CS2105

An *Awesome* Introduction to Computer Networks

Lecture 12: Physical Layer and Wrap Up

Department of Computer Science
School of Computing

Last Lecture!

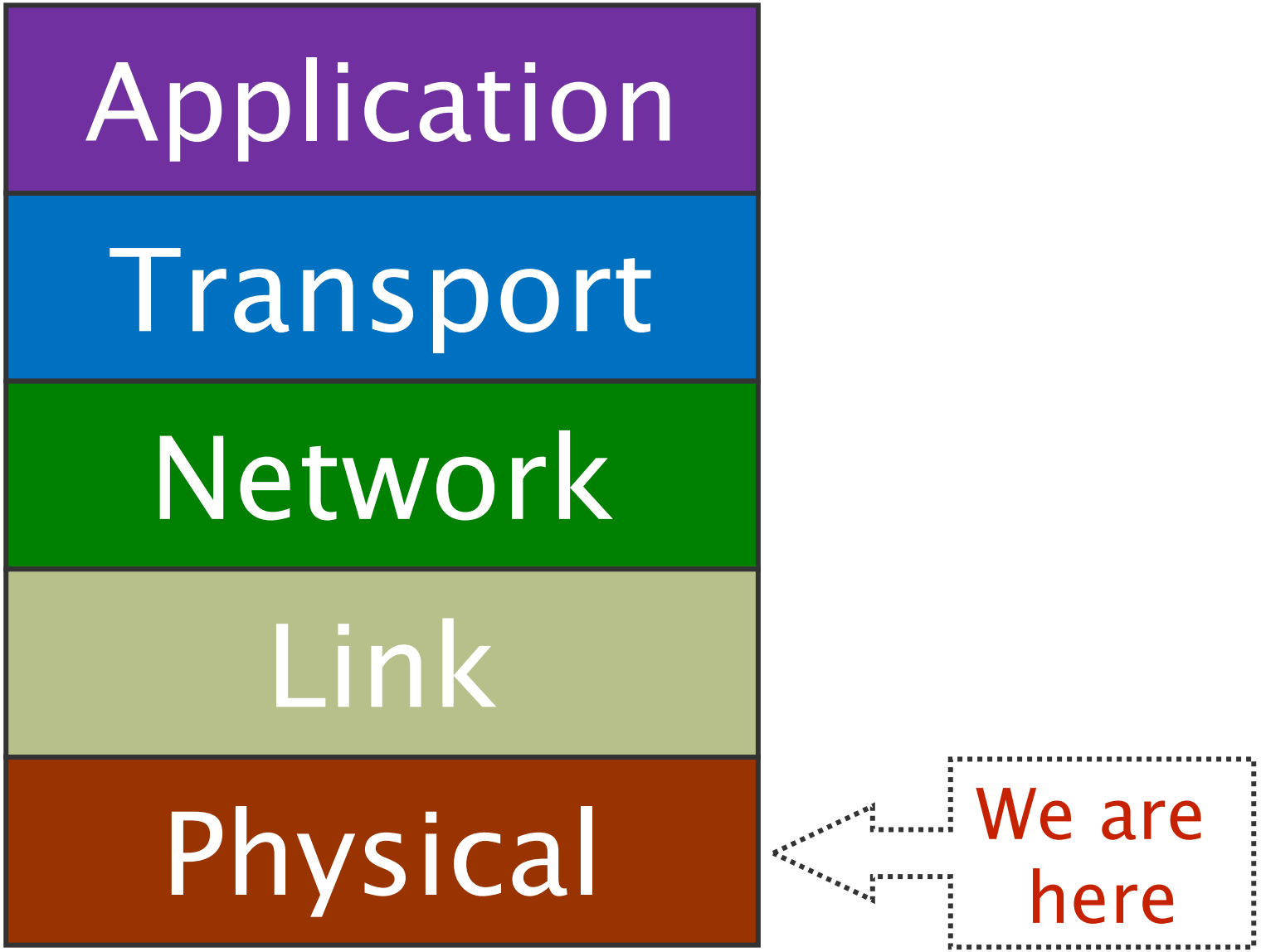
Network Security (previous)

- Principles of cryptography
  - Symmetric key encryption
  - Public-key encryption
- Message integrity and digital signatures
  - Digital signature: 1. A, compute message digest, 2. encrypt digest with A's private key, 3. decrypt with A's public key, 4. compute new digest and compare with sent and signed digest
  - Send secure message: 1. encrypt with B's public key, 2. decrypt with B's private key.
- VPN's and firewalls (non-examinable)

