Chapter 4

The Medium Access Control Sublayer

The Channel Allocation Problem

- The channel allocation problem concerns broadcast channels
- Static Channel Allocation in LANs and MANs
- Dynamic Channel Allocation in LANs and MANs

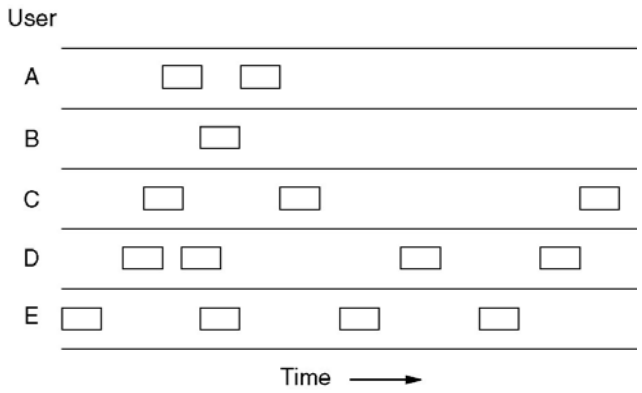
Dynamic Channel Allocation in LANs and MANs

1. Station Model
   - N independent stations that remain blocked until the end of the transmission
2. Single Channel Assumption
   - Communication happen on a single channel
3. Collision Assumption
   - When two frames are transmitted at the same time
4. (a) Continuous Time.
   (b) Slotted Time.
5. (a) Carrier Sense.
   (b) No Carrier Sense.

Multiple Access Protocols

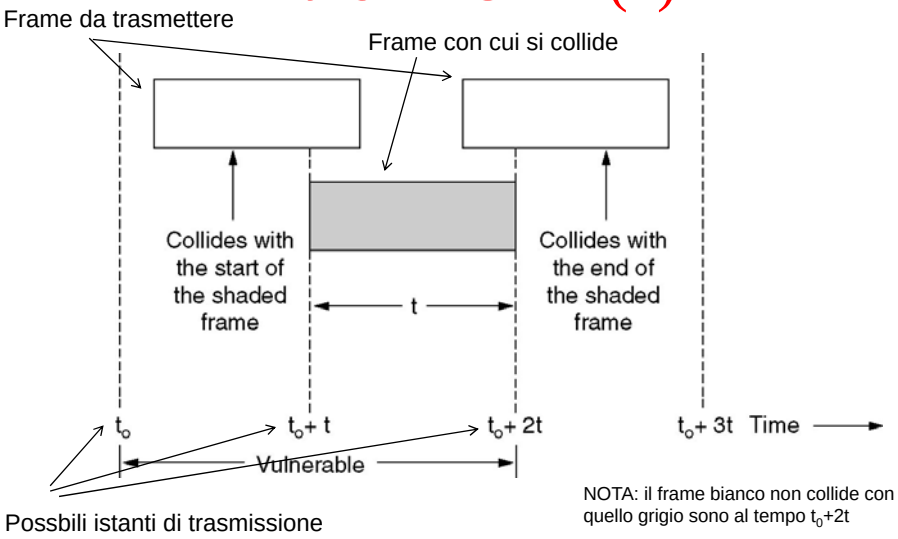
- ALOHA
- Carrier Sense Multiple Access Protocols
- Collision-Free Protocols
- Limited-Contention Protocols
- Wavelength Division Multiple Access Protocols
- Wireless LAN Protocols

Pure ALOHA



- In pure ALOHA, frames are transmitted at completely arbitrary times
- Collisions are detected by listening the channel after transmission or using acknowledge

Pure ALOHA (2)



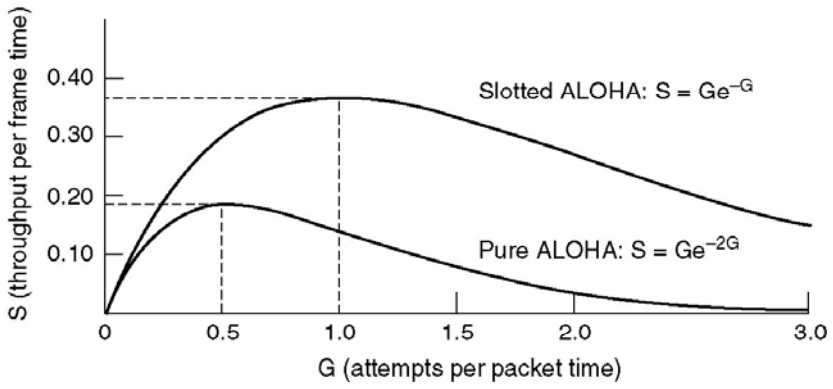
- The vulnerable period for the shaded frame is 2t

Channel Throughput

- $S = GP_0$ where P_0 is the probability that a frame will not collide with another, G are the total transmission trials
- Consider that probability that k frames are generated during a frame time follows the Poisson distribution:

  $Pr[k] = (G^k e^{-G})/k!$
- This implies $P_0 = e^{-2G}$ because the vulnerable period is 2 frame time, for which the number of generated frames is 2G
- Then $S = GP_0 = Ge^{-2G}$
- For slotted aloha the vulnerable time is one single frame time, because transmissions are aligned to time slots

Pure ALOHA (3)

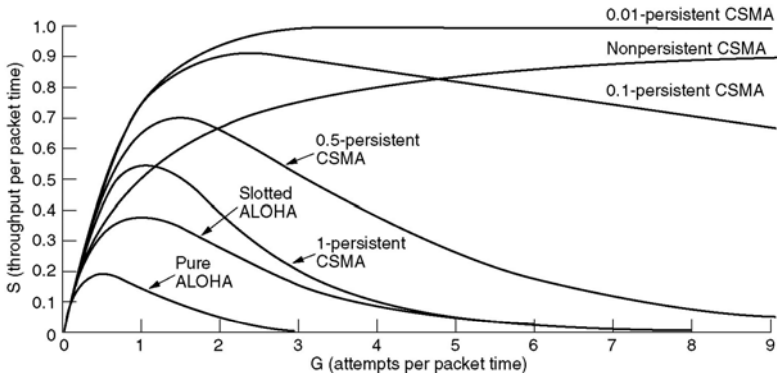


- Throughput versus offered traffic for ALOHA systems
- $S_{max} = 1/2e$ for G=2 (pure ALOHA)
- $S_{max} = 1/e$ for G=1 (slotted ALOHA)

