Ethernet Protocol

- TCP/IP accepts any protocol at these two layers that can provide services to the network layer
- data-link layer and the physical layer are actually the territory of the local and wide area networks
- Local area network (LAN) is a computer network that is designed for a limited geographic area such as a building or a campus
- In the 1980s and 1990s several different types of LANs were used
  - problem of sharing the media
    - Solution media-access method

Type of LAN

Type of LAN	media-access method
Ethernet	CSMA/CD approach
Token Ring/Bus, and FDDI (Fiber Distribution Data Interface)	token-passing approach

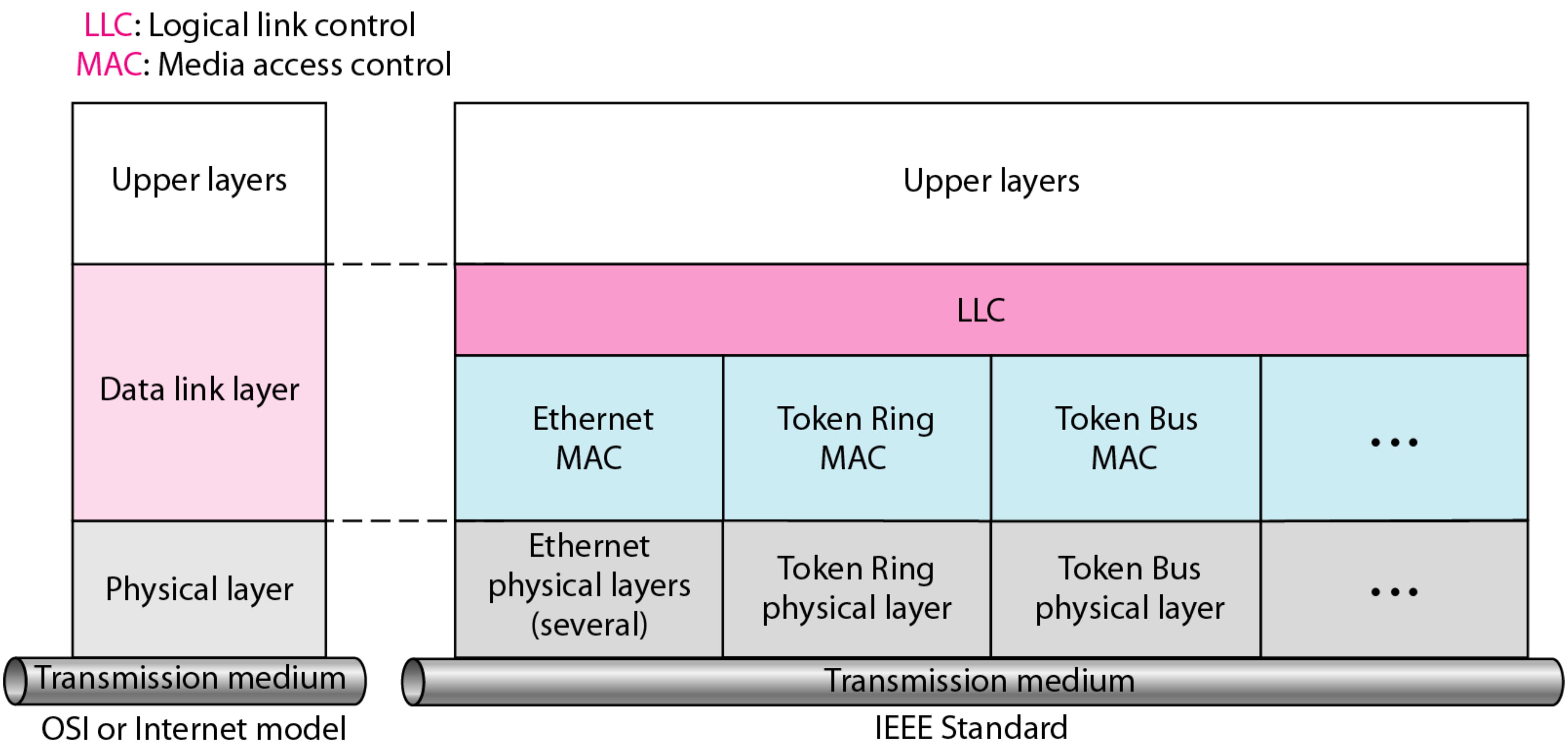
disappeared from the marketplace because Ethernet was able to update itself to meet the needs of the time

- ATM LAN deployed the high speed WAN technology
- An organization that has used an Ethernet LAN in the past and now needs a higher data rate would update to the new generation Ethernet instead of switching to another technology, which might cost more

IEEE standard

- In 1985, the Computer Society of the IEEE started a project, called Project 802
  - Set standards to enable intercommunication among equipment from a variety of manufacturers
  - does not seek to replace any part of the OSI model or TCP/IP protocol suite
  - a way of specifying functions of the physical layer and the data-link layer of major LAN protocols
- The IEEE has subdivided the data-link layer into two sublayers:
  - logical link control (LLC)
  - Media access control (MAC)
- IEEE has also created several physical-layer standards for different LAN protocols.

IEEE standard for LANs



Logical Link Control (LLC)

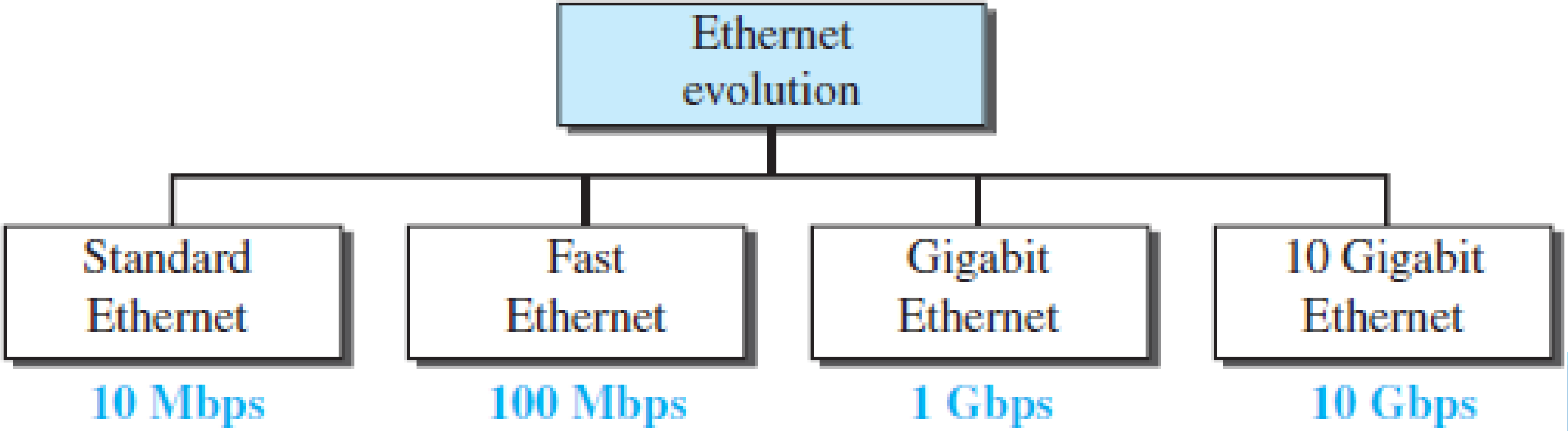
- OSI or TCP/IP Data link control handles framing, flow control, and error control
- In IEEE Project 802, flow control, error control, and part of the framing duties are collected into one sublayer called the logical link control (LLC)
- Framing is handled in both the LLC sublayer and the MAC sublayer
- The LLC provides a single link-layer control protocol for all IEEE LANs
  - LLC protocol can provide interconnectivity between different LANs because it makes the MAC sublayer transparent.

