Medium Access Control

- Gaining access to a LAN is a fundamental requirement for data transmission between stations.
- Access can be controlled either:
  - *Centrally*: Stations must obtain permission before accessing the transmission medium.
  - *Distributed:* Access is controlled by stations acting *together.*

Medium Access Control

- Characteristics of *Centrally Controlled Access* techniques:
  - Advantages:
    - The access logic required at each station is *simple.*
    - There is no co-ordination required between stations.
  - Disadvantages:
    - Single point of failure. If the controlling device develops a fault all stations are affected.
    - Potential *bottleneck.* All “requests for access” must be sanctioned by the central device.

Medium Access Control

- Distributed Access techniques are more commonly used and will be explored later.

Medium Access Control

- There are three generalised access control techniques:
  - Reservation (will not be covered)
    - Medium is divided into *time slots.*
    - Station wishing to send *reserves* future slots.
    - Very suited to stream traffic i.e. long and continuous transmissions on an *irregular* basis.
  - Round Robin (see slides on Token Ring)
    - Each station takes a turn to transmit data.
    - Efficient only if stations have a lot of data to transmit on a regular basis.
  - Contention – see next slide.

MAC – Contention.

- Characteristics of the Contention MAC technique:
  - Each station *contends* for access when needed.
  - The technique is *distributed* by nature.
  - Works on a "*first come/first served"* basis and is easy to implement.
  - Very suited to *bursty* traffic i.e. short, sporadic transmissions.

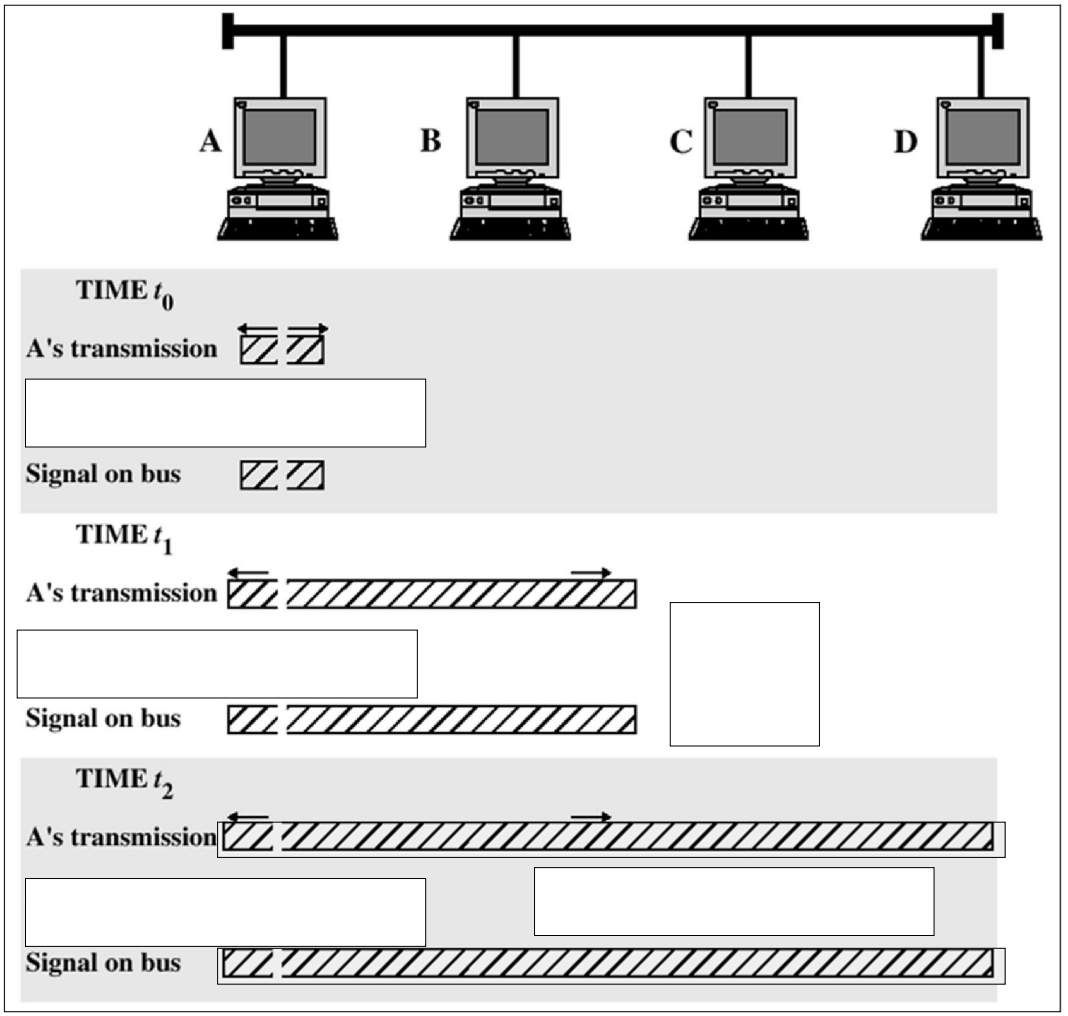
Ethernet's Contention Access Technique

- *Ethernet* – an example of a *Bus/Star LAN*
  - It employs a *Contention* MAC technique:
    - Known as "*Carrier Sense Multiple Access with Collision Detection (CSMA/CD)"*
      - It is *random* and requires each station to *contend* for access to the shared transmission medium.
      - The most commonly used MAC technique for *bus* and *star* LANs.
      - Defined under IEEE802.3 standard

CSMA – Basic Operation

- If a station wishes to transmit Data frames the following steps are followed:
  - The station listens to the medium for activity (known as *carrier sense*).
  - If the medium is clear of traffic the station begins transmission immediately.
  - If the medium is in use, the station waits a random period of time before it attempts to transmit the Data frame.