Carrier Sense Protocols (CSMA)

- CSMA 1-persistent
  - If channel busy, wait until it is free
  - If channel free, transmit (with probability 1).
  - If collision, wait a random time before trying to retransmit
  - Collision may happen because of i) propagation delays. An interfering station may start its transmission before the signal of the first station is arrived; ii) simultaneous transmission right after a channel busy period
- CSMA non persistent
  - When channel is busy, wait a random time before sensing the channel again
- CSMA p-persistent
  - Mostly applied to slotted channels
  - When channel free, transmit with probability p
  - If not transmitted, wait the next slot and sense the channel: if it is free transmit with probability p
  - If channel is busy, wait for a random time and try again

Persistent and Nonpersistent CSMA

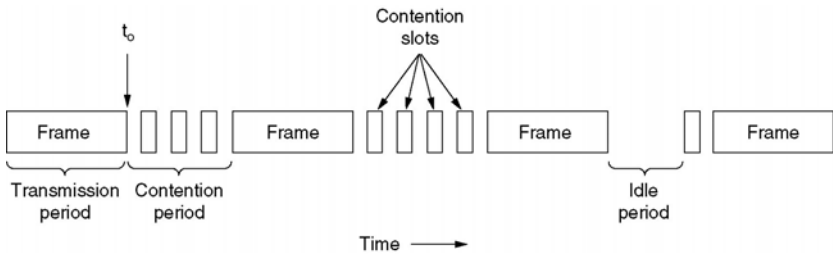


Comparison of the channel utilization versus load for various random access protocols.

Collision Detection Protocols (CSMA/CD)

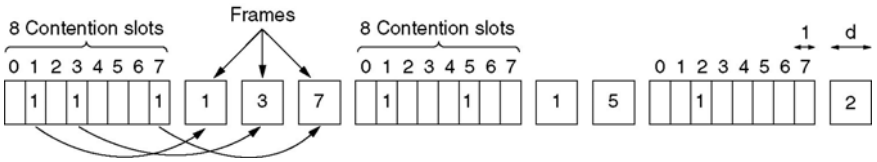
- Cancel transmission upon collision detection to save bandwidth
- Collisions are detected by listening the received signal
- How much time is required to detect a collision?
  - The time needed for a signal to arrive from a station to another and back (the time a distortion on the last bit is propagated back to the transmitter)

CSMA with Collision Detection



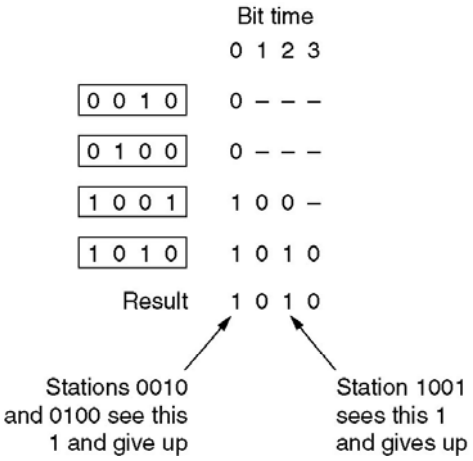
CSMA/CD can be in one of three states: contention, transmission, or idle.

Collision-Free Protocols



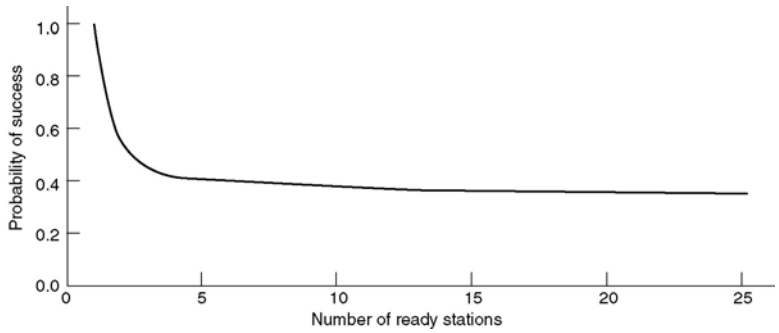
The basic bit-map protocol.

Collision-Free Protocols (2)



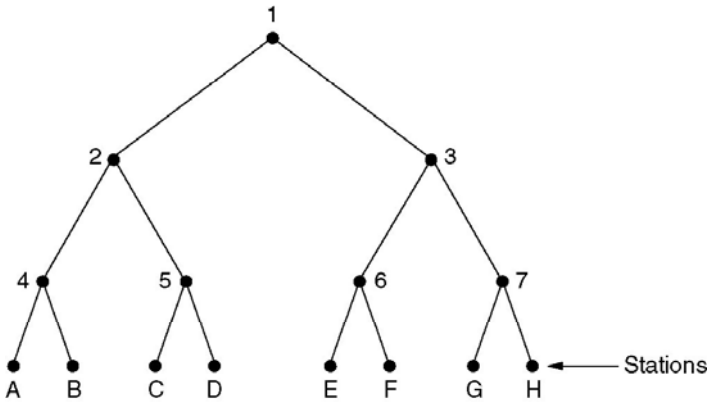
The binary countdown protocol. A dash indicates silence.

Limited-Contention Protocols



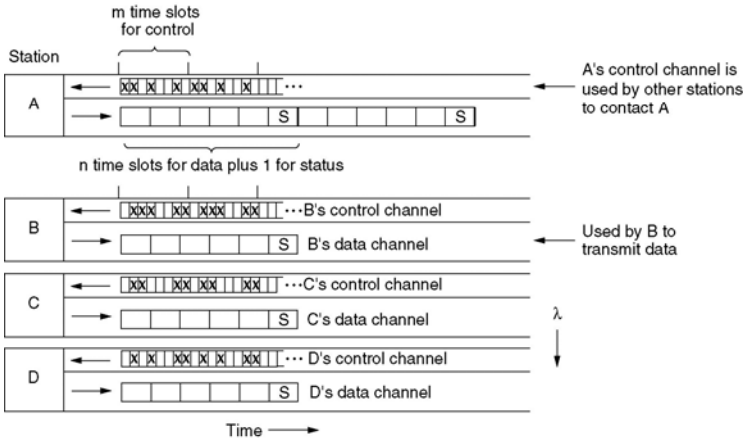
Acquisition probability for a symmetric contention channel.

