CEG3185 Tutorial 7

CSMA/CD and Ethernet

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Ethernet

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- Ethernet is a family of computer networking technologies for LANs. Typical Ethernet standards (e.g. IEEE 802.3) model the Physical and Data Link Layers of OSI/RM.

- Not all Ethernet standards utilize CSMA/CD MAC, the most commonly used 3 Ethernet Standards that support shared transmission medium are:
  - Ethernet: 10BASE-2, 10BASE-5, 10BASE-T
  - Fast Ethernet: 100BASE-T, 100BASE-TX
  - Gigabyte Ethernet: 1000BASE-T

- The 'BASE' refers to baseband signaling

CSMA

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- Carrier Sense Multiple Access (CSMA) is a probabilistic media access control (MAC) protocol in which a node verifies the absence of other traffic before transmitting on a shared medium.
  - Carrier Sense: A transmitter uses feedback from a receiver to determine medium status.
  - Multiple Access: Multiple stations send and receive on the shared medium.

CSMA/CD

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- CSMA/CD improves CSMA performance by **terminating transmission as soon as a collision is detected.**
  - Collision produces much higher voltage feedback than original signal on baseband buses and thus can be detected.
  - Upon detection of a collision nodes stop transmission, the time required before a retry can be attempted is shortened.

CSMA/CD

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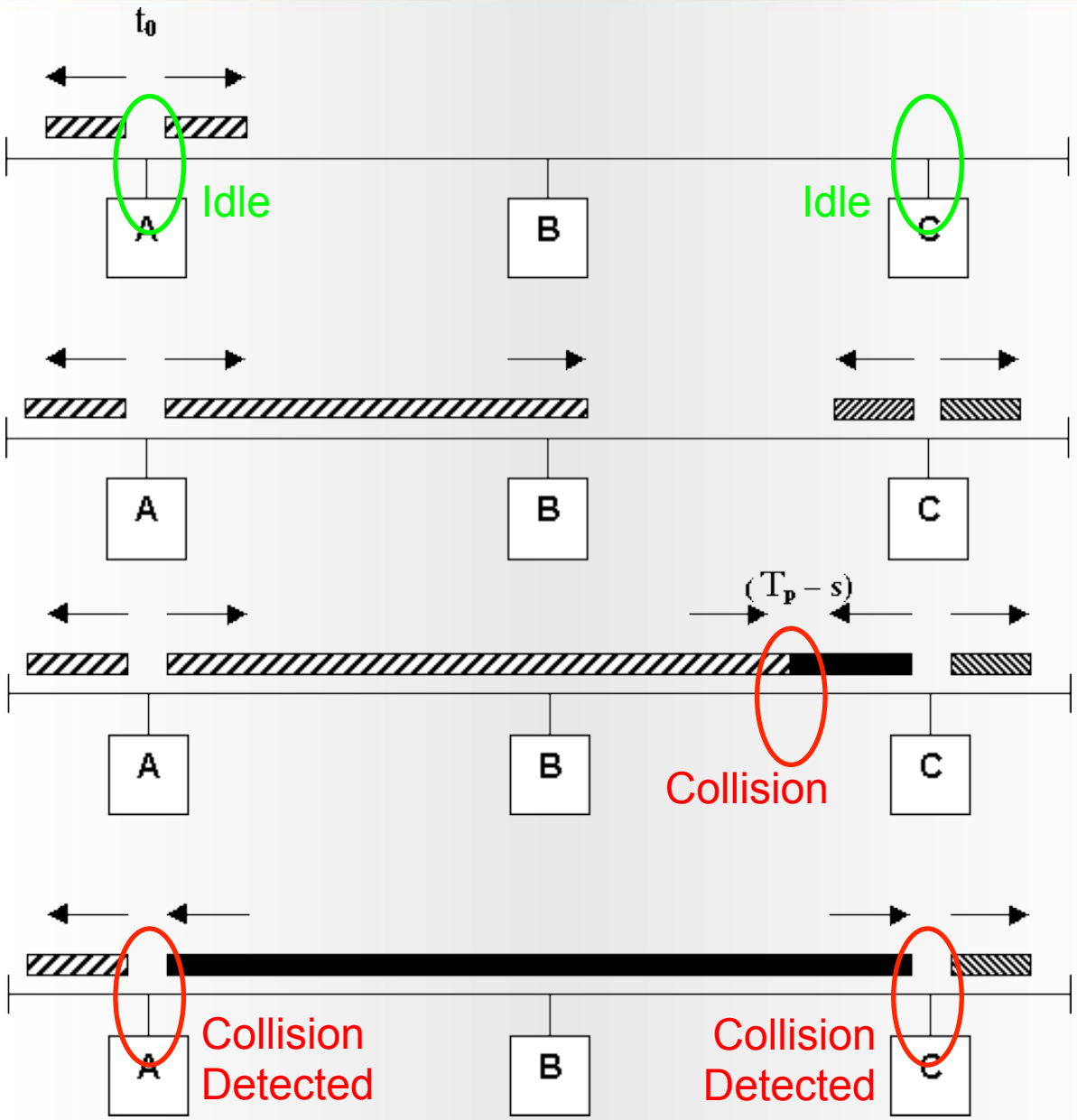
Carrier Sense