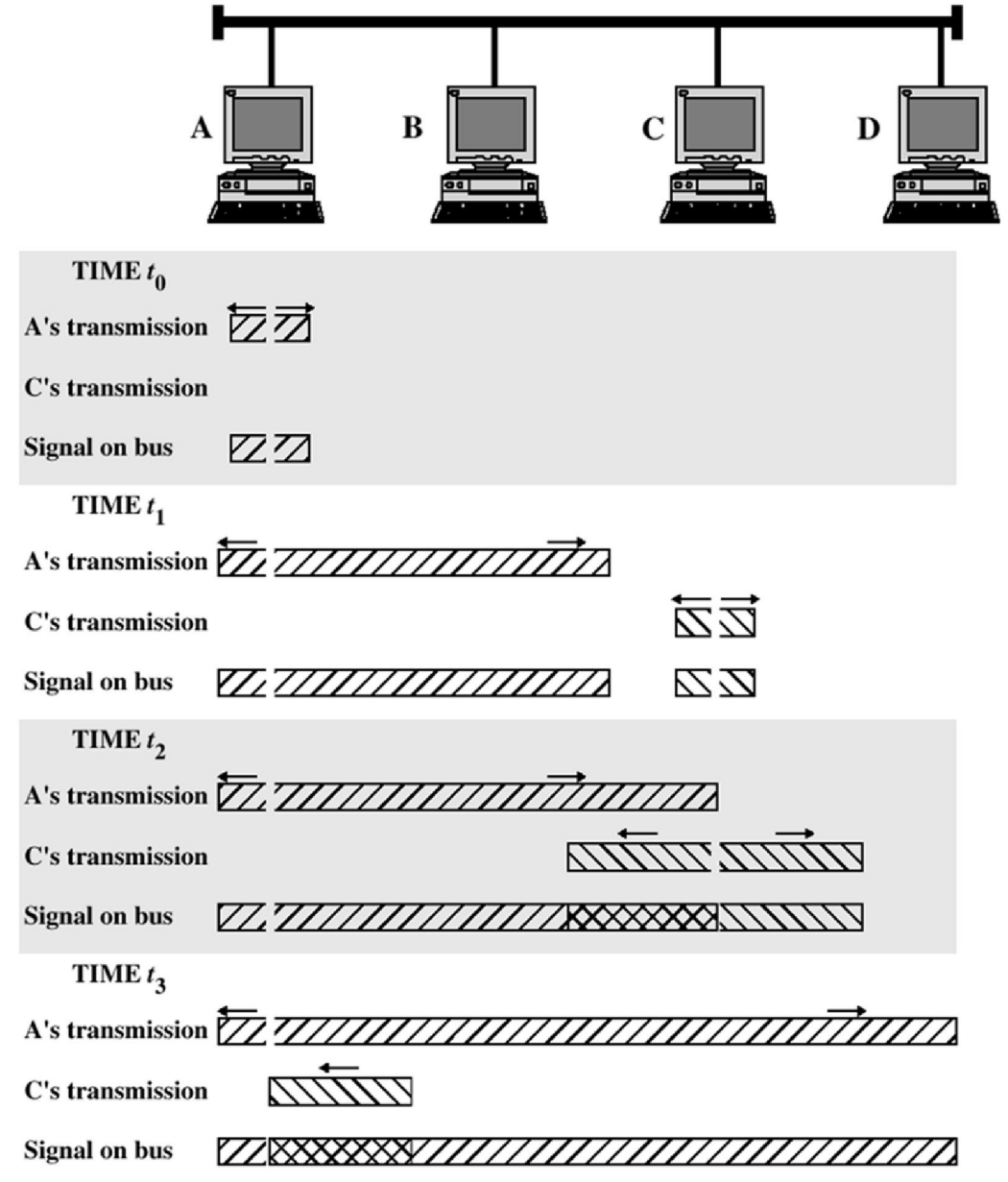
CSMA Normal Operation



CSMA – Basic Operation (contd.)

- In normal operation, transmitting stations can send multiple frames and would expect ACKs in the return direction:
  - Recall ARQ techniques: Go-Back-N and Selective Reject,
- The problem with this access technique:
  - It is possible for two or more stations to attempt to transmit at approx. the same time:
  - This will lead to a *collision* i.e. a *garbled* transmission.
    - Recall what happens when *digital* signals meet?

CSMA Operation



CSMA – Basic Operation (contd.)

- Collisions are an example of frames “going missing”:
  - Recall scenarios outlined in discussions on Go-Back-N and Selective Reject.
  - Collisions can lead to “out-of-sequence” frames and/or ‘missing’ RR messages.
  - Recall in the ARQ techniques that a transmitting station:
    - Sets a timer for each frame transmission.
    - Expects an ACK from the destination station.
    - Takes action after a *timeout* period using command-responses (Poll/Final bit).

CSMA Characteristics

- CSMA results in *poor utilization* of the link:
  - The medium remains *unusable* for the time taken to clear the collision.
  - The *transmitting* station is reliant upon the non-return of an acknowledgement to detect a problem.
- To counteract this inefficiency CSMA was extended to include *collision detection* (CSMA/CD).

CSMA/CD – Basic Operation

- As before, the station listens to the medium before attempting to transmit.
- During transmission the station continues to *listen* to the medium for a **collision:**
  - Known as *Collision Detection:*
    - If present, the station ceases transmission immediately.
    - The station then transmits a brief *jamming signal* to inform all other stations of the collision.
    - The station waits a random amount of time (*delta*) before attempting to retransmit.
  - Additonal collisions are dealt with using a *binary exponential backoff* (see explanation in class)

CSMA Versus CSMA/CD

- Without the use of CSMA/CD collisions would not be detected:
  - If the affected frame was a data frame, then the Rx'er would likely interpret the next frame as an out-of-sequence frame and would return a REJ message,
  - If the collided frame was a returning ACK, the Tx'er would not receive a RR message for an outstanding frame:
    - Recall: Its timer would expire and it would have to send a *RR* message with the *Poll* bit set.
  - Consequently the overall time to send multiple frames would be extended as the communicating station would have to rely on *Timers* and *REJ* messages to recover from collisions.

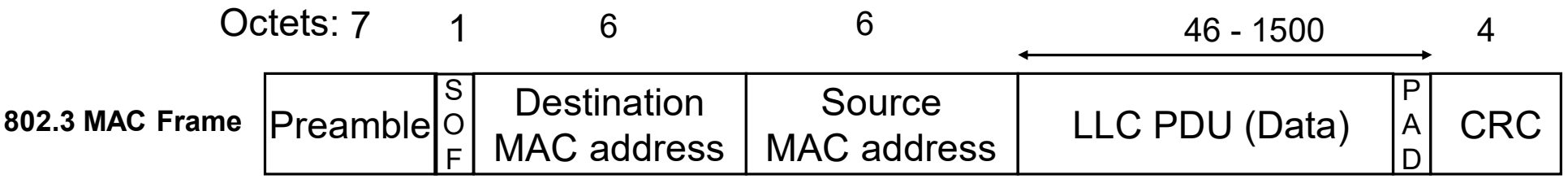
CSMA Versus CSMA/CD - Contd.

- With Collision Detection collisions would be detected:
  - The Tx'ing station would stop transmitting the frame and would wait a random period before attempting to re-transmit:
    - The Rx'er should eventually receive the frame.
  - Collision Detection, in part, addresses some of the issues normally addressed with error control, namely 'lost' frames:
    - The Tx'er does not have to rely on returning ACKs/NACKs.
  - Consequently the overall time to send multiple frames would be reduced as the Tx'er would only have to wait for the collision to disappear from the segment in order to re-transmit the frame.

CSMA/CD Characteristics

- The use CSMA/CD is beneficial:
  - By reducing the “down-time” of the LAN segment, “Link Utilization” is improved.
  - The time to deliver multiple frames is improved.
- However, *frame size* (length) is critical:
  - Short frames prevent *collision* detection
  - Frames have to be a minimum length (see explanation and calculations in class).
  - Consequently the MAC frame format includes a special field called *Pad.*
    - Extra octets (“random data”) can be added to the frame.