Media Access Control (MAC)

- OSI or TCP/IP multiple access methods including random access, controlled access, and channelization
- IEEE Project 802 has created a sublayer called media access control that defines the specific access method for each LAN
  - CSMA/CD as the media access method for Ethernet LANs
  - Token-passing method for Token Ring and Token Bus LANs
- Part of the framing function is also handled by the MAC layer in IEEE 802

Ethernet Evolution

- The Ethernet LAN was developed in the 1970s by Robert Metcalfe and David Boggs.
- Since then, it has gone through four generations
  - Standard Ethernet (10 Mbps)
  - Fast Ethernet (100 Mbps)
  - Gigabit Ethernet (1 Gbps)
  - 10 Gigabit Ethernet (10 Gbps)



Standard Ethernet

- Original Ethernet technology with the data rate of 10 Mbps
- Although most implementations have moved to other technologies in the Ethernet evolution, there are some features of the Standard Ethernet that have not changed during the evolution
- Characteristics of the Standard Ethernet
  - Connectionless and Unreliable Service
  - Frame Format
  - Frame Length

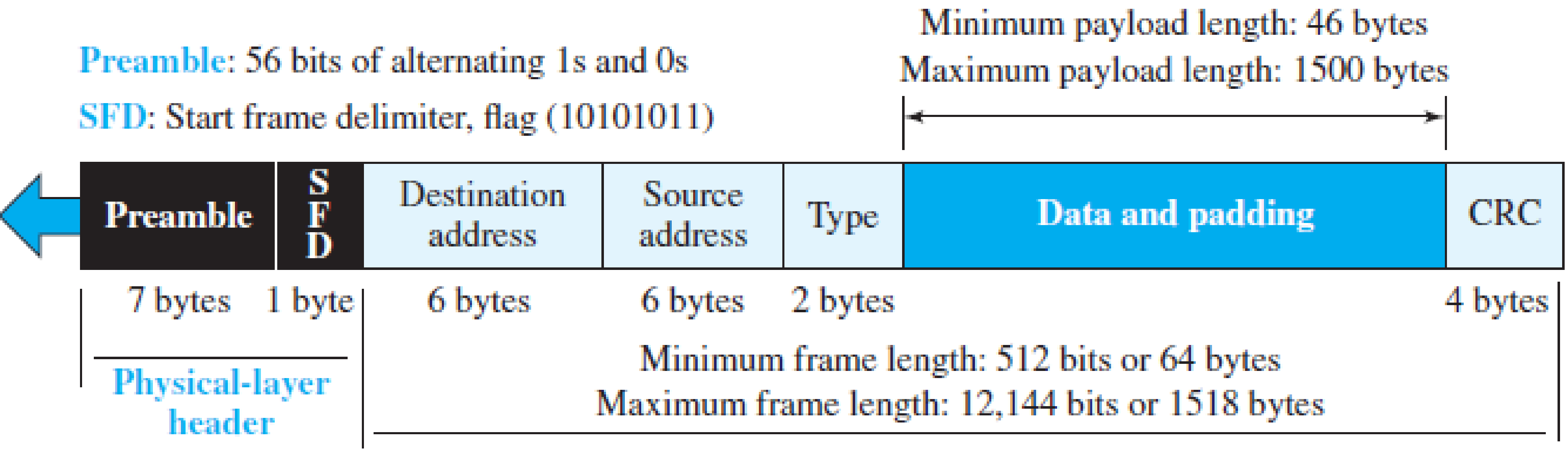
Connectionless and Unreliable Service

- A connectionless service means each frame sent is independent of the previous or next frame
- Ethernet has no connection establishment or connection termination phases
  - The sender sends a frame whenever it has it; the receiver may or may not be ready for it.
  - The sender may overwhelm the receiver with frames, which may result in dropping frames
  - If a frame drops, the sender will not know about it
    - Since IP, which is using the service of Ethernet, is also connectionless
    - If the transport layer is also a connectionless protocol, such as UDP, the frame is lost and salvation may only come from the application layer
    - If the transport layer is TCP, the sender TCP does not receive acknowledgment for its segment and sends it again

Connectionless and Unreliable Service

- Ethernet is also unreliable like IP and UDP
  - If a frame is corrupted during transmission and the receiver finds out about the corruption, which has a high level of probability of happening because of the CRC-32, the receiver drops the frame silently
    - It is the duty of high-level protocols to find out about it

Ethernet frame



- Remember that an Ethernet frame is a variable-length frame
- Contains seven fields

Ethernet frame

- Preamble. This field contains 7 bytes (56 bits) of alternating 0s and 1s
    - alert the receiving system to the coming frame
    - enable it to synchronize its clock if it’s out of synchronization
    - The pattern provides only an alert and a timing pulse
    - The 56-bit pattern allows the stations to miss some bits at the beginning of the frame
    - actually added at the physical layer and is not (formally) part of the frame

Ethernet frame

- Start frame delimiter (SFD)
  - 1 byte: 10101011) signals the beginning of the frame as the size of Ethernet frame is variable size
  - The SFD warns the station or stations that this is the last chance for synchronization
  - The last 2 bits are $(11)_2$ and alert the receiver that the next field is the destination address
  - The SFD field is also added at the physical layer

Ethernet frame

- Destination address (DA)
  - Six bytes (48 bits)
  - contains the linklayer address of the destination station or stations to receive the packet
  - When the receiver sees its own link-layer address, or a multicast address for a group that the receiver is a member of, or a broadcast address, it decapsulates the data from the frame and passes the data to the upperlayer protocol defined by the value of the type field
- Source address (SA)
  - Six bytes and contains the link-layer address of the sender of the packet

Ethernet frame

- Type
  - Defines the upper-layer protocol whose packet is encapsulated in the frame
    - This protocol can be IP, ARP, OSPF, and so on
  - It is used for multiplexing and demultiplexing.

