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Week4 Physical Layer and Data-Link Layer

COMP90007 Internet Technology

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Your Tutor

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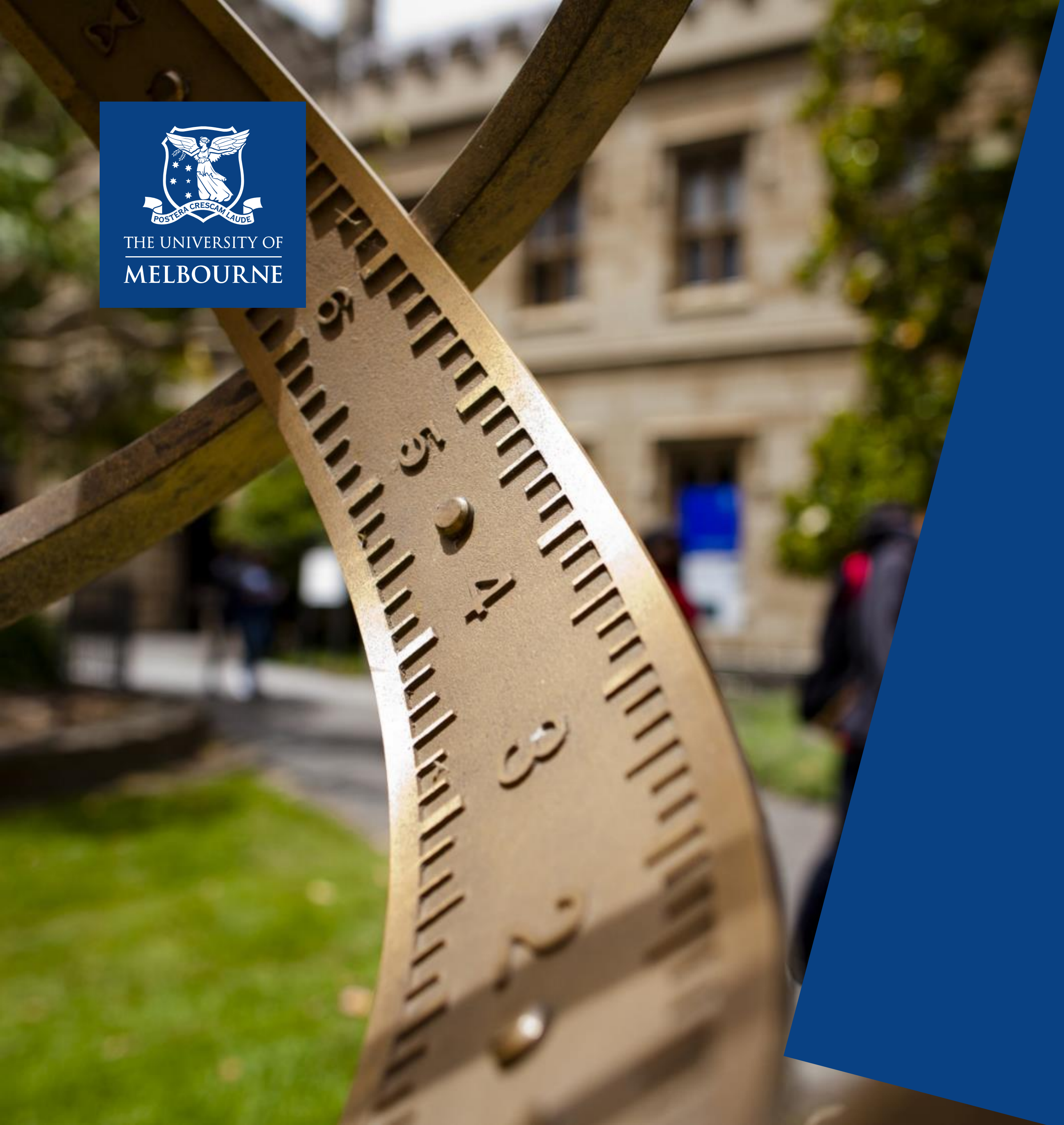
- Workshop Slides: https://github.com/LuChenyang3842/Internet-technology-teaching-material