Multiple Access

Collision

Detection



Time to Detect Collisions

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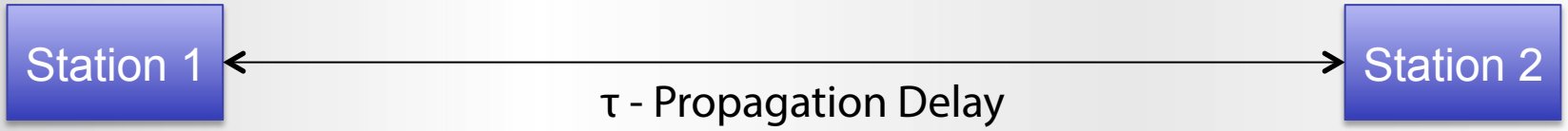

- Assume τ is the maximum one-way propagation delay on the transmission medium then if a collision occurs, it can take up to 2τ seconds for all nodes involved in the collision to detect and stop transmission.
  - Station 2 starts transmission just before the first bit from Station 1 arrives, or vice versa.

Ethernet Slot Time

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- Slot time is the time required for a signal to traverse from one end of the network to another, plus the time required to send the jam signal in case of collision.
  - For 10/100Mbps Ethernets, the slot time is 512 bit times (5.12 μs)
  - For 1Gbps Ethernet, the slot time is 4096 bit times (4.096 μs)

- Theoretically, the maximum length of an Ethernet network can be calculated by

$$\text{PropagationSpeed} \times \text{SlotTime} / 2$$

Assume the propagation speed is 2×10^8 m/s, the maximum length can be 5120m or 4096m. However, the allowed length is much shorter due to delays caused by network devices/connectors, signal attenuation, EMI, etc.

Late Collision

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- Late collision is a type of collision that occurs after the first slot time of a data transmission. According to Ethernet specifications, late collisions are not detectable. Thus the error and retransmission management is left for the upper layers of the protocol stack.

- As a correctly set up CSMA/CD network link should not have late collisions, the usual possible causes are exceeded network radius limit, or defective hardware which may result longer propagation delay or shorter frame length than the specification allowed.

Approximate Model for CSMA/CD

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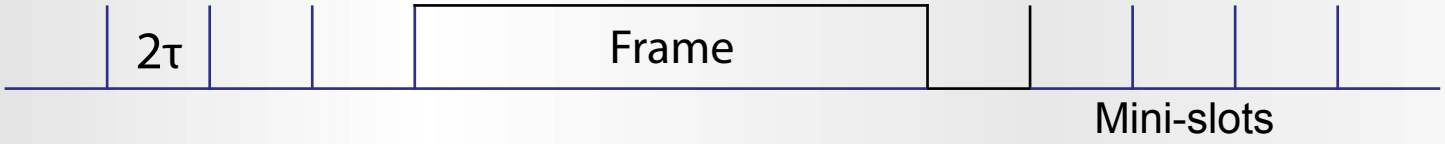
- Consider a slotted system with 'mini-slots' of duration 2τ



- For a network whose max propagation delay $\leq \tau$
  - If a node starts transmission at the beginning of a mini-slot, by the end of the mini-slot either:
    - No collision occurred, and the rest of the transmission will be uninterrupted
    - A collision occurred, but by the end of the mini-slot the channel would be idle again
  - Hence a collision at most affects on mini-slot