802.3 MAC Frame Format



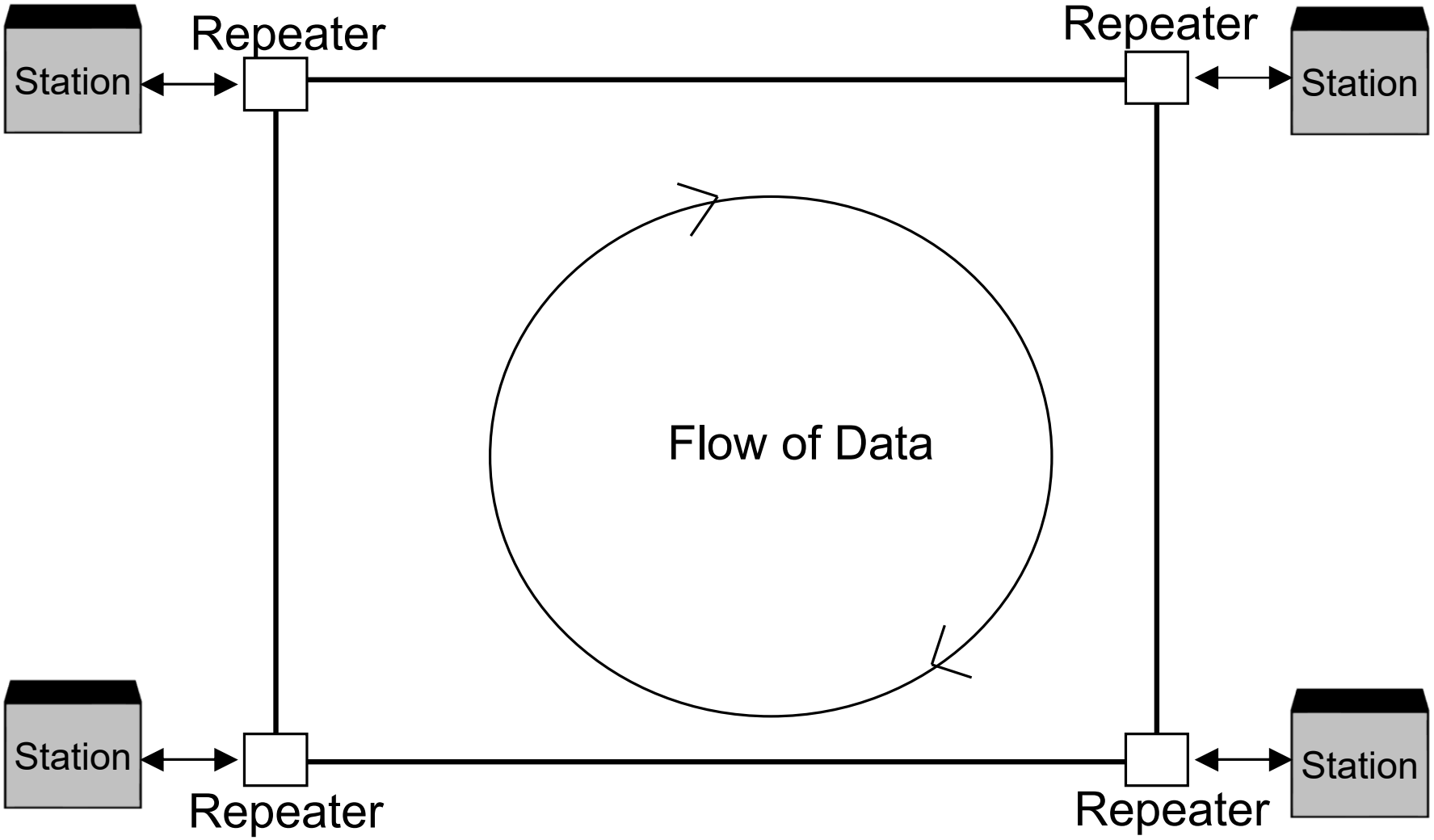
CSMA/CD Simple Algorithm

```
WHILE (Do always - Infinite loop)
    IF Frame on Tx medium;
        Check Destination Address field;
        IF (own address)
            Copy frame;
        ELSE ignore frame;
    WHILE (Have Frame to Transmit)
        Listen to Transmission medium;
        IF Clear;
            Commence frame Transmission;
            WHILE (Frame is transmitting)
                Continue to Listen to Transmission medium;
                IF Collision detected;
                    Stop transmission;
                    Transmit Jamming signal;
                    Wait random period to Retransmit;
        ELSE wait random period to transmit;
    END Transmit WHILE Loop;
END Infinite WHILE Loop;
```

Ring LANs

- Consists of a number of stations each of which is connected to a *repeater.*
- These in turn are connected to two other repeaters by *unidirectional* transmission links to form a ring.
- Data are transferred *bit-by-bit* around the ring from one repeater to the next.
- The repeaters *regenerate* and *retransmit* each bit.

Ring LANs


Station
Repeater
Repeater
Station
Flow of Data
Station
Repeater
Repeater
Station

Ring LANs – Repeater Functionality

- Repeaters perform three functions:
  - *Frame insertion*: *Frames* (with addresses) are placed onto the Tx medium by the repeater.
  - *Frame reception*: As a frame passes through a repeater the address field is copied to the station. If the station recognises the address, the entire frame is copied.
  - *Frame removal*: A repeater can remove a frame by not repeating it to the next link:
    - Either the *addressed repeater* can remove the data or, the *transmitting station* can (after one round trip).

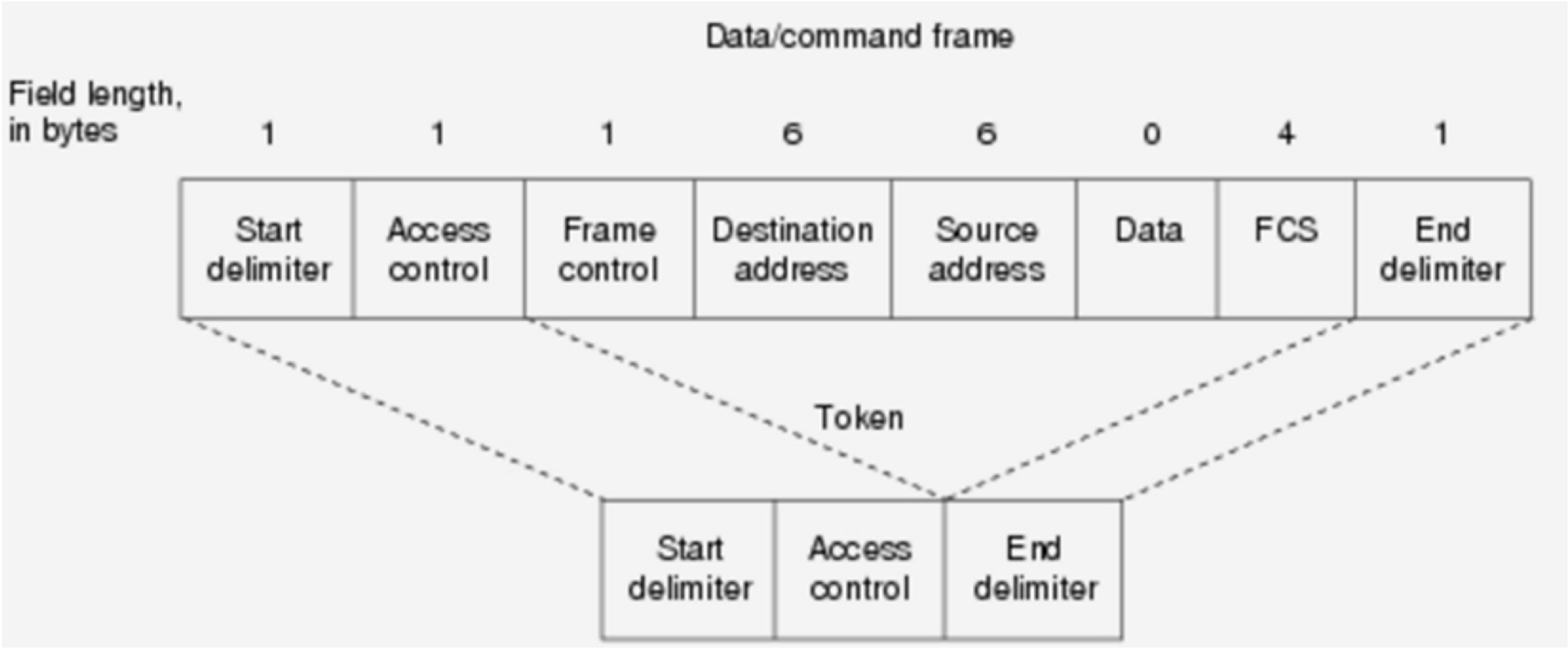
Example Access Technique - *Token Ring*

- The most commonly used MAC technique for *ring* LANs is *IBM Token Ring:*
  - This is a *Round Robin* technique and is defined under the IEEE802.5 standard.
- Token Ring uses a small frame, called a *Token:*
  - The token circulates around the *ring* indefinitely.
  - A station wishing to transmit must seize the token and remove it from the LAN.