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



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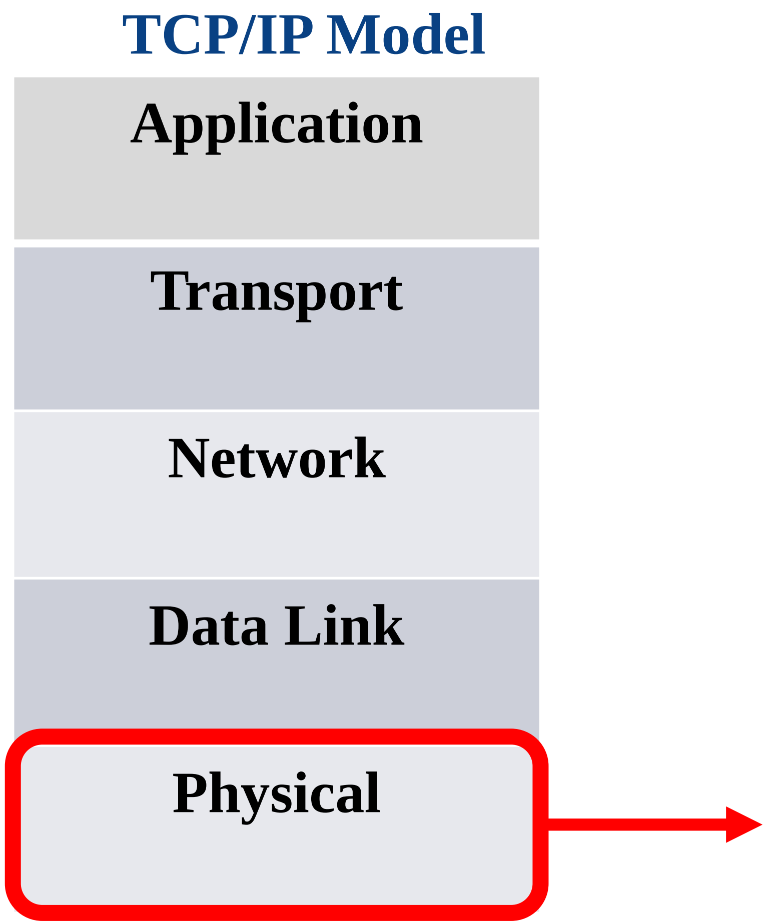
Physical Layer

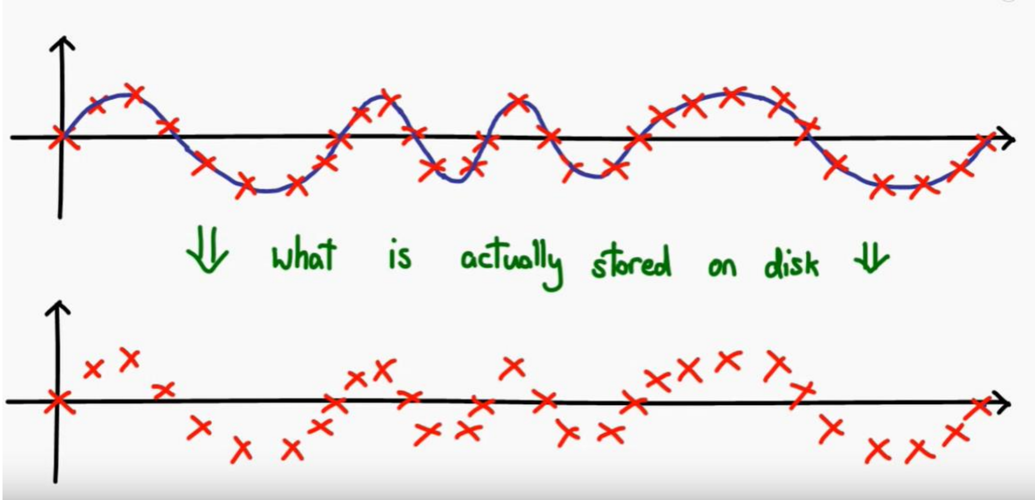
Physical Layer



1. Latency = Transmission Delay + Propagation Delay
2. Topology (Linear, Ring, Full Mesh, Simplex, Half Duplex, Full Duplex)
3. Sampling
4. Max Data Rate

