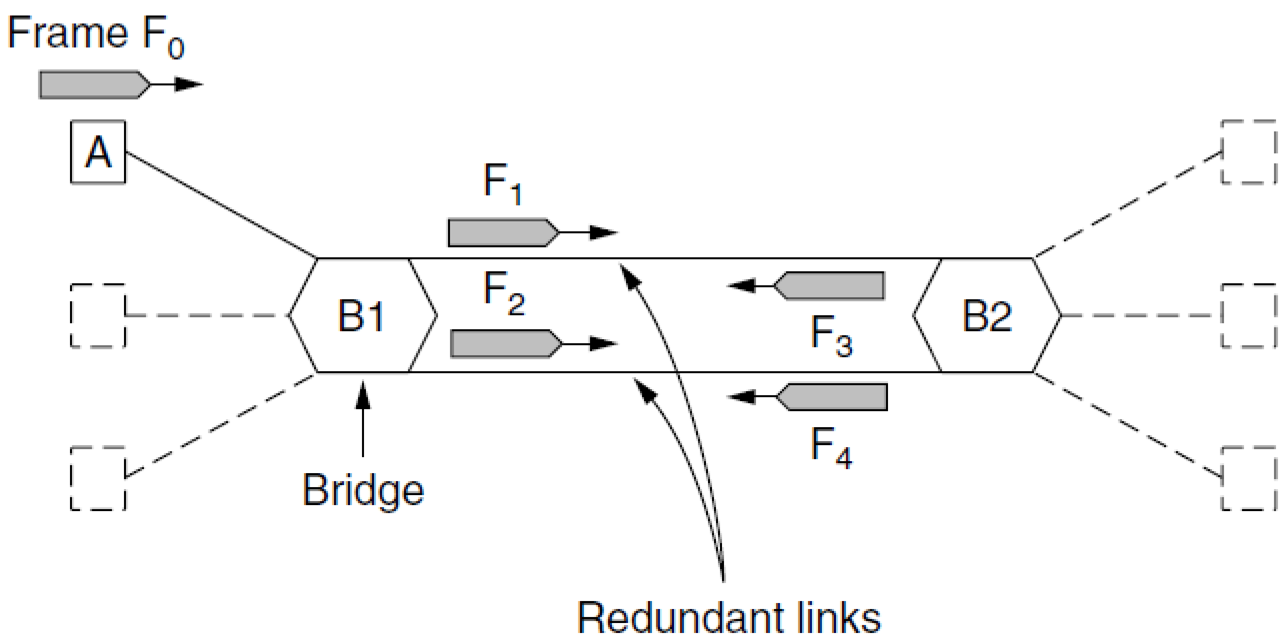
Spanning Tree Bridges



Spanning Tree (1) – Problem

Bridge topologies with loops and only backward learning will cause frames to circulate for ever

- Need spanning tree support to solve problem



Spanning Tree (2) – Algorithm

- Subset of forwarding ports for data is use to avoid loops
- Selected with the spanning tree distributed algorithm by Perlman