Lecture 12

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 a constellation diagram


Application
Transport
Network
Link
Physical
We are here

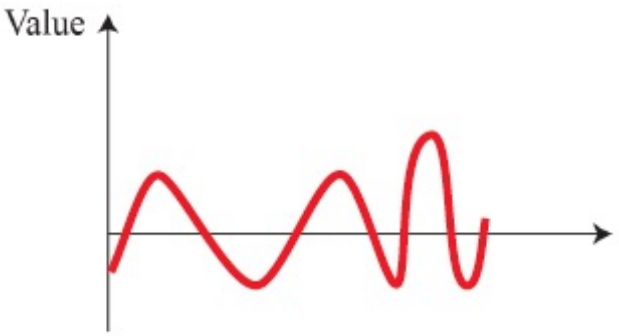
Lecture 12: Roadmap

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

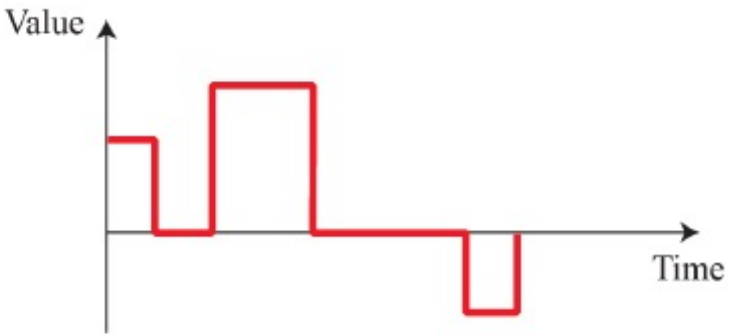
Digital and Analog Signals

- Physical layer moves data in the form of electro-magnetic signals across transmission medium

- 0s and 1s can be transmitted as either analog signals or digital signals
  - Analog signal is continuous, with infinitely many levels
  - Digital signal has a limited number of defined values



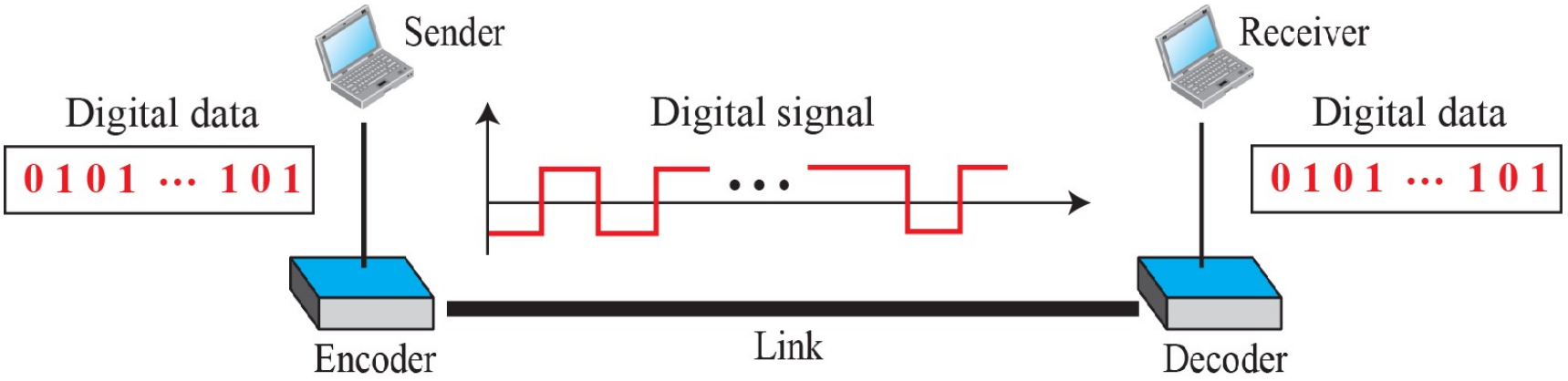
a. Analog signal



b. Digital signal

Digital Transmission

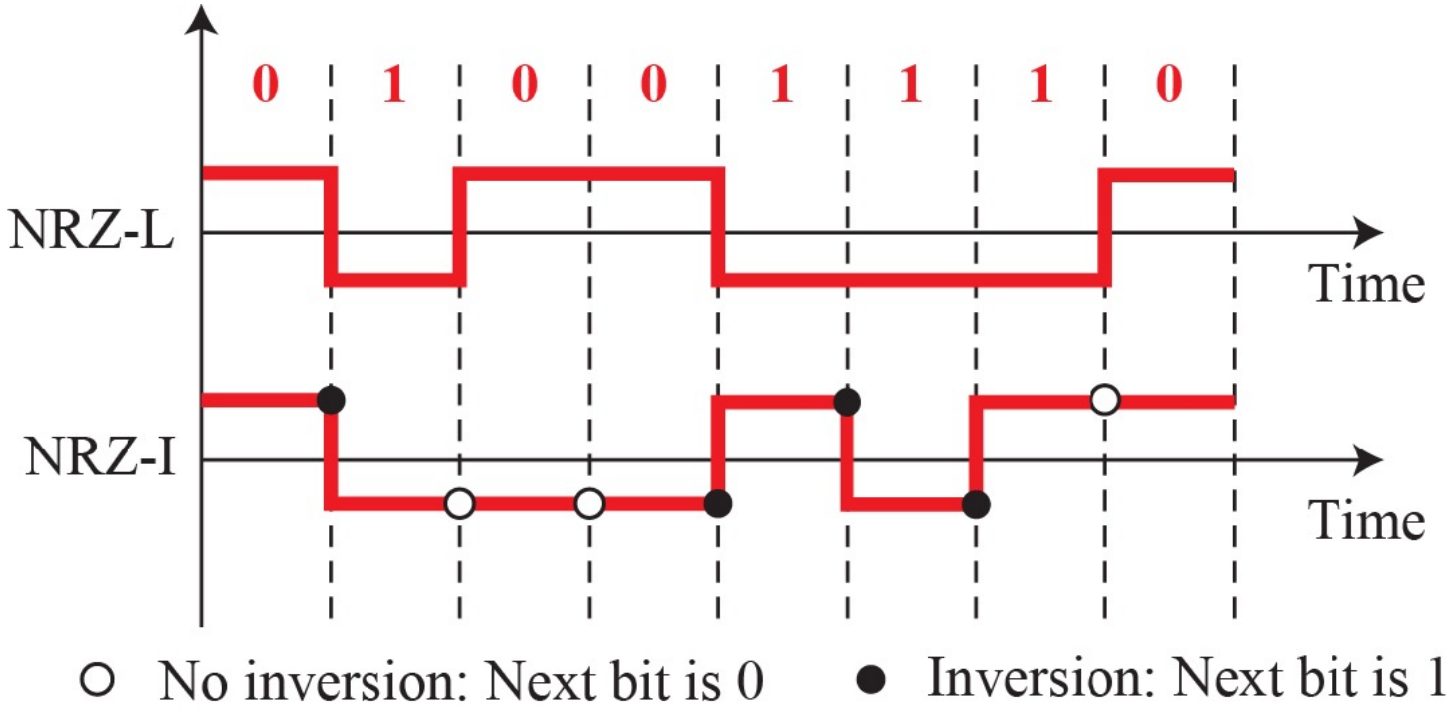
- In digital transmission, we encode 0s and 1s with different voltages to be transmitted over the wire