Adaptive Tree Walk Protocol



The tree for eight stations.

Wavelength Division Multiple Access Protocols

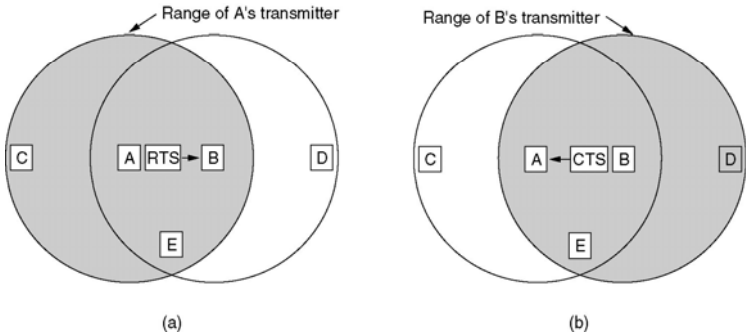


Wavelength division multiple access.

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

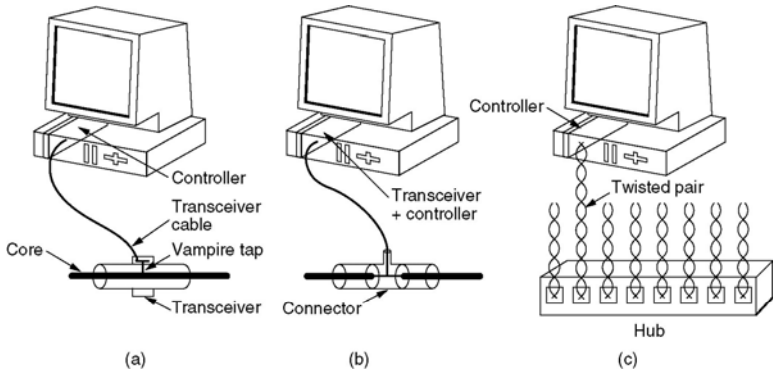
- Ethernet Cabling
- Manchester Encoding
- The Ethernet MAC Sublayer Protocol
- The Binary Exponential Backoff Algorithm
- Ethernet Performance
- Switched Ethernet
- Fast Ethernet
- Gigabit Ethernet
- IEEE 802.2: Logical Link Control
- Retrospective on Ethernet

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

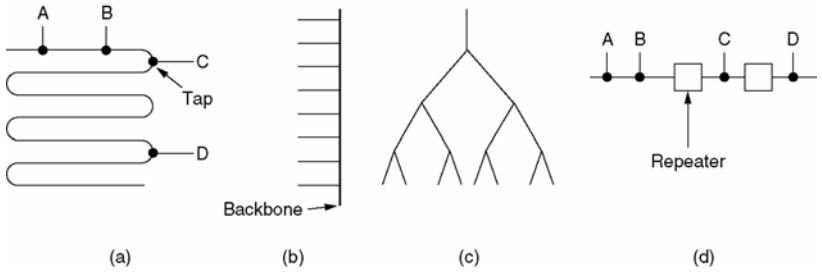
The most common kinds of Ethernet cabling.

Ethernet Cabling (2)



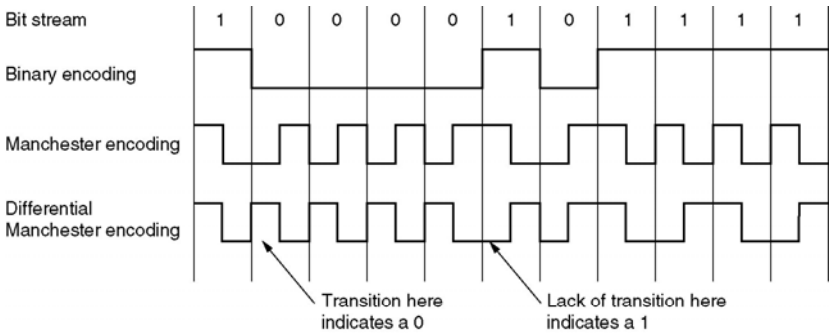
Three kinds of Ethernet cabling.
(a) 10Base5, (b) 10Base2, (c) 10Base-T.

Ethernet Cabling (3)



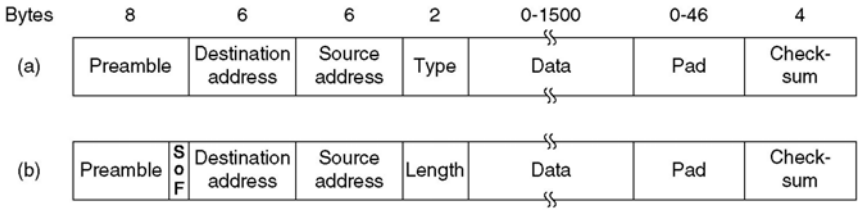
Cable topologies. (a) Linear, (b) Spine, (c) Tree, (d) Segmented.

Ethernet Cabling (4)



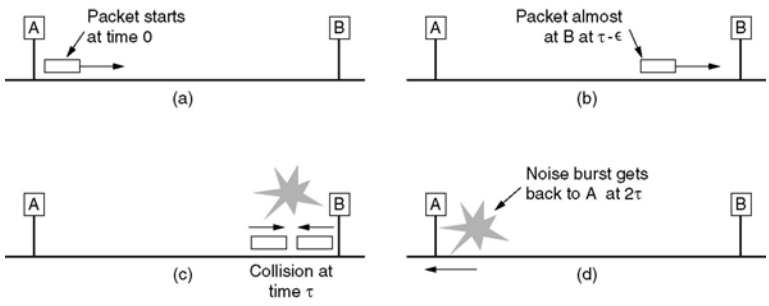
(a) Binary encoding, (b) Manchester encoding,
(c) Differential Manchester encoding.