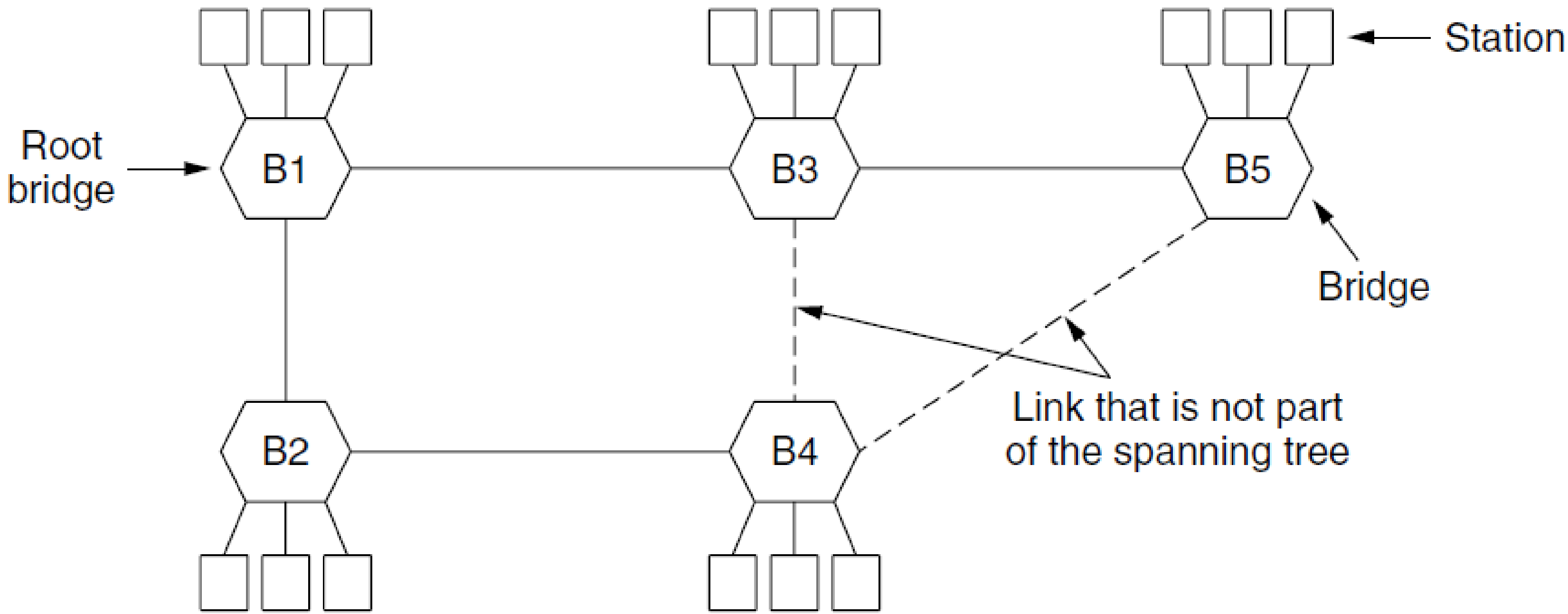
I think that I shall never see
A graph more lovely than a tree.
A tree whose crucial property
Is loop-free connectivity.
A tree which must be sure to span.
So packets can reach every LAN.
First the Root must be selected
By ID it is elected.
Least cost paths from Root are traced
In the tree these paths are placed.
A mesh is made by folks like me
Then bridges find a spanning tree.

– Radia Perlman, 1985.