Analysis of CSMA/CD

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- Assume N users and that each attempts transmission during a free 'mini-slot' with probability p

$$P(i \text{ simultaneous attempts}) = \binom{N}{i} p^i (1-p)^{N-i}$$

$$P(\text{no collision}) = Np(1-p)^{N-1}$$

- To maximize *P(no collision)*

$$\frac{d}{dp}[Np(1-p)^{N-1}] = N(1-p)^{N-1} - N(N-1)p(1-p)^{N-2} = 0$$

$$\Rightarrow \quad p = {}^{1}/_{N}$$

Analysis of CSMA/CD (cont'd)

$$P(no\ collision) = (1 - {}^{1}/_{N})^{N-1}$$

$$P_s = \lim_{n \to \infty} P(no\ collision) = {}^{1}/_{e}$$

- Let X be the average number of slots per successful transmission

$$P(X = i) = (1 - P_s)^{i-1} P_s$$

$$\Rightarrow \quad E[X] = {}^{1}/_{P_s} = e$$

Analysis of CSMA/CD (cont'd)

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- Let S be the average time between successful packet transmission

$$S = (e - 1)2\tau + t_{tr} + \tau$$

Average consecutive wasted slots

Frame transmission time

Average time until start of next mini-slot

$$Efficiency = {}^{t_{tr}}/_{S}$$

- Ethernet Example
  - Data Rate = 10 Mbps
  - Packet Length = 64 Bytes, t_{tr} = 5.12*10^{-5} s
  - Network size = 2500m, propagation delay τ = 1.25*10^{-5} s

  Efficiency = 48%

Binary Exponential Backoff

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- In Ethernet, for each retransmission, the transmitter constructs a set of numbers:

  $\{0, 1, \ldots, L\}$ where L is $2^k - 1$, k = Retry < 10 ? Retry Count : 10

  - After 2 collisions, N = 2, k = 2, the set is {0, 1, 2, 3}
  - After 12 collisions, N = 12, k = 10, the set is {0, 1, 2, … , 1023}
  - The maximum allowed N is 16

- Then a random value *R* is picked from this set, and the transmitter waits for a period of *R* * (slot time)

Ethernet w/ CSMA/CD Flowchart

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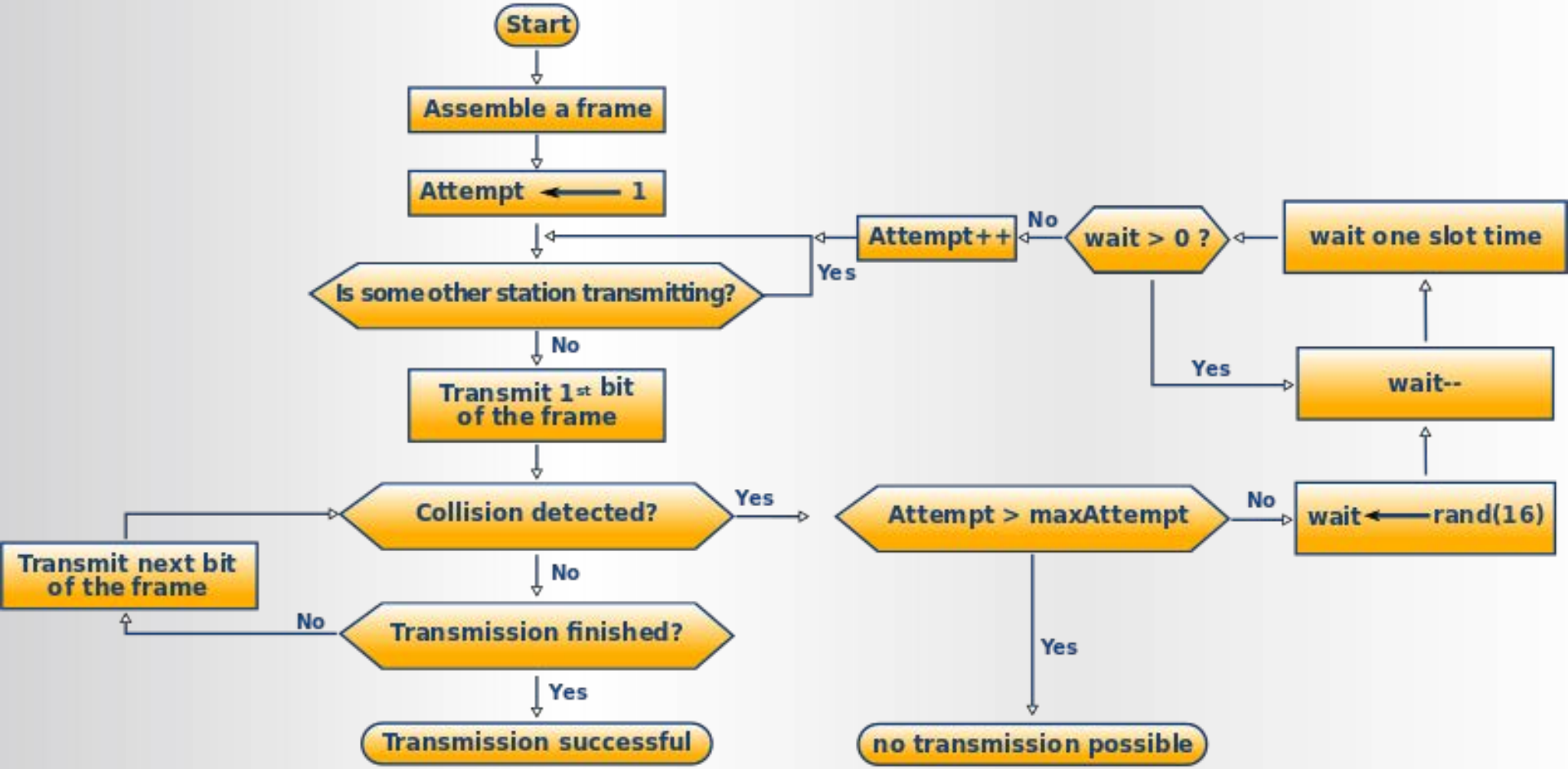