Ethernet MAC Sublayer Protocol



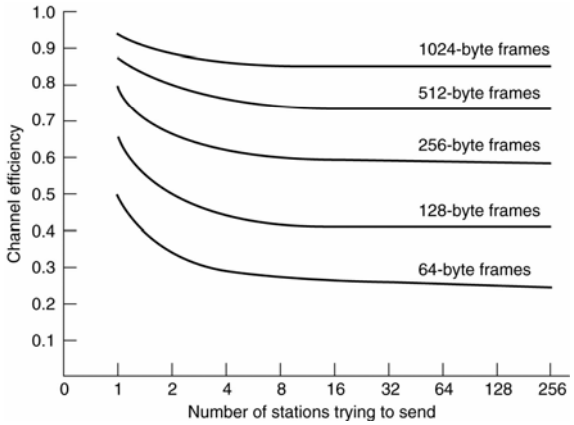
Frame formats. (a) DIX Ethernet, (b) IEEE 802.3.

Ethernet MAC Sublayer Protocol (2)



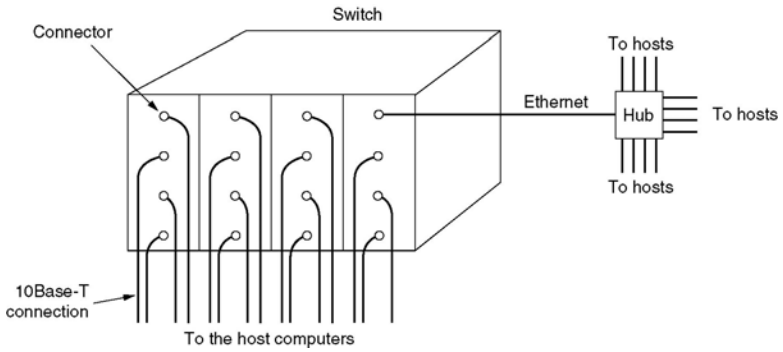
Collision detection can take as long as 2τ.

Ethernet Performance



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

Switched Ethernet



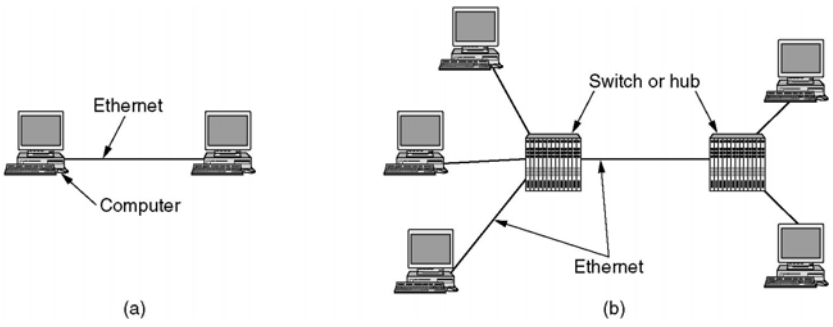
A simple example of switched Ethernet.

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



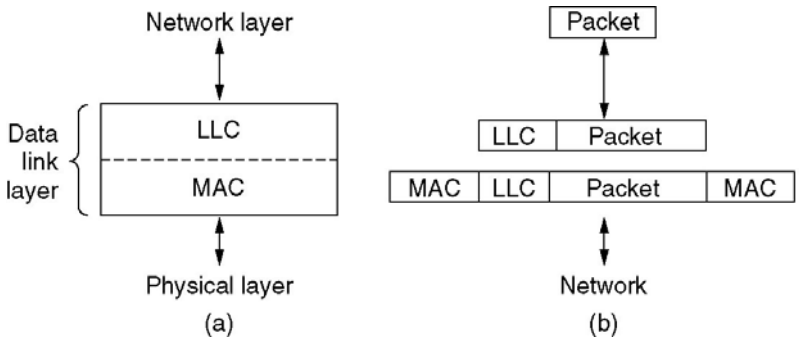
(a) A two-station Ethernet. (b) A multistation Ethernet.

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

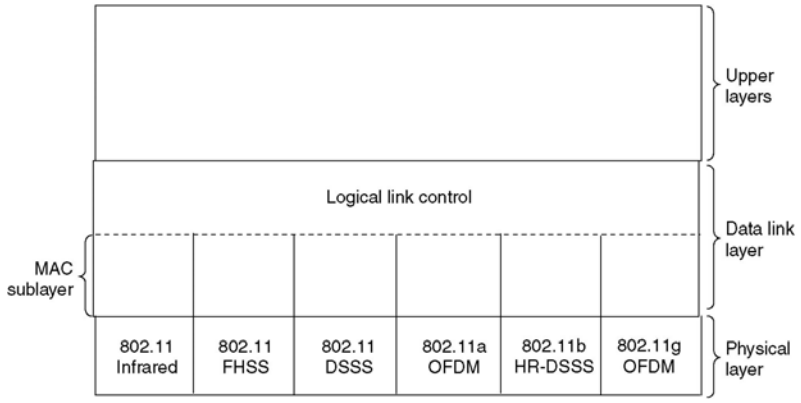


(a) Position of LLC. (b) Protocol formats.

Wireless LANs

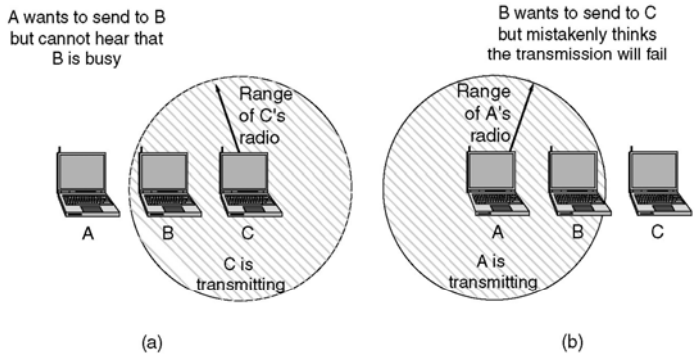
- The 802.11 Protocol Stack
- The 802.11 Physical Layer
- The 802.11 MAC Sublayer Protocol
- The 802.11 Frame Structure
- Services

The 802.11 Protocol Stack



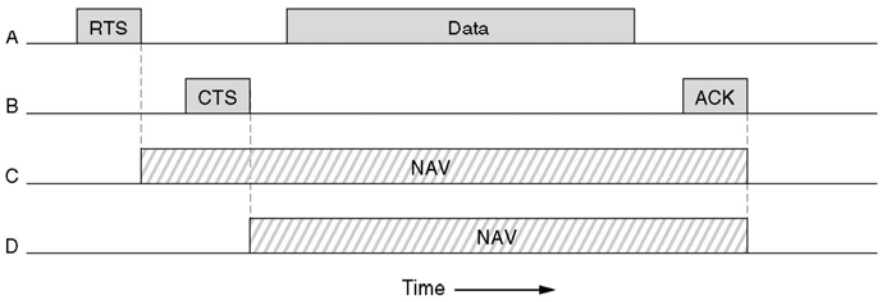
Part of the 802.11 protocol stack.