Sampling

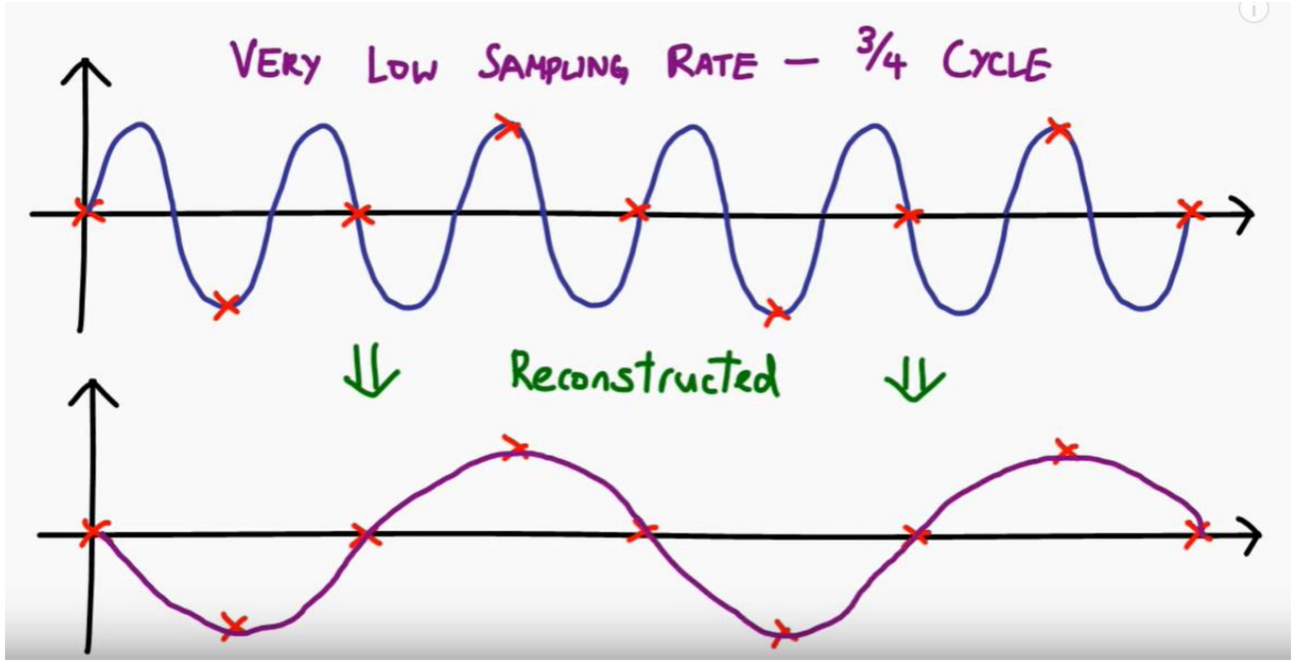
- Information is transmitted by varying physical properties (voltage, current etc). They are typically continuous signals.
- **Sampling** is a fundamental bridge between continuous signals and discrete (digital) signals.



- The red dots represents the discrete samples collected from continuous signals, we use these red dots to reconstruct the continuous signals