- We will introduce 3 digital encoding methods

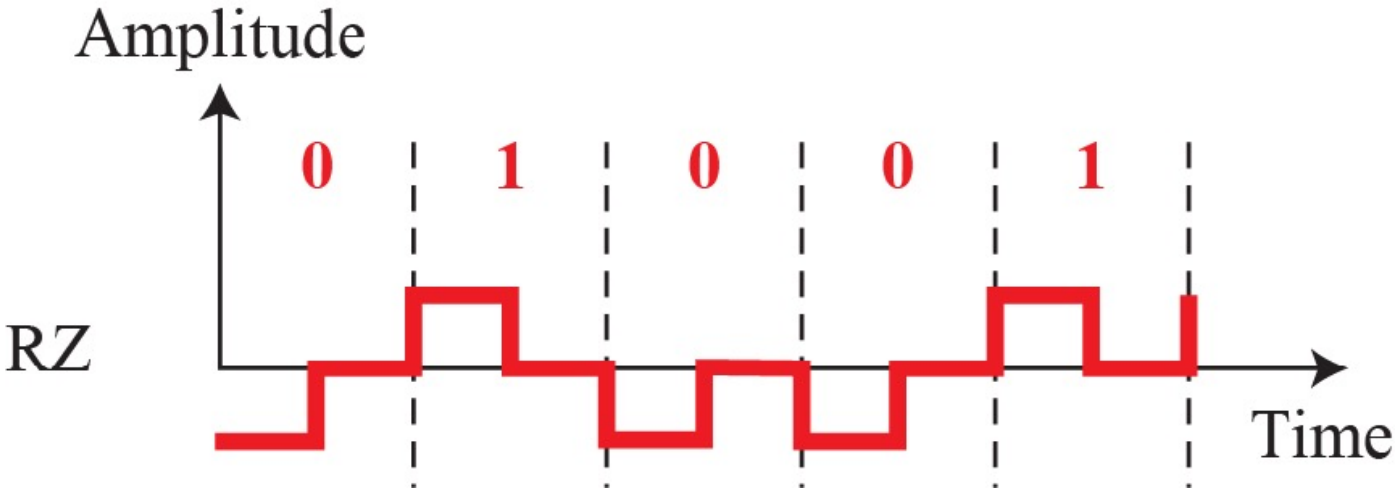
NRZ (Non-Return-to-Zero)

- 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.



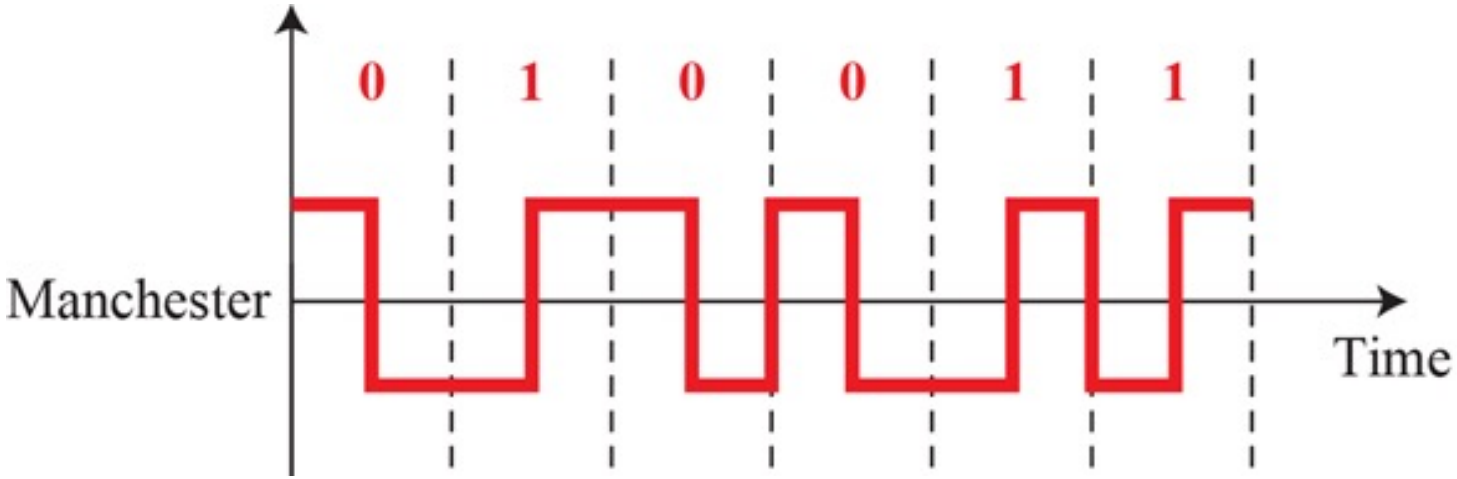
RZ (Return-to-Zero)