Ethernet frame

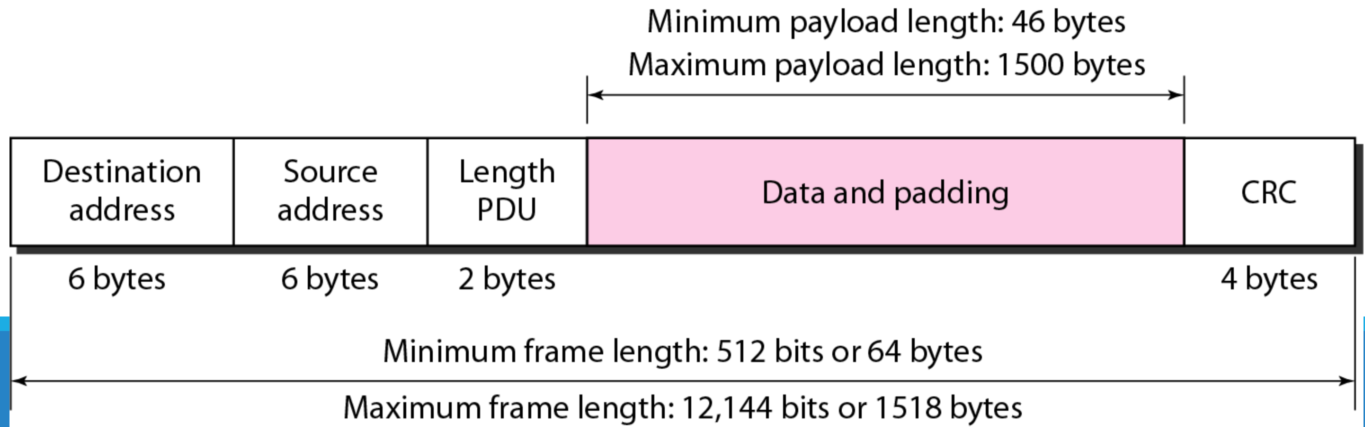
- Data
  - encapsulated from the upper-layer protocols
  - minimum of 46 and a maximum of 1500 bytes
    - If the data coming from the upper layer is more than 1500 bytes, it should be fragmented and encapsulated in more than one frame
    - If it is less than 46 bytes, it needs to be padded with extra 0s
      - A padded data frame is delivered to the upper-layer protocol as it is (without removing the padding)
        - means that it is the responsibility of the upper layer to remove or, in the case of the sender, to add the padding
        - The upper-layer protocol needs to know the length of its data. For example, a datagram has a field that defines the length of the data

Ethernet frame

- CRC
  - contains error detection information, in this case a CRC-32
  - The CRC is calculated over the addresses, types, and data field
  - If the receiver calculates the CRC and finds that it is not zero (corruption in transmission), it discards the frame.

Frame Length

- Ethernet has imposed restrictions on both the minimum and maximum lengths of a frame
- The minimum length restriction is required for the correct operation of CSMA/CD
  - An Ethernet frame - a minimum length of 512 bits or 64 bytes
- Part of the length is the header and the trailer
  - If 18 bytes of header and trailer (6 bytes of source address, 6 bytes of destination address, 2 bytes of length or type, and 4 bytes of CRC), then the minimum length of data from the upper layer is 64 − 18 = 46 bytes
    - If the upper-layer packet is less than 46 bytes, padding is added to make up the difference



Frame Length

- The standard defines the maximum length of a frame (without preamble and SFD field) as 1518 bytes
- If we subtract the 18 bytes of header and trailer, the maximum length of the payload is 1500 bytes
- The maximum length restriction has two historical reasons
  - First, memory was very expensive when Ethernet was designed; a maximum length restriction helped to reduce the size of the buffer
  - Second, the maximum length restriction prevents one station from monopolizing the shared medium, blocking other stations that have data to send

frame length in bytes		data length in bytes	
Minimum	Maximum	Minimum	Maximum
64	1518	46	1500

Standard Ethernet - Addressing

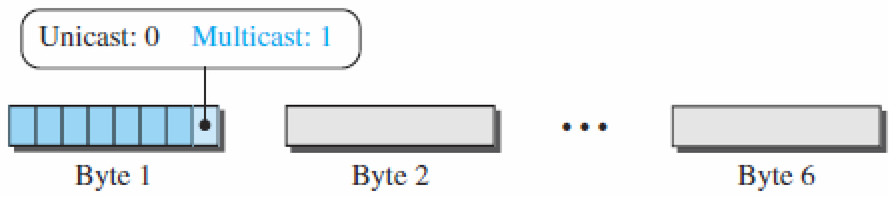
- Each station on an Ethernet network (such as a PC, workstation, or printer) has its own network interface card (**NIC**)
- The NIC fits inside the station and provides the station with a **link-layer address**
- The Ethernet address is **6 bytes** (48 bits), normally written in hexadecimal notation, with a **colon** between the bytes

06 : 01 : 02 : 01 : 2C : 4B

6 bytes = 12 hex digits = 48 bits

Standard Ethernet - Addressing

- A source address is always a *unicast address—the frame comes from only one station*
- The destination address can be *unicast, multicast, or broadcast*
  - If the least significant bit of the first byte in a destination address is 0, the address is unicast; otherwise, it is multicast.
  - The broadcast address is a special case of the multicast address: the recipients are all the stations on the LAN
    - A broadcast destination address is forty-eight 1s



Standard Ethernet - Addressing

- Define the type of the following destination addresses:

a. 4A:30:10:21:10:1A

b. 47:20:1B:2E:08:EE

c. FF:FF:FF:FF:FF:FF

- Look at the second hexadecimal digit from the left to find the type of the address
  - If it is even, the address is unicast
  - If it is odd, the address is multicast
  - If all digits are Fs, the address is broadcast

a. This is a unicast address because A in binary is 1010 (even)

b. This is a multicast address because 7 in binary is 0111 (odd)

