CS2105

An *Awesome* Introduction to Computer Networks

Lecture 11: Physical Layer and Wrap up

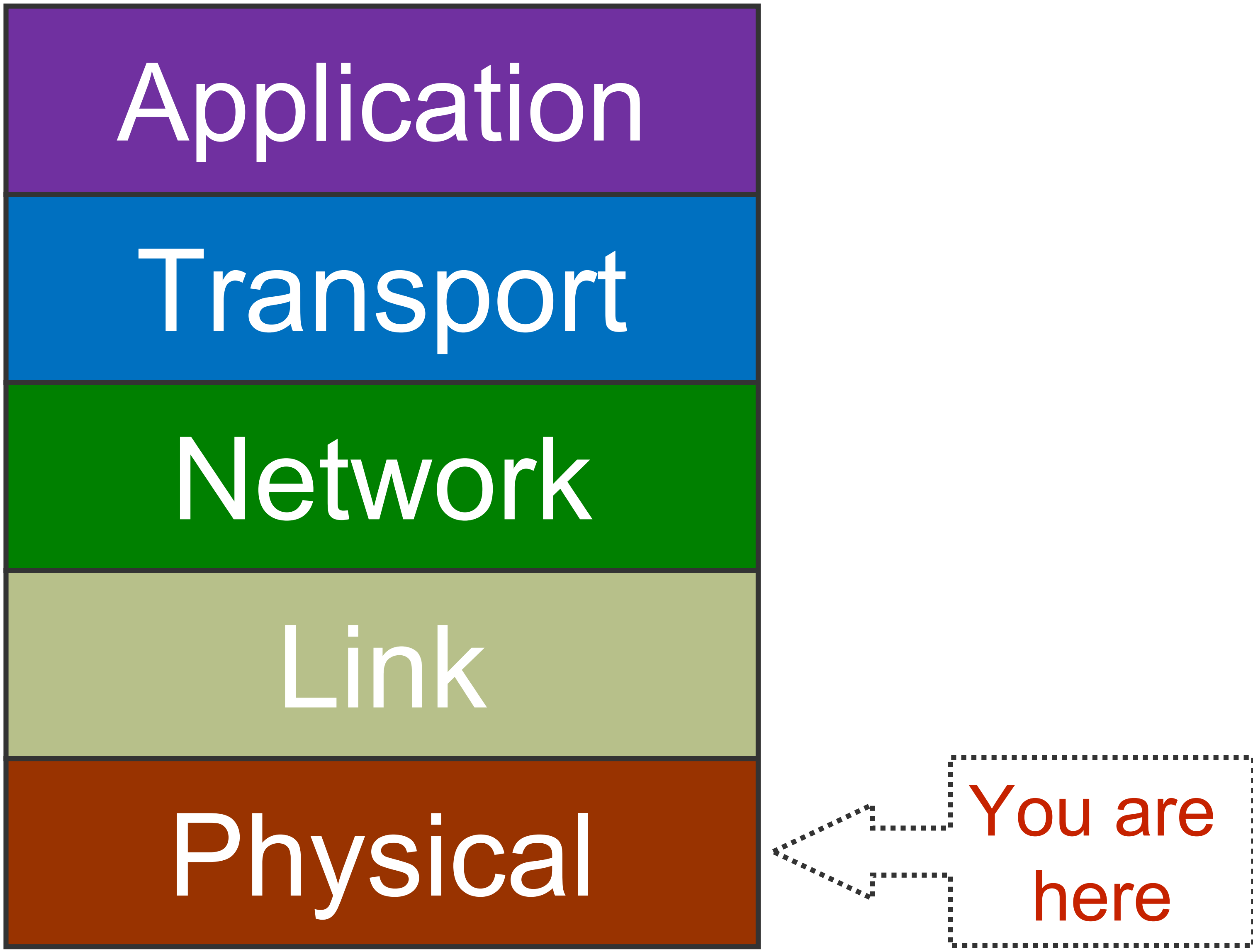
NUS National University of Singapore
Department of Computer Science
School of Computing

Last lecture!

Lecture 11: Physical Layer

After this class, you are expected to understand:

- different methods of digital transmission.
- the theoretical capacity of a channel calculated from Shannon’s formula.
- how modulation techniques work and the concept of constellation diagram.

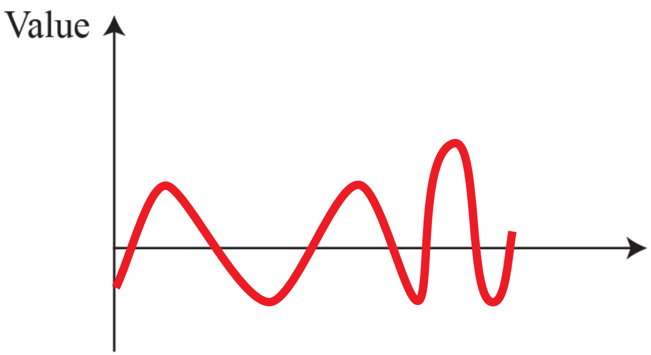

Application
Transport
Network
Link
Physical
You are here

Lecture 11: Roadmap

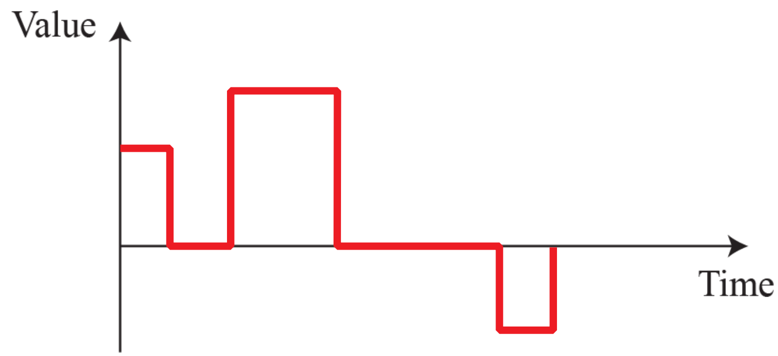
1. Digital transmission
2. Analog transmission
3. A quick revision
4. Exam matters

Digital and Analog Signals

- Physical layer moves data in the form of electro-magnetic signals across transmission medium.
- 0s and 1s can be transmitted as either analog signal or digital signal.
  - Analog signal is continuous, with infinitely many levels.
  - Digital signal has a limited number of defined values.