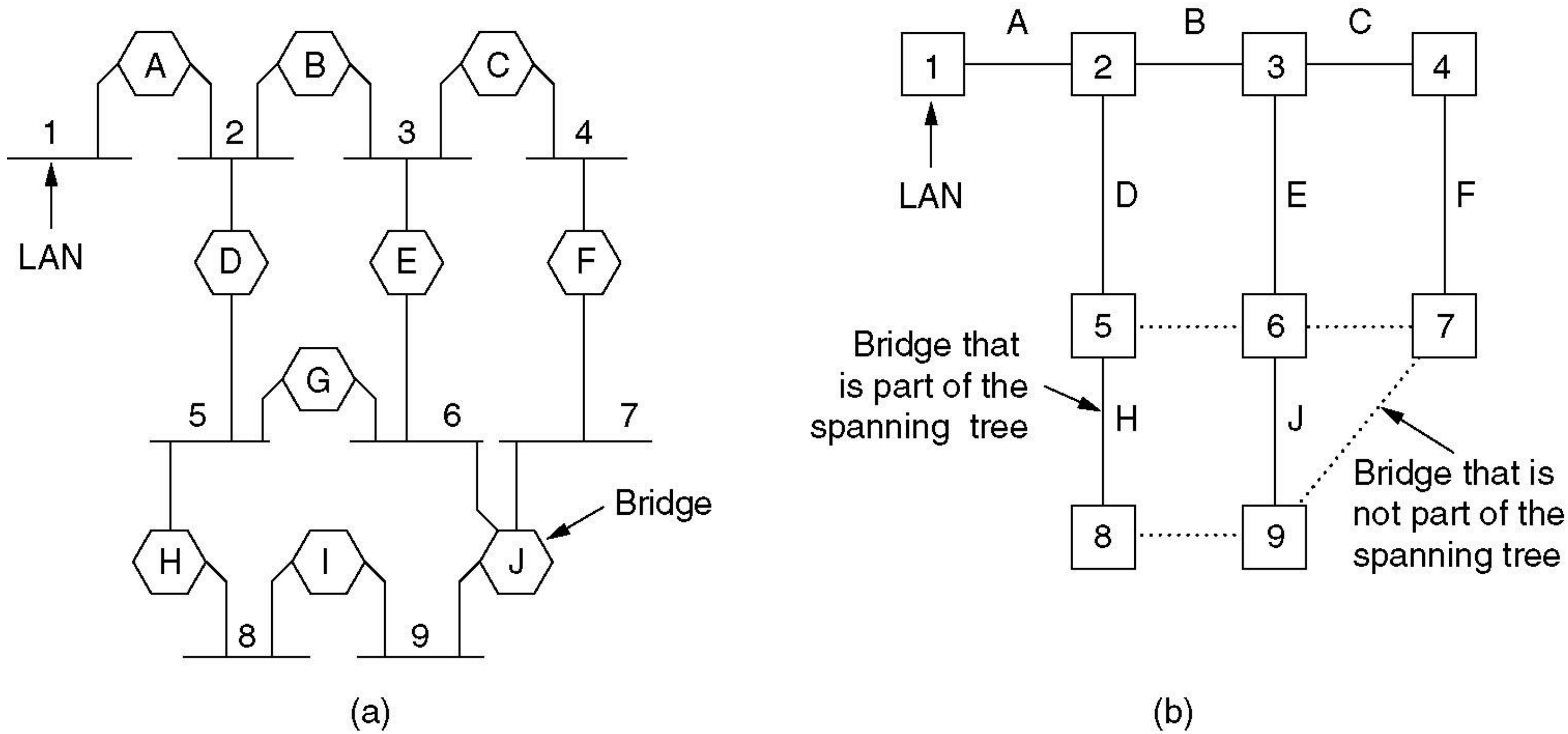
Spanning Tree (3) – Example

After the algorithm runs:

- B1 is the root, two dashed links are turned off
- B4 uses link to B2 (lower than B3 also at distance 1)
- B5 uses B3 (distance 1 versus B4 at distance 2)



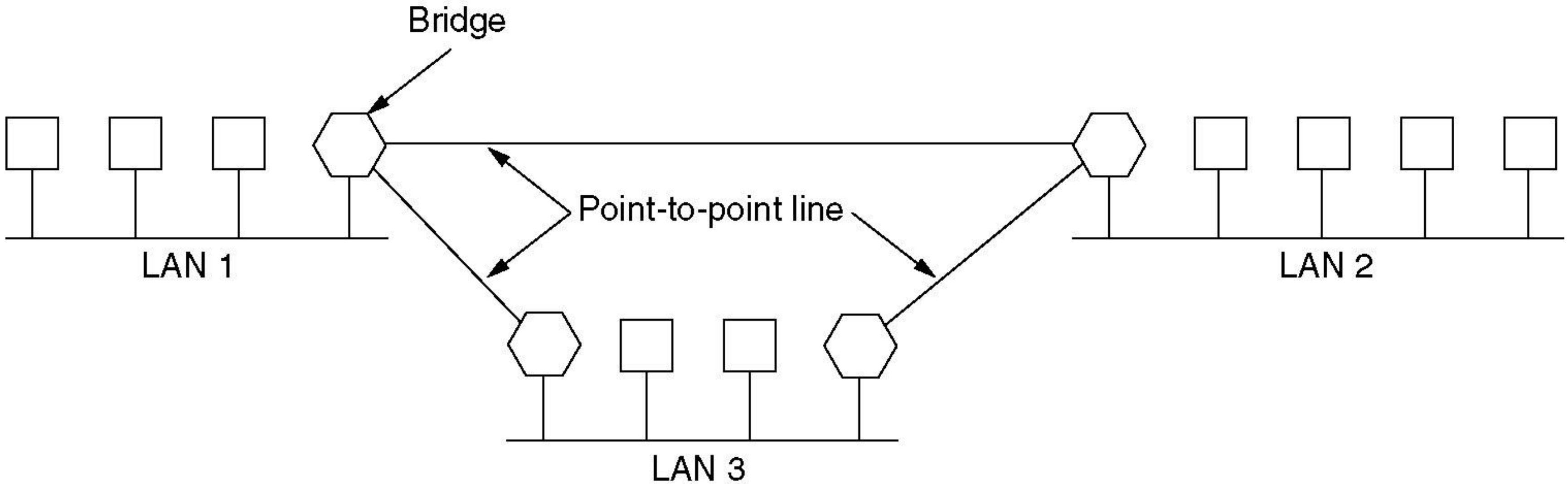
Spanning Tree Bridges (2)