c. This is a broadcast address because all digits are Fs in hexadecimal

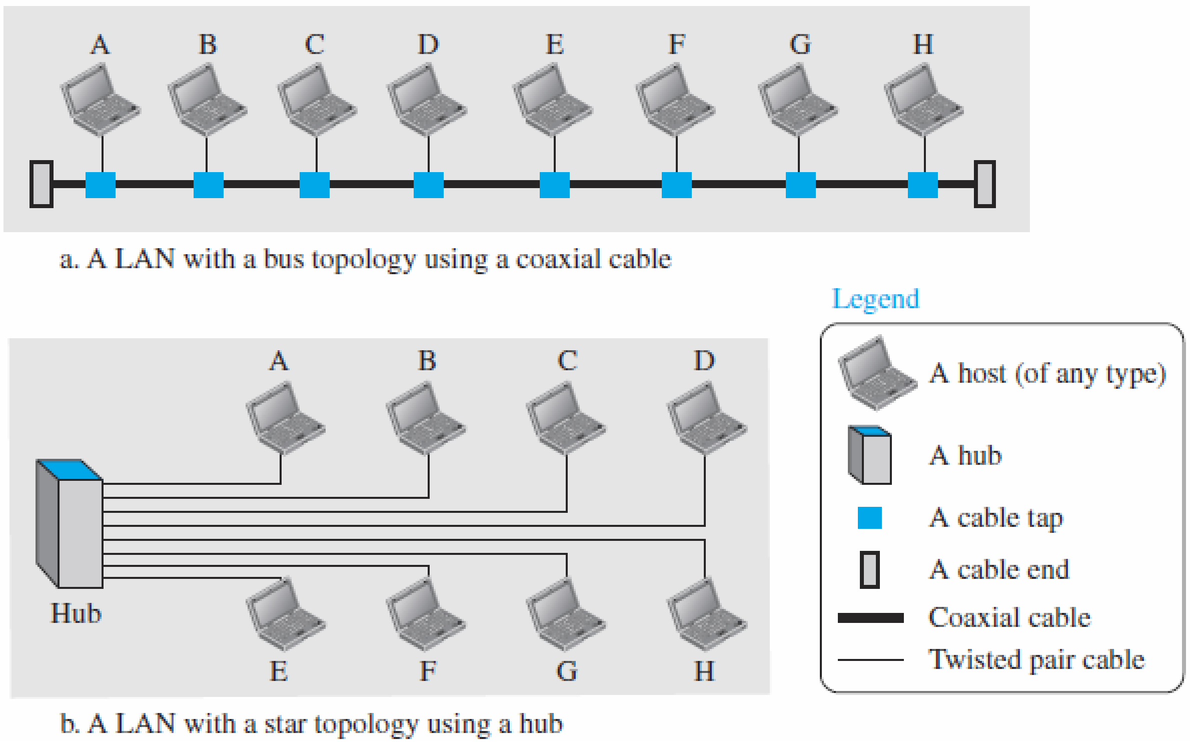
Transmission of Address Bits

- Addresses are sent out online using different way they are written in hexadecimal notation
- The transmission is left to right, byte by byte
  - Each byte, the least significant bit is sent first and the most significant bit is sent last
  - bit that defines an address as unicast or multicast arrives first at the receiver
    - Receiver to immediately know if the packet is unicast or multicast
- How the address 47:20:1B:2E:08:EE is sent out online?

Hexadecimal	47	20	1B	2E	08	EE
Binary	01000111	00100000	00011011	00101110	00001000	11101110
Transmitted ←	11100010	00000100	11011000	01110100	00010000	01110111

Medium in standard Ethernet

- Standard Ethernet uses a coaxial cable (bus topology) or a set of twisted-pair cables with a hub (star topology)



Unicast, Multicast, and Broadcast Transmission

- Transmission in the standard Ethernet is always broadcast, no matter if the intention is unicast, multicast, or broadcast
  - In the bus topology, when station A sends a frame to station B, all stations will receive it
  - In the star topology, when station A sends a frame to station B, the hub will receive it
    - Since the hub is a passive element, it does not check the destination address of the frame; it regenerates the bits (if they have been weakened) and sends them to all stations except station A
    - In fact, it floods the network with the frame
- How the actual unicast, multicast, and broadcast transmissions are distinguished from each other?
  - It is based on the way the frames are kept or dropped

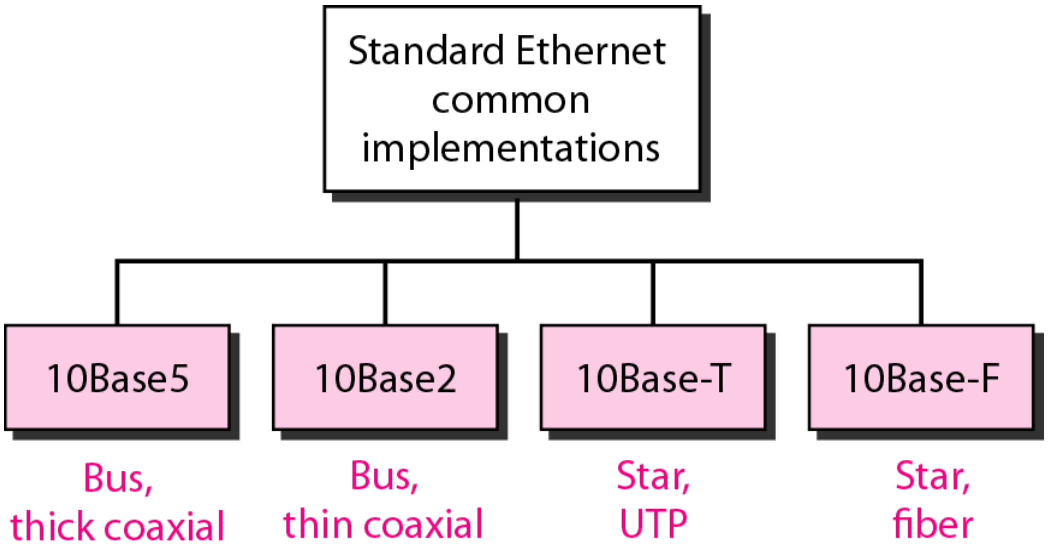
Unicast, Multicast, and Broadcast Transmission

transmission	all stations (except the sender)	intended recipient keeps and handles the frame	Non- intended recipient
unicast	receive the frame	destination	discard it
multicast	receive the frame	members of the group	discard it
broadcast	receive the frame	all stations (except the sender)	-

Standard Ethernet Implementations

- Four popular standard Ethernet implementations during the 1980s

Implementation	*Medium*	*Medium Length*	*Encoding*
10Base5	Thick coax	500 m	Manchester
10Base2	Thin coax	185 m	Manchester
10Base-T	2 UTP	100 m	Manchester
10Base-F	2 Fiber	2000 m	Manchester



IEEE 802.11 Wireless LAN Standard

- In response to lacking standards, IEEE developed the first internationally recognized wireless LAN standard – IEEE 802.11
- IEEE published 802.11 in 1997, after seven years of work
- Scope of IEEE 802.11 is limited to Physical and Data Link Layers.

- *wireless Ethernet or WiFi (short for* wireless fidelity) or *wireless LAN*
  - WiFi Alliance is a global, nonprofit industry association of more than 300 member companies devoted to promoting the growth of wireless LANs

IEEE 802 Standards Working Groups

Number	Topic
802.1	Overview and architecture of LANs
802.2 ↓	Logical link control
802.3 *	Ethernet
802.4 ↓	Token bus (was briefly used in manufacturing plants)
802.5	Token ring (IBM's entry into the LAN world)
802.6 ↓	Dual queue dual bus (early metropolitan area network)
802.7 ↓	Technical advisory group on broadband technologies
802.8 †	Technical advisory group on fiber optic technologies
802.9 ↓	Isochronous LANs (for real-time applications)
802.10 ↓	Virtual LANs and security
802.11 *	Wireless LANs
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)
802.13	Unlucky number. Nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth)
802.16 *	Broadband wireless
802.17	Resilient packet ring

The important ones are marked with *. The ones marked with ↓ are hibernating. The one marked with † gave up.

Benefits of 802.11 Standard

- Appliance Interoperability
- Fast Product Development
- Stable Future Migration
- Price Reductions
- The 802.11 standard takes into account the following significant differences between wireless and wired LANs:
  - Power Management
  - Security
  - Bandwidth

IEEE 802.11 Terminology

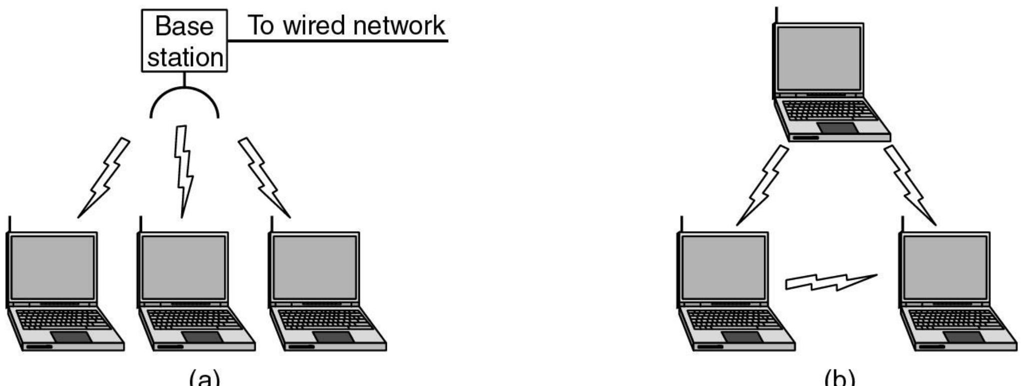
- Access point (AP): A station that provides access to the DS.
- Basic service set :

  a set is of stationary or mobile wireless stations and an optional central base station, known as the access point (AP).