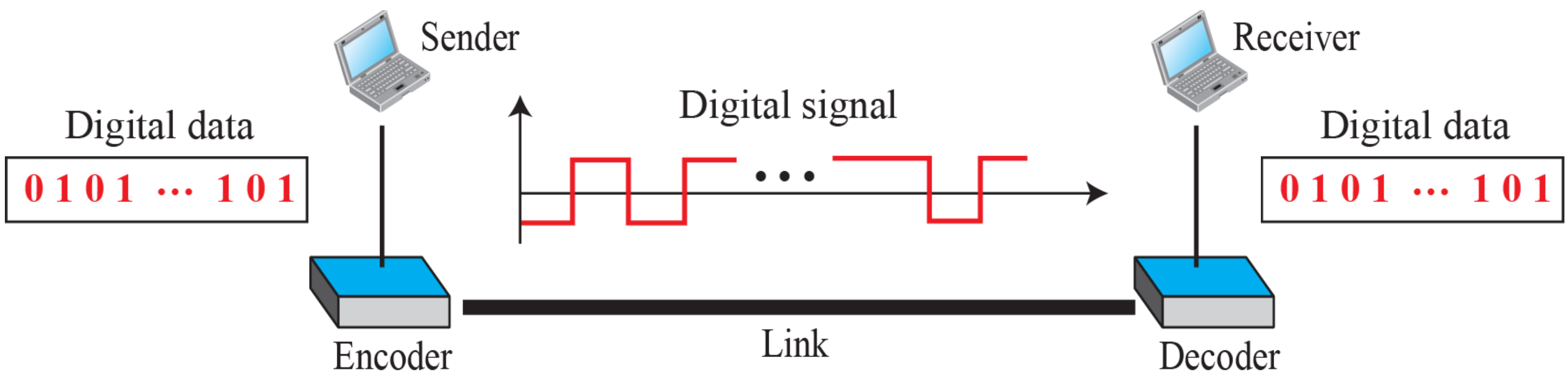
a. Analog signal



b. Digital signal

Digital Transmission

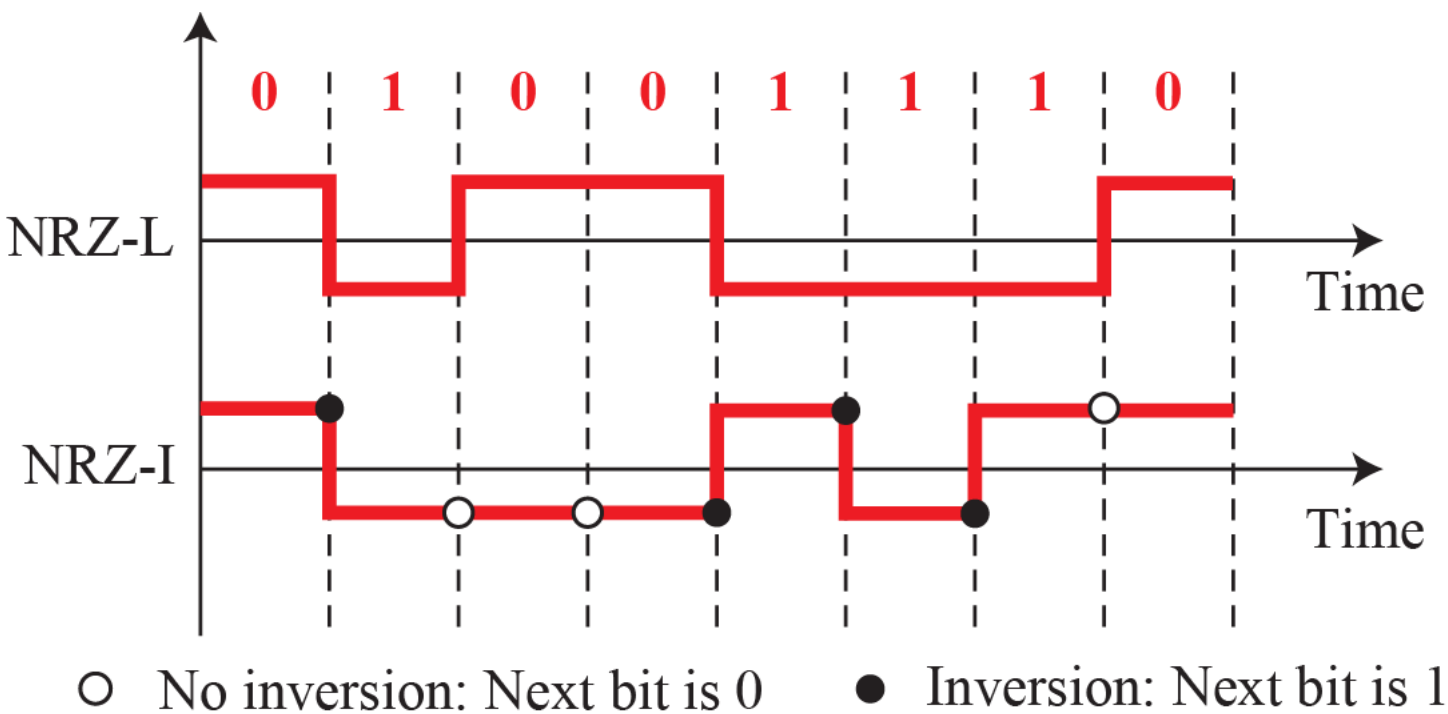
- In digital transmission, we encode 0s and 1s with different voltages to be transmitted over the wire.



- We will introduce 3 digital encoding methods.