(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



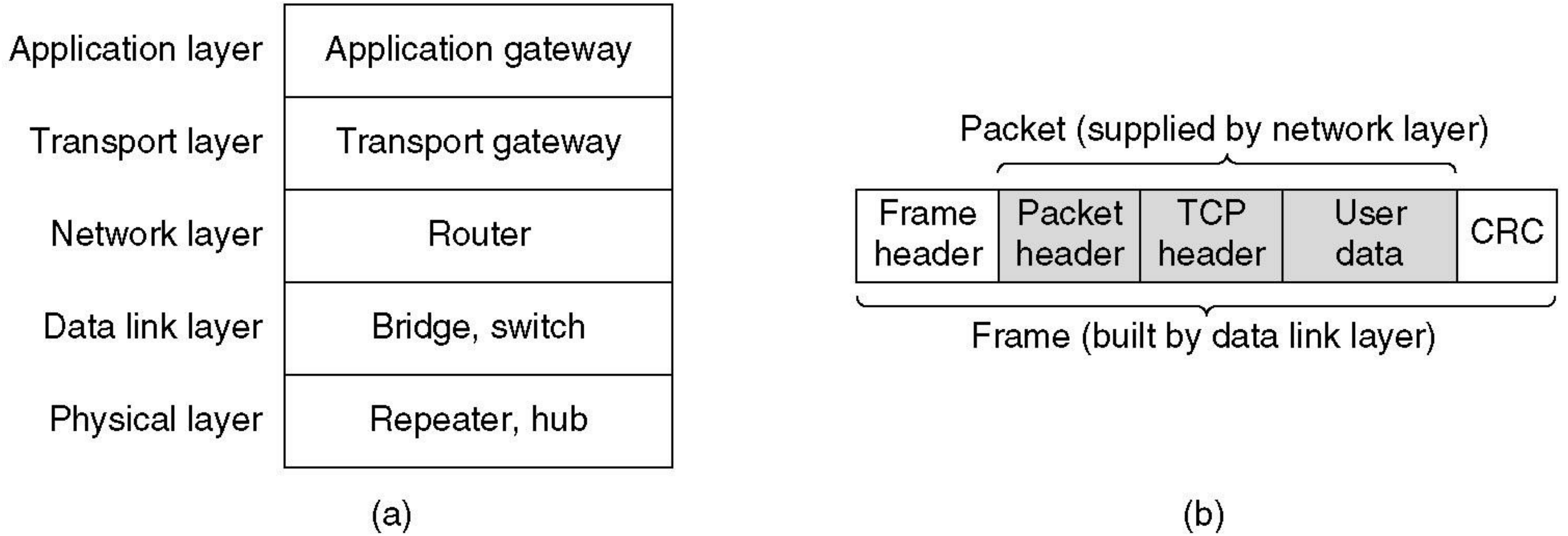
Repeaters, Hubs, Bridges, Switches, Routers, and Gateways

