THE UNIVERSITY OF MELBOURNE

Week6 Data-Link Layer and Network Layer

COMP90007 Internet Technology

Prepared by: Chenyang Lu (Luke)

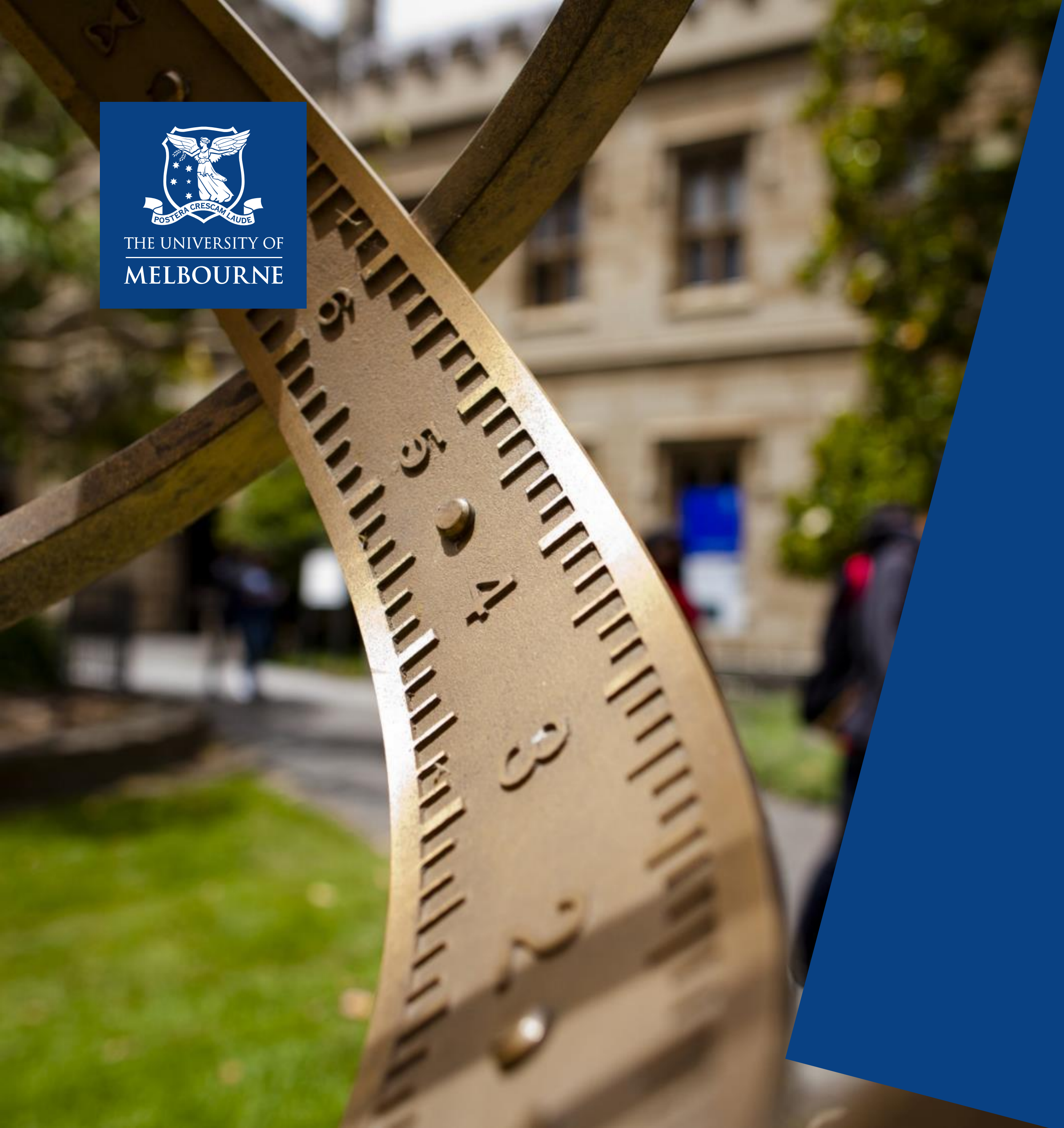
Your Tutor

Chenyang Lu (Luke)

- Email: chenyang.lu@unimelb.edu.au

- Workshop Slides: https://github.com/LuChenyang3842/Internet-technology-teaching-material

Day	Time	Location
Tue	18:15	Bouverie st –B114
Wed	10:00	Elec Engineering -122
Wed	17:15	Bouverie-sr 132



THE UNIVERSITY OF MELBOURNE

Data-Link Layer

Data Link Layer

TCP/IP Model

Application
Transport
Network
Data Link
Physical

Function of Data link layer:

- Provide service to network layer
- Transmission control
- Error Control

Primary Method:

- Take packets from network layer
- Encapsulate them into frames

This terminology only used in Datalink Layer

Data Link Layer

TCP/IP Model

Application

Transport

Network

Data Link

Physical

1. Framing methods
    - Character Count
    - Flag Bytes with Byte stuffing
    - Flag with Bit stuffing
2. Error Control
    - Error Bounds (Hamming Distance)
    - Detecting (parity, checksum, CRC)
    - Correcting (Hamming code)
    - Re-transmission
3. Flow Control
    - Feedback Based Flow Control
        - Stop and wait
        - Sliding window
    - ~~Rate based flow control~~

Error Control – Error Bound (Hamming distance)

Hamming distance :

- **minimum** **bit flips** to turn one **valid** codeword into another valid one
- Correct d errors : d = $\frac{n-1}{2}$(n: hamming distance)
- Detect d error where d = n - 1 (n: hamming distance)

Error Control

❑ Parity(1bit)

- Add one check bit use XOR
- Even parity (XOR every bit to be 0)
- Odd Parity (XOR every bit to be 1)
- Hamming distance = 2
- Example for even parity:

    111111110

    111111101

XOR

	0	0	1	1
^	0	1	0	1
	0	1	1	0

❑ Checksum(16 bit)

- Add 16 bits of data (calculate 1's complement)
- Hamming distance = 2

❑ Cyclic Redundancy Check

Error Control – Error Detecting Code (Checksum)

❑ Cyclic Redundancy Check

- Based on generator polynomial G(x) --- (Don't need to know the detail of G(x), will be prvided)

1. Determine **bits polynomial** based on generator,
   1. For $G(x) = x^4 + x^1 + 1$, the bits polynomial is 10011.
   2. For $G(x) = x^5 + x^2 + 1$, the bits polynomial is 100101
2. Determine **r**. (The degree of G(x), same as the length of bits polynomial -1)
   1. For $G(x) = x^4 + x^1 + 1$, r = 4
   2. For $G(x) = x^5 + x^2 + 1$, r =5
3. Append r zeros into the frame
4. using **modulo 2 division** (frame with r zero appended divided by bits polynomial)
5. subtract the r bits remainder Frame with r zero appended using modulo 2 substraction. (Same as append remainder r bits to the end of frame)

- Hamming distance = 2

Question2 - CRC

Using the polynomial code method, compute the CRC for the frame: 1101011111 having a generator polynomial $G(x) = x^4 + x^1 + 1$