Token Ring – Basic Operation

- The *token* is then transformed into a *start-of-frame* field for a *data frame* (a single bit is changed – see next slide):
  - More fields are added to construct a *data frame.*
  - The token is effectively removed from the ring and replaced by a ***Data*** *frame.*
  - When the frame returns to the *transmitting* station it removes the *frame* from the ring and inserts a new token.

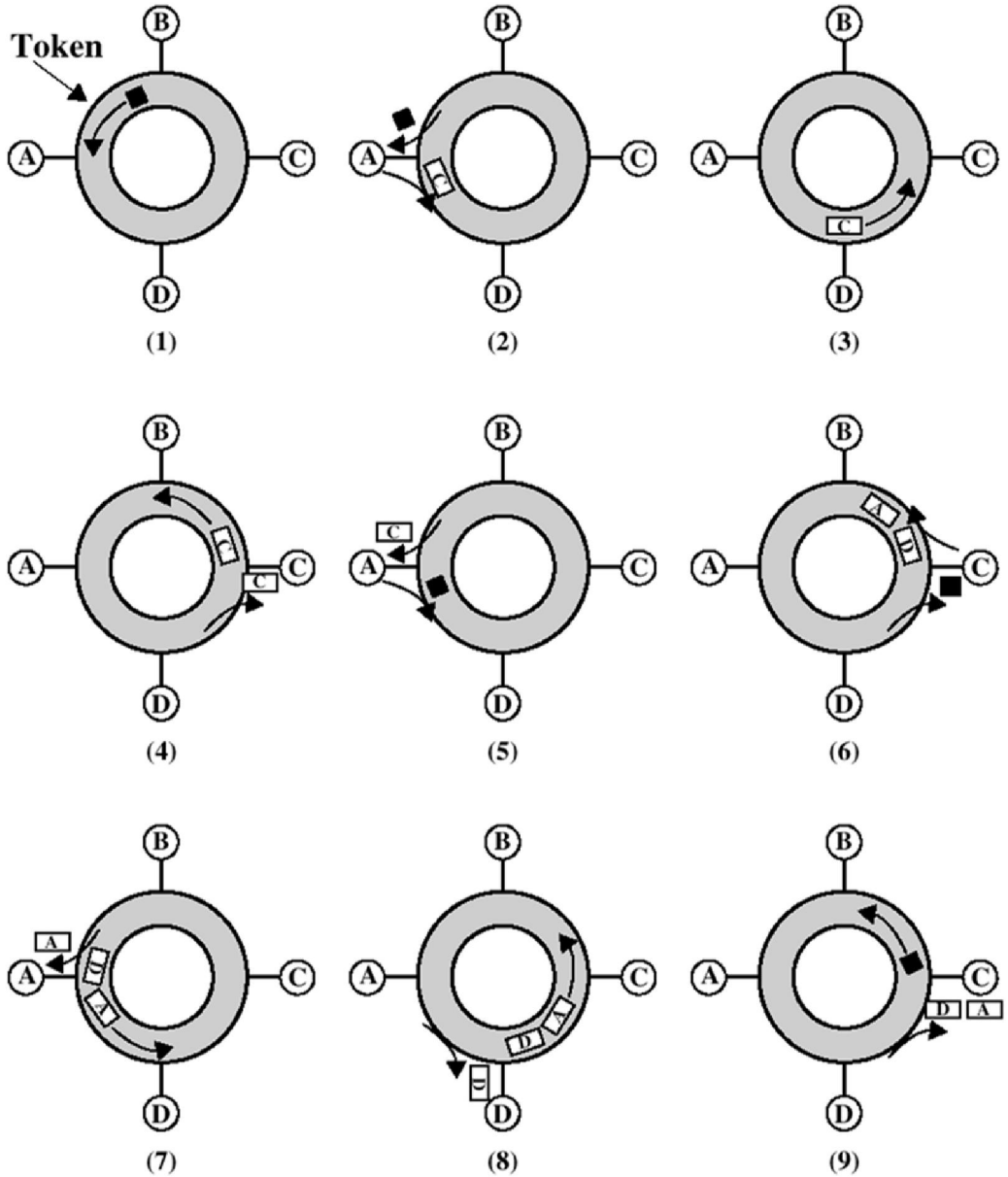
802.5 MAC Frame Format



Token Ring - Simple Algorithm

```
WHILE (Do always - Infinite loop)
    IF Frame on Tx medium;
        Check Destination Address field;
        IF (own address)
            Copy frame;
        ELSE ignore frame;
    WHILE (Have Frame to Transmit)
        IF Token available;
        Remove Token;
        Transmit frame;
        While (Frame in Transit);
                If Frame returns;
                Remove Frame;
                Place Token on Tx'ion medium
        End "Frame Transit" WHILE Loop;
    End "Have Frame to Transmit" WHILE
    Loop;
END Infinite WHILE Loop;
```

Token Ring Operation



Token Ring Advantages/Disadvantages

- Advantages:
  - Access is *efficient* and *fair* under heavy traffic loads.
- Disadvantages:
  - Access can be inefficient under light traffic loads:
    - A station must wait for a token before transmitting.
  - There is a requirement for *token maintenance*:
    - Tokens can be *lost* or *duplicated.*
    - One station is assigned responsibility for token maintenance.