Devices are named according to the layer they process

- A bridge or LAN switch operates in the Link layer

Application layer	Application gateway
Transport layer	Transport gateway
Network layer	Router
Data link layer	Bridge, switch
Physical layer	Repeater, hub

Repeaters, Hubs, Bridges, Switches, Routers and Gateways

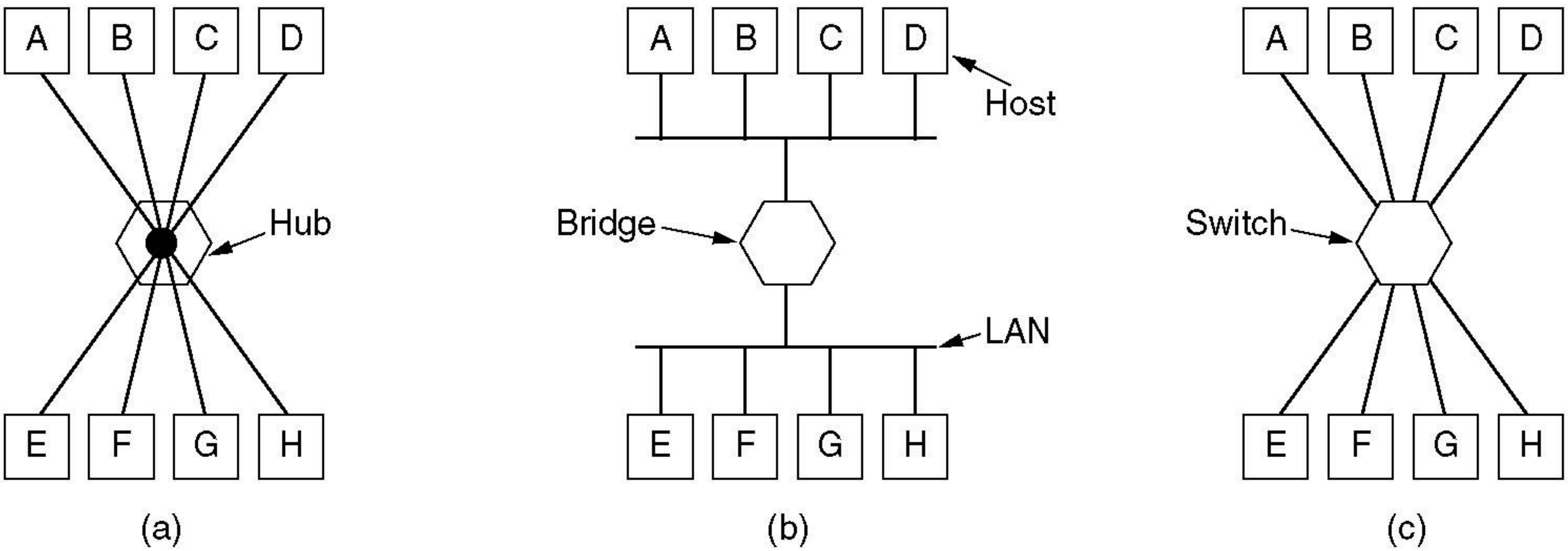


(a) Which device is in which layer.

(b) Frames, packets, and headers.