- 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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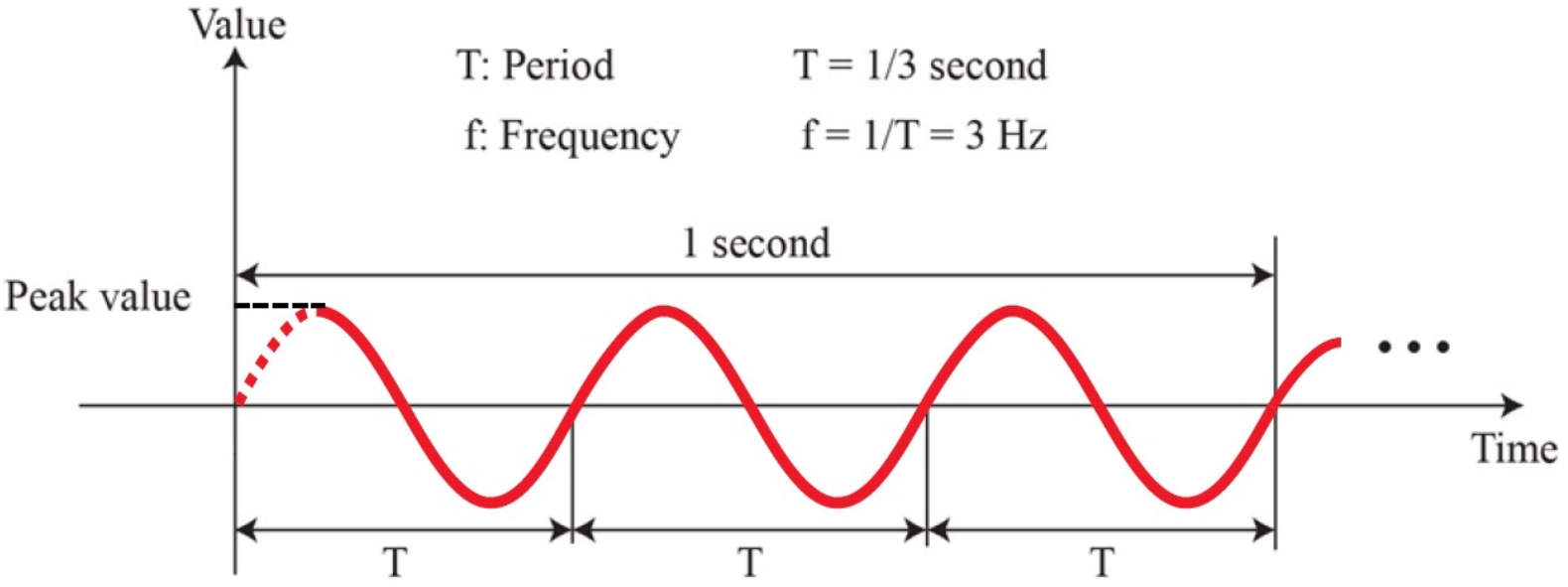
Analog Signal

- The most basic analog signal is a sine wave.