Sampling

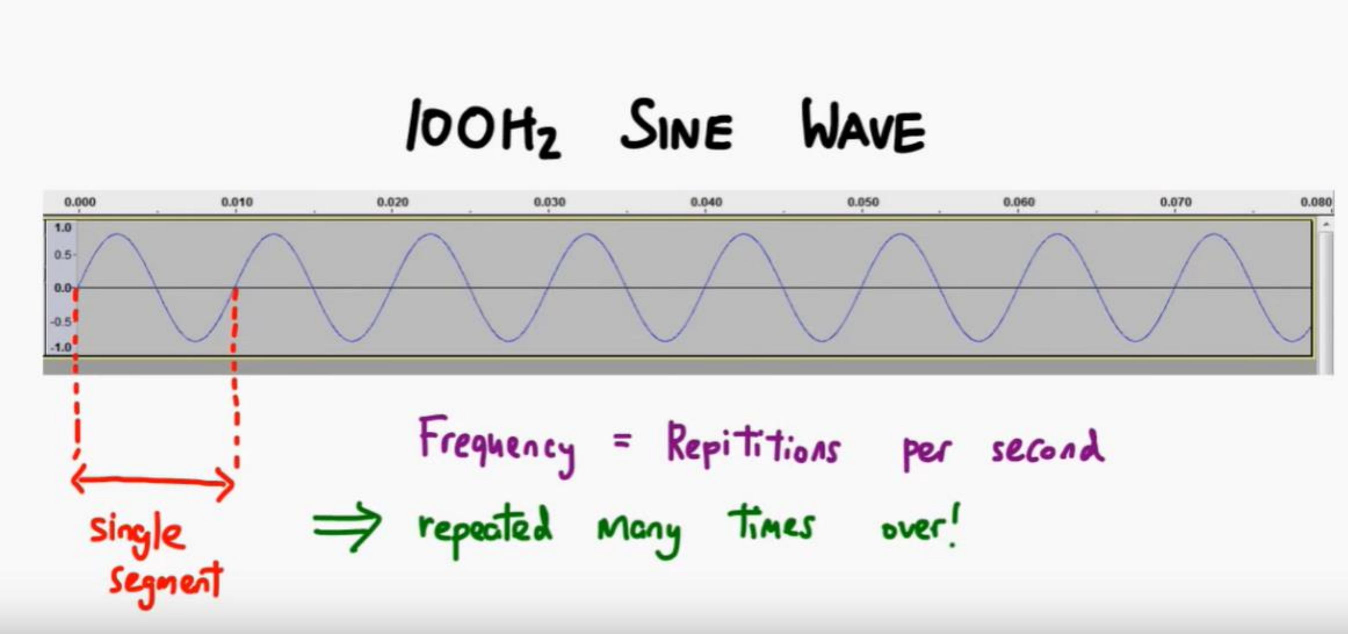
Low sampling rate will result in aliasing. So the sample rate need to be high enough



Sampling

What is the minimum sampling rate given the maximum frquency in the link is f?

Frequency: the number of oscillations per second is called frequency, measured in Hertz(Hz)
Frequency is the **second concept about bandwidth**: the frequency range in the given medium –continuous signal (Hz)



Sampling Theorem

The **minimum sampling rate** we need to recover a single **is double of the maximum frequency (f)** in a signal. Higher rate would be better, can provide more details

- Minimum Sampling Rate = 2f

More Information: https://www.youtube.com/watch?v=yWqrx08UeUs

Question1 (Sampling)

Consider a telephone signal that is bandwidth limited to 4 kHz.

(a) At what rate should you sample the signal so that you can completely reconstruct the signal?

min. sampling rate = 2f = 2 × 4000 = 8 kHz = 8000 symbols/s

Note: This is a direct application of the Sampling Theorem and forms the basics of the application of the theorem, i.e. without considering data rates.

The rest questions of Question1 will be covered later.

Question2 (Sampling)

Is the Sampling theorem true for optical fibre or only for copper wire?

- The Sampling theorem is a property of mathematics and has nothing to do with technology.

- The Sampling theorem states that if you have a function whose Fourier spectrum (frequency domain representation) does not contain any frequency components (sines or cosines) above f, then by sampling at a frequency of $2f$, you capture all the information there is. The Sampling theorem is independent of the transmission medium.

- **Note**: You do not need to know the Fourier transform, law, etc.

Conclusion for Sampling

1. Minimum Sampling Rate = 2f (f represent the max transmission frequency)
2. The Sampling theorem is independent of the transmission medium.

Maximum Data Rate of Transmission

Nyquist’s theorem (Without noise)

$$\text{Max. data rate} = 2B \log_2 V \text{ bits/sec}$$

How fast signal can transmit

V: Number of signal levels

Shanon theorem (with Noise)

$$\text{Max. data rate} = B \log_2(1 + S/N) \text{ bits/sec}$$

How fast signal can change

How many levels can be seen

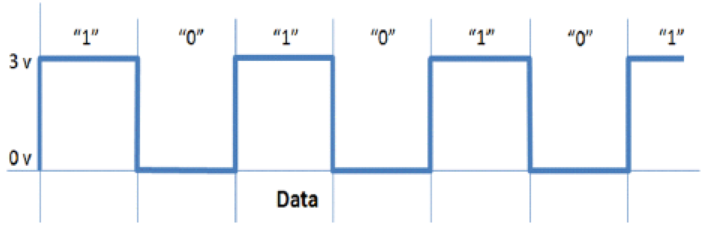


Figure 1. Data bits where logical “0” and “1” are represented by 0 volts and 3 volts respectively