Lab 5

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- The provided framework has implemented the Physical and Data Link Layers
  - Switchable between simulated frame and real frame
  - FCS calculation and validation are not implemented

- The PDU of MAC Emulator is defined as follow

0	1 … 7	8 … 15	16 … 31
R	MAC Type	Frame Length	
Transmission Timestamp			
Location			
Real Layer 2 Frame (if R=1)			

Lab 5

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- The sample program provided is capable of demonstrating CSMA/CD with random station location and frame size. The Server simulates physical transmission.
- All collisions will be displayed on the server side:

U – Global Utilization

```
Layer 2 Emulator Server is starting ...
Emulated MAC is Ethernet with CSMA/CD
Server is listening on 0.0.0.0/0.0.0.0:1234 ...
- Auto-Negotiation Request from /127.0.0.1:52123
- Auto-Negotiation Request from /127.0.0.1:52124
[U=0.97] Node at location   234 detected collision at bit    16, the other party is at location  1120
[U=0.55] Node at location  1120 detected collision at bit    71, the other party is at location   234
[U=0.84] Node at location  1120 detected collision at bit     7, the other party is at location   234
- Auto-Negotiation Request from /127.0.0.1:52125
[U=0.78] Node at location  1120 detected collision at bit    10, the other party is at location   145
```

- CSMA/CD status will be displayed on each client:

U – Local Utilization
A – Average Attempts

```
Station location is: 1120m
Client is connected on /127.0.0.1:1234
Auto-Negotiating ... Successful!
Emulated MAC is Ethernet with CSMA/CD
[U=0.97] [A=1.00] Frame 1 Attempt  1: Transmission successful!
[U=----] [A=----] Frame 2: Medium is busy, waiting ...
[U=0.27] [A=1.00] Frame 2 Attempt  1: Collision detected at bit 71, retrying ...
[U=0.33] [A=1.50] Frame 2 Attempt  2: Transmission successful!
```