Step1: generate bits polynomial: 10011

Step2: determine r = 4

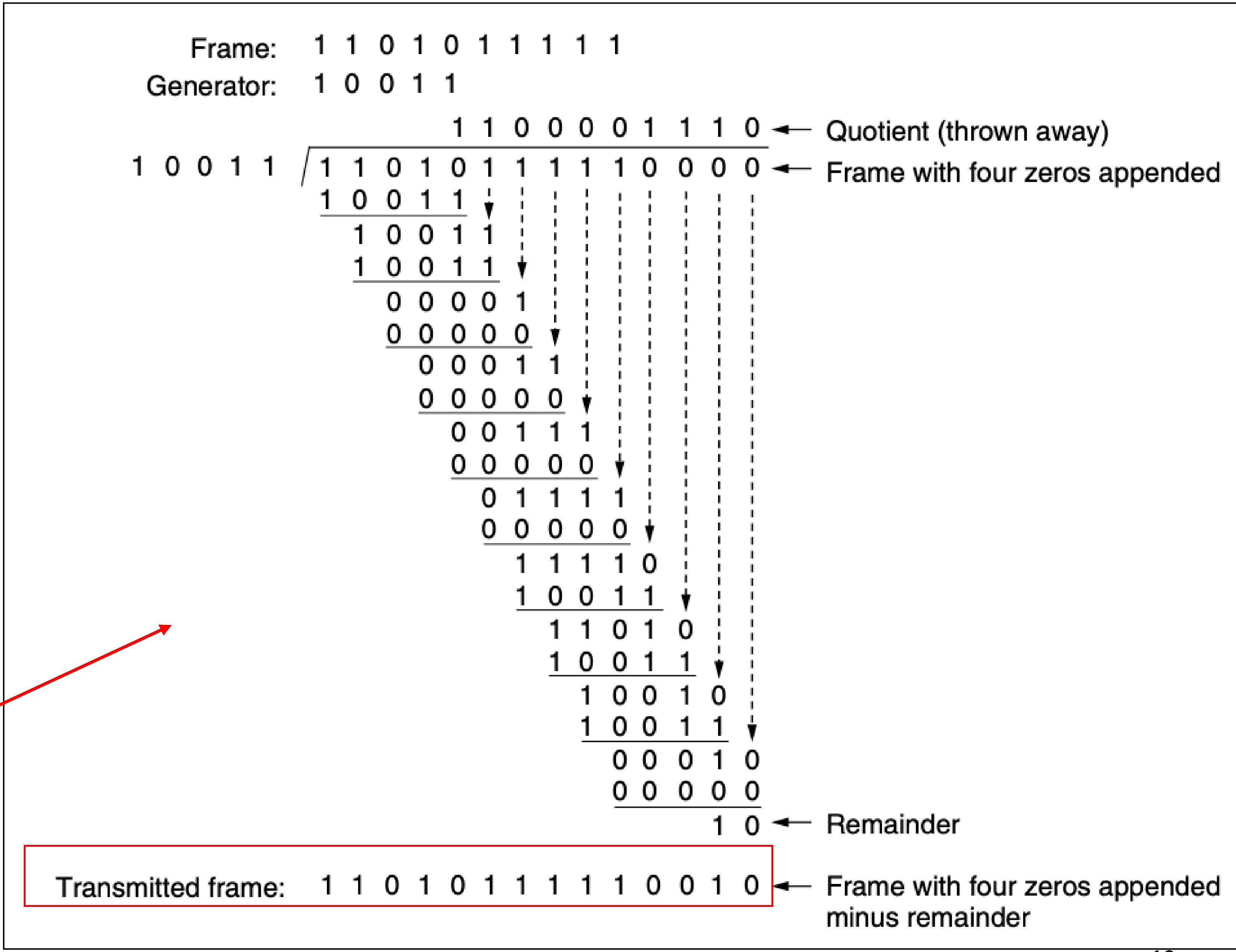
Step3: append r zeros at the end of the bit string: 11010111110000

Step4: bit string divided by bit polynomial using modulo 2 division

Step5: subtract the r bits remainder Frame with r zero appended using modulo 2 substraction.

(Same as append remainder r bits to the end of frame)

- Step1: bits polynomial: 10011
- Step2: R = 4
- Step3: append r zeros at the end of the bit string: 11010111110000
- Step4: bit string divided by bit polynomial <u>using modulo 2 division</u>
- Step5: subtract the r bits remainder Frame with r zero appended using <u>modulo 2 substraction.</u>



On the receiver side, they use transmitted data divided by bit polynomial using modulo 2 division

- if the remainder is 0, there no error detected
- If the remainder is not 0, some error occurs during transmission

Video of CRC (12minutes): https://www.youtube.com/watch?v=6gbkoFciryA
Modulo 2 Division and substraction: https://hubpages.com/technology/Modulo-2-Arithmetic

Error Control – Error Correcting Code Hamming code

- Hamming distance = 3
- We need to put check bits in position p that are power of 2

A byte of data: 10011010
Create the data word, leaving spaces for the parity bits: _ _ 1 _ 0 0 1 _ 1 0 1 0
Calculate the parity for each parity bit (a ? represents the bit position being set):

- Position 1 checks bits 1,3,5,7,9,11:
  ? _ 1 _ 0 0 1 _ 1 0 1 0. Even parity so set position 1 to a 0: 0 _ 1 _ 0 0 1 _ 1 0 1 0
- Position 2 checks bits 2,3,6,7,10,11:
  0 ? 1 _ 0 0 1 _ 1 0 1 0. Odd parity so set position 2 to a 1: 0 1 1 _ 0 0 1 _ 1 0 1 0
- Position 4 checks bits 4,5,6,7,12:
  0 1 1 ? 0 0 1 _ 1 0 1 0. Odd parity so set position 4 to a 1: 0 1 1 1 0 0 1 _ 1 0 1 0
- Position 8 checks bits 8,9,10,11,12:
  0 1 1 1 0 0 1 ? 1 0 1 0. Even parity so set position 8 to a 0: 0 1 1 1 0 0 1 0 1 0 1 0
- Code word: 011100101010.

Data Link Layer

TCP/IP Model

Application

Transport

Network

Data Link

Physical

1. Framing methods
    - Character Count
    - Flag Bytes with Byte stuffing
    - Flag with Bit stuffing
2. Error Control
    - Error Bounds (Hamming Distance)
    - Detecting (parity, checksum, CRC)
    - Correcting (Hamming code)
    - Re-transmission
3. Flow Control
    - Feedback Based Flow Control
        - Stop and wait
        - Sliding window
    - ~~Rate based flow control~~