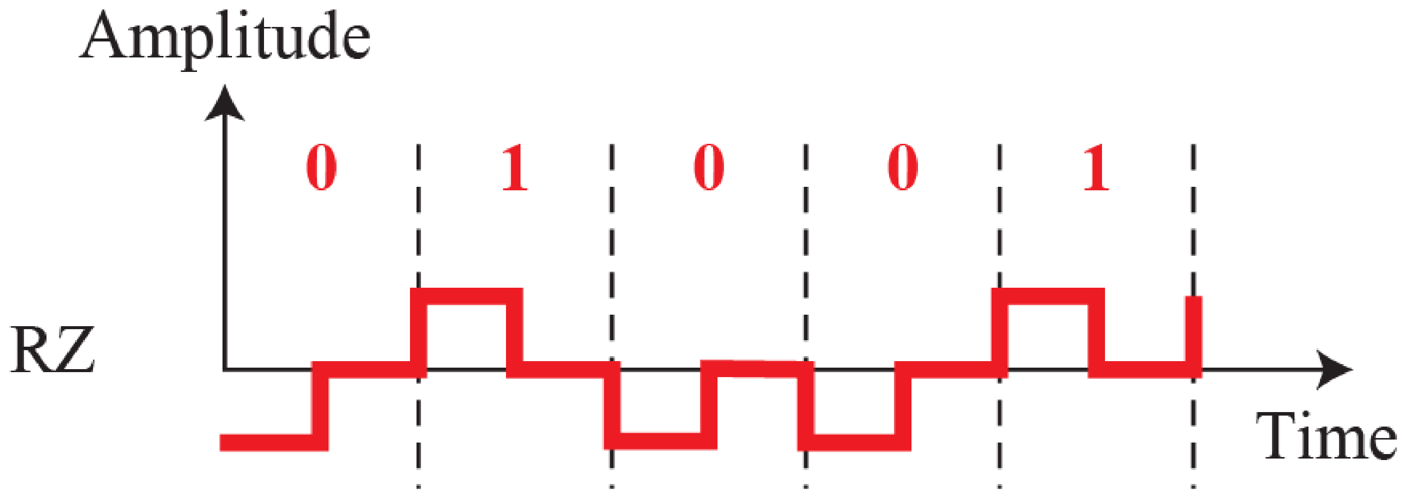
NRZ (Non-Return-to-Zero)

- NRZ encoding uses two voltage levels. It has two variations.
  - NRZ-L: absolute voltage level determines value of a bit.
  - NRZ-I: inverts the voltage if bit 1 is encountered.



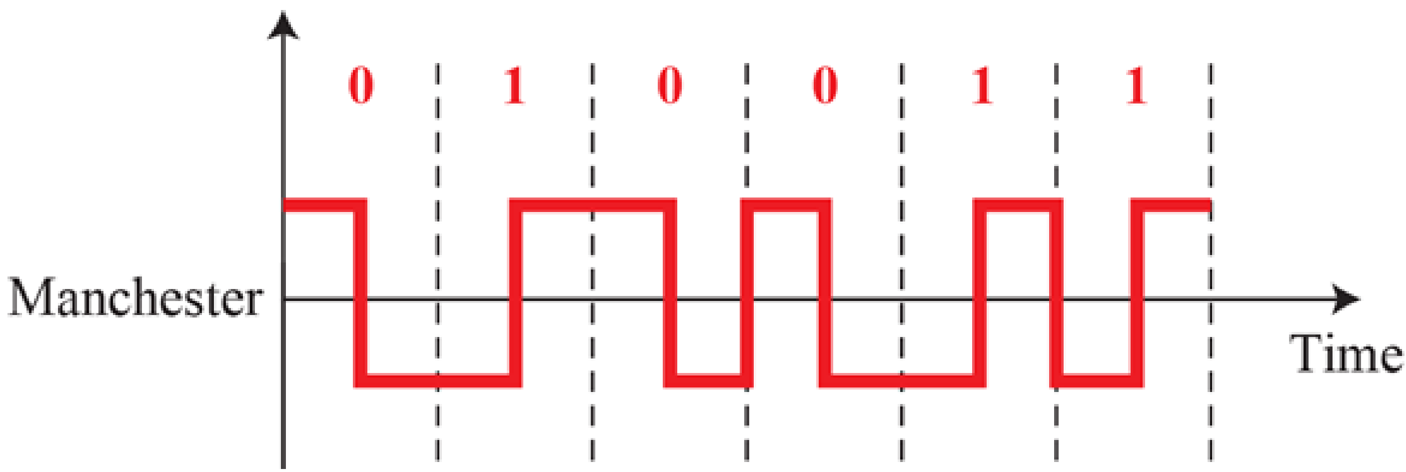
RZ (Return-to-Zero)

- RZ encoding uses three voltage levels. It always returns the voltage to zero halfway through a bit interval.



Manchester

- Manchester coding inverts the signal in the middle of a bit.
  - A $-ve$ to $+ve$ transition represents 1. A $+ve$ to $-ve$ transition represents 0.



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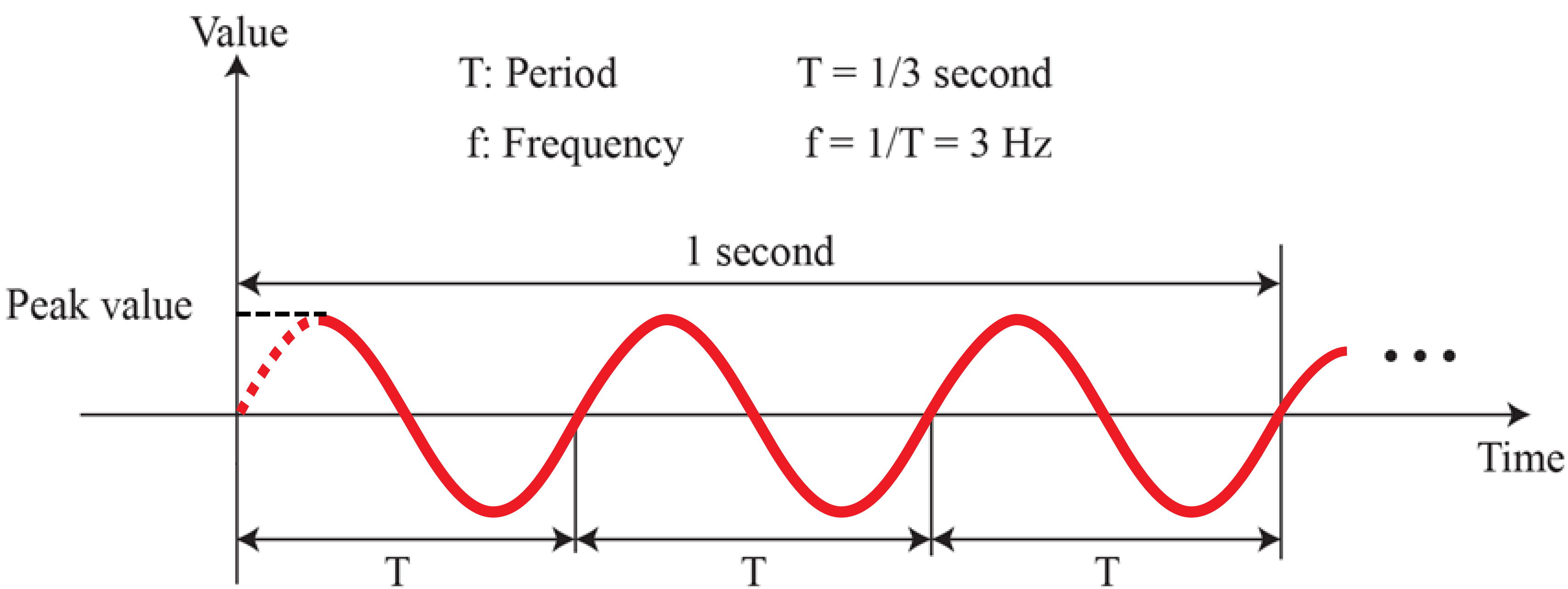
Analog Signal