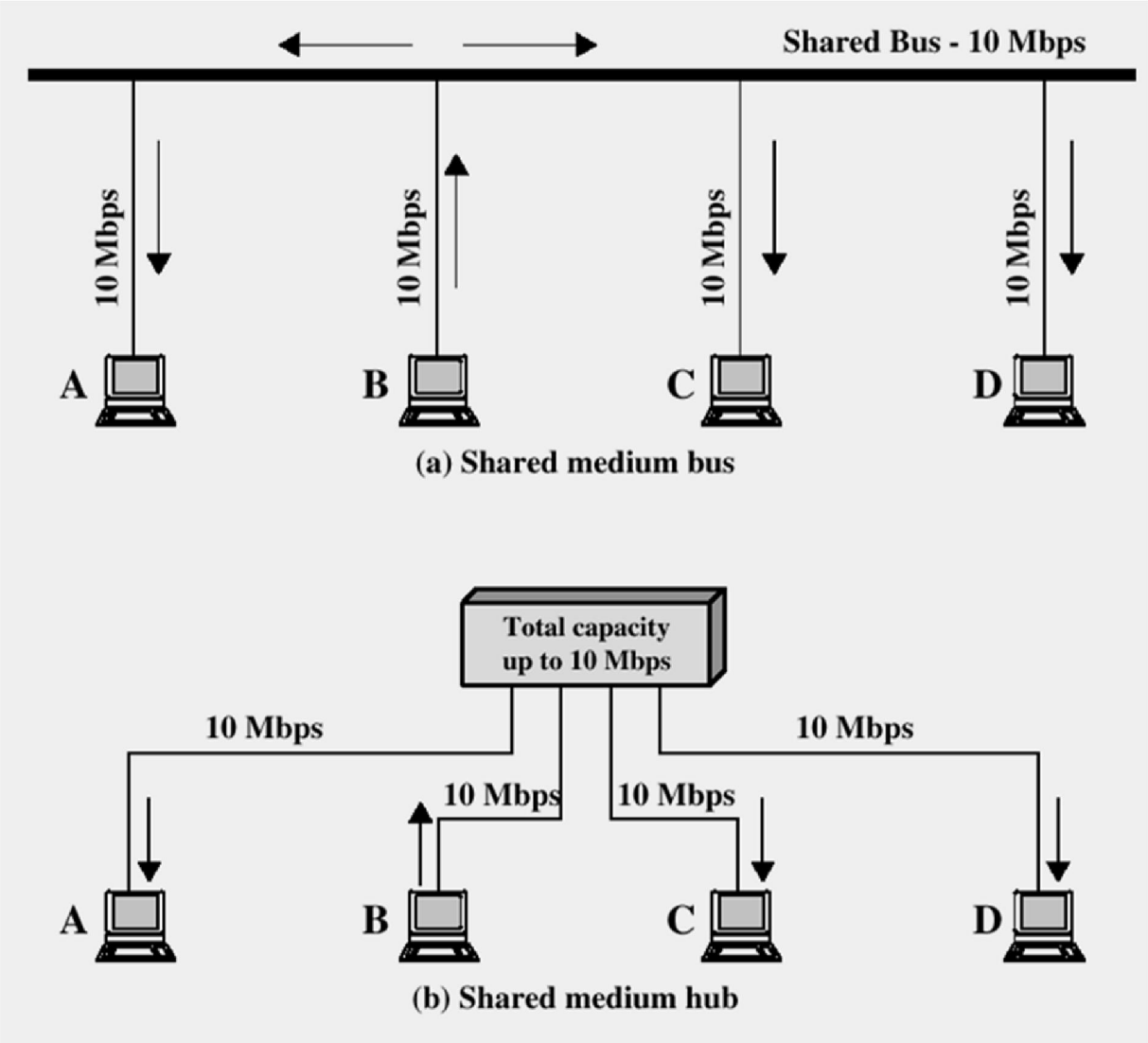
Star LANs

- Uses a central component known as a *hub*
- Two types of hub:
  - *Shared-medium hub* and,
  - *Switched LAN hub*

Shared-medium hub LAN

- *Shared-medium hub (Hub-star LAN)*
  - Transmission from any station is repeated to all stations
  - Only one station can transmit at any one time
  - This is the same behaviour as a Bus Lan
    - Hence this type of *star* LAN is also known as a *star-shaped bus* (as opposed to a *simple bus* LAN)
  - Advantages of *star-shaped bus* LAN:
    - Can use existing building wiring

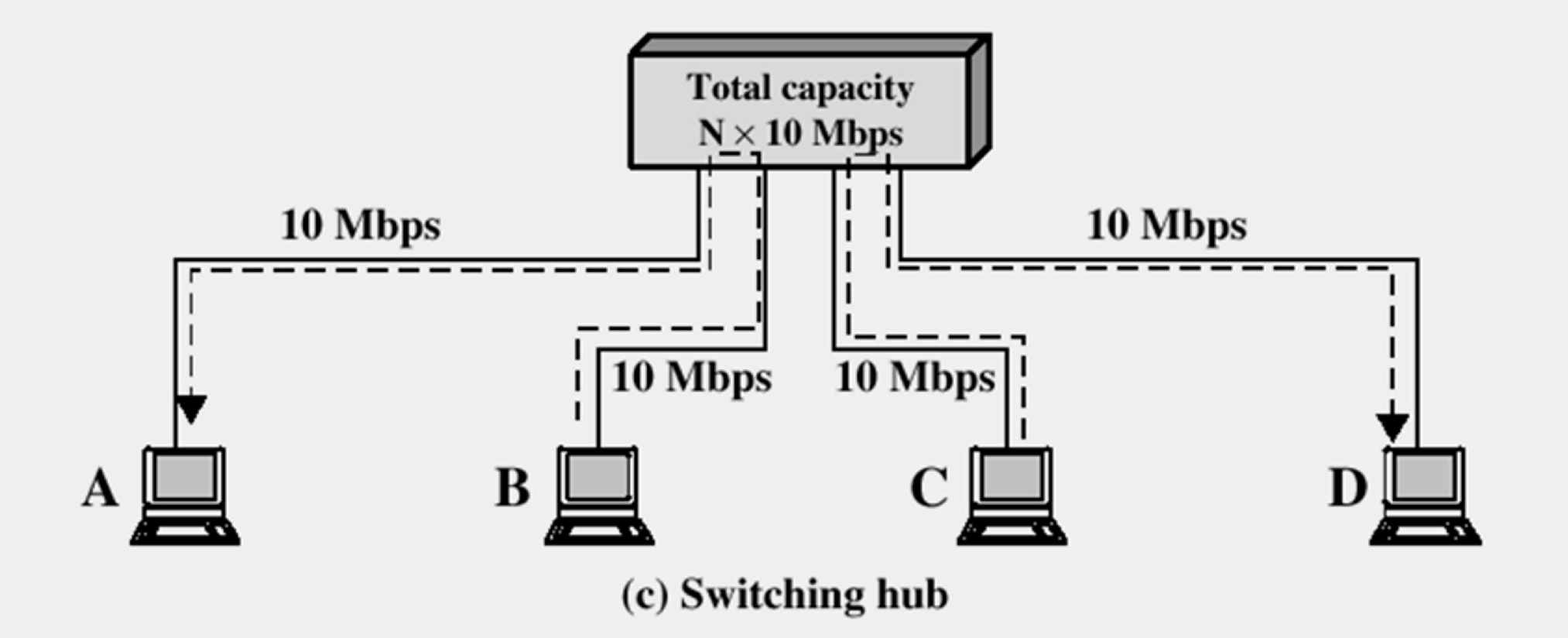
Hub-Star LAN Configuration



Switched LAN hub LAN

- *Switched LAN hub (Switched-star LAN)*
  - Acts as a switch i.e. incoming frame is only passed to the addressed station
  - Frames from other stations can be switched simultaneously
- Greater performance can be achieved with a *switched LAN hub* over a *shared-medium hub*

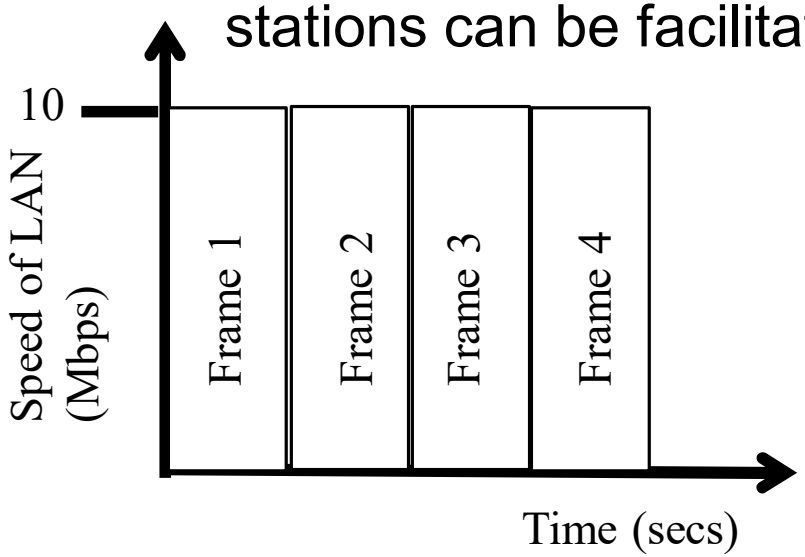
Star LAN Configurations



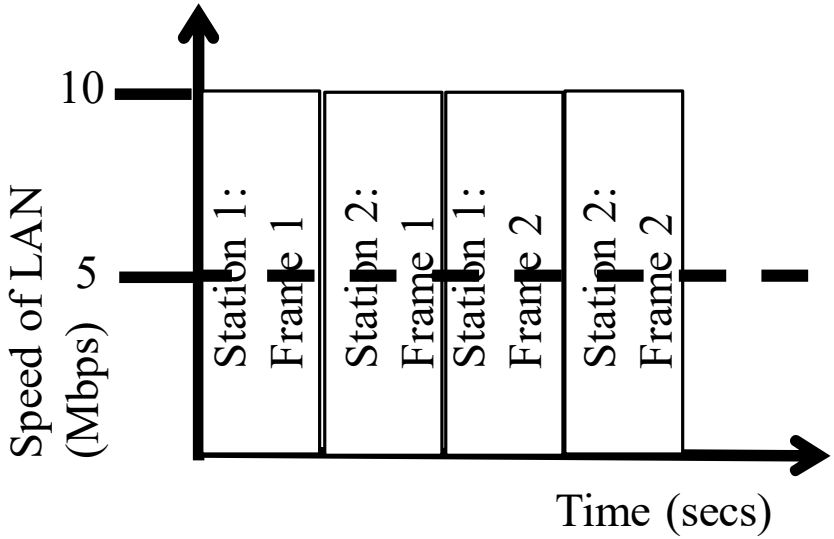
(c) Switching hub

Switched-star LANs – Performance consideration

- Switched-LANs provides improved performance because there is no contention
  - Multiple simultaneous communications between pairs of stations can be facilitated