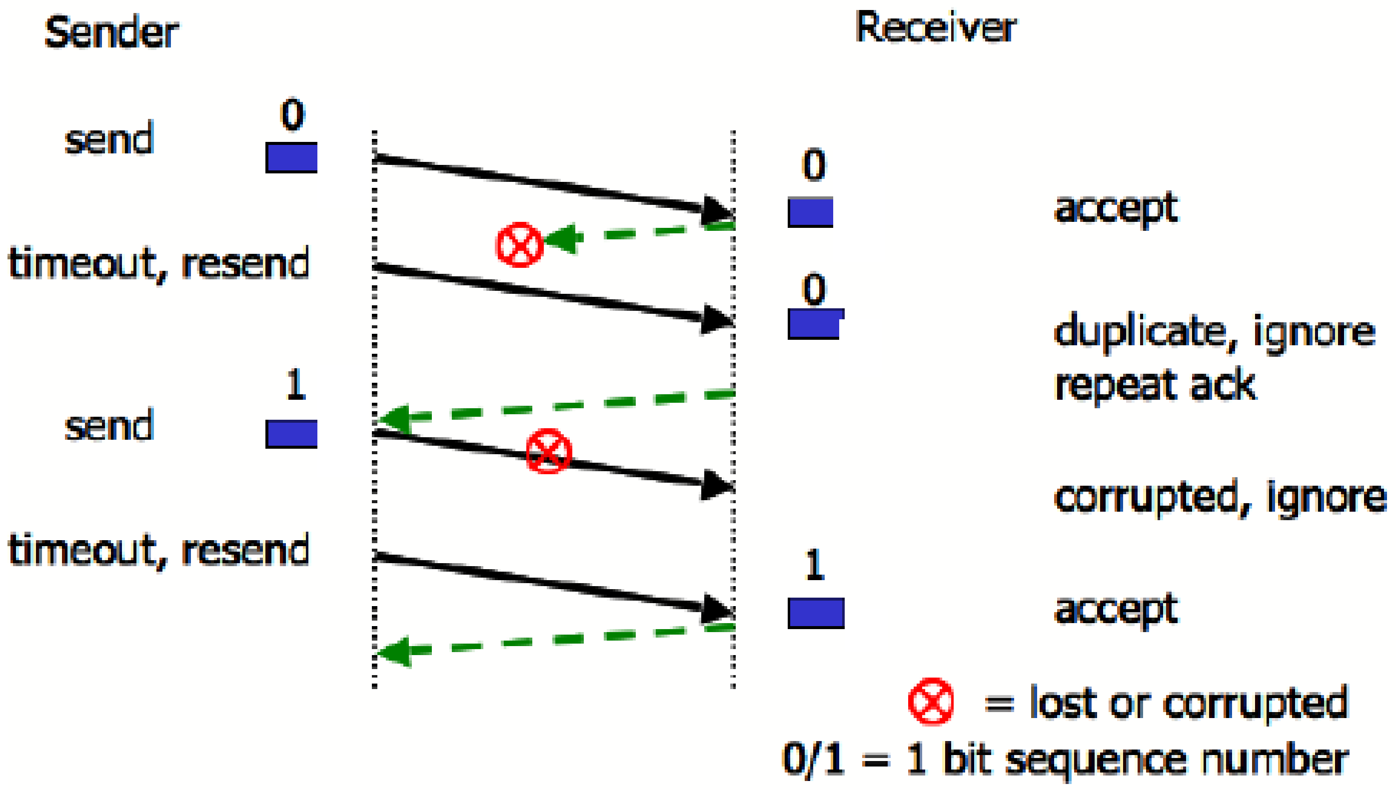
Data Link Layer

TCP/IP Model

- **Application**
- **Transport**
- **Network**
- **Data Link**
- **Physical**

1. Framing methods
   - Character Count
   - Flag Bytes with Byte stuffing
   - Flag with Bit stuffing
2. Error Control
   - Error Bounds (Hamming Distance)
   - Detecting (parity, checksum, CRC)
   - Correcting (Hamming code)
   - Re-transmission
3. Flow Control
   - Feedback Based Flow Control
     - Stop and wait
     - Sliding window
   - ~~Rate based flow control~~

Flow Control – Stop and wait



- Send one data unit at one time
- If Ack, then send another.
- If timeout, send the same one again

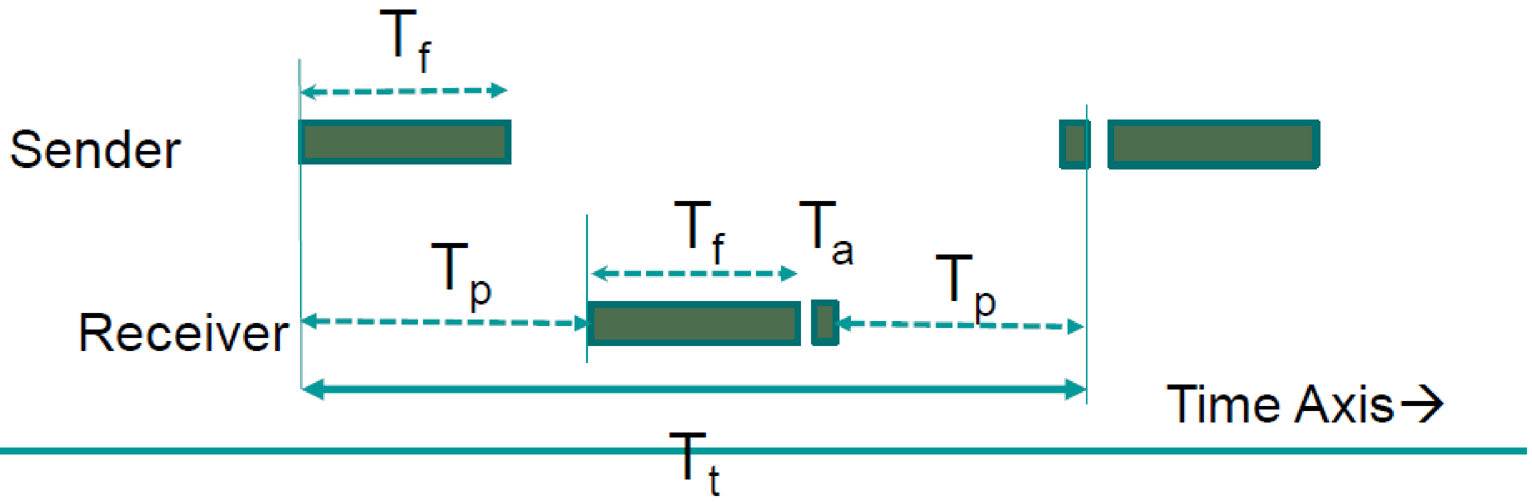
Flow Control – Stop and wait (Efficiency)

$$Efficiency = \frac{Tranmission\ Delay}{Total\ Latency} = \frac{T_f}{T_t}$$

$$T_f = \frac{Length(size)\ of\ Frame}{Bit\ rate} = \frac{L}{B}$$

$$T_t = T_f + 2T_p + T_a = T_f + 2T_p$$

T_f = *Time for transmitting an ACK, assume to be zero*



Question1

A channel has a bit rate of <u>4 kbps</u> and a propagation delay of <u>20 ms.</u> For what range of frame sizes does stop-and-wait give an efficiency of at least 50 percent?

$$Efficiency = \frac{Tranmission\ Delay}{Total\ Latency} = \frac{T_f}{T_t}$$

$$T_f = \frac{Length(size)\ of\ Frame}{Bit\ rate} = \frac{L}{B}$$

$$T_t = T_f + 2T_p$$

Question1

A channel has a bit rate of 4 kbps and a propagation delay of 20 ms. For what range of frame sizes does stop-and-wait give an efficiency of at least 50 percent?