- The most basic analog signal is a sine wave.

$$A \sin(2\pi f t + \phi)$$

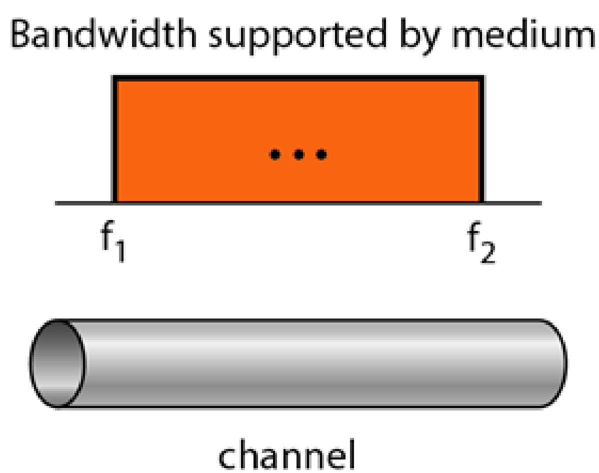
Peak amplitude   frequency   phase



Channel Bandwidth

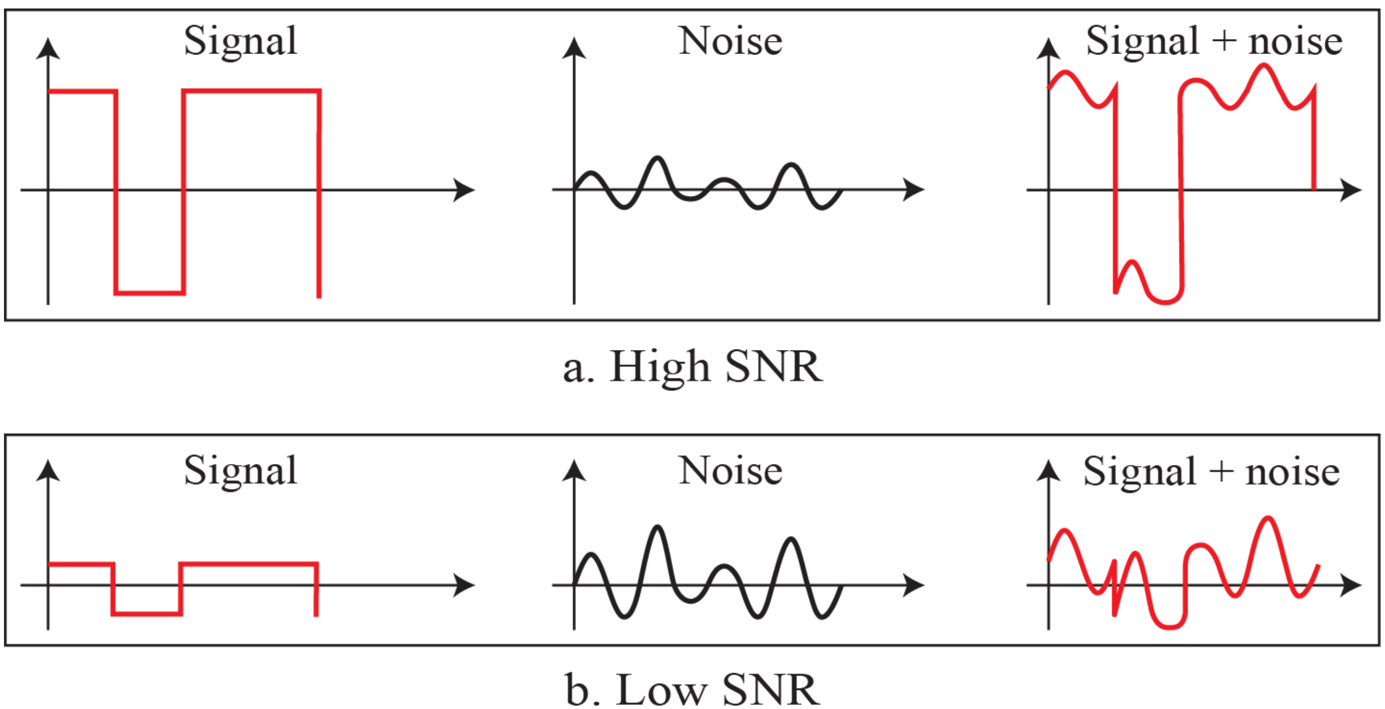
- A transmission channel only allows signals in a certain frequency range to pass through.

- The difference in the highest frequency and lowest frequency that can pass through a channel is known as the bandwidth of the channel.



Signal to Noise Ratio (SNR)

- A transmission channel introduces noise that distorts signal.
  - Signal to noise ratio (SNR) measures the strength of signal over noise.



Shannon Channel Capacity

- The theoretical maximum bit rate of a noisy channel is given by Shannon Capacity:

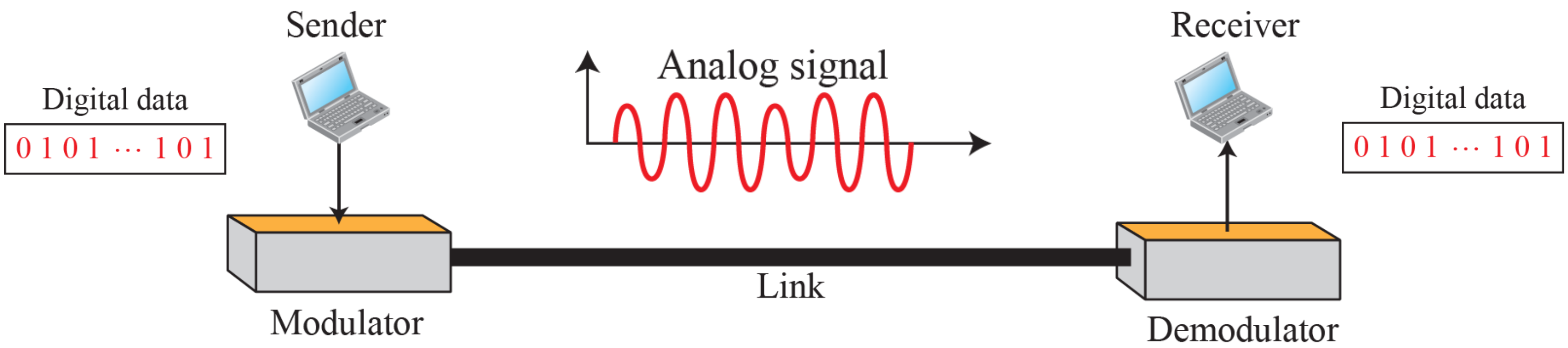
$$C = B * log_2(1 + SNR)$$

Channel bandwidth

Signal to noise ratio of channel

- Example: Phone line has a bandwidth of 3,000 Hz (300 to 3,300 Hz) and SNR of 3,162. The capacity of the channel is 34,881 bps.
    - The highest bit rate for a telephone line is 34.881 kbps

Analog Transmission

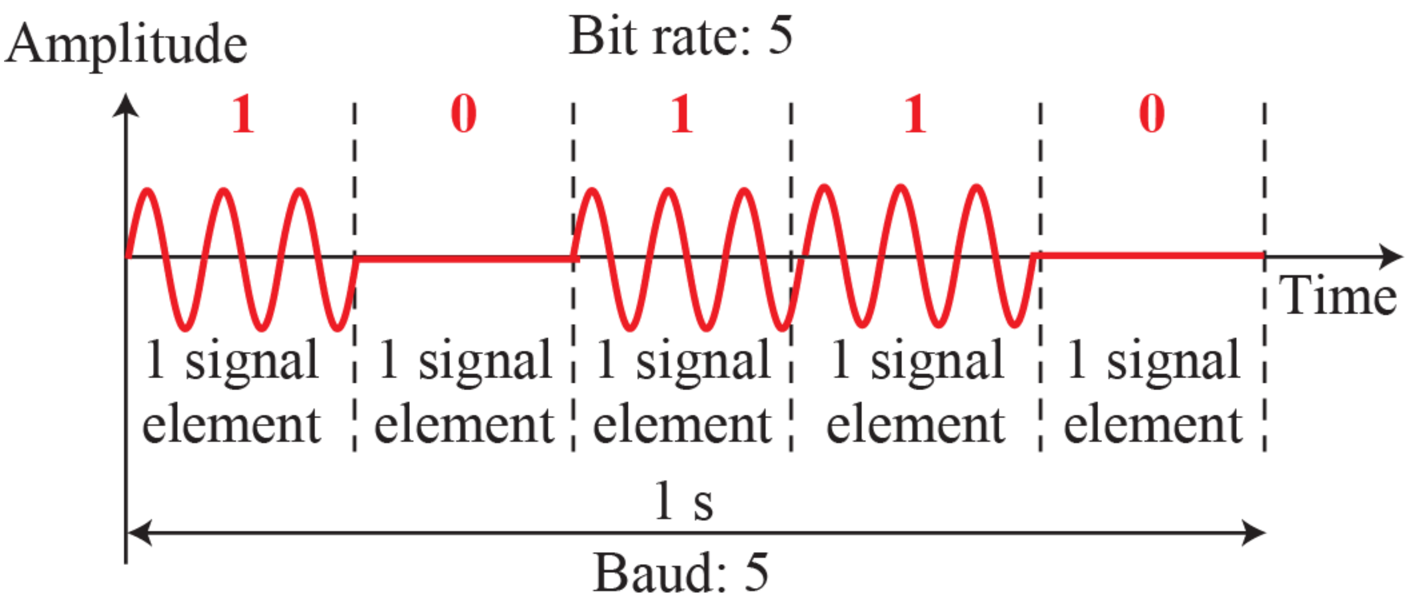


- Modem = <u>mo</u>dulator + <u>dem</u>odulator

Analog Encoding

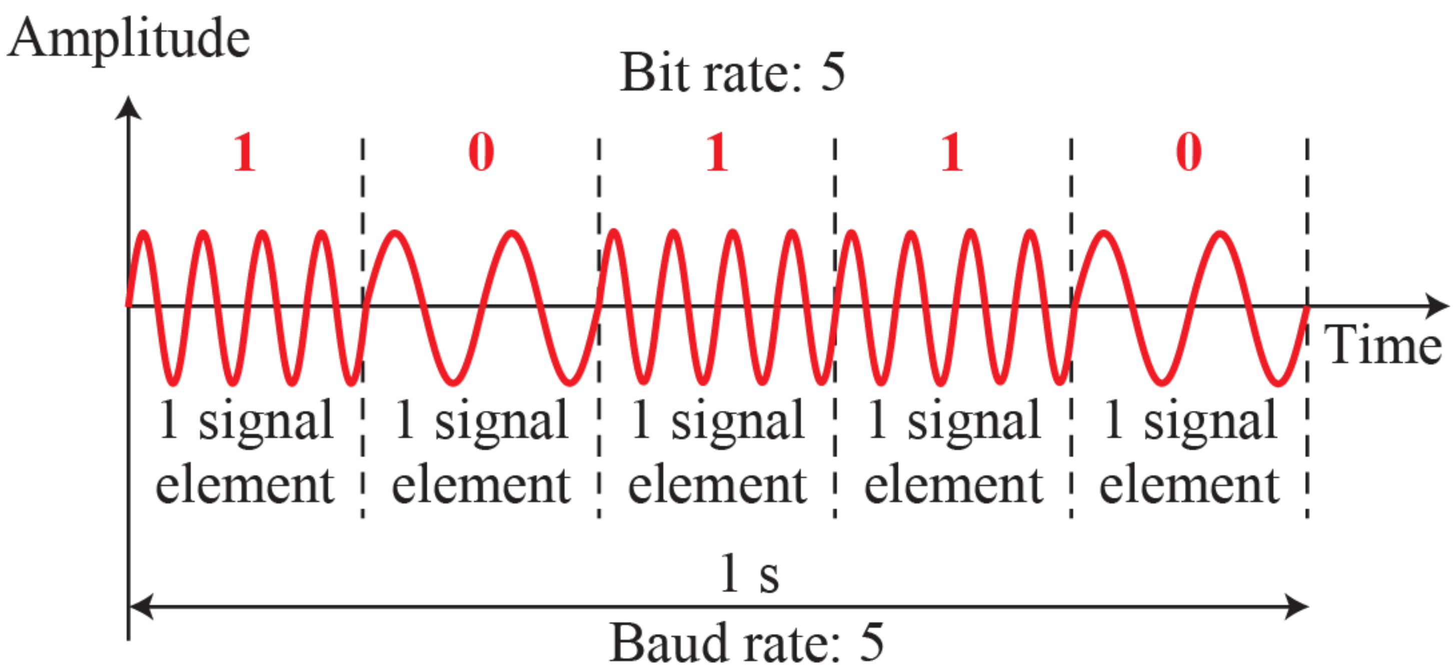
- To transmit 0s and 1s with analog signal, we can change A, f, or ϕ.
- Amplitude Shift Keying (ASK) changes peak amplitude (A) to represent 0s and 1s.
- Frequency Shift Keying (FSK) changes frequency (f) to represent 0s and 1s.
- Phase Shift Keying (PSK) changes phase (ϕ) to represent 0s and 1s.