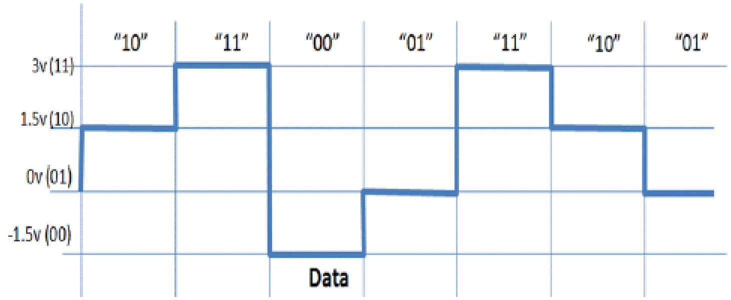


Figure 2. Four signaling levels per clock cycle can represent two data bits.

Maximum Data Rate of Transmission

Nyquist's theorem (Without noise)

$$\text{Max. data rate} = 2B \log_2 V \text{ bits/sec}$$

B: How fast signal can transmit(bandwidth)
V: Number of signal levels
2B (Baud Rate): Given a bandwidth B, we can send 2*B symbols/second at max. (Note, you don't need to know why 2B, it is related to Fourier Analysis, which is out of scope)
log2V: bits/ symbol

Max.Data Rate (bits/second) = Symbols/ Second * bits/Symbol

Shanon theorem (with Noise)

$$\text{Max. data rate} = B \log_2(1 + S/N) \text{ bits/sec}$$

B: How fast signal can transmit(bandwidth), symbols/second equals to B
S/N: Noise rate
log2(1+S/N): bits/ symbol

Max.Data Rate (bits/second) = Symbols/ Second * bits/Symbol

Question1 continue…. (Max Data Rate)

(b) If each sample of the signal is to be encoded at 256 levels, how many bits/symbol are required for each sample?

256 possible values per sample requires $\log_2(256) = 8$ bits/ symbol

(c) If we have 8000 symbols/s, What is the minimum bit rate required to transmit this signal?

8 bits/symbol × 8000 symbols/s = 64 kbps

Question3 (Max Data Rate)

Given a **noiseless** 4 kHz channel, what is the maximum data rate of the communications channel?

- A noiseless channel can carry an arbitrarily large amount of information, no matter how many levels of signals to use (i.e. there can be an infinite number of signalling levels because there is no noise)

- Just use many levels of signals, so that each symbol can carry many bits
  1. First Calculate baud rate = 2 * 4KHZ = 8k symbols/sec.
  2. If each symbol can represent 16 bits data, the channel can send 128 kbps.
  3. If each symbol can represent 1024 bits, the channel can send 8.2 Mbps..

- The key word here is "noiseless." With a normal noisy 4 kHz channel, Shannon specifies a limit on the information rate on the channel known as its *capacity*.

Question4 (Max Data Rate)

The bandwidth of a television video stream is 6 MHz. How many bits/sec are sent if four-level digital signals are used? Assume **<u>a noiseless channel.</u>**

- The maximum baud rate is 12 symbols/sec
- Four levels of signalling provide: log2 4 = 2 bits/symbol
- Hence, the total data rate is: 12 million symbols/s × 2 bits/symbol = 24 Mbps

Question4.1 (Max Data Rate)

The bandwidth of a television video stream is 6 MHz. How many bits/sec are sent if four-level digital signals are used? **Now assume a S/N of 20db.**

- Using Shannon's theorem, we have: B x log(1+S/N)