Lab 5 Requirements

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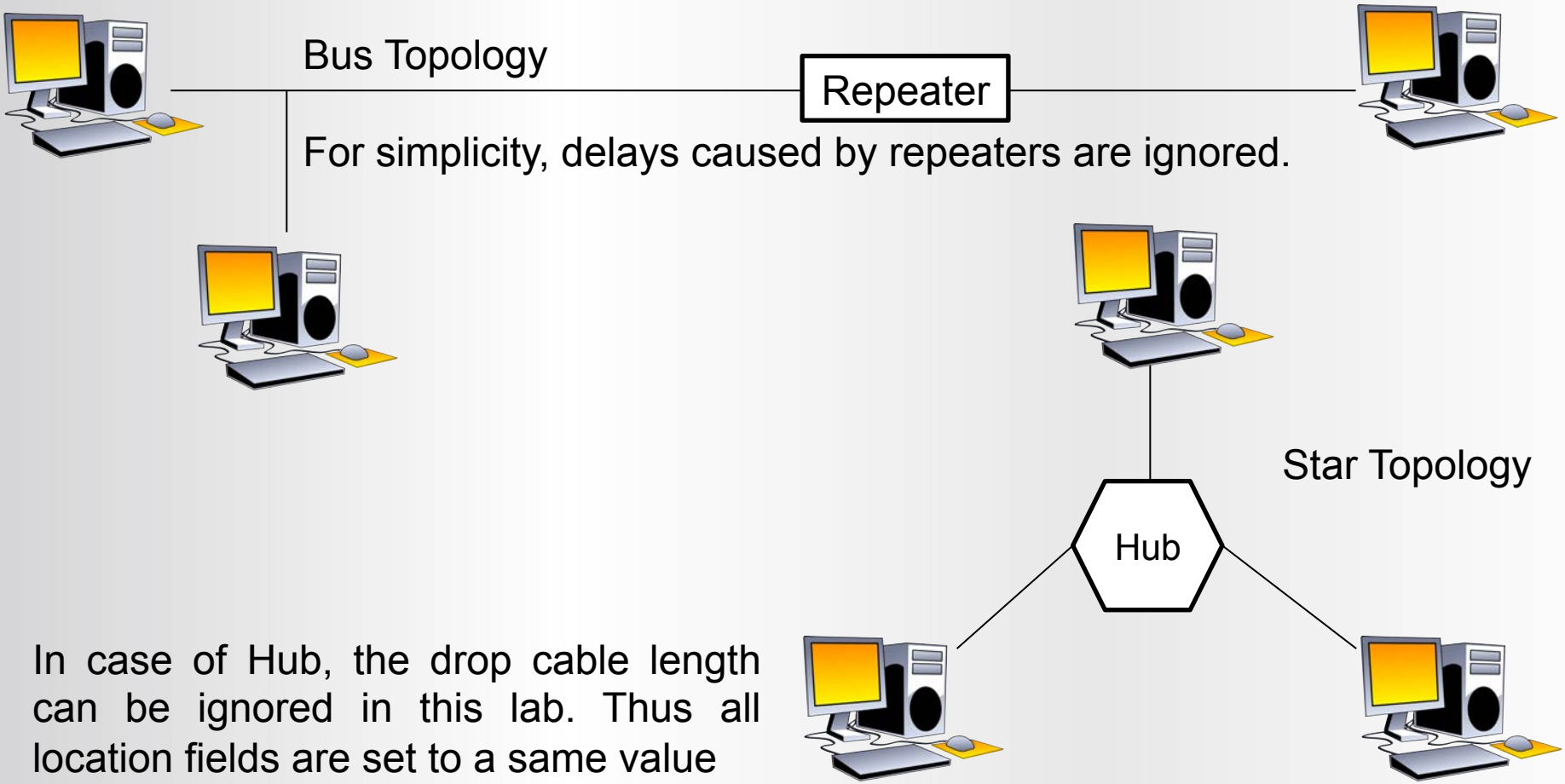
- The intended LAN is a correctly set up network which consists of at least three hosts connected to a Ethernet bus or hub, which can be simulated by three or more Java programs on the same computer or different computers.
- The CSMA/CD is used for medium access control.
- The Ethernet II frame format is used for this lab.
- The identification (MAC address) and the role (hub/medium or host) are known when a program starts up.
- The communications can be made between these computers by directly using Ethernet frames. When host B sends a message to host C, C should print the message on its screen.
- Set up another LAN consists of two hosts that will result late collision.
- The numerical results of both normal/late collision, as well as the CSMA/CD status should be calculated manually, and then compared to the simulation results.

Lab 5 Assumptions

- Two topologies can be simulated for the Ethernet on a shared transmission:



In case of Hub, the drop cable length can be ignored in this lab. Thus all location fields are set to a same value

Appendix: Ethernet Frame Structure

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- The established fact of Ethernet frame structure is Ethernet II

Ethernet II (aka DIX Ethernet)

IEEE 802.3

- Besides Preamble bits, there is a Inter-Frame Gap (IFG) before each transmission. The IFGs vary due to network properties.