Amplitude Shift Keying (ASK)



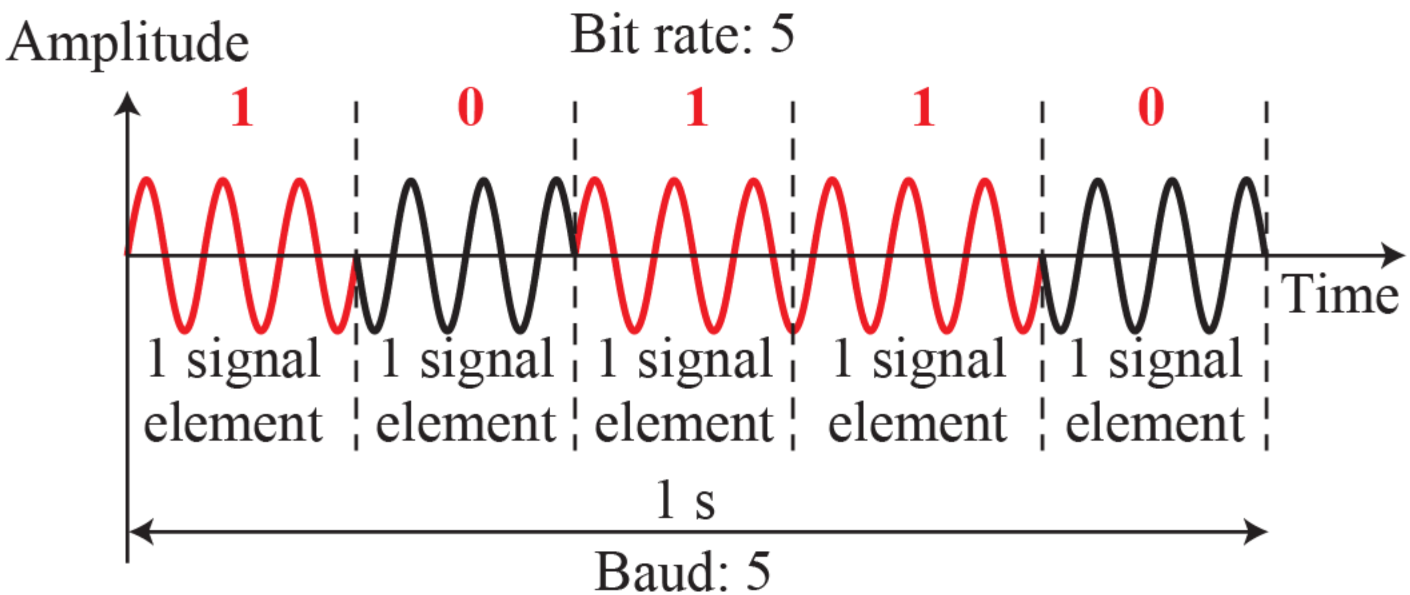
- Peak amplitude of the signal varies with data values.
- ASK is susceptible to noise.

Frequency Shift Keying (FSK)



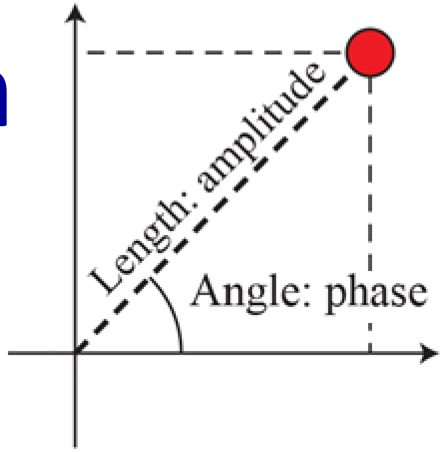
- Amplitude and phase remain constant.
- FSK is limited by the bandwidth of the channel.

Phase Shift Keying (PSK)



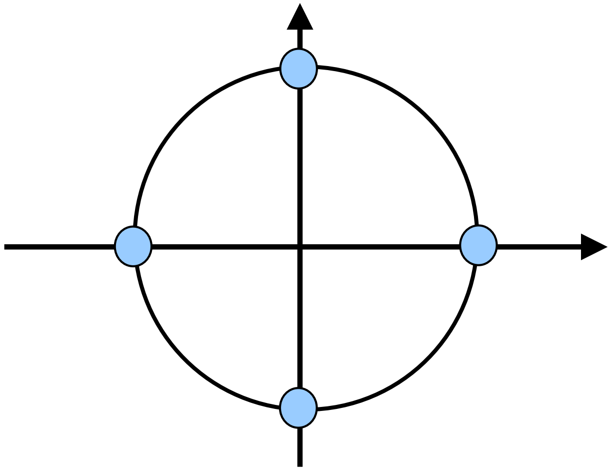
- One signal element with phase 0^0
- Another with phase 180^0

QPSK Constellation Diagram



- Can we transmit faster?
  - Send signals with 4 possible phases:

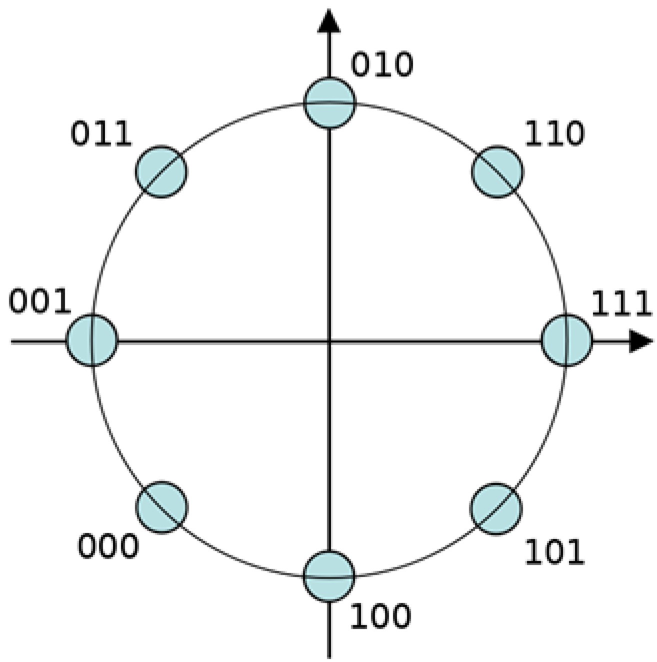
Phase	Values represent
0^0	11
90^0	01
180^0	00
270^0	10



- Now every signal tells receiver 2 bits of data!