The 802.11 MAC Sublayer Protocol



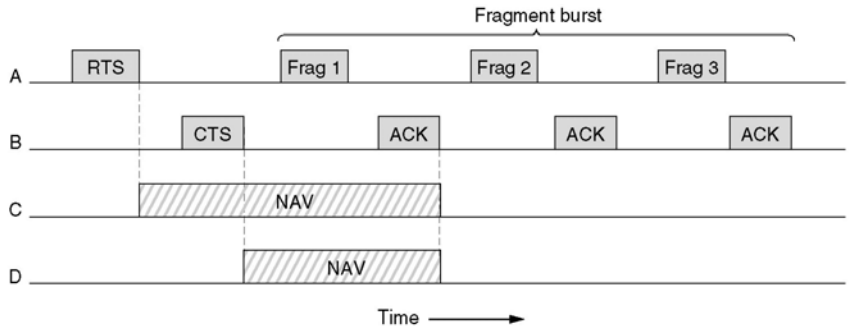
(a) The hidden station problem.
(b) The exposed station problem.

The 802.11 MAC Sublayer Protocol (2)



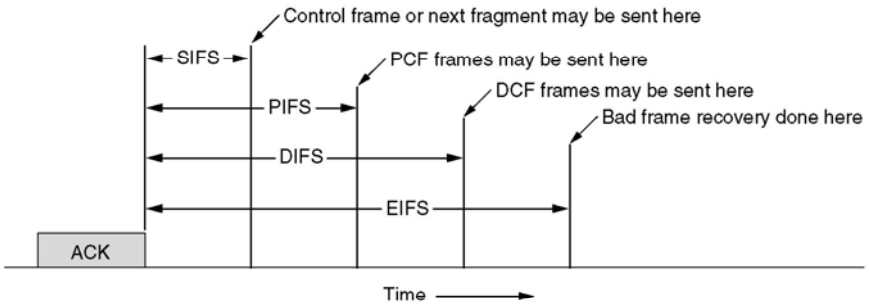
The use of virtual channel sensing using CSMA/CA.

The 802.11 MAC Sublayer Protocol (3)



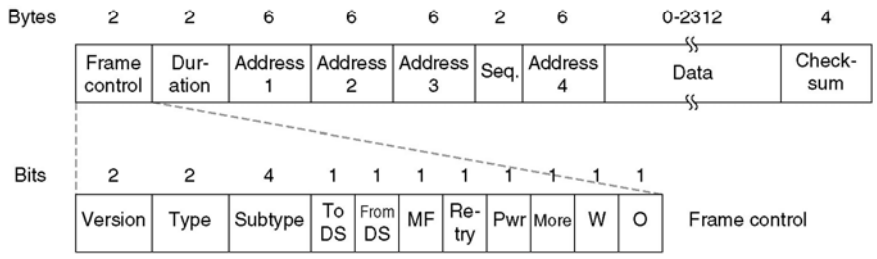
A fragment burst.

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

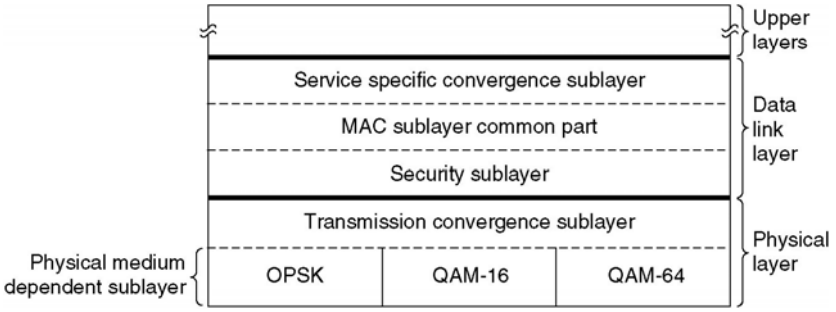
Intracell Services

- Authentication
- Deauthentication
- Privacy
- Data Delivery

Broadband Wireless

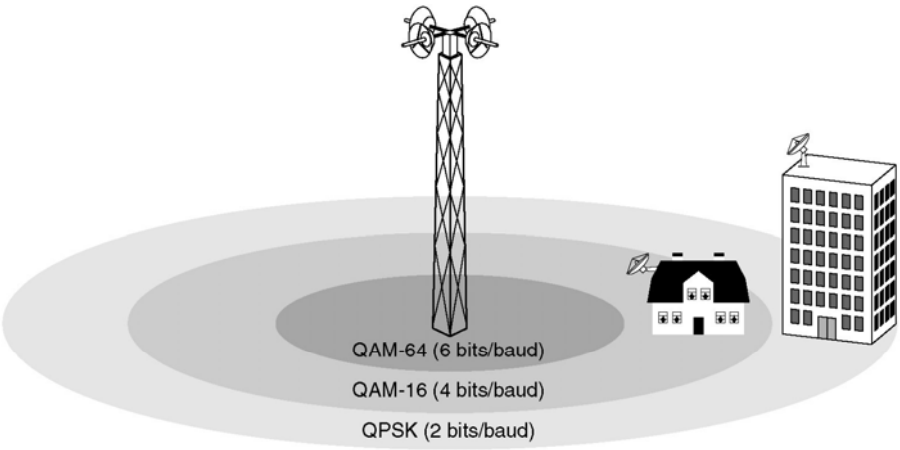
- Comparison of 802.11 and 802.16
- The 802.16 Protocol Stack
- The 802.16 Physical Layer
- The 802.16 MAC Sublayer Protocol
- The 802.16 Frame Structure

The 802.16 Protocol Stack



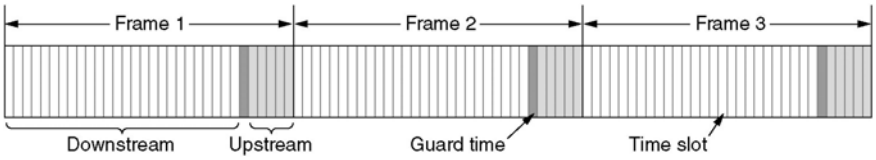
The 802.16 Protocol Stack.