- Distribution system (DS): A system used to interconnect a set of BSSs to create an ESS.
  - DS is implementation-independent. It can be a wired 802.3 Ethernet LAN, 802.4 token bus, 802.5 token ring or another 802.11 medium.
- Extended service set (ESS):Two or more BSS interconnected by DS
  - extended service set uses two types of stations: mobile and stationary
  - The mobile stations are normal stations inside a BSS. The stationary stations are AP stations that are part of a wired LAN.

Categories of Wireless Networks

- ***Base Station*** :: all communication through an ***access point*** {note hub topology}. Other nodes can be fixed or mobile.
  - ***Infrastructure Wireless*** :: base station network is connected to the wired Internet.
- ***Ad hoc Wireless*** :: wireless nodes communicate directly with one another.
  - ***MANETs* (Mobile Ad Hoc Networks) ::** ad hoc nodes are mobile.



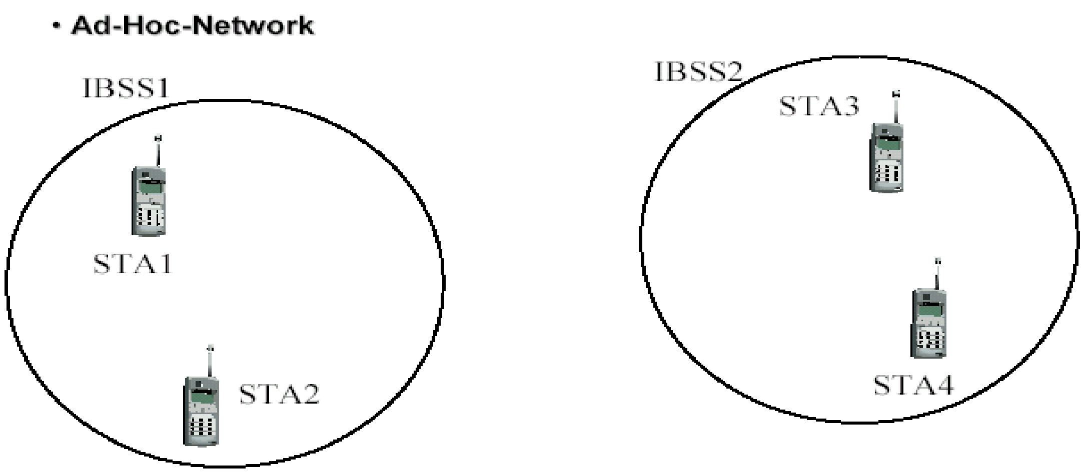
(a) Wireless networking with a base station. (b) Ad hoc networking.

Architecture

- The standard defines two kinds of services:
  - the basic service set (BSS)
    - building blocks of a wireless LAN
    - made of stationary or mobile wireless stations and an optional central base station, known as the *access point (AP)*
  - the extended service set (ESS)
    - made up of two or more BSSs with Aps
- Three types of stations based on their mobility in a wireless LAN:
  - no-transition - either stationary (not moving) or moving only inside a BSS
  - BSS-transition mobility - move from one BSS to another, but the movement is confined inside one ESS
  - ESS-transition mobility - move from one ESS to another
- IEEE 802.11 does not guarantee that communication is continuous during the move

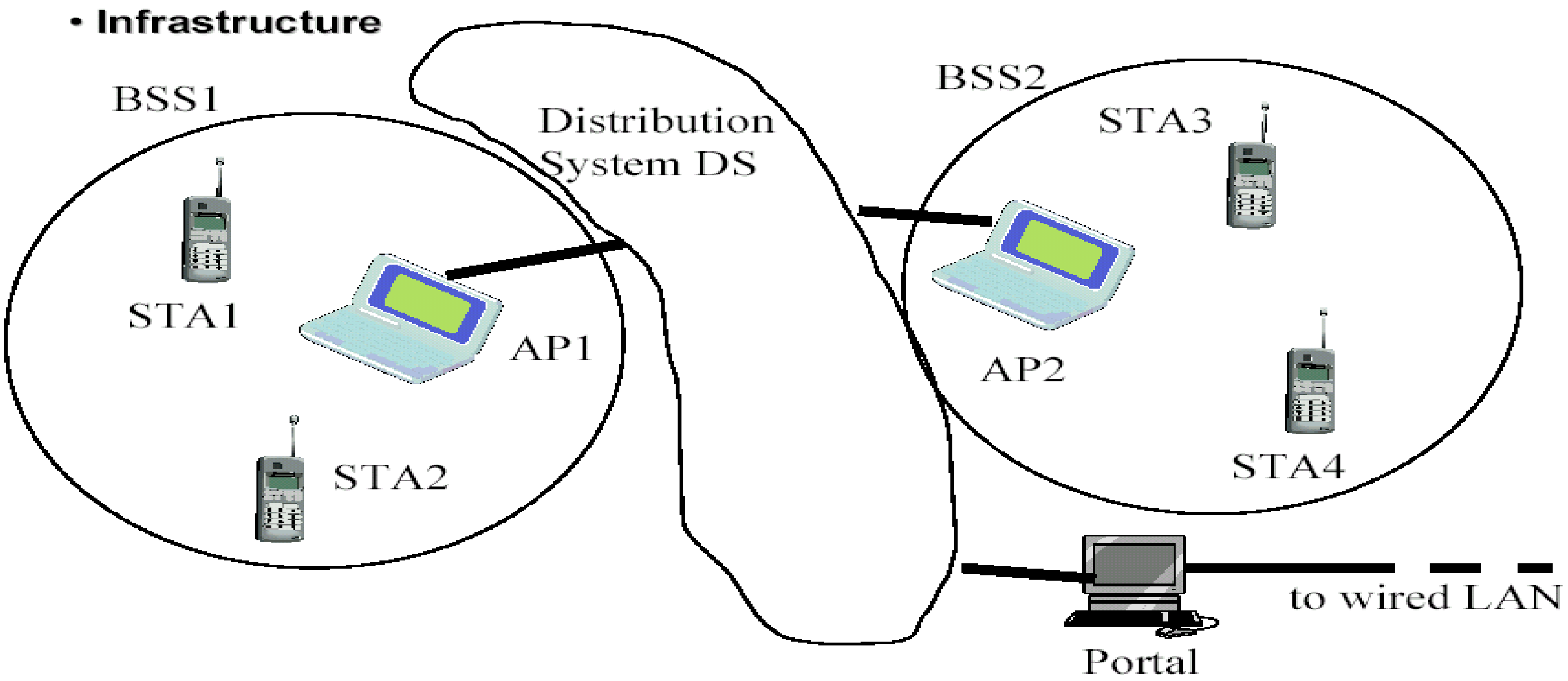
WLAN Topology - Ad-Hoc Network

- The BSS without an AP is a stand-alone network and cannot send data to other BSSs
- They can locate one another and agree to be part of a BSS