$$Efficiency = \frac{Tranmission\ Delay}{Total\ Latency} = \frac{T_f}{T_t}$$

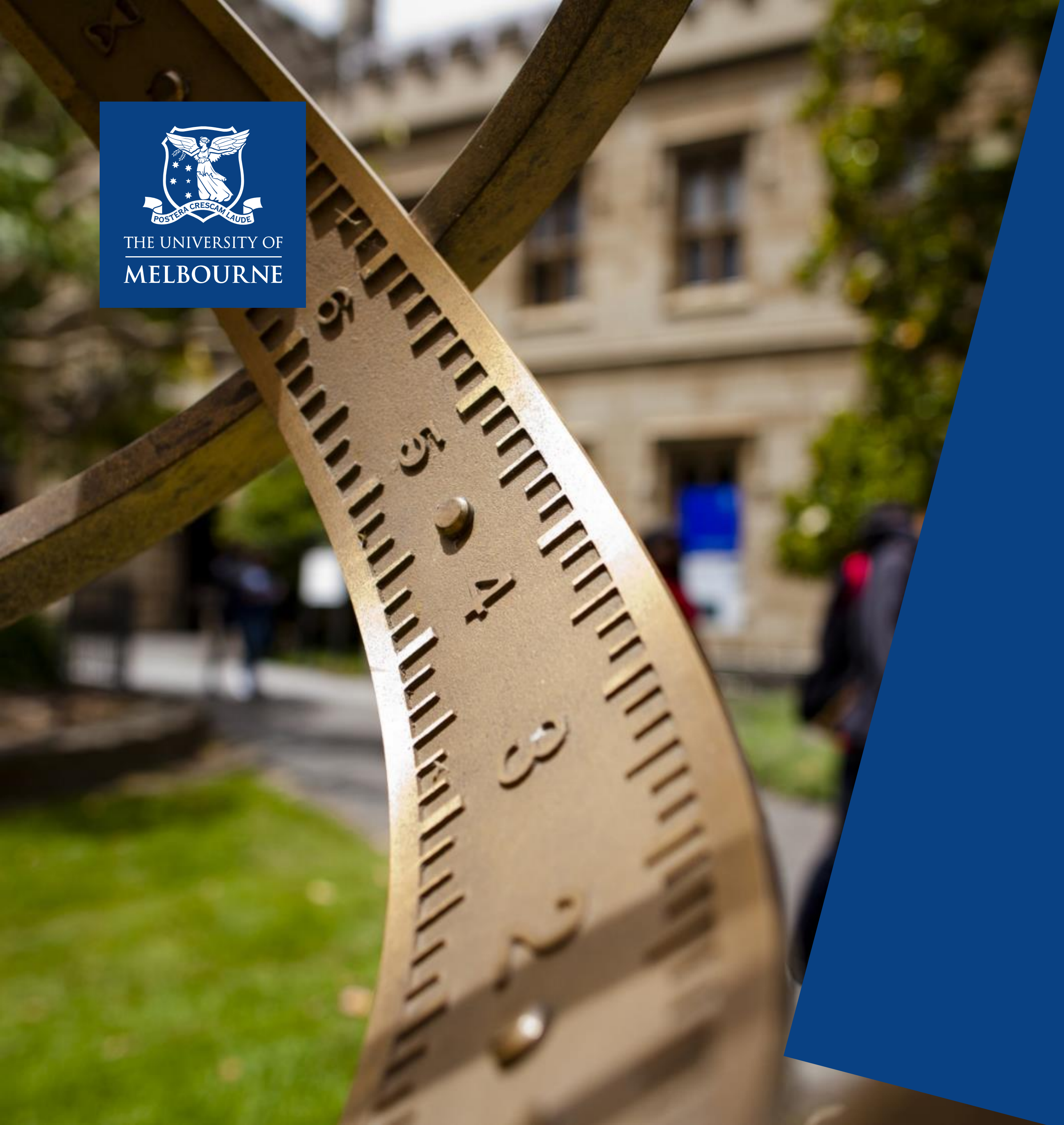
L > 160bits

Data Link Layer

TCP/IP Model

- **Application**
- **Transport**
- **Network**
- **Data Link**
- **Physical**

1. Framing methods
   - Character Count
   - Flag Bytes with Byte stuffing
   - Flag with Bit stuffing
2. Error Control
   - Error Bounds (Hamming Distance)
   - Detecting (parity, checksum, CRC)
   - Correcting (Hamming code)
   - Re-transmission
3. Flow Control
   - Feedback Based Flow Control
     - Stop and wait
     - Sliding window
   - ~~Rate based flow control~~



THE UNIVERSITY OF MELBOURNE

MAC Sub-Layer

Data Link Layer

TCP/IP Model

Application
Transport
Network
Data Link
MAC SUB-Layer
Physical

Question: What is MAC Sub-Layer and what is the function of MAC Sub-Layer

Data Link Layer

TCP/IP Model

Application
Transport
Network
Data Link
MAC SUB-Layer
Physical

Medium Access Control Sub-Layer:

- Lives near the bottom of data link layer
- Control how we can allocate multiple users over a single shared channel in a broadcast

Data Link Layer

TCP/IP Model

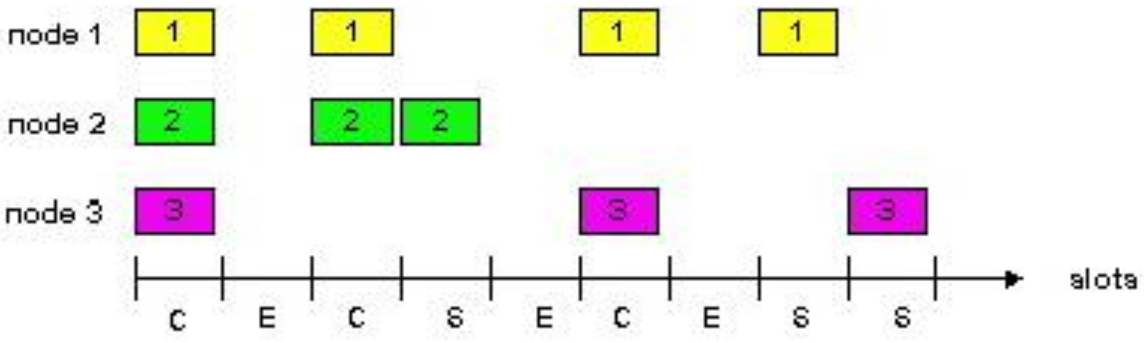
Application
Transport
Network
Data Link
MAC SUB-Layer
Physical

1. **Contention**
   - **ALOHA**
   - **Carrier Sense Multiple Access (CSMA)**
2. Collision Free
   - CSMA/CD – Binary Countdown
   - CSMA/CD - bit map
3. Limited Contention
   - CSMA/CD - Adaptive Tree Walk Protocol
4. MACA/MACAW (for Wireless LANs)