The 802.16 Physical Layer



The 802.16 transmission environment.

The 802.16 Physical Layer (2)



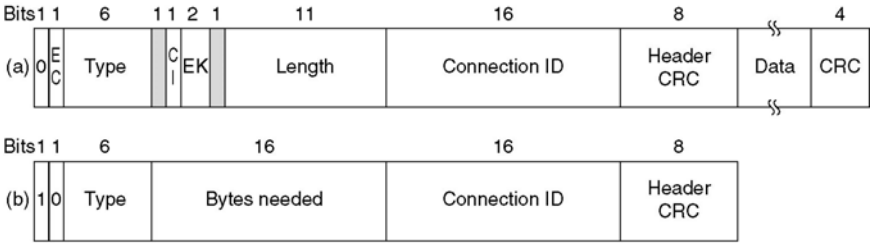
Frames and time slots for time division duplexing.

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

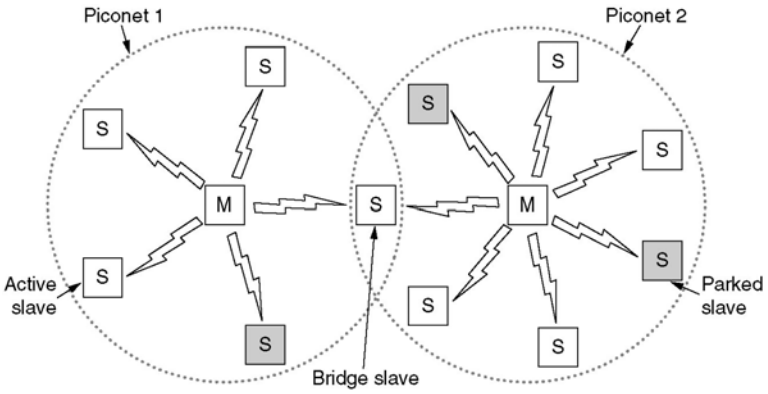


(a) A generic frame. (b) A bandwidth request frame.

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



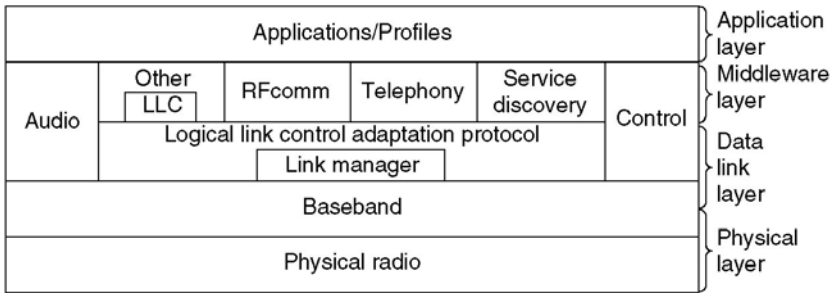
Two piconets can be connected to form a scatternet.

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

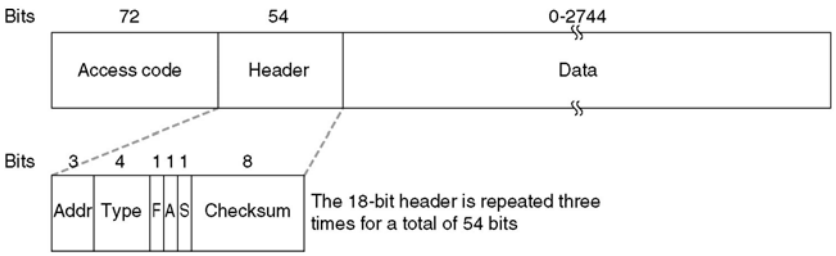
The Bluetooth profiles.

The Bluetooth Protocol Stack



The 802.15 version of the Bluetooth protocol architecture.

The Bluetooth Frame Structure

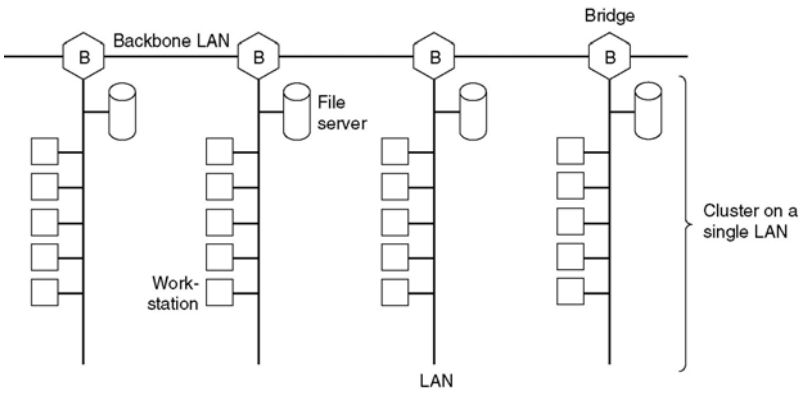


A typical Bluetooth data frame.