Single station transmitting without contention on a Bus LAN experiences full LAN throughput of 10Mbps. All stations on a switched-star LAN experience the same maximum throughput because there is no contention.



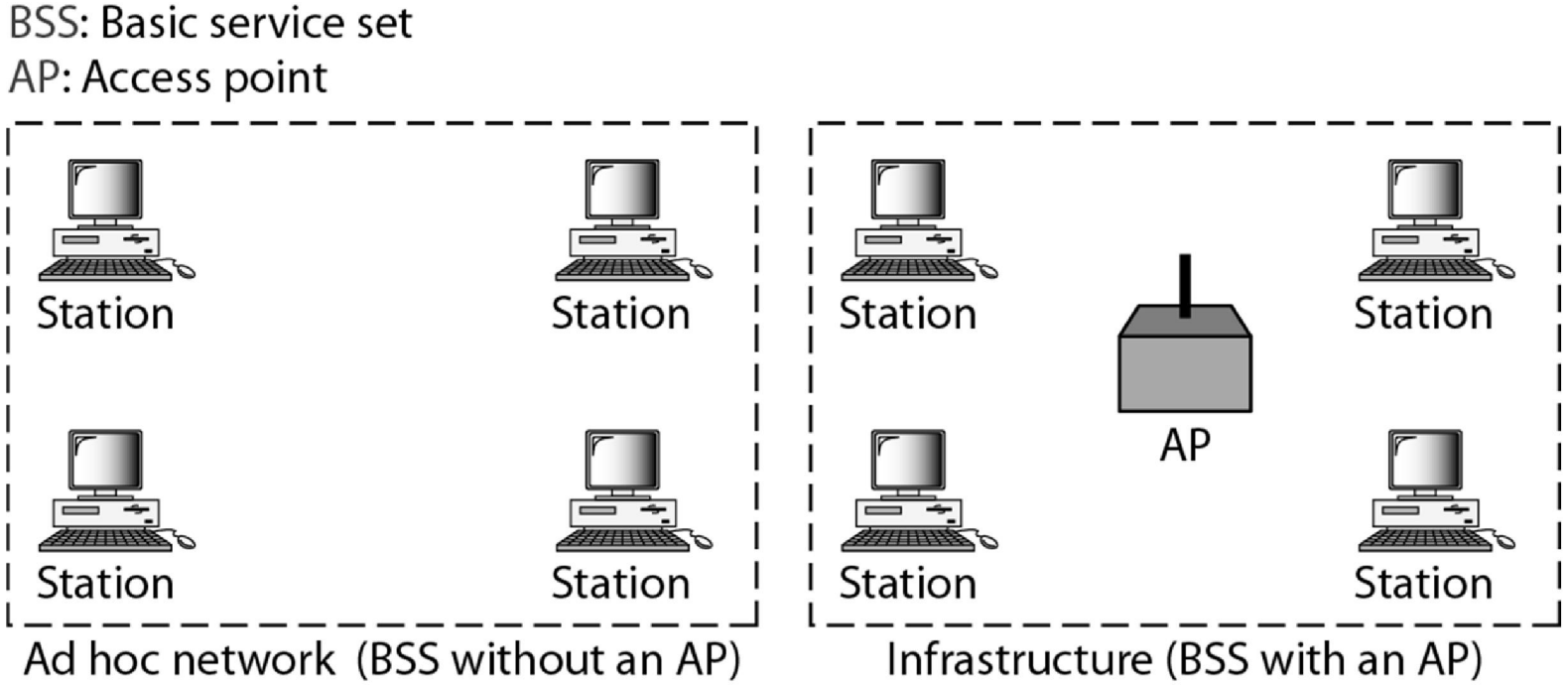
Two stations transmitting with contention on a Bus LAN experiences reduced LAN throughput of approx. 5Mbps.

Wireless LAN

- The specification for wireless LANs is called IEEE 802.11.
- This specification defines two types of architecture:
  - The Basic Service Set (BSS), and,
  - The Extended Service Set (ESS).

BSS Wireless LAN

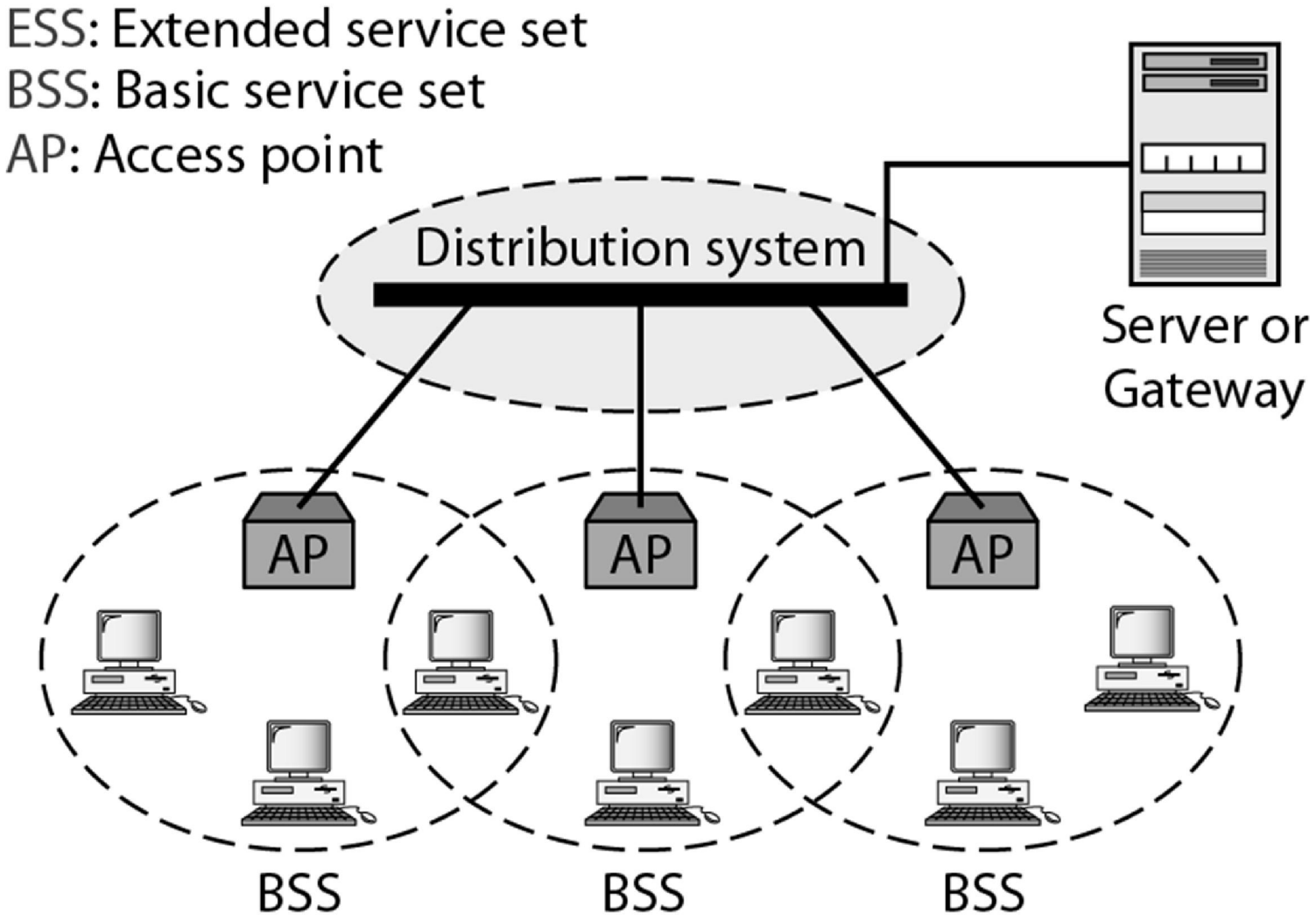
- The BSS typically comprises a number of mobile stations and a central **base** station known as an *Access Point* (AP).