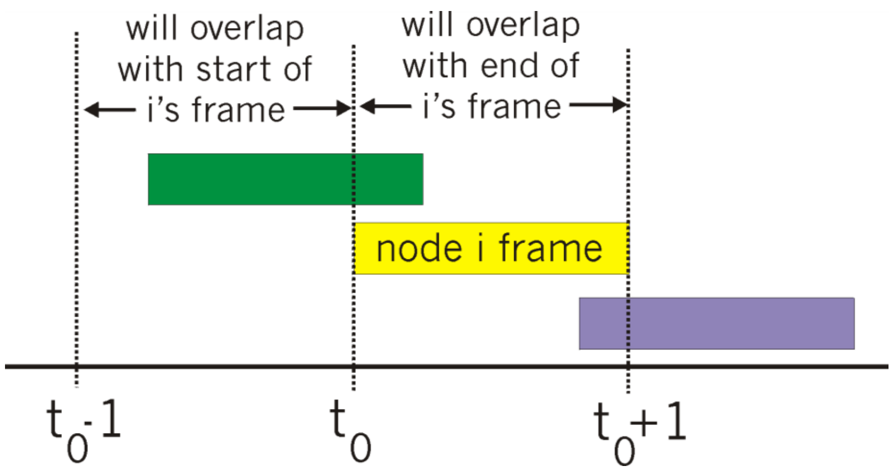
Contention - ALOHA

- Two types of ALOHA, Pure and slotted
- **The basic idea** :
  - Users transmit whenever they have data to be sent.
  - Deal with collisions when the come and wait random time (random) and retransmit

Slotted ALOHA

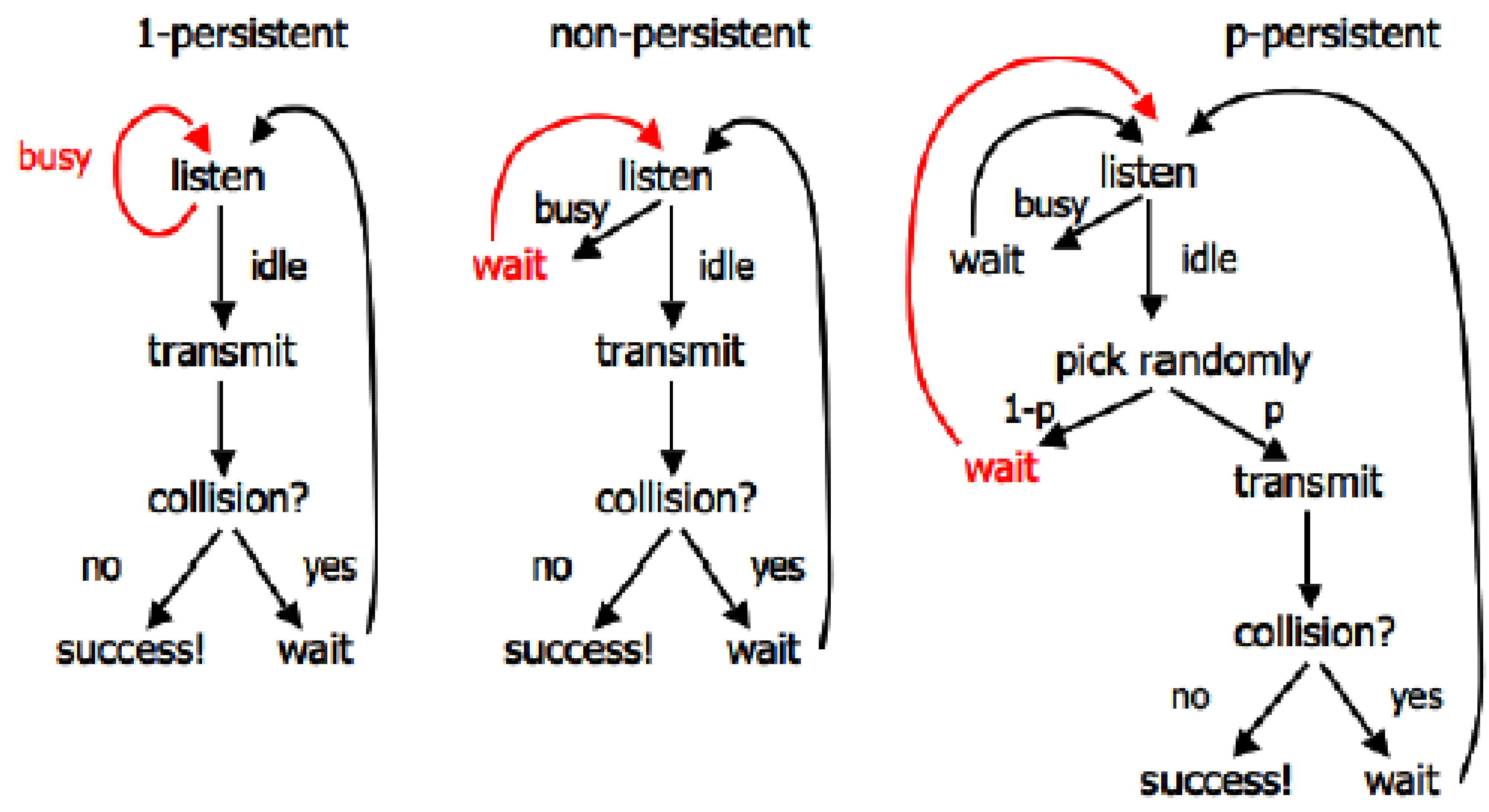


Unslotted ALOHA



Contention – CSMA (Carrier Sense Multiple Access)

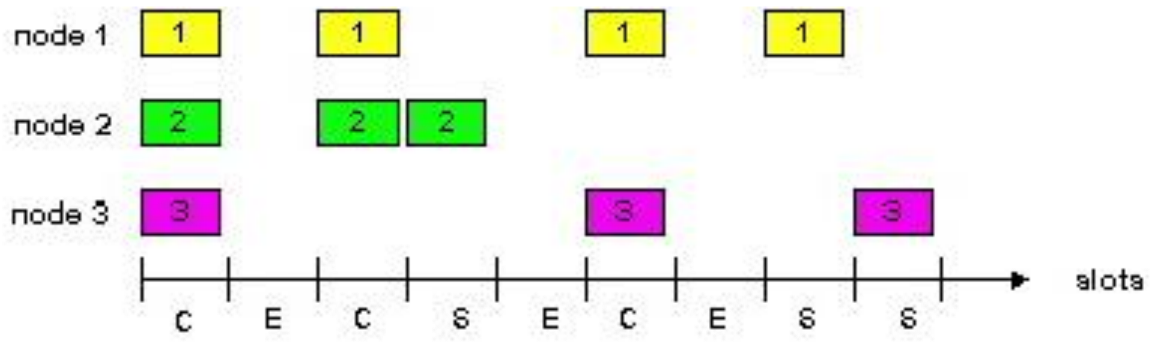
Stations listen for a carrier (i.e., a transmission) and act accordingly are called **carrier sense protocols**.



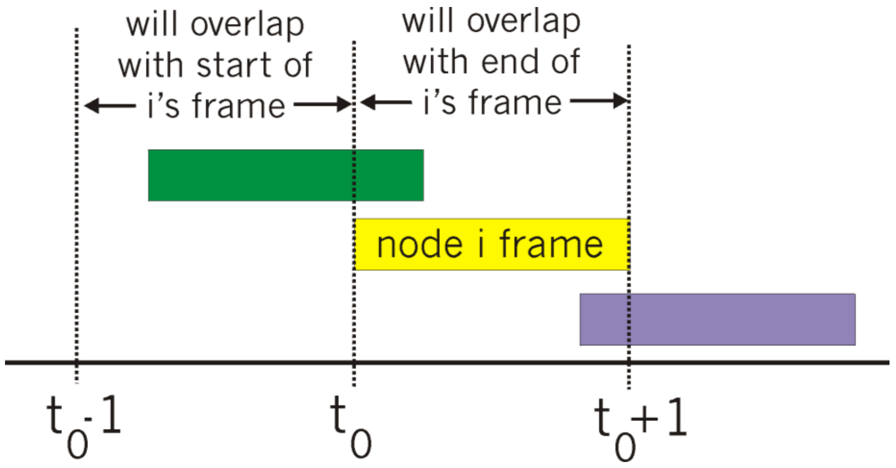
Question3

Consider the delay of pure ALOHA versus slotted ALOHA at low load. Which one is less? Explain your answer.