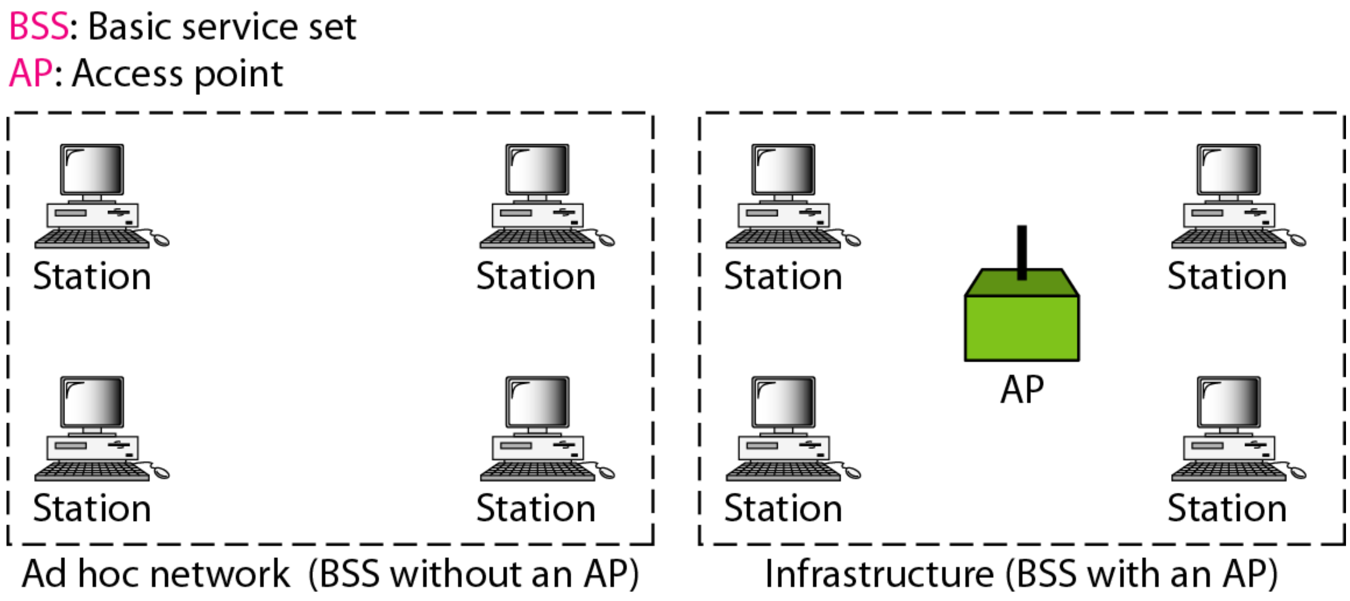
WLAN Topology Infrastructure

- EX: cellular network if we consider each BSS to be a cell and each AP to be a base station.



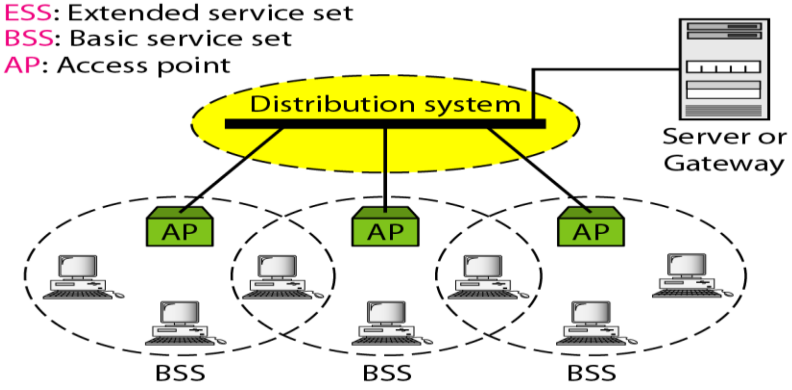
Basic service sets (BSSs)

- Building blocks of a wireless LAN
- Made of stationary or mobile wireless stations and an optional central base station, known as the *access point (AP)*
- The BSS without an AP is a stand-alone network and cannot send data to other BSSs - an *ad hoc architecture*
  - *stations* can locate one another and agree to be part of a BSS
- A BSS with an AP is sometimes referred to as an *infrastructure BSS.*



Distribution of Messages

- Distribution service (DS) - connects the APs in the BSSs
  - Used to exchange MAC frames from station in one BSS to station in another BSS



- When BSSs are connected, the stations within reach of one another can communicate without the use of an AP
  - uses two types of stations:
    - mobile - normal stations inside a BSS
    - Stationary - AP stations that are part of a wired LAN
- A mobile station can belong to more than one BSS at the same time

Fragmentation

- The wireless environment is very noisy.
- corrupt frame has to be retransmitted.
- Fragmentation is recommended.
  - the division of a large frame into smaller ones.
- It is more efficient to resend a small frame than a large one.

MAC Frame Format

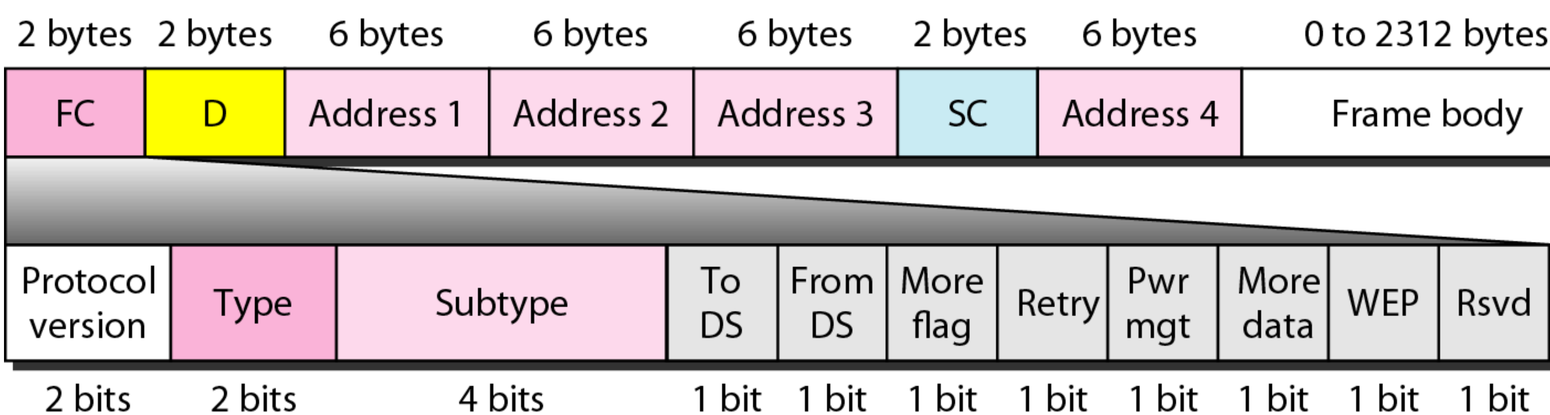
- The MAC layer frame consists of nine fields

duration of the transmission that is used to set the value of NAV. In one control frame, it defines the ID of the frame.

four address fields - meaning of each address field depends on the value of the To DS and From DS subfields

Sequence control (SC) - first four bits define the fragment number; the last 12 bits define the sequence number, which is the same in all fragments.