ESS Wireless LAN

- The ESS typically comprises two or more BSSs with APs.
- The APs are usually connected via a *distribution network* (typically a wired LAN).
- Like BSSs, ESSs define two types of stations:
  - Stationary stations which usually connect via the wired LAN. These stations include the APs.
  - Mobile stations. Some of these stations can only communicate within a single BSS, others between BSSs and yet others between ESSs.

ESS Wireless LAN



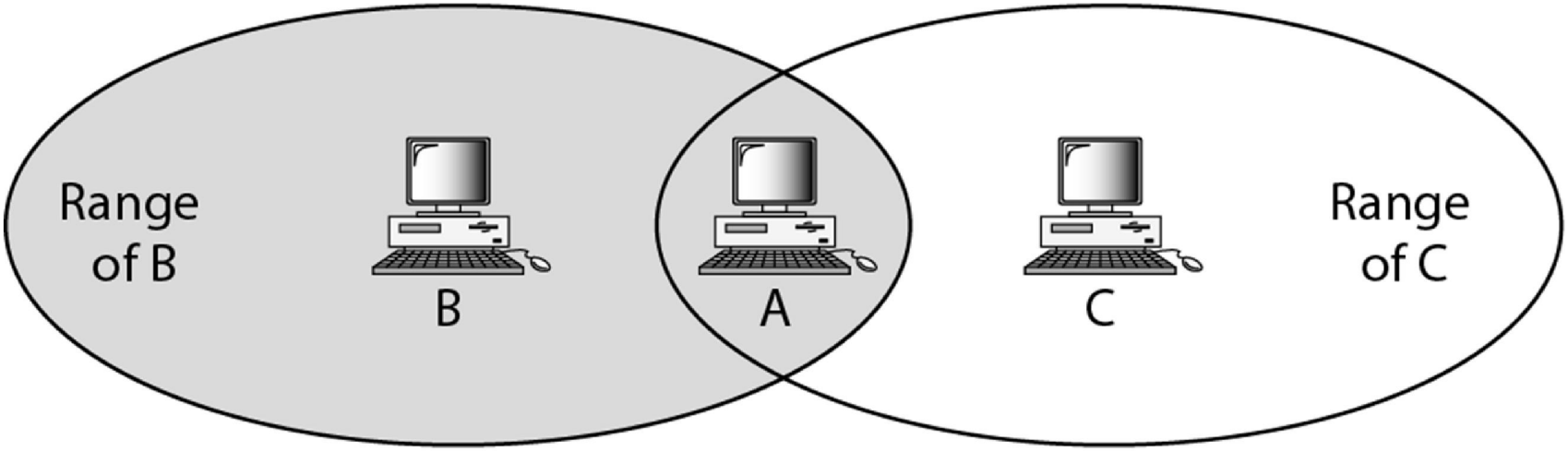
Wireless LAN Access Technique

- The access technique employed on a wireless LAN is CSMA/CA (Collision Avoidance)
- This is similar to CSMA/CD as follows:
  - Before a station can transmit a frame it must detect activity on the shared medium (in this case the air interface).
  - Timers and Back-off periods are used in the event that the medium is in use.
- As with wired Bus LANs collisions can occur.

Collision Detection on a WLAN

- Collision Detection (CD) within a Wired LAN relies on a transmitting station being able to detect a collision:
  - This is not always the case with a Wireless LAN.
  - Due to distances between stations not all transmissions are visible to all stations as per the "Hidden Station Problem".

The Hidden Station Problem



B and C are hidden from each other with respect to A.