Slotted ALOHA



Unslotted ALOHA



Question3

Consider the delay of pure ALOHA versus slotted ALOHA at low load. Which one is less? Explain your answer.

- With slotted ALOHA, it has to wait for the next slot. This introduces half a slot time of delay.
- With pure ALOHA, transmission can start instantly. <u>At low load with minimal collisions, pure ALOHA will have less delay.</u>

At higher loads, there is more probability for collisions in pure ALOHA compared to slotted ALOHA. This is because frames can collide in midway. By enforcing synchronization, slotted ALOHA is able to achieve much greater efficiency.

Data Link Layer

TCP/IP Model

Application

Transport

Network

Data Link

MAC SUB-Layer

Physical

1. Contention
   - ALOHA
   - Carrier Sense Multiple Access (CSMA)
2. **Collision Free**
   - **CSMA/CD – Binary Countdown**
   - **CSMA/CD - bit map**
3. Limited Contention
   - CSMA/CD - Adaptive Tree Walk Protocol
4. MACA/MACAW (for Wireless LANs)

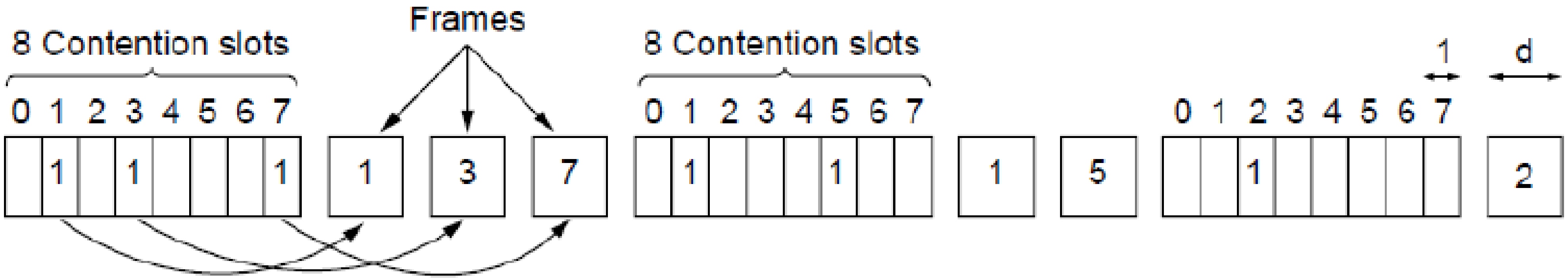
Collision Free – CSMA with Collision Detection

- Imagine two stations sense the channel to be idle and begin transmitting simultaneously, their signals will still collide.
- Another improvement is for the stations to quickly detect the collision and abruptly stop transmitting. This protocol is known as **CSMA/CD (Collision Detection)**

Collision Free – CSMA/CD (bit map protocol)

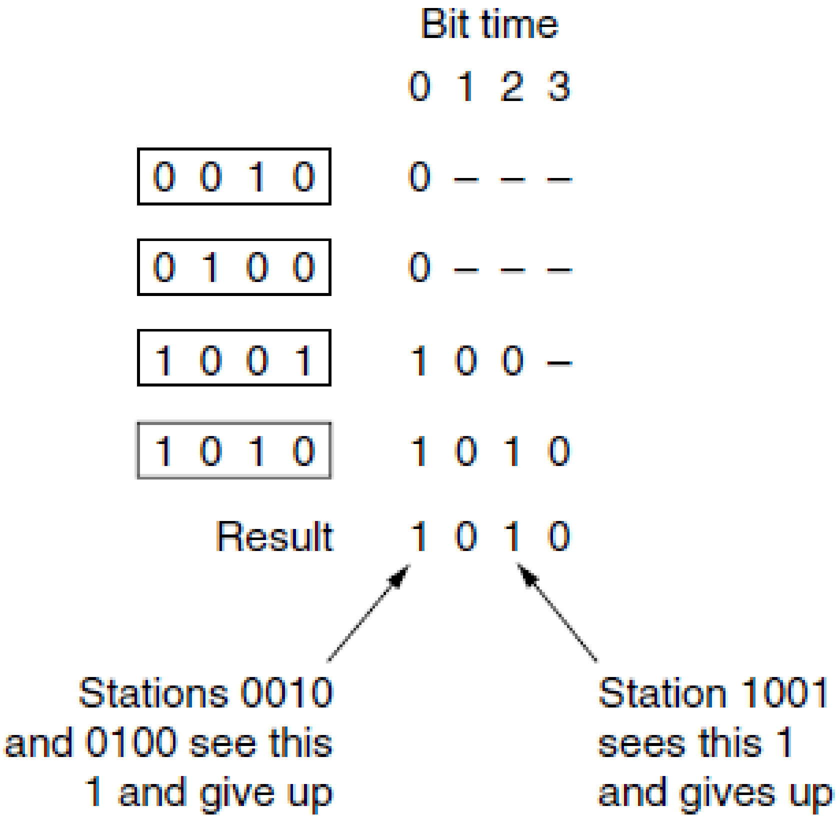
a. Bit-map method –'reservation during the contention time (reservation interval)

Protocols like this in which the desire to transmit is broadcast before the actual transmission are called **reservation protocols** because they reserve channel ownership in advance



Collision Free – CSMA/CD (Binary Countdown)

b. Binary Count Down method



Station send their address in contention slot (log2N bits instead of N)