Appendix: Ethernet Frame Structure (cont'd)

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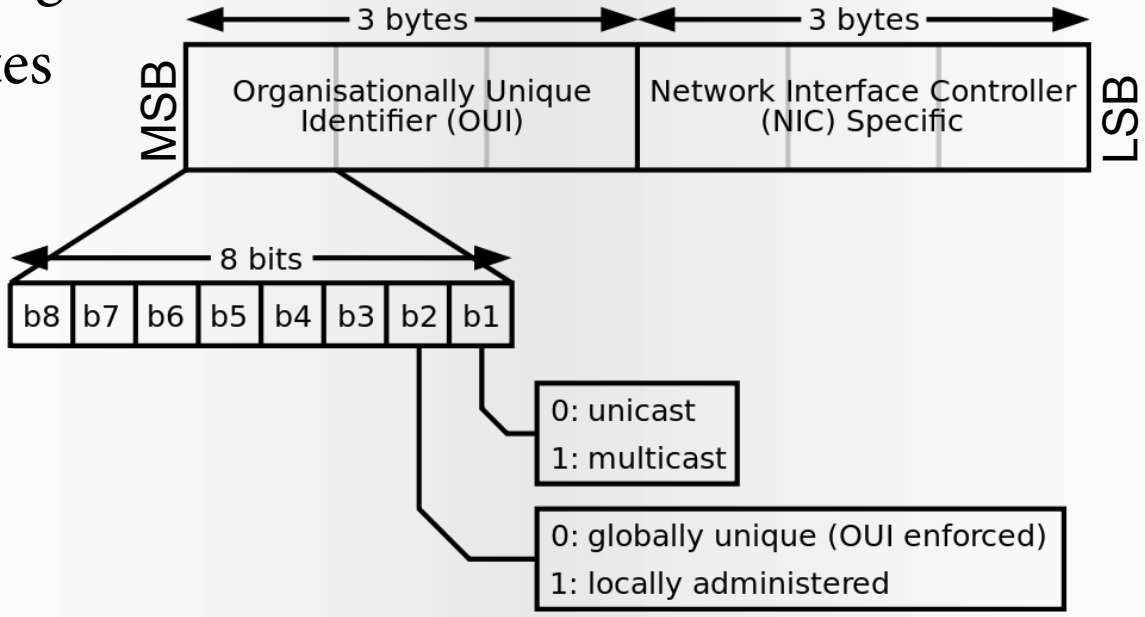
- The preamble bits are alternating 0s and 1s. They are put in by the Physical layer, used mostly for synchronization. The SOF bits indicates the first frame that is not a preamble.

- Destination Address and Source Address are both MAC address of corresponding NICs, they also indicates unicast or multicast.



Appendix: Ethernet Frame Structure (cont'd)