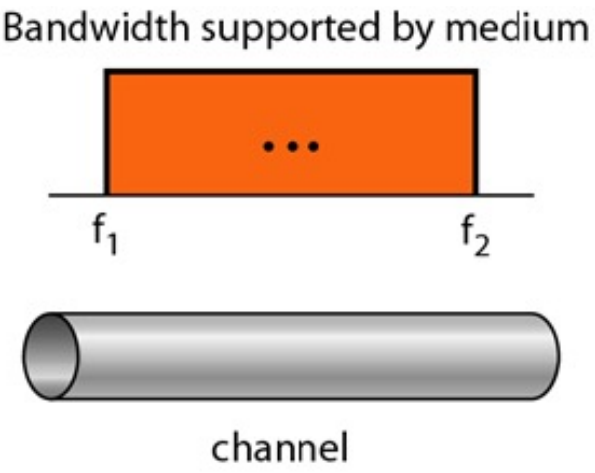
$$A\sin(2\pi f t + \phi)$$

Peak amplitude frequency phase



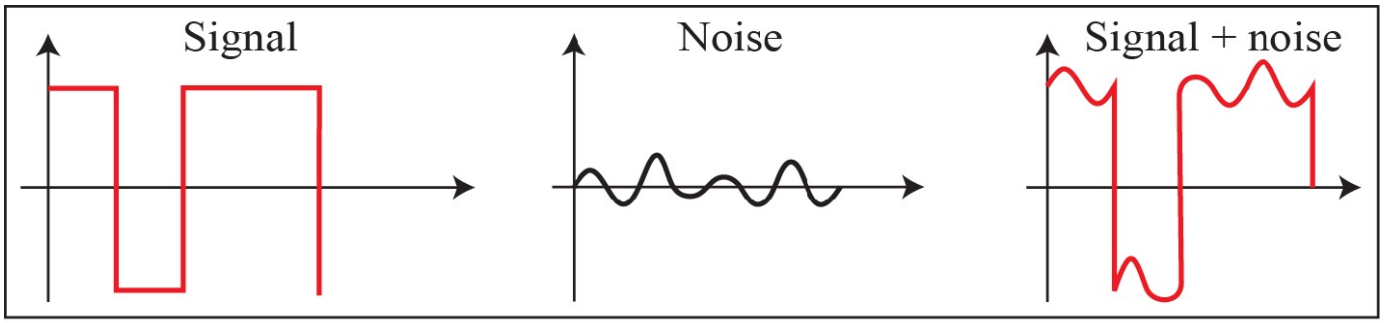
Channel Bandwidth

- 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.

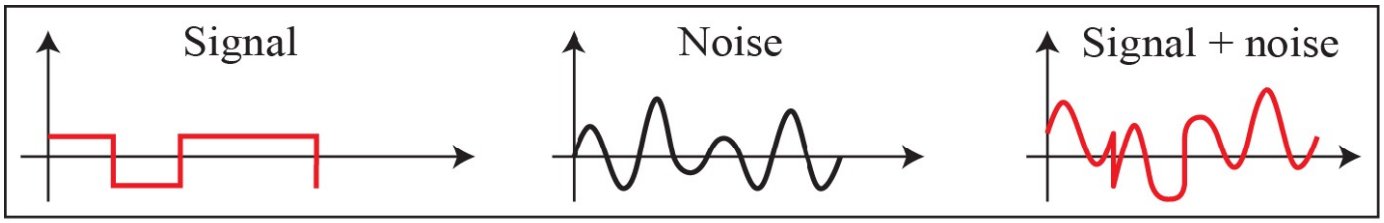


Signal to Noise Ratio (SNR)

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



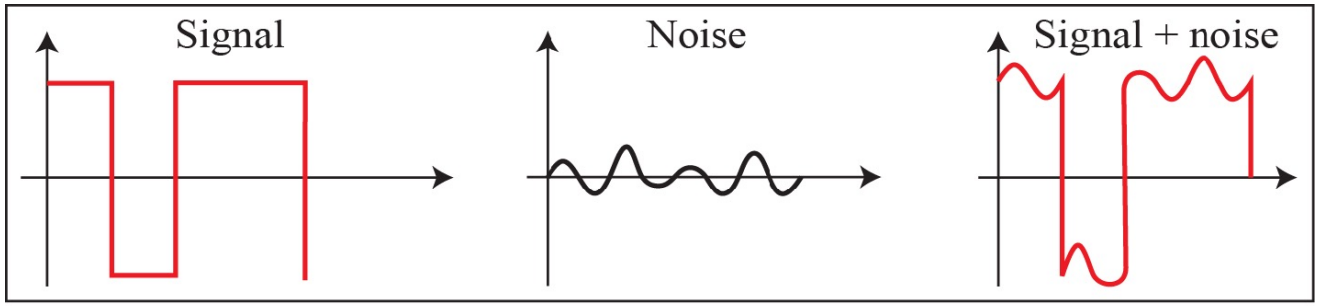
a. High SNR

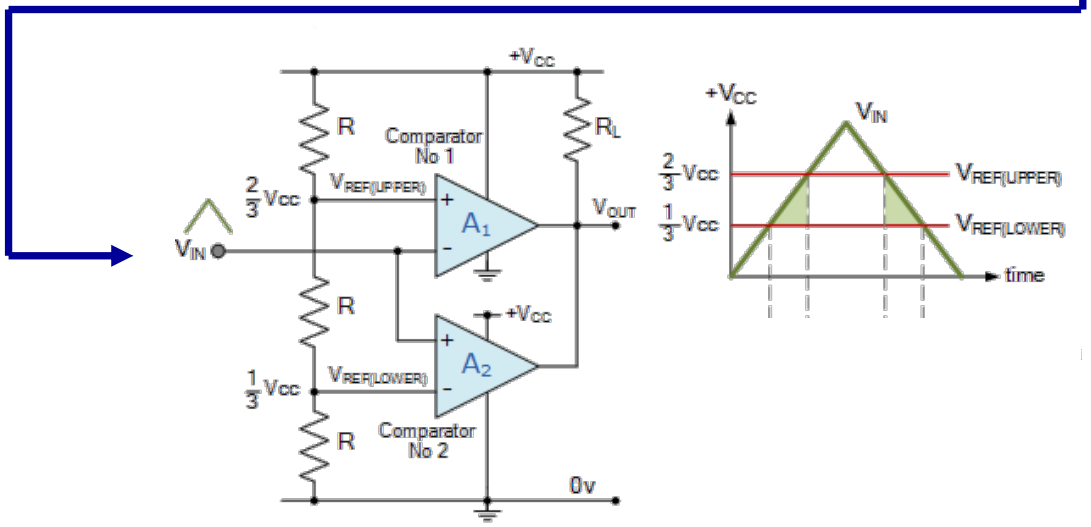


b. Low SNR

Receiver Comparator

- At the receiver side, the signal is generally sent to a comparator circuit of some sort.