Data Link Layer

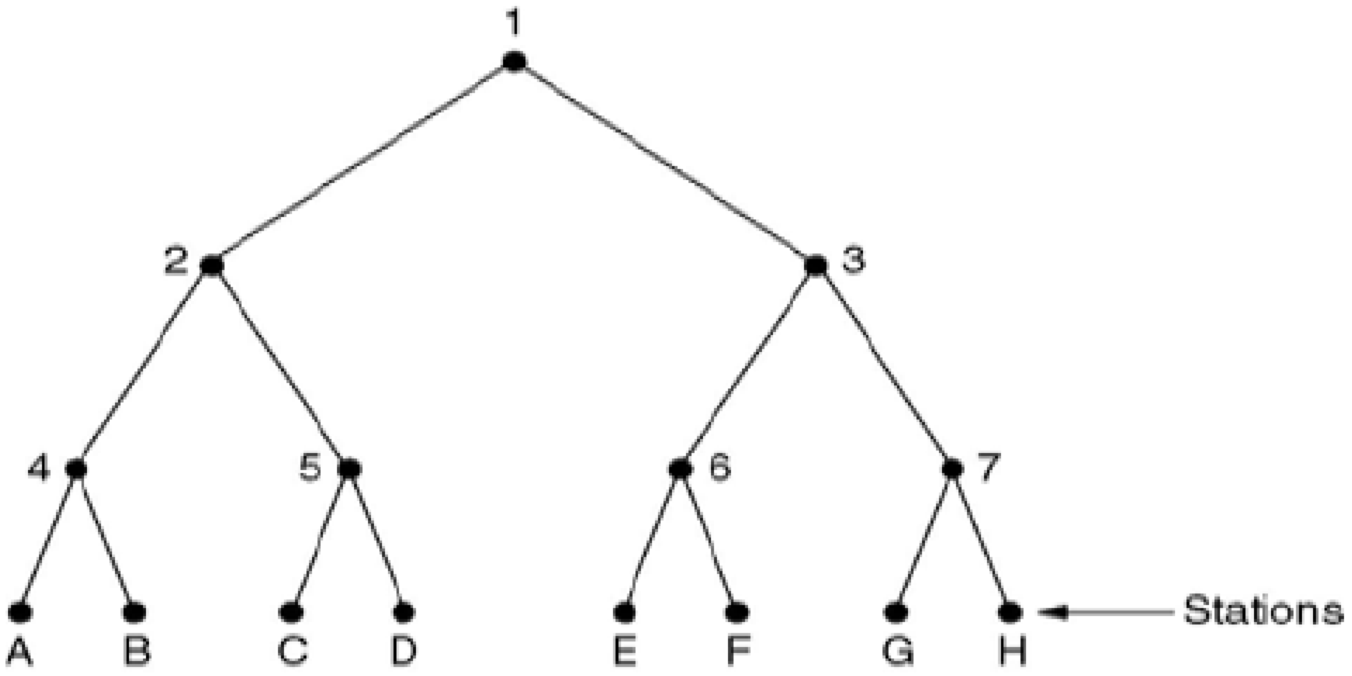
TCP/IP Model

- **Application**
- **Transport**
- **Network**
- **Data Link**
  - **MAC SUB-Layer**
- **Physical**

1. Contention
   - ALOHA
   - Carrier Sense Multiple Access (CSMA)
2. Collision Free
   - CSMA/CD – Binary Countdown
   - CSMA/CD - bit map
3. **Limited Contention**
   - **CSMA/CD - Adaptive Tree Walk Protocol**
4. MACA/MACAW (for Wireless LANs)

Limited- Contention protocols – Adaptive Tree Walk Protocol

Adaptive Tree Walk Protocol –evenly distribute the resource (depth first search)



Example 1: D G
Slot 1 → D, G – collision
Slot 2 → D
Slot 3 → G

Example 2: B D G
Slot 1 → B, D, G – collision
Slot 2 → B, D - collision
Slot 3 → B
Slot 4 → D
Slot 5 → G

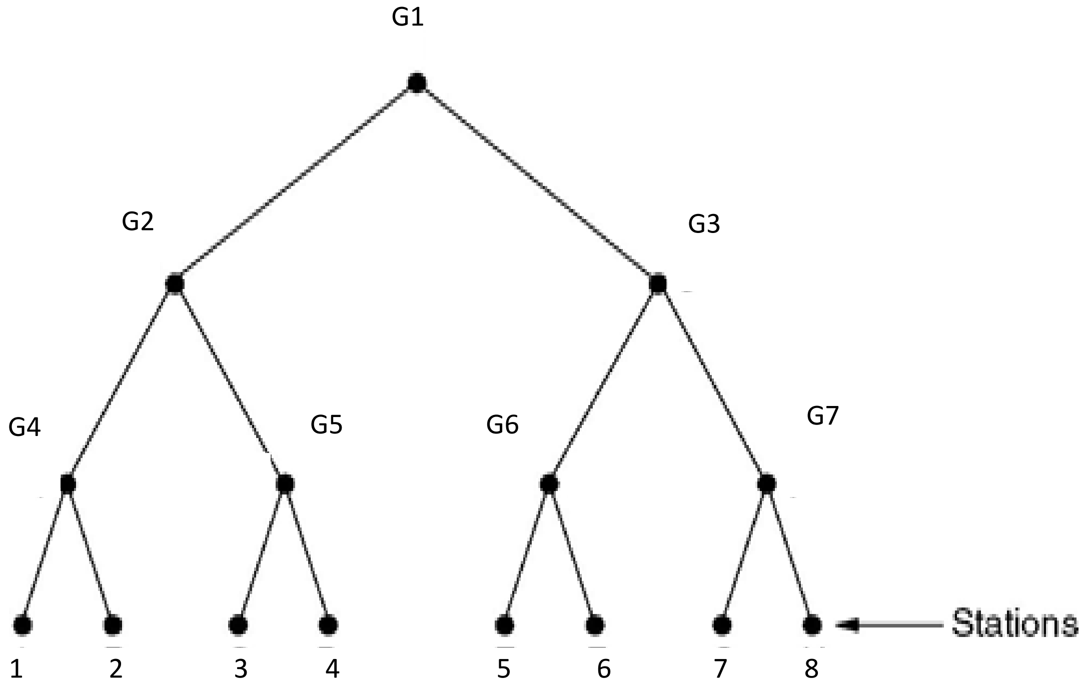
Question4

Eight stations, numbered 1 through 8, are contending for the use of a shared channel by using the adaptive tree walk protocol. If all the stations whose addresses **<u>are prime numbers</u>** suddenly became ready at once, **<u>how many slots</u>** are needed to resolve the contention?

Answer:

Stations 2,3,5,7 want to send. 7 slots are needed, with the contents of each slot being as follows:

slot 1: 2, 3, 5, 7 (collision)
slot 2: 2, 3 (collision)
slot 3: 2 (success)
slot 4: 3 (success)
slot 5: 5, 7 (collision)
slot 6: 5 (success)
slot 7: 7 (success)