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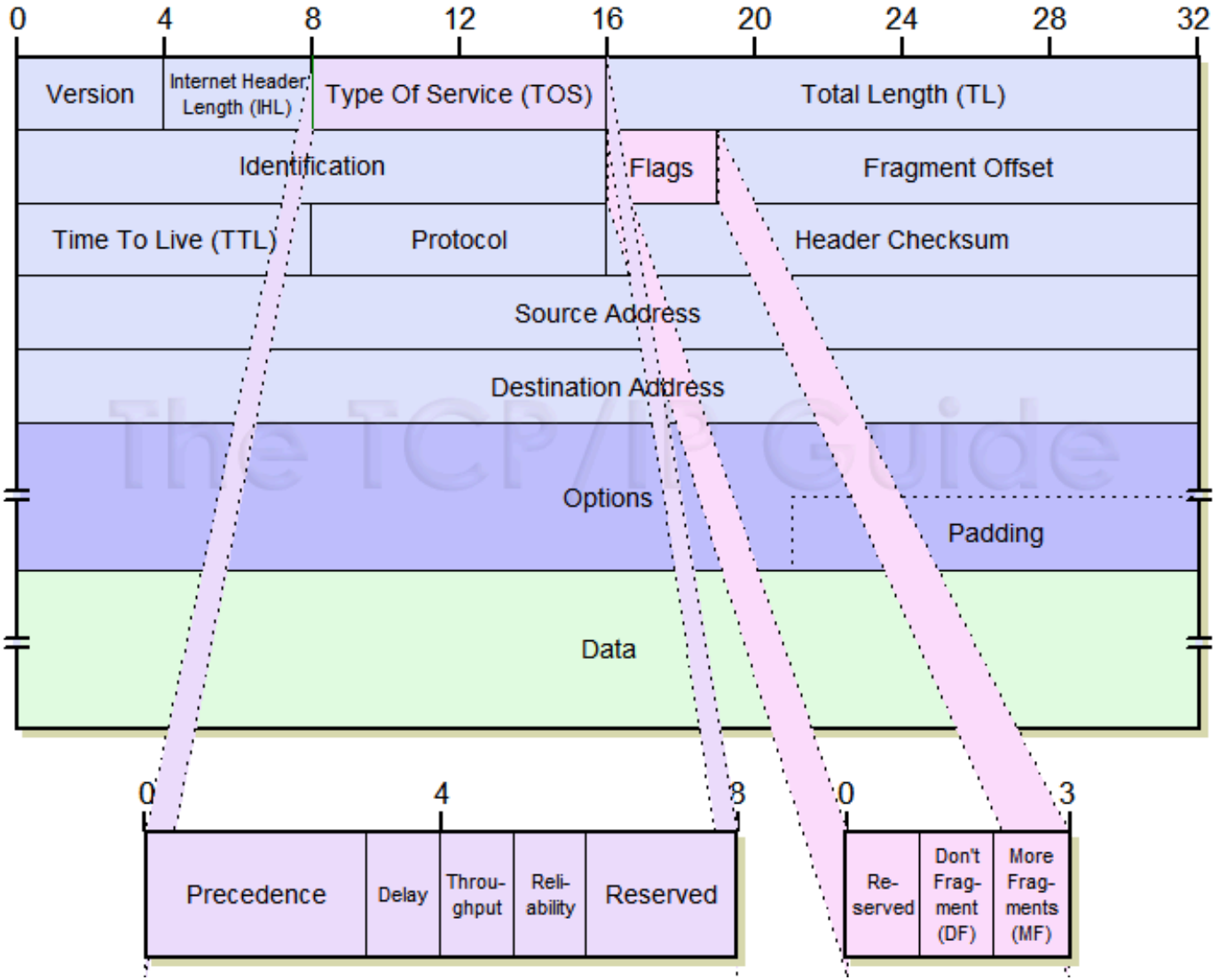
- LLC sublayer provides multiplexing mechanisms that allow different network layer protocols coexist and transported over the same medium. It can also provide flow control and error management mechanisms.
  - For Ethernet II frame, the type field is used as LSAP.
  - For IEEE 802.3 frame, The 802.2 header is used as LSAP.

  Most common LSAP values:

  0x0800 – IPv4, 0x0806 – ARP, 0x86DD – IPv6
- Data field can be a minimum of 46 bytes to a maximum of 1500 bytes. Theoretically, a jumbo frames can carry up to 12000 bytes due to the limitation of CRC-32, 9000 byte is commonly used size for jumbo frames.
- FCS is a 4 bytes CRC-32 checksum of the frame payload.

Appendix: IP version 4



Appendix: ARP

- Address Resolution Protocol (ARP) is used for resolution of Network Layer address into Data Link layer.
- In this Lab, we only inclined to implement its minimum functionality. We should maintain a static ARP table for address resolution at each station, this can be simply implemented with an array.

Appendix: DNS

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- Domain Name System (DNS) translates easily memorized domain names to numerical IP addresses.
- In this Lab, we only inclined to implement its minimum functionality. We should maintain a static DNS table for address resolution at the server side, this can be simply implemented with Java enum.
- IPv4 address is a 32-bit binary number. Notations like 173.194.36.48 is called dotted-decimal notation, they are equivalent to unsigned integer representation like 2915181616, try http://2915181616 in your browser ☺

Appendix: More Information about Lab 5

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- The lab can be conducted in a group of three students.
- One lab report is required per group to detail the design of the system, all assumptions made, algorithms (flowcharts) for the hub and hosts, and all other information needed for the design and implementation.

- The Java programs for both the hub and hosts must be submitted. Sufficient comments should be added in the source codes.