  = 6MHz x log(1+100) = 6MHz x 6.65 = 39.9Mbps

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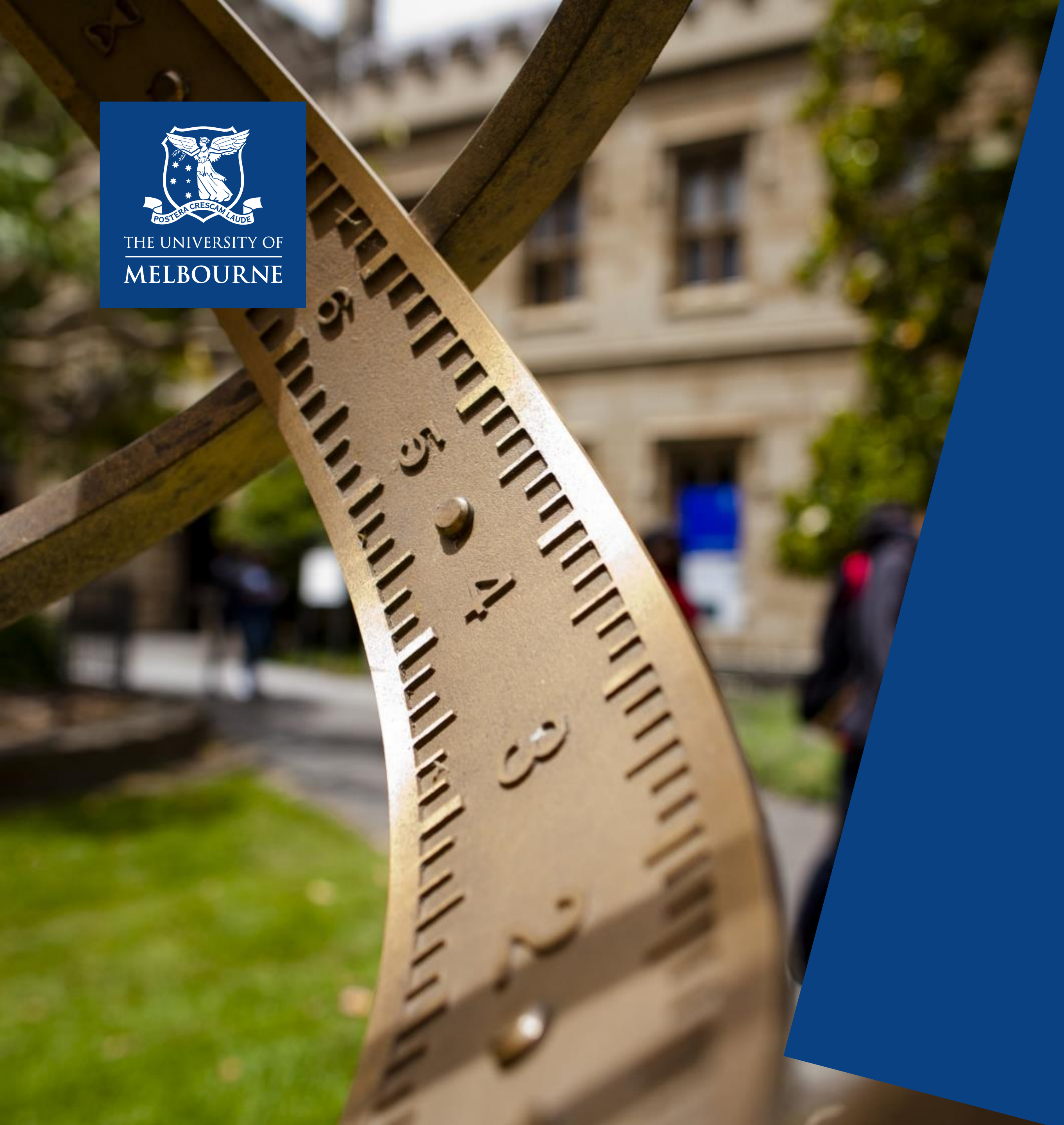


Data-Link Layer

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

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
    - Detecting
    - Correcting
3. Flow Control
    - Feedback Based Flow Control
        - Stop and wait
        - Sliding window
    - ~~Rate based flow control~~

Frame

Frame

- What is a frame?
- What does a frame look like?

Frame

A frame is a digital data transmission unit in the data link layer.

An overview of a frame:

FLAG	Header	Payload field	Trailer	FLAG

Question: Why do we need to split our data up into frames?