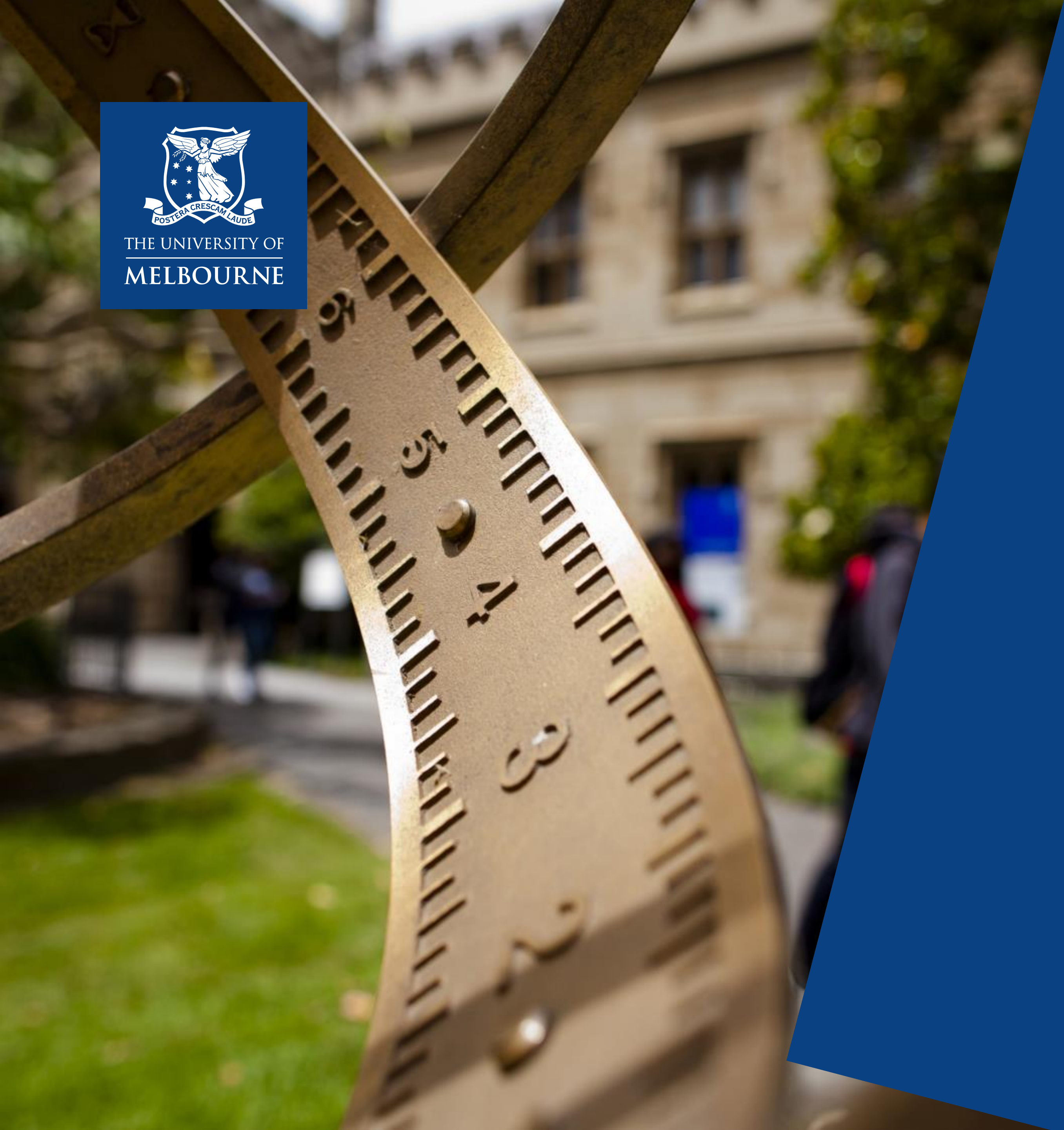
Data Link Layer

TCP/IP Model

Application
Transport
Network
Data Link
MAC SUB-Layer
Physical

1. Contention
   - ALOHA
   - Carrier Sense Multiple Access (CSMA)
2. Collision Free
   - CSMA/CD – Binary Countdown
   - CSMA/CD - bit map
3. Limited Contention
   - CSMA/CD - Adaptive Tree Walk Protocol

4. MACA/MACAW (for Wireless LANs)



THE UNIVERSITY OF MELBOURNE

Network Layer

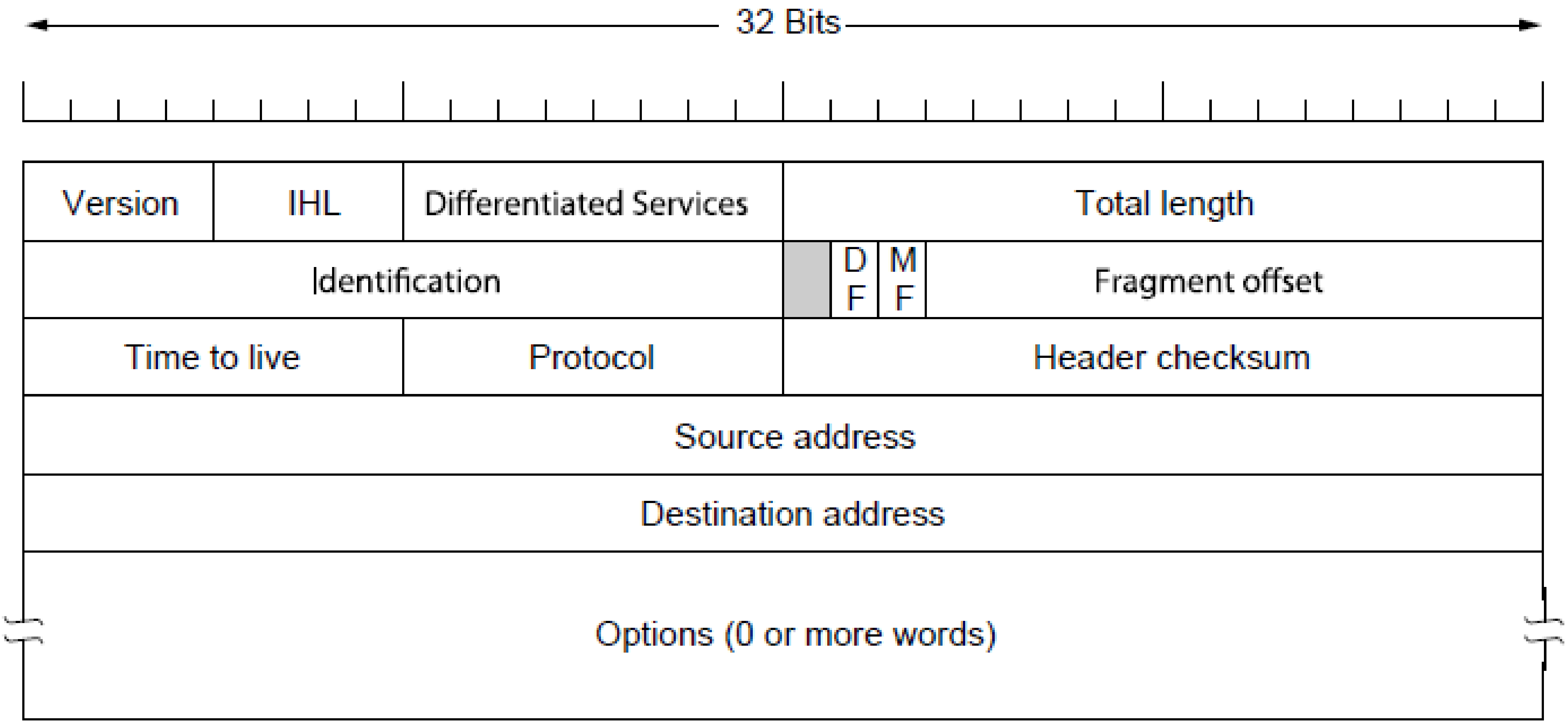
Data Link Layer

TCP/IP Model

Application
Transport
Network
Data Link
Physical

1. IPV4
2. IPV6
3. Routing Algorithms
    1. Non-adaptive
    2. Adaptive
    3. Hierarchical Routing
    4. Broadcasting routing
    5. Multicasting routing

IP4 Datagram Structure



Question5

Convert the IP address 11000001.01010010.11010010.00001111 to dotted decimal notation.

Ans. 193.82.210.15

Question 6

Convert the IP address 240.68.10.10 to binary format

Ans. 1111 0000 . 0100 0100 . 0000 1010 . 0000 1010