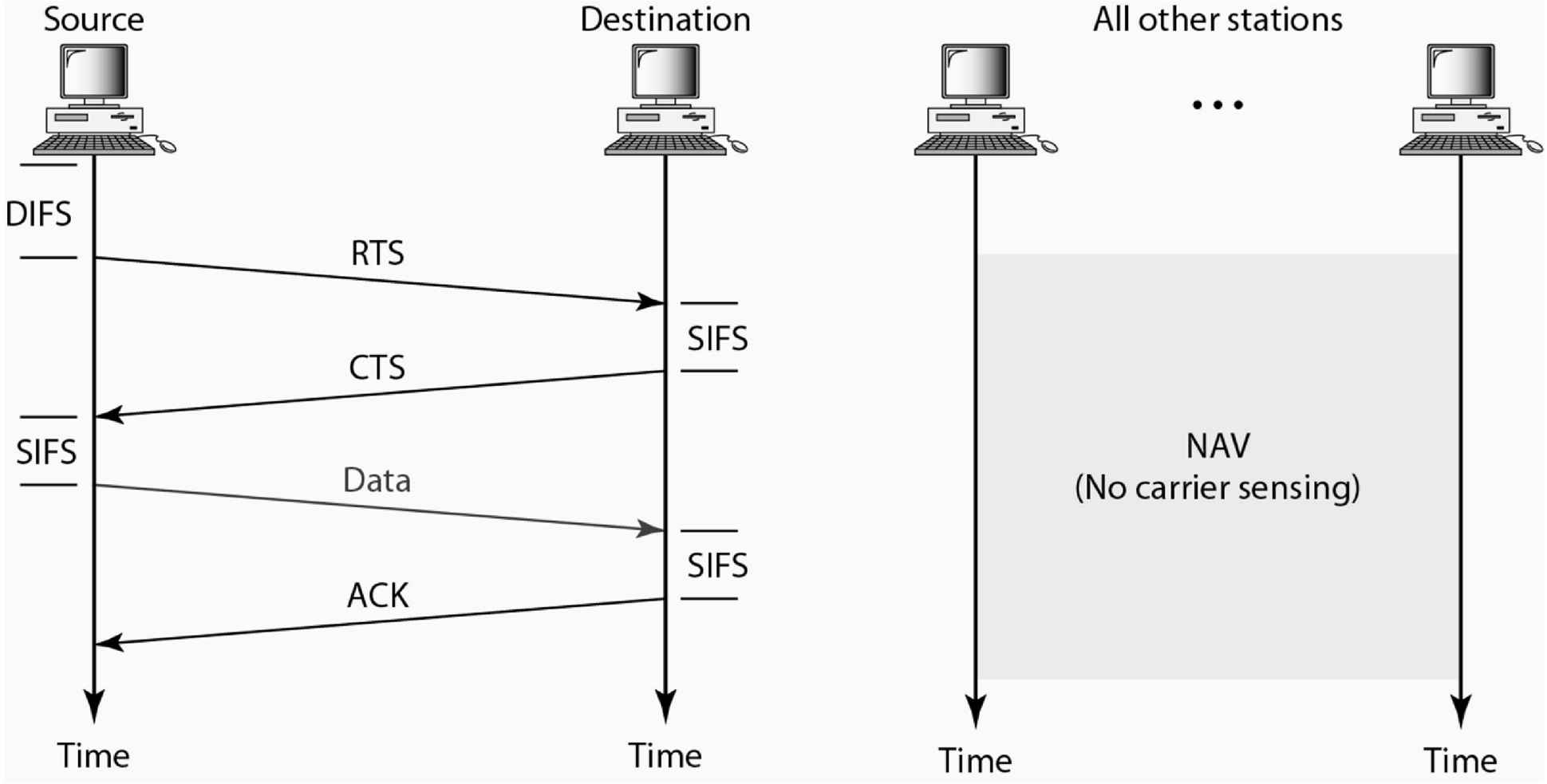
Collision Avoidance on WLAN

- The approach to dealing with collisions on a WLAN is to avoid collisions in the first instance.
- The technique is known as Collision Avoidance:
  - This technique uses fixed timers and a message exchange technique.
  - When used with CSMA the technique is called CSMA/CA.

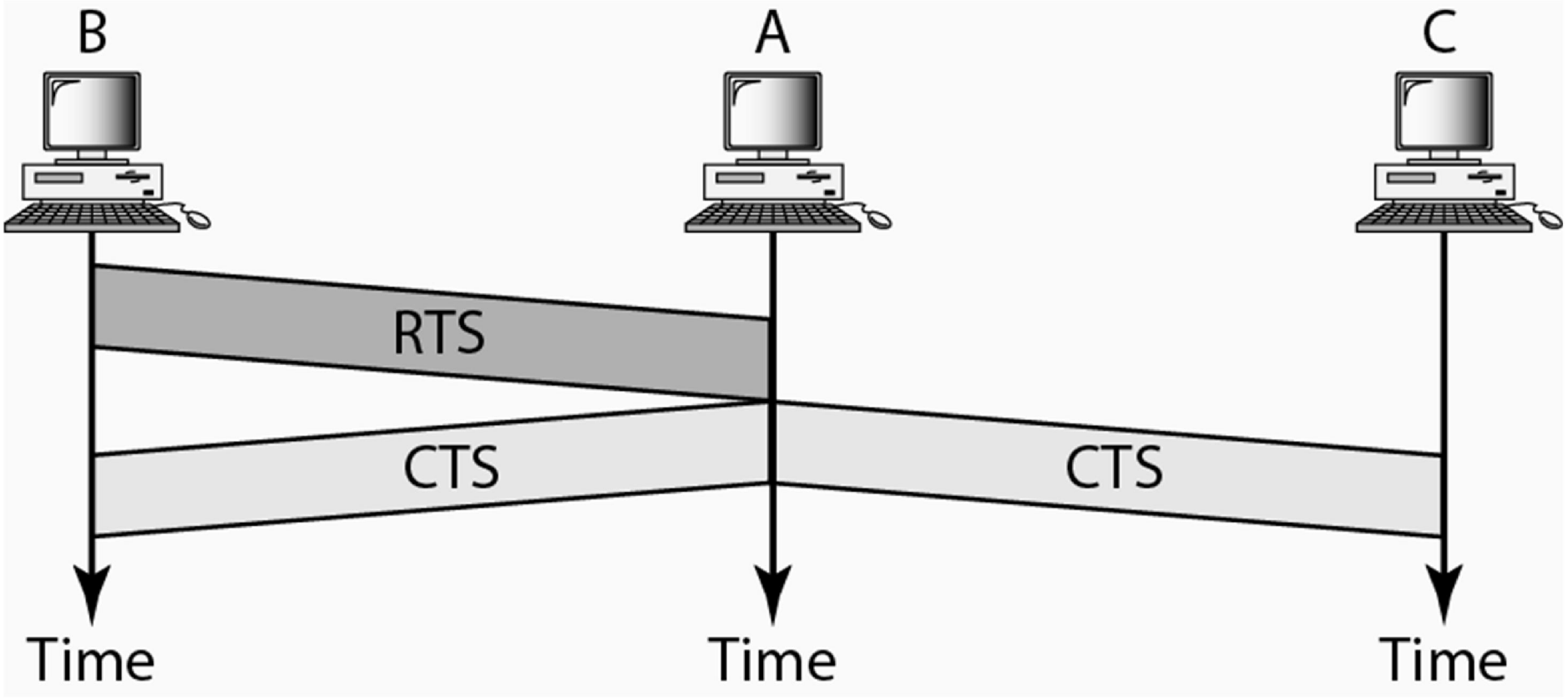
CSMA/CA

- Message exchange technique uses two messages:
  - *Ready To Send* (**RTS**) and *Clear To Send* (**CTS**).
- The timers used are called:
  - *Short Inter-Frame Space* (**SIFS**) and *Distributed Inter-Frame Space* (**DIFS**) and,
  - *Network Allocation Vector* (**NAV**).
- These will be explained in class with reference to following slide.

Operation of CSMA/CA

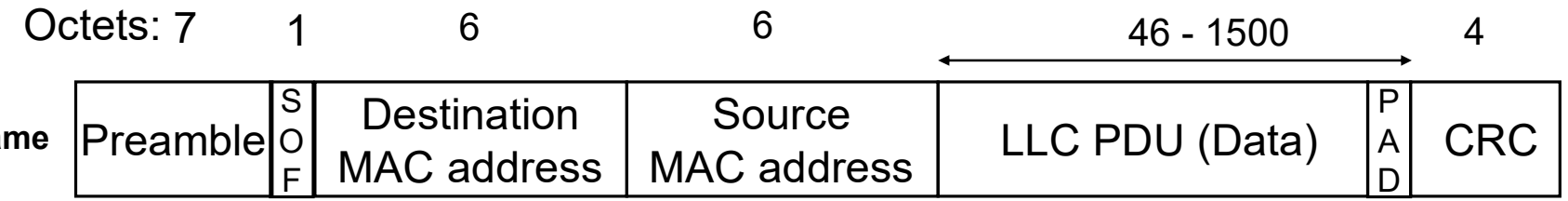


CSMA/CA for Hidden Station

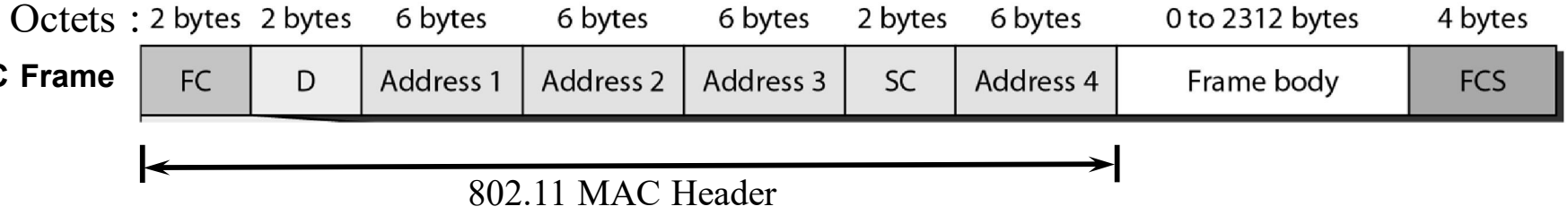


MAC Frame Formats

802.3 MAC Frame



802.11 MAC Frame



802.5 MAC Frame