Cite from: Yang, Lu, S 2018, Workshop3(physical layer), workshop notes, COMP90007 Internet Technology, University of Melbourne, delivered 19 Mar, 2018

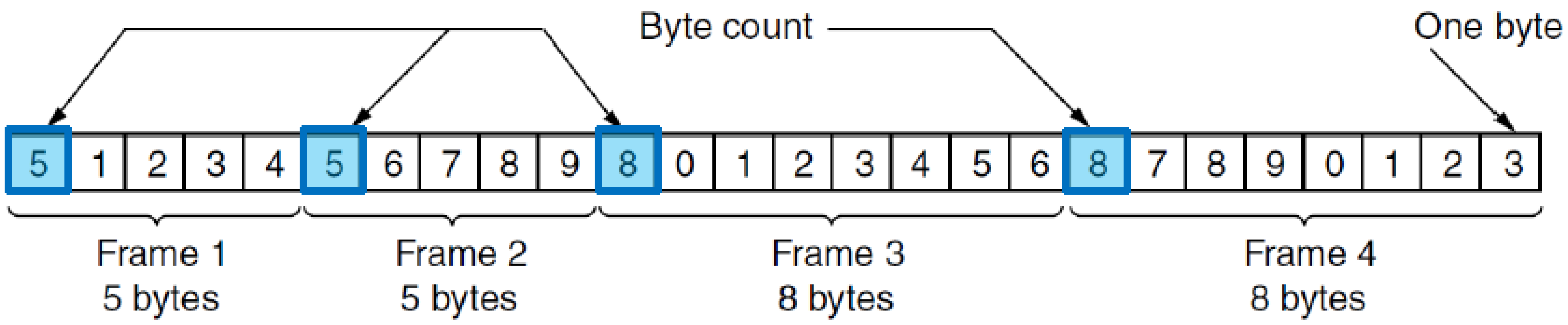
Framing

Framing methods

- Character counts
- Frame with flags
  - Flag bytes with byte stuffing
  - Flag bits with bit stuffing

Framing method: Character count

Character Counts: it uses a field in the **frame header** to specify the number of characters in a frame.



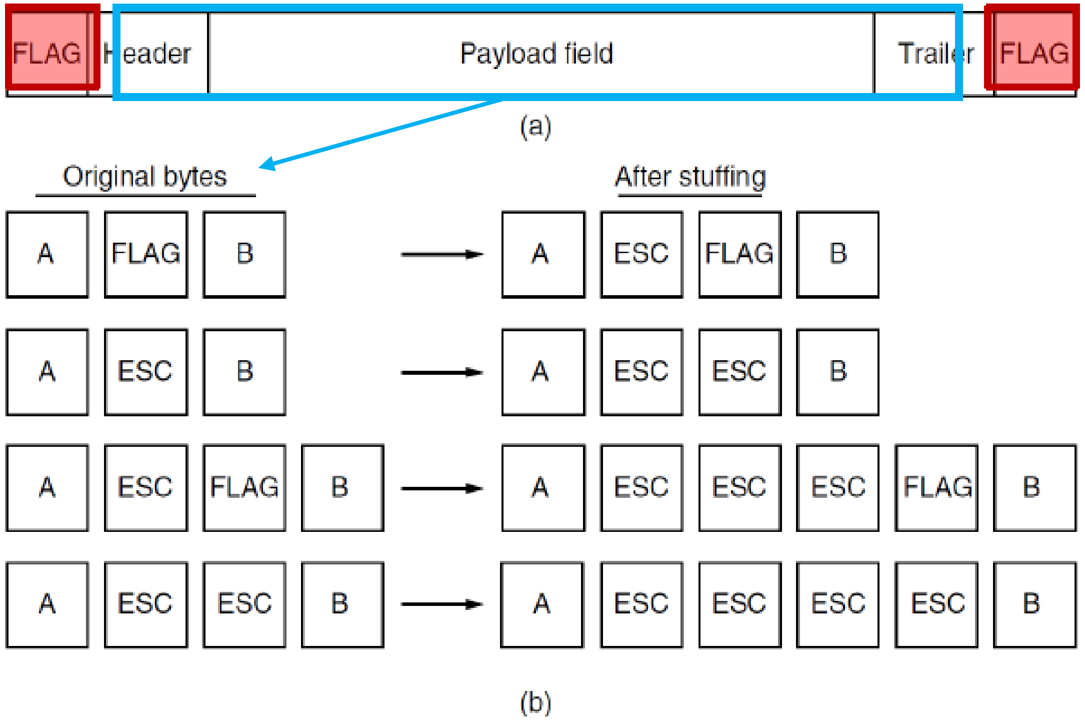
(a)

Question: : What if the character count gets corrupted (and gets read as a different value) at the receiver end?