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

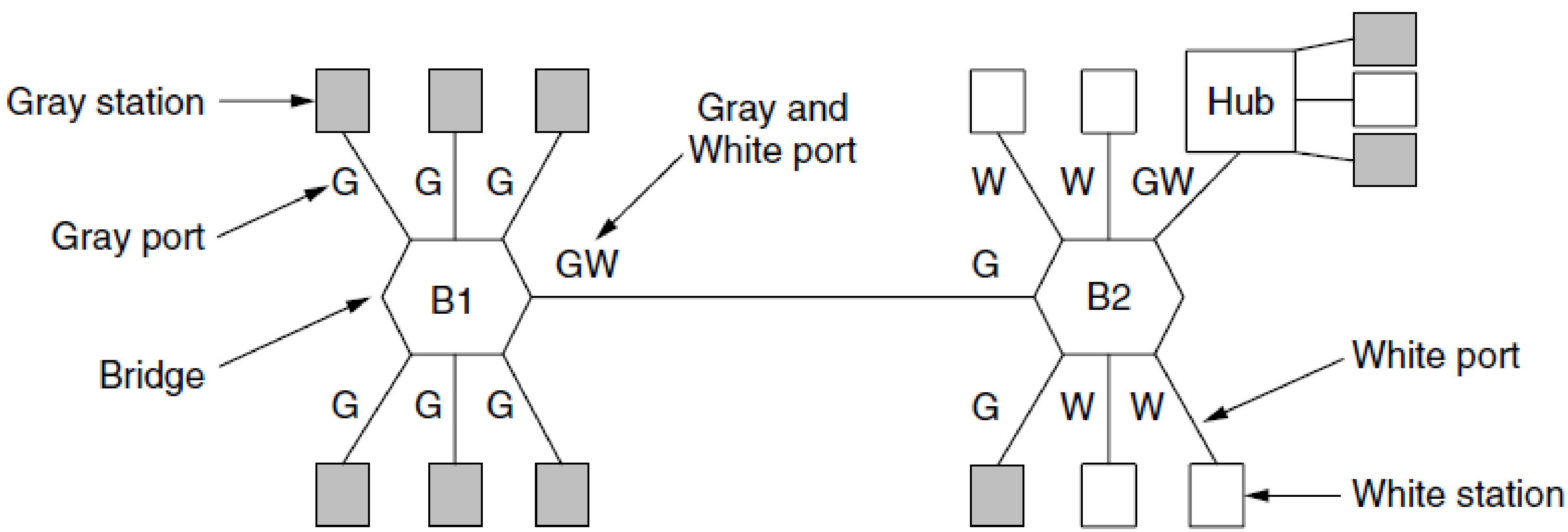
(a) A hub. (b) A bridge. (c) a switch.



Virtual LANs

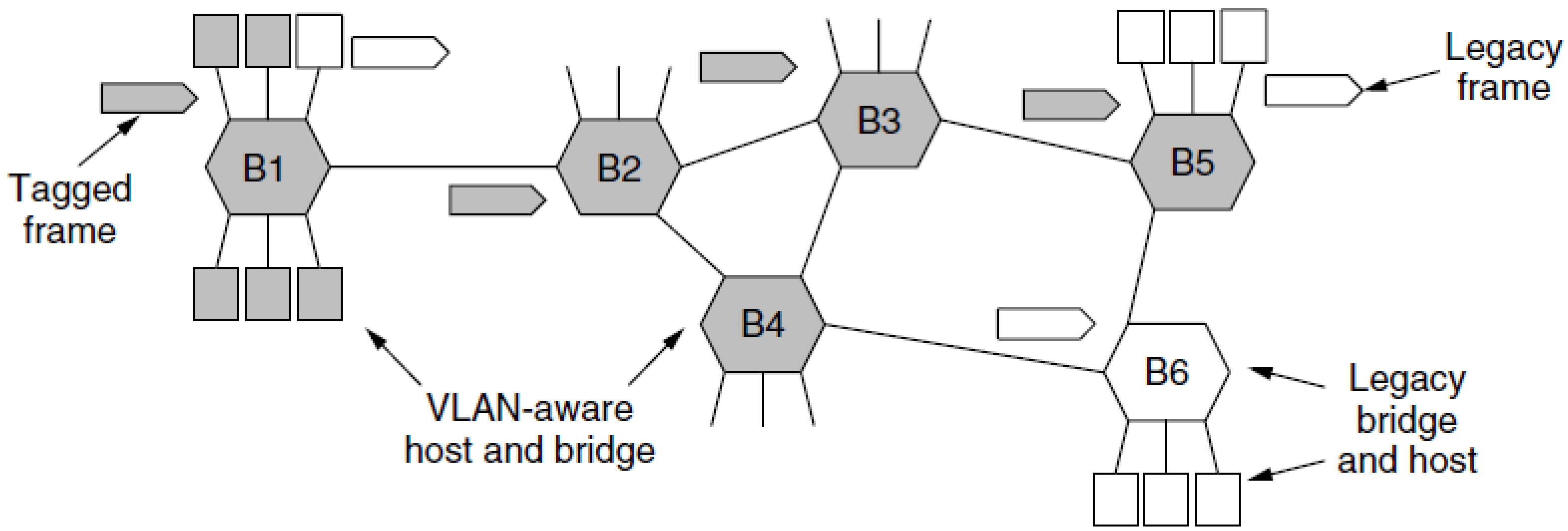
VLANs (Virtual LANs) splits one physical LAN into multiple logical LANs to ease management tasks