Shannon Channel Capacity

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

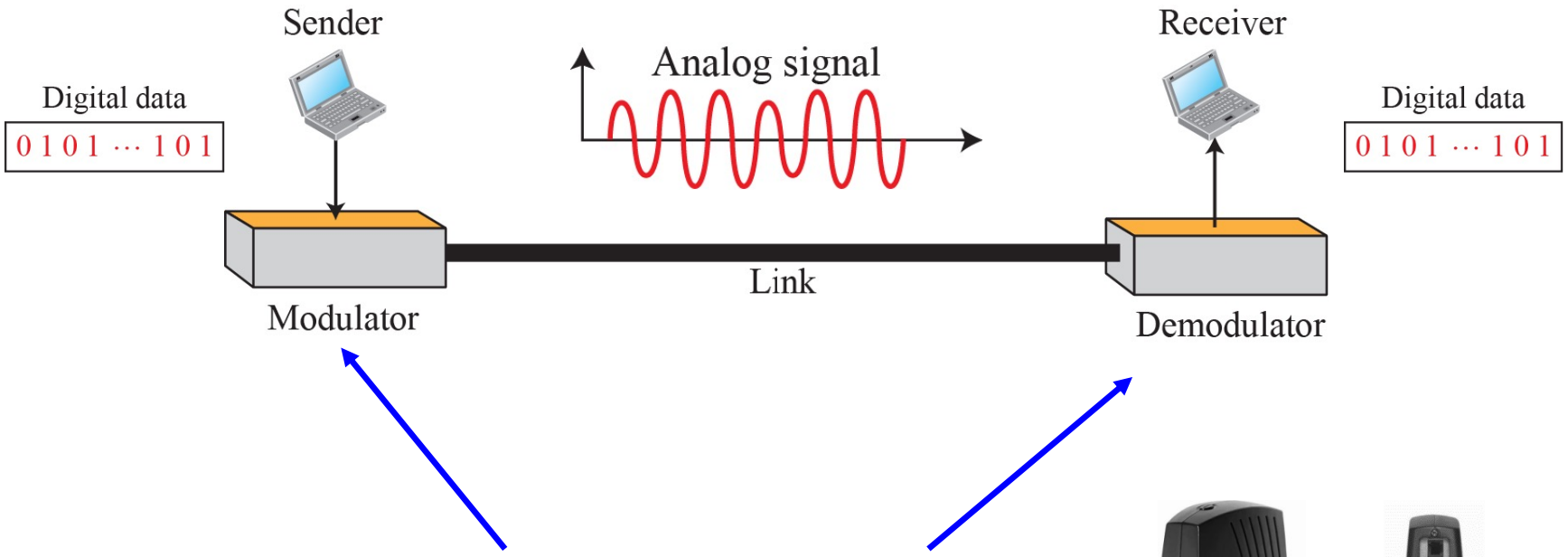
$$C = B * log_2(1 + SNR)$$

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

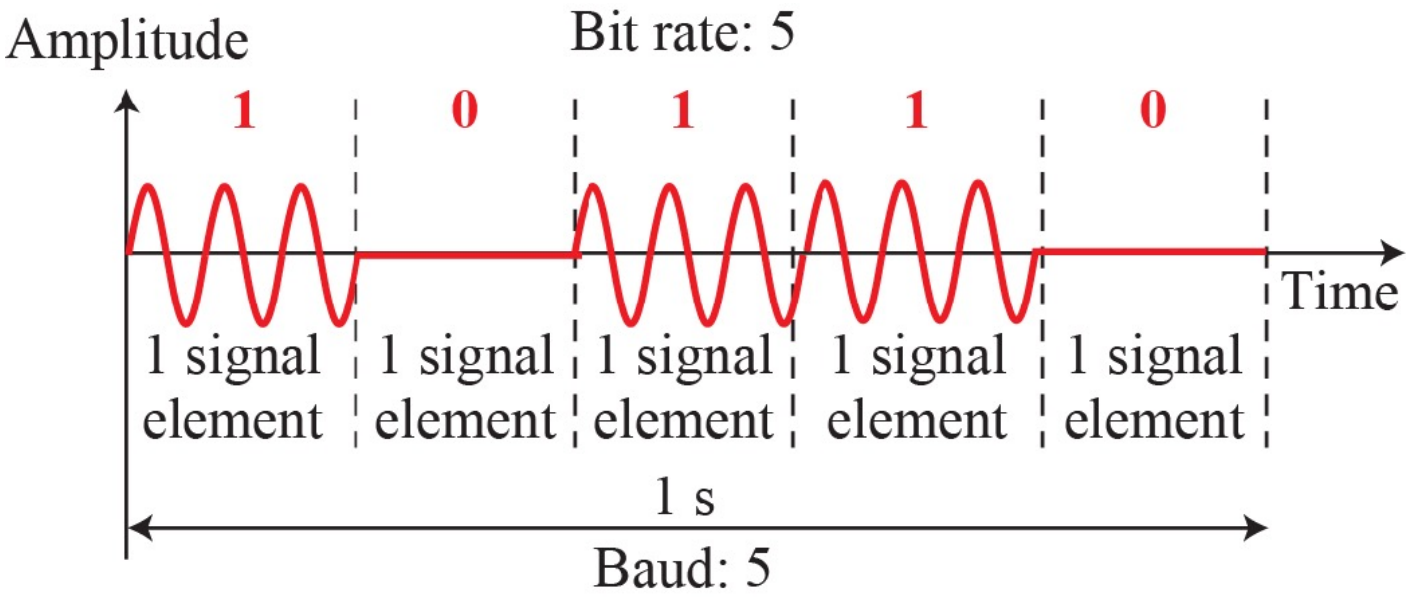


- Modem = modulator + demodulator

Analog Encoding

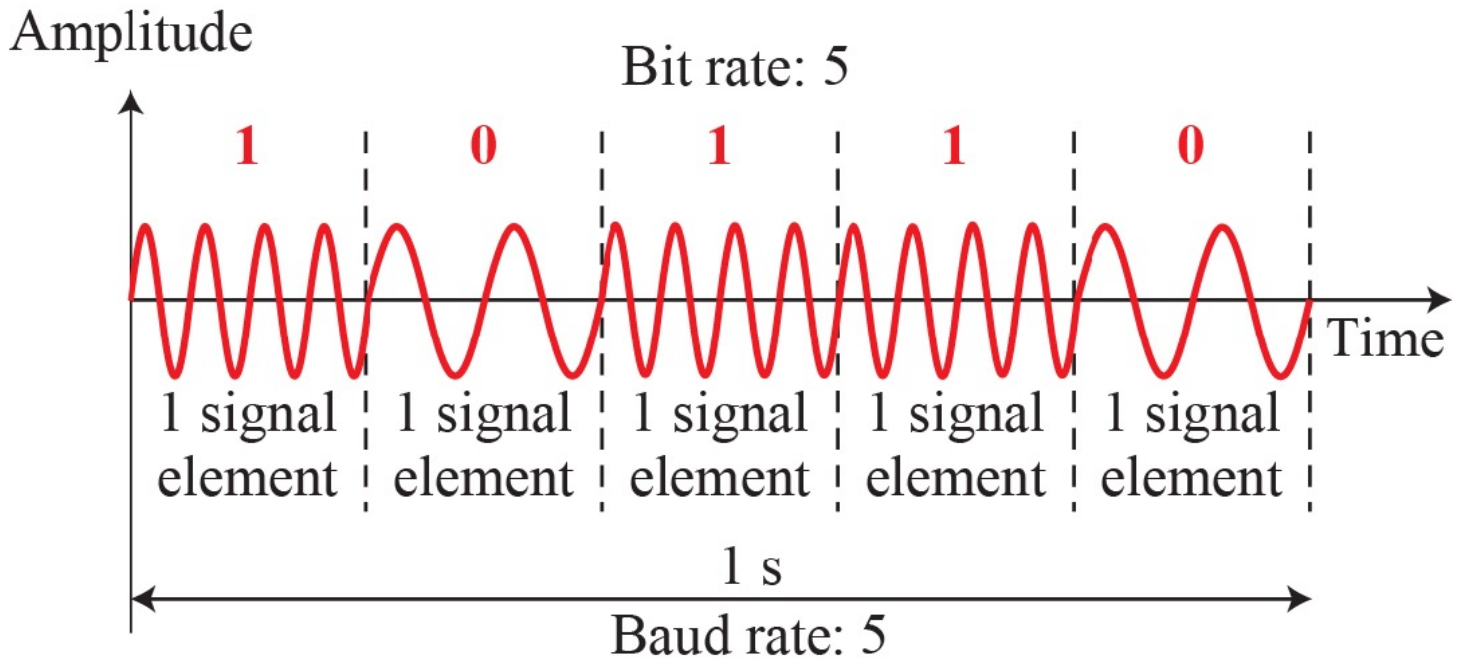
- To transmit 0s and 1s with analog signal, we can change A, f, or ϕ.
- Amplitude Shift Keying (ASK) changes peak amplitude (A) to represent 0s and 1s.
- Frequency Shift Keying (FSK) changes frequency (f) to represent 0s and 1s.
- Phase Shift Keying (PSK) changes phase (ϕ) to represent 0s and 1s.

Amplitude Shift Keying (ASK)