Data Link Layer Switching

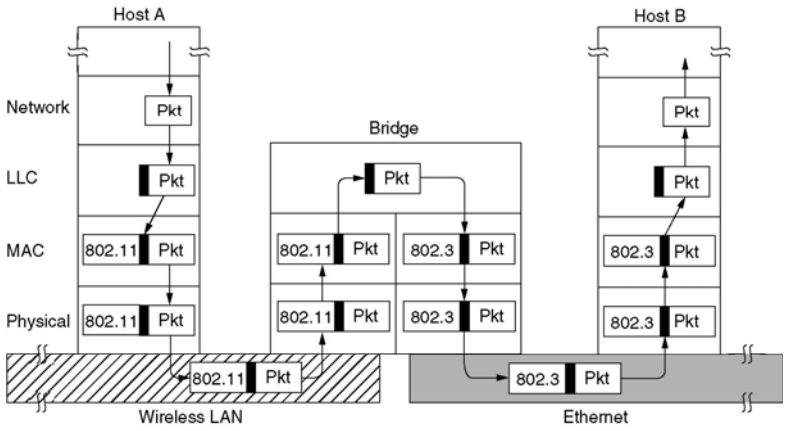
- Bridges from 802.x to 802.y
- Local Internetworking
- Spanning Tree Bridges
- Remote Bridges
- Repeaters, Hubs, Bridges, Switches, Routers, Gateways
- Virtual LANs

Data Link Layer Switching



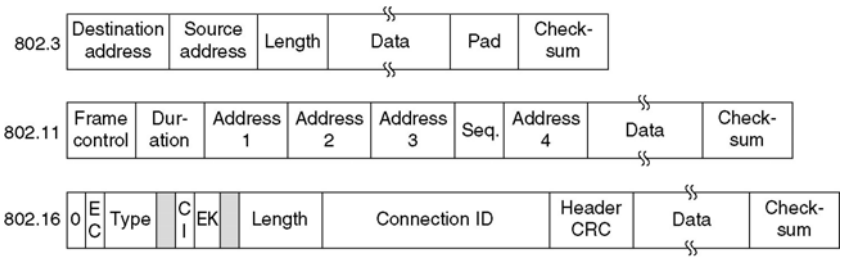
Multiple LANs connected by a backbone to handle a total load higher than the capacity of a single LAN.

Bridges from 802.x to 802.y



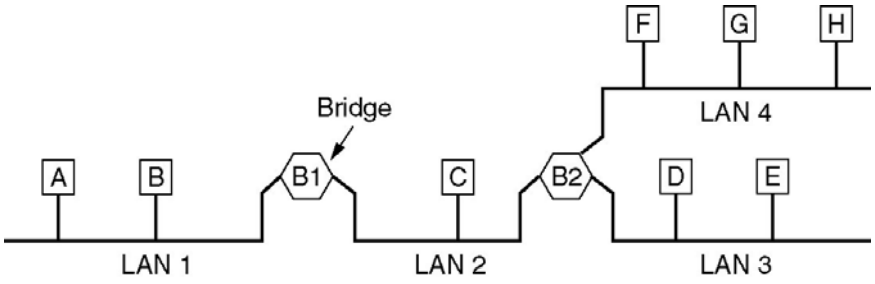
Operation of a LAN bridge from 802.11 to 802.3.

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



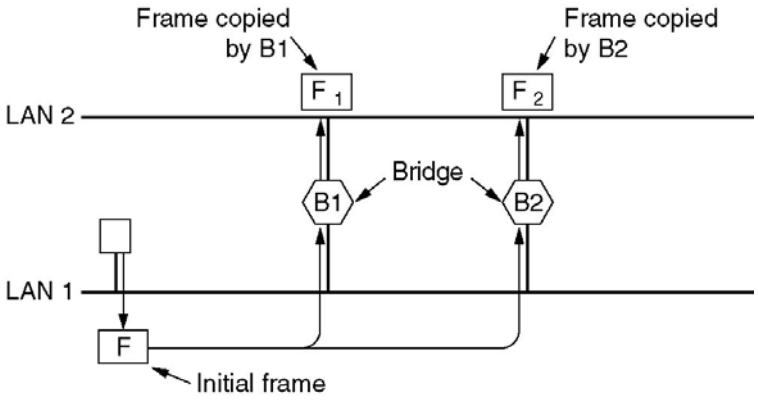
The IEEE 802 frame formats. The drawing is not to scale.

Local Internetworking



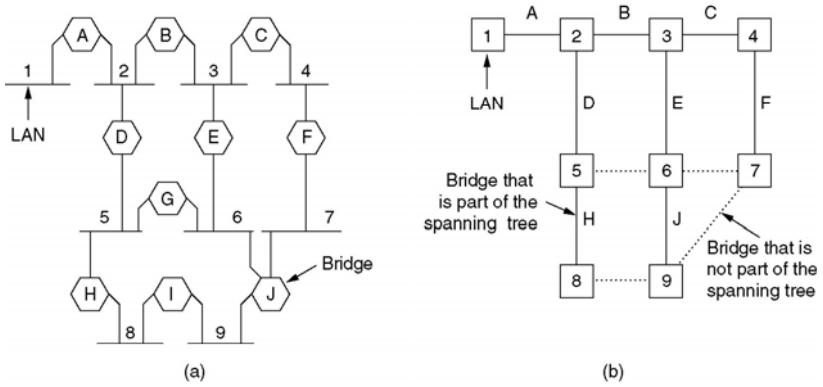
A configuration with four LANs and two bridges.

Spanning Tree Bridges



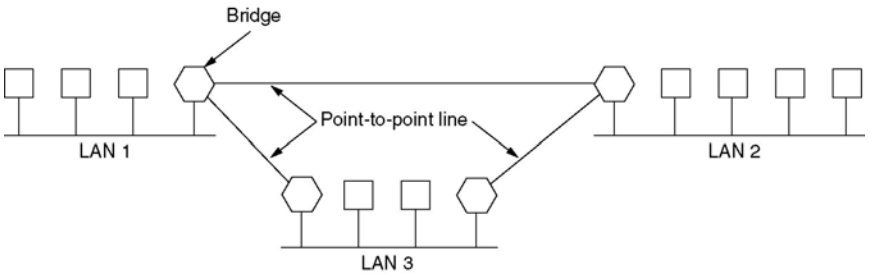
Two parallel transparent bridges.