- Ports are "colored" according to their VLAN



Virtual LANs– IEEE 802.1Q

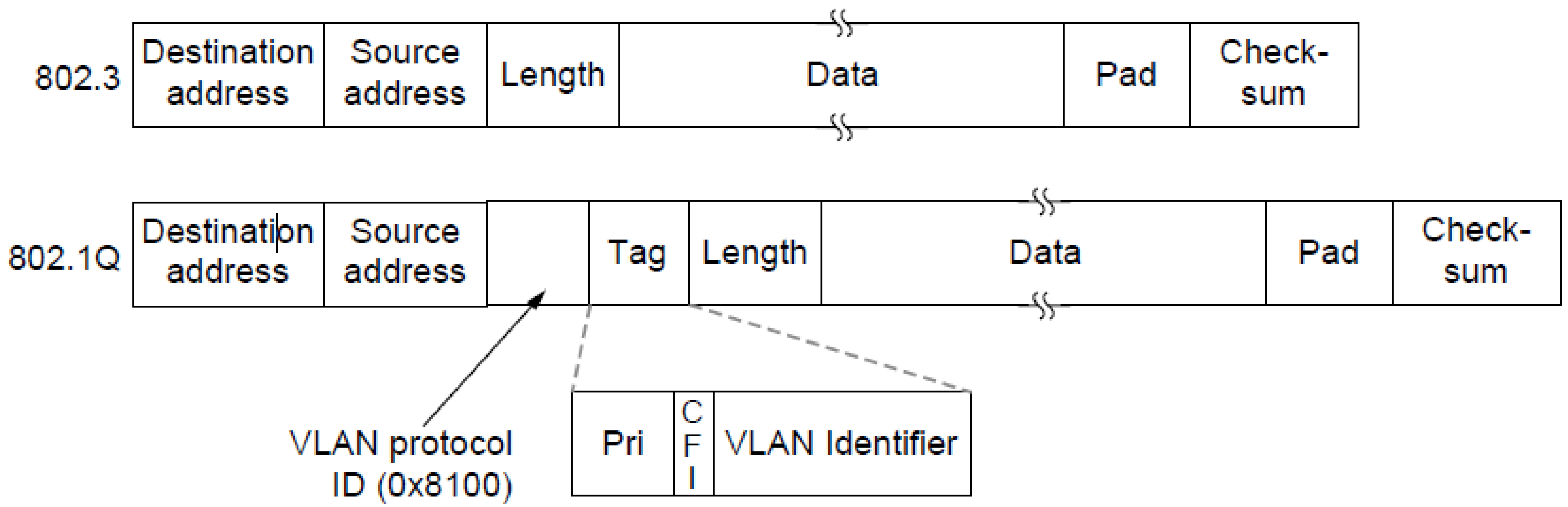
- Bridges need to be aware of VLANs to support them
  - In 802.1Q, frames are tagged with their "color"



Virtual LANs (3) – IEEE 802.1Q

802.1Q frames carry a color tag (VLAN identifier)

– Length/Type value is 0x8100 for VLAN protocol



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.