Cite from: Yang, Lu, S 2018, Workshop3(physical layer), workshop notes, COMP90007 Internet Technology, University of Melbourne, delivered 19 Mar, 2018

Framing method: Flag Bytes with Byte stuffing

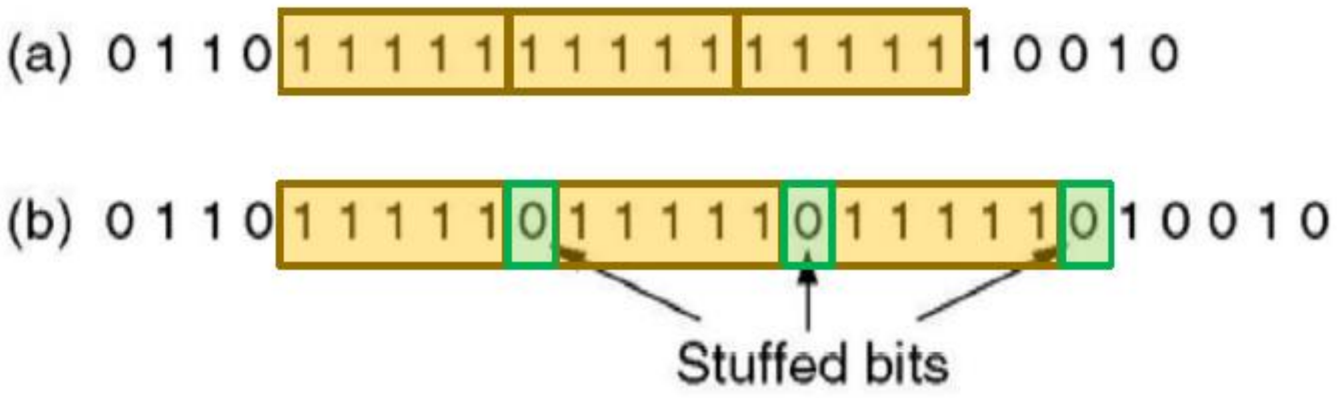
Byte Stuffing: Flag bytes with **byte stuffing**: each frame starts and ends with a special byte –“flag byte”



Framing method: Flag with Bit stuffing

Bit Stuffing: Flag bytes with **bit stuffing**: each frame starts and ends with a special bit pattern –“flag byte”.

The flag byte is: 01111110
Bit stuffing adds a “0” to every five “1”s.



Question5 (Framing)

The following character encoding is used in a data link protocol:

A:	01000111	B:	11100011
FLAG:	01111110	ESC:	11100000

Show the bit sequence transmitted (in binary) for the four-character frame payload *A B ESC FLAG*, when each of the following framing methods are used:

(a) Character count

(b) Flag bytes with byte stuffing

(c) Starting and ending flag bytes, with bit stuffing

Answer:

1. 00000101 01000111 11100011 11100000 01111110
   5 A B 'ESC' 'FLAG'
2. 01111110 01000111 11100011 11100000 11100000 11100000 01111110 01111110
   FLAG A B ESC 'ESC' ESC 'FLAG' FLAG
3. 01111110 01000111 110100011 111000000 011111010 01111110
   FLAG A B 'ESC' 'FLAG' FLAG

Question 6 (Framing)

The following data fragment occurs in the middle of a data stream for which the byte-stuffing algorithm as described in the lecture is used:
A B ESC C ESC FLAG FLAG D.

What is the output after stuffing?

Answer:
After stuffing we get:
A B ESC ESC C ESC ESC ESC FLAG ESC FLAG D