8-PSK Constellation Diagram

- Let’s use more phases to carry more data over every signal.



- Now every signal tells receiver 3 bits of data!

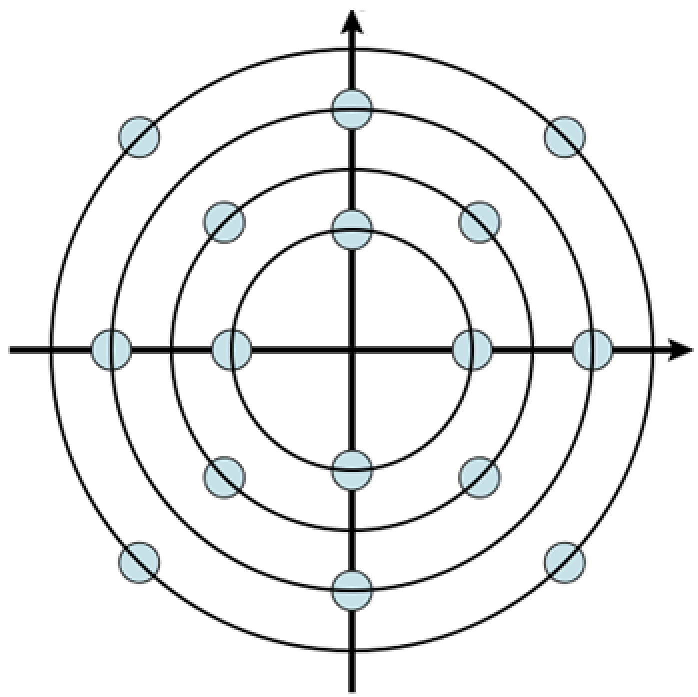
QAM

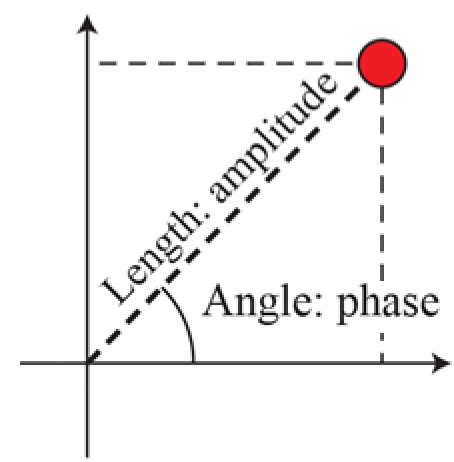
- Can we transmit even faster?
  - Three parameters to tune: $\boldsymbol{A}$, $\boldsymbol{f}$ or $\boldsymbol{\phi}$.
  - Many combinations are possible.

- Quadrature Amplitude Modulation (QAM) combines ASK and PSK.
  - A signal unit in a 2^k-QAM scheme is a combination of amplitude and phase that represents k bits.
  - Baud rate is the number of signal units per second.
  - Bit rate is the number of bits receiver receives per second.

16-QAM

- 16-QAM: 16 different signal elements.
- Every signal differs in either amplitude or phase.
  - Receiver checks both to determine the data carried by a signal.





Summary of Physical Layer

- Wi-Fi transmits analog signal and Ethernet transmits digital signal.
- Ethernet, RFID, and NFC use Manchester coding.
- USB uses NRZ-I.
- Singapore TV broadcast uses DVB-T, which uses QPSK, 16-QAM, or 64-QAM.
- Wi-Fi uses PSK, QPSK, 16-QAM or 64-QAM.

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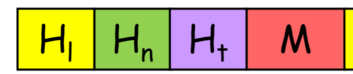
A day in the life of a web request

- You enter a programming lab, turn on a PC and want to visit www.facebook.com.
  - Let's sketch out the steps and protocols involved in such a seemingly simple scenario.
  - Some details are omitted and can be referred to from previous lecture notes ☺

A day in the life of a web request

- Step 1:

  - On start-up, your PC needs an IP → from DHCP server
    - DHCP request encapsulated in UDP segment, then in IP datagram, then in Ethernet frame.



    - Frame is broadcasted on subnet.
  - DHCP server receives and processes this frame, starts negotiation with your PC for IP.

Details in lectures 6, 9 notes

  - Intermediate switches learn your position when forwarding your frames.

Details in lecture 10 notes

A day in the life of a web request

- Step 2:
  - DHCP server also tells you IP addresses of first-hop router and local DNS server.
  - After you type www.facebook.com, browser needs to know IP of this website → from local DNS server
    - To know the MAC address of local DNS server, PC broadcasts ARP query. Local DNS server replies with its MAC address.
    - DNS query encapsulated in UDP segment, then in IP datagram, then in Ethernet frame, sent to local DNS server.
    - Local DNS server reply your PC with IP of Facebook.

Details in lecture 10 notes

Details in lecture 2 notes

A day in the life of a web request

- Step 3:
  - PC sends HTTP request to Facebook.
    - TCP socket opened; 3-way handshake with Facebook server.
    - http messages exchanged after TCP connection setup
  - Frames sent to first-hop router.
  - IP datagrams forwarded from campus network to ISP SingNet.
    - Private IP translated by NUS NAT router.
    - IP Datagram routed on the Internet using RIP or other routing protocols.