Frame body - information based on the type and the subtype defined in the FC field



FCS - CRC-32 error-detection sequence

Frame control (FC)- type of frame and some control information

MAC Sublayer - *Frame Format*

- Subfields in FC field

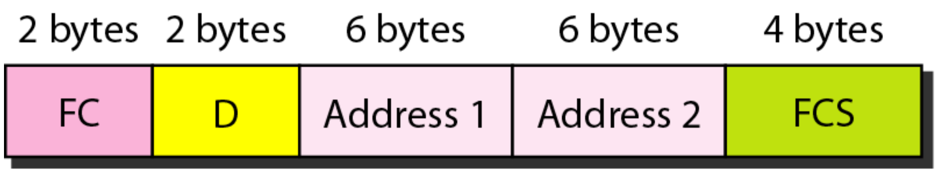
Field	*Explanation*
Version	Current version is 0
Type	Type of information: management (00), control (01), or data (10)
Subtype	Subtype of each type (see Table 14.2)
To DS	Defined later
From DS	Defined later
More flag	When set to 1, means more fragments
Retry	When set to 1, means retransmitted frame
Pwr mgt	When set to 1, means station is in power management mode
More data	When set to 1, means station has more data to send
WEP	Wired equivalent privacy (encryption implemented)
Rsvd	Reserved

Frame Types

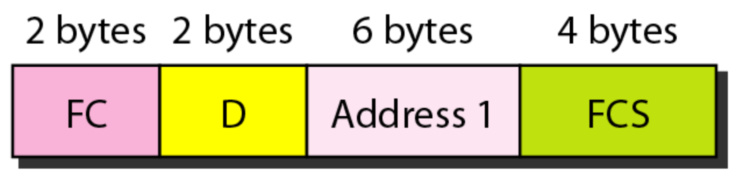
- IEEE 802.11 has three categories of frames:
  - management frames:

    used for the initial communication between stations and access points.
  - control frames.

    used for accessing the channel and acknowledging frames



RTS



CTS or ACK

value of the type field is 01; the values of the subtype fields

Subtype	*Meaning*
1011	Request to send (RTS)
1100	Clear to send (CTS)
1101	Acknowledgment (ACK)

  - data frames.

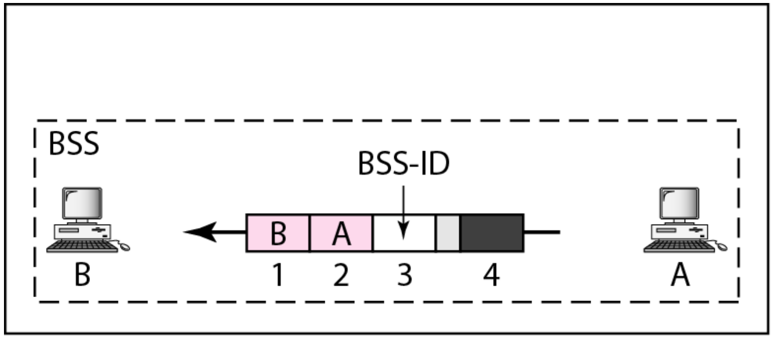
    Data frames are used for carrying data and control information.

Addressing Mechanism

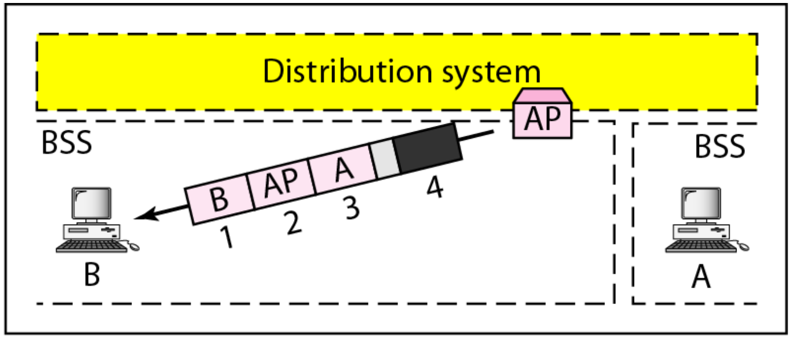
- IEEE 802.11 addressing mechanism specifies four cases defined by the value of the two flags in the FC field, *To DS and From DS*
  - Each flag can be either 0 or 1, resulting in four different situations
  - The interpretation of the four addresses (address 1 to address 4) in the MAC frame depends on the value of these flags

Addressing Mechanism

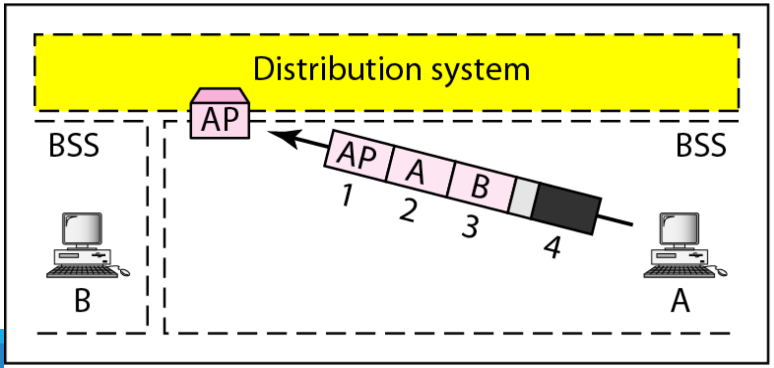
To DS	From DS	Address 1	Address 2	Address 3	Address 4
0	0	Destination	Source	BSS ID	N/A
0	1	Destination	Sending AP	Source	N/A
1	0	Receiving AP	Source	Destination	N/A
1	1	Receiving AP	Sending AP	Destination	Source