Spanning Tree Bridges (2)



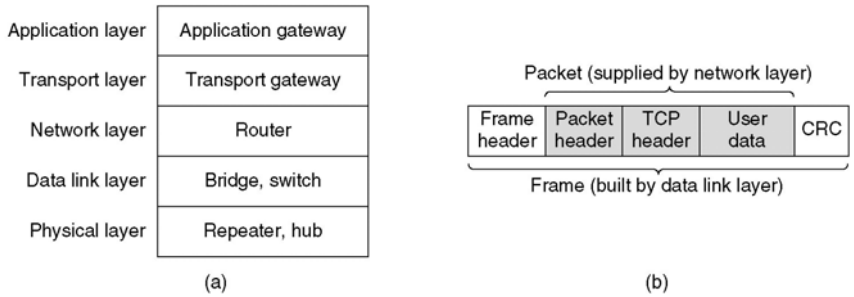
(a) Interconnected LANs. (b) A spanning tree covering the LANs. The dotted lines are not part of the spanning tree.

Remote Bridges



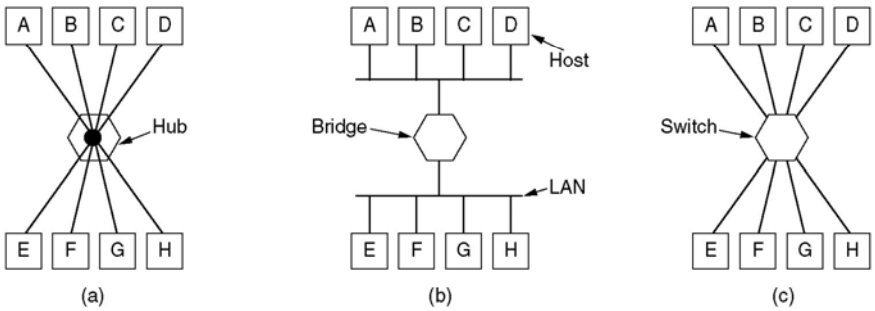
Remote bridges can be used to interconnect distant LANs.

Repeaters, Hubs, Bridges, Switches, Routers and Gateways



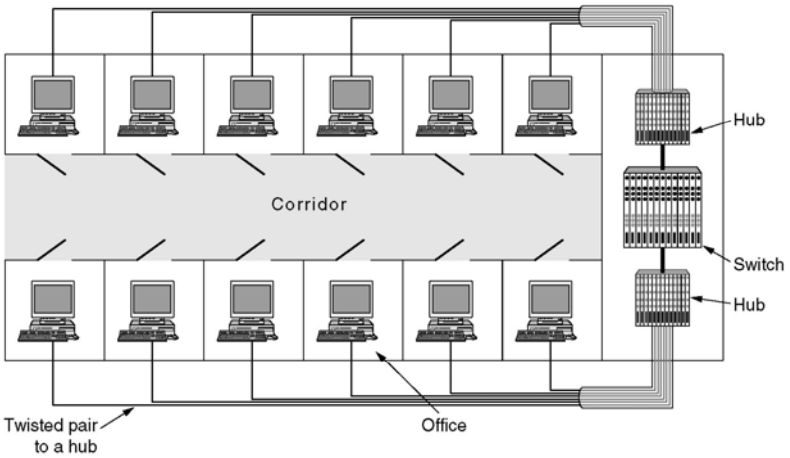
(a) Which device is in which layer.
(b) Frames, packets, and headers.

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



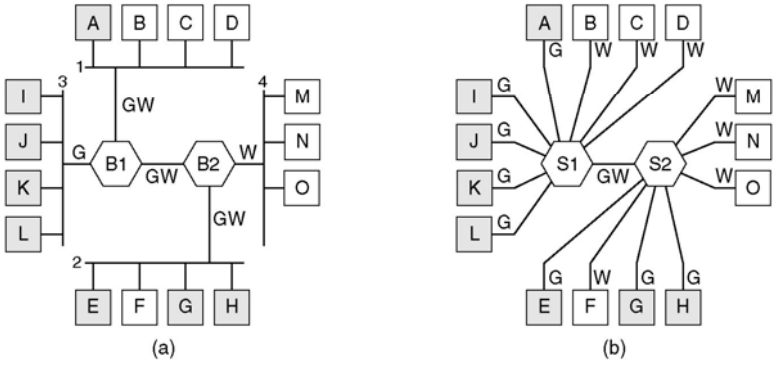
(a) A hub. (b) A bridge. (c) a switch.

Virtual LANs



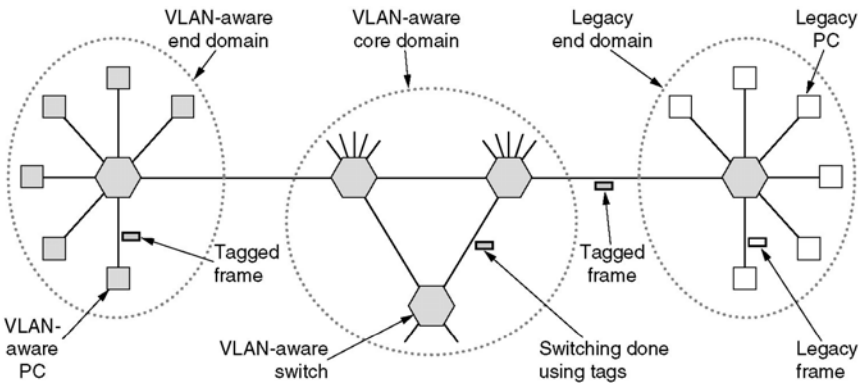
A building with centralized wiring using hubs and a switch.

Virtual LANs (2)



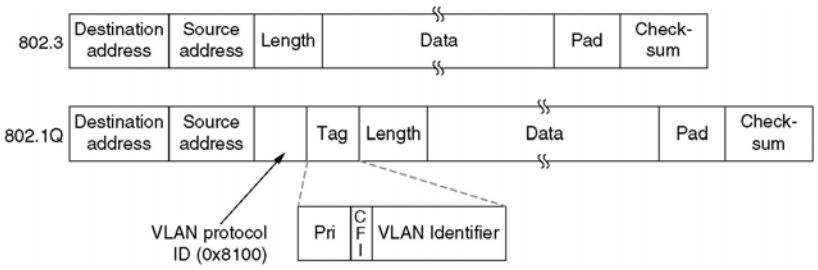
(a) Four physical LANs organized into two VLANs, gray and white, by two bridges. (b) The same 15 machines organized into two VLANs by switches.

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.