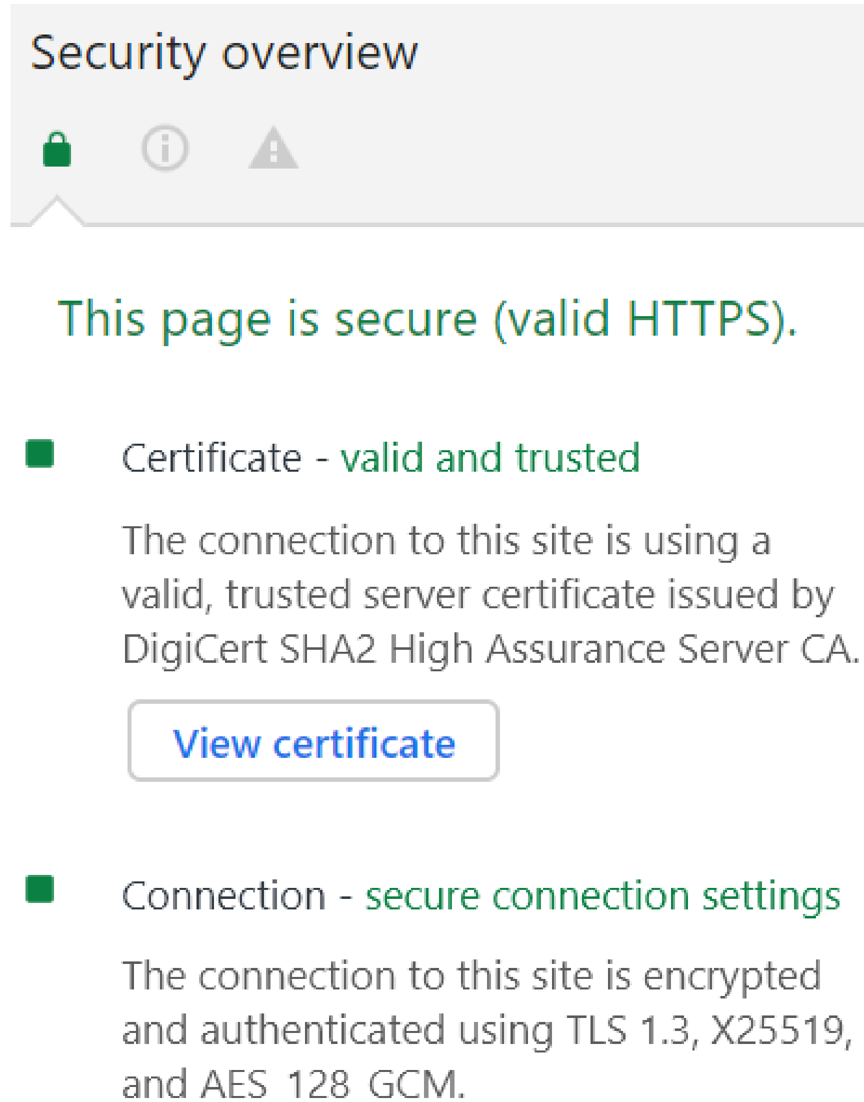
Details in lecture 5 notes

Details in lecture 2, 3 notes

Details in lecture 7 notes

A day in the life of a web request

- Step 4:
  - When Facebook is contacted
    - Negotiate for secure connection.
    - https = http + SSL/TLS
    - Digital certificate of Facebook verified.
    - Message encryption and authentication

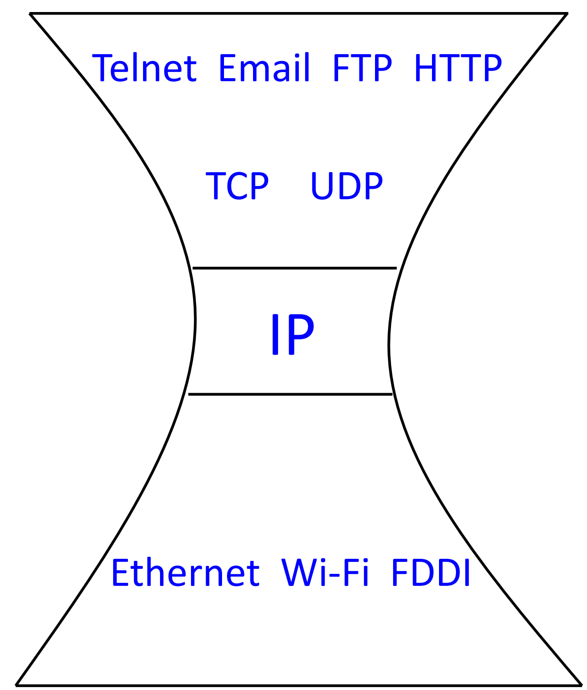


Details in lecture 8 notes

Lessons from CS2105

- Network system is so complex!
  - There are many issues to consider, to support different applications running on large number of hosts through different access technology and physical media.

- To deal with complexity:
  - separation of concerns
  - 5 protocol layer



What's Next?

- CS3103 Computer Networks and Protocols
  - Continuation of CS2105 in selected areas
  - Use the same textbook as ours.
  - Cover network management, TCP congestion control and routing protocols in more details.
- CS4222 Wireless and Sensor Networks
- CS4274 Mobile and Multimedia Networking

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CS2105 Final Assessment

- Time: **Mon, 2 Dec 2019, 5pm**
- Venue: **MPSH**
- **Open book** assessment
  - You may bring in any printed materials
- Format
  - MCQs
  - Short questions
    - Each question may contain multiple parts

Tips for Final Assessment

- Preparation
  - Review lecture notes and tutorial questions.
  - Focus on understanding rather than memorization.
  - A mock paper will be released on LumiNUS in week 13.
    - Answers provided.
    - For your practice; don't unload them onto the Internet.

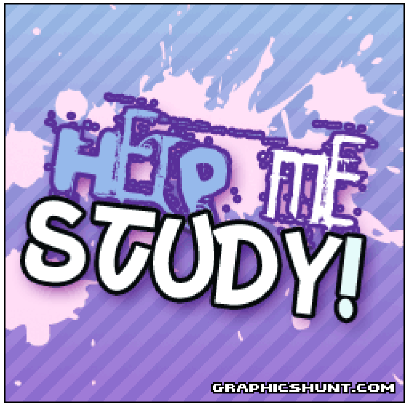
- During exam
  - Read instructions carefully.
  - A calculator may be helpful.

Consultation

- Discuss on LumiNUS forum

- Email me or co-lecturer
  - Me: zhoulifeng@nus.edu.sg
  - Wai Kay waikay@comp.nus.edu.sg

- Office hour
  - Upon email appointment
  - My office: COM2 #02-56
  - Wai Kay's office: COM2 #02-11



Thank you!


May you come out with
flying colors...
All the BEST
for your exam!
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