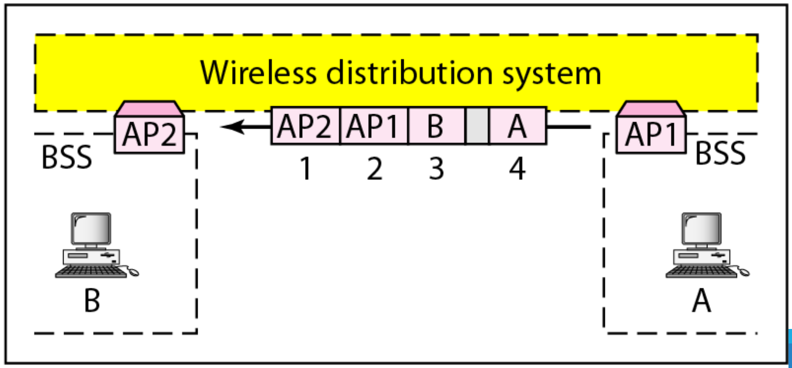
a. Case 1



b. Case 2



c. Case 3



d. Case 4

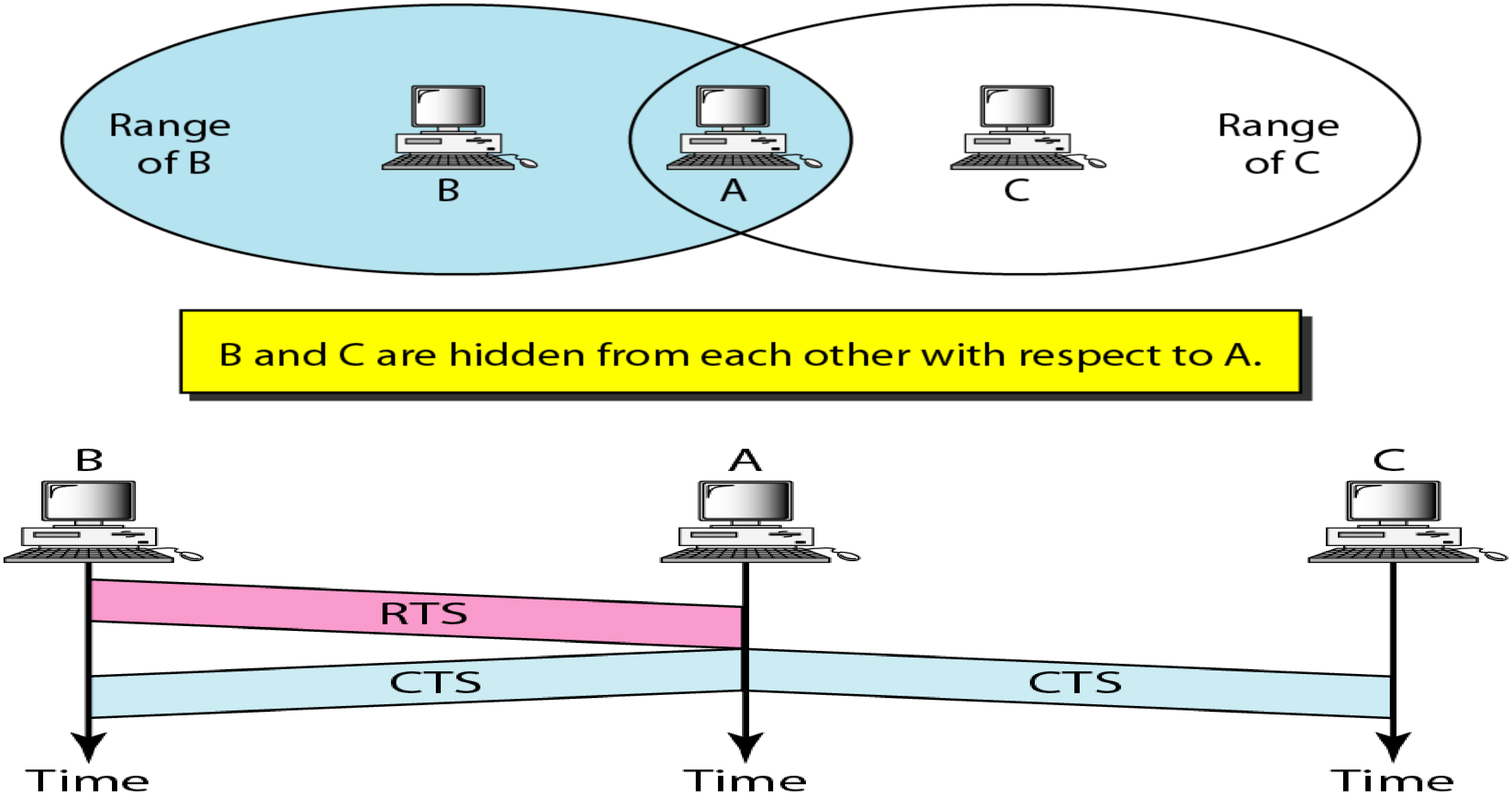
Addressing Mechanism

- Case 1: 00, To DS = 0 and From DS = 0
  - This means that the frame is not going to a distribution system and is not coming from a distribution system.
  - The ACK frame should be sent to the original sender.
- Case 2: 01, In this case, To DS = 0 and From DS = 1.
  - This means that the frame is coming from a distribution system (coming from an AP).
  - The ACK should be sent to the AP
  - The addresses are as address 3 contains the original sender of the frame (in another BSS).

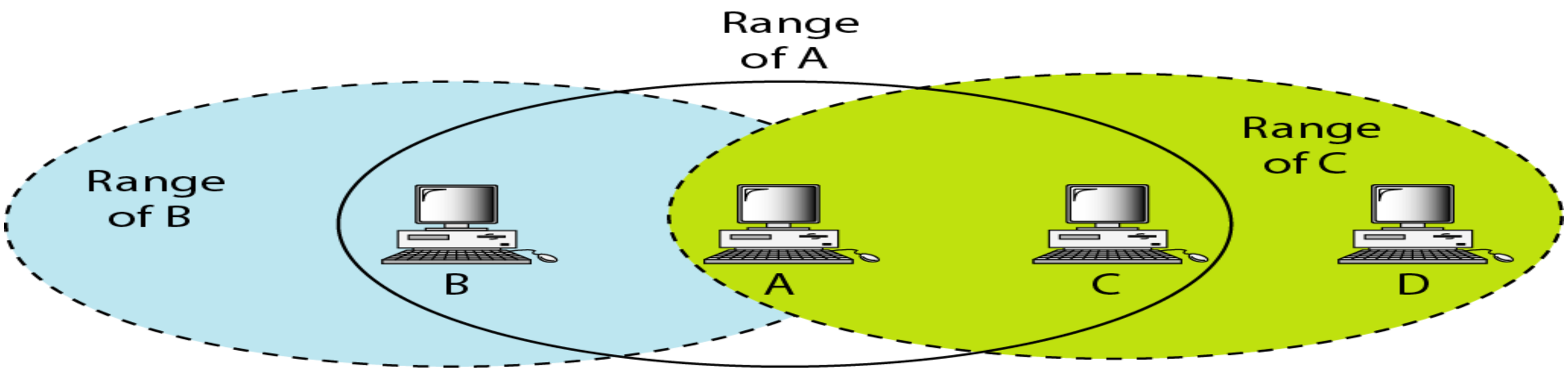
Addressing Mechanism

- Case 3: 10, To DS =1 and From DS =O.
  - This means that the frame is going to a distribution system (frame is going from a station to an AP)
  - The ACK is sent to the original station.
  - address 3 contains the final destination of the frame (in another BSS).
- Case 4:11, To DS =1 and From DS =1.
  - This is the case in which the distribution the frame is going from one AP to another AP in a wireless distribution system.
  - We do not need to define addresses if the distribution system is a wired LAN because the frame in these cases has the format of a wired LAN frame (Ethernet, for example).
  - Here, we need four addresses to define the original sender, the final destination, and two intermediate APs.

Hidden Station Problem



Exposed Station Problems



C is exposed to transmission from A to B.

- Station A is transmitting to station B.
- Station C has some data to send to station D, which can be sent without interfering with the transmission from A to B
- However, station C is exposed to transmission from A; it hears what A is sending and thus refrains from sending
- The handshaking messages RTS and CTS cannot help in this case
- Station C hears the RTS from A and refrains from sending, even though the communication between C and D cannot cause a collision in the zone between A and C; station C cannot know that station A's transmission does not affect the zone between C and D.