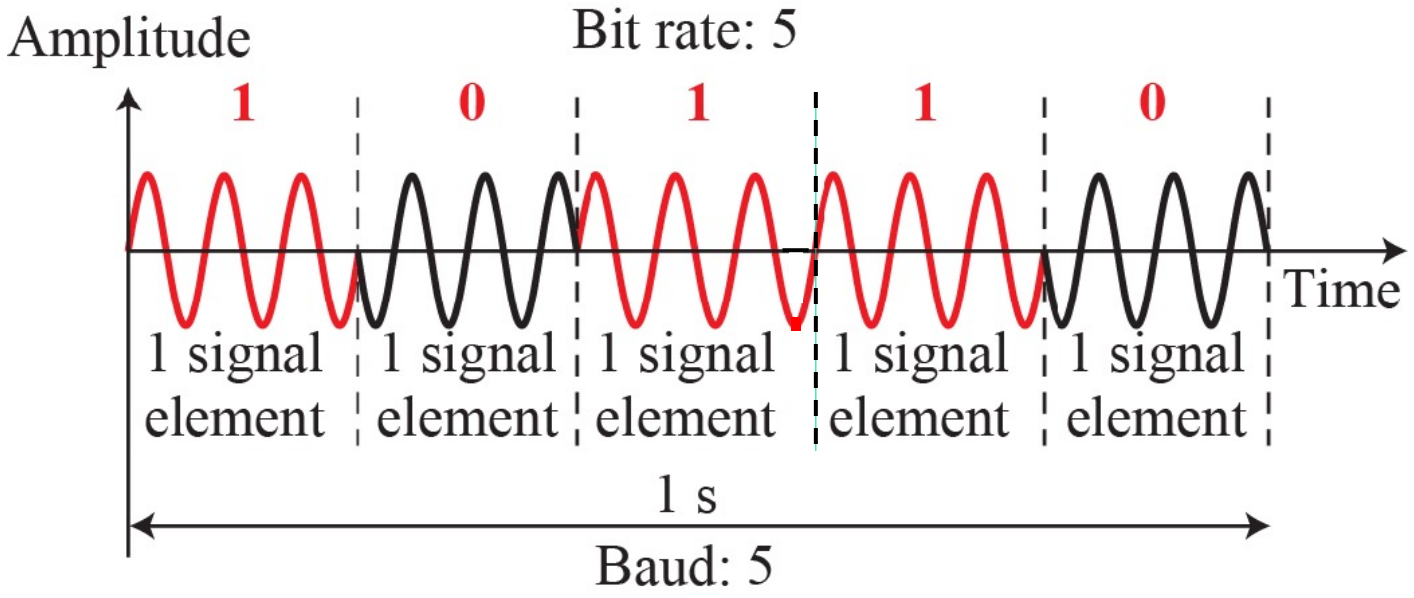
- Peak amplitude of the signal varies with data values.
- ASK is susceptible to noise.

Frequency Shift Keying (FSK)



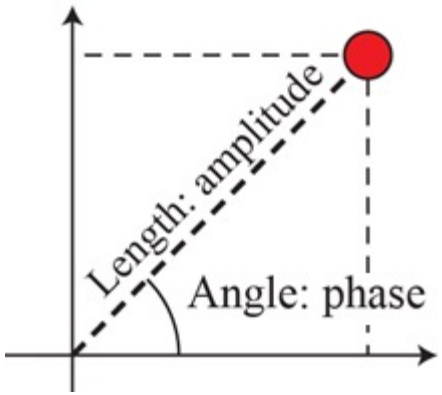
- Amplitude and phase remain constant.
- FSK is limited by the bandwidth of the channel.

Phase Shift Keying (PSK)



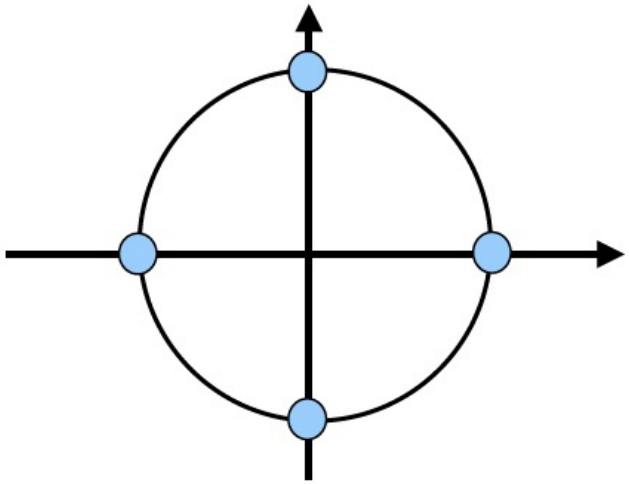
- One signal element with phase 0°.
- Another with phase 180°.

QPSK Constellation Diagram



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

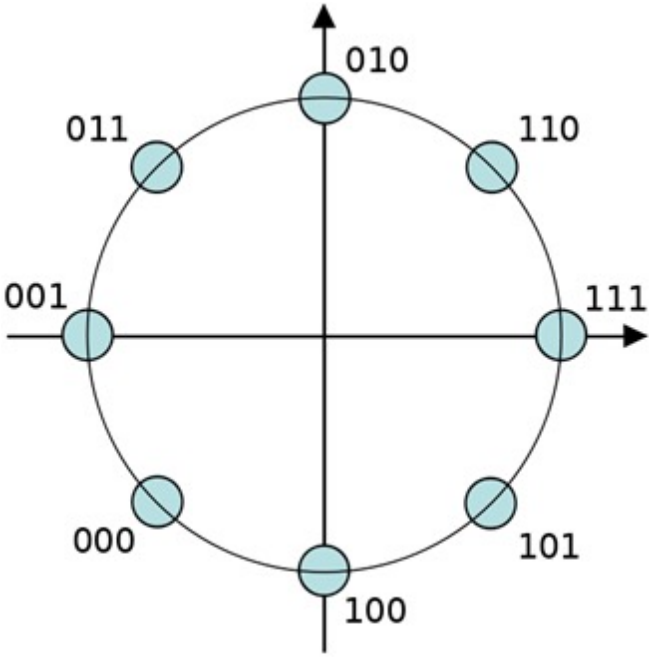
Phase	Values represent
0^0	11
90^0	01
180^0	00
270^0	10



- Now every signal tells the 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 the receiver 3 bits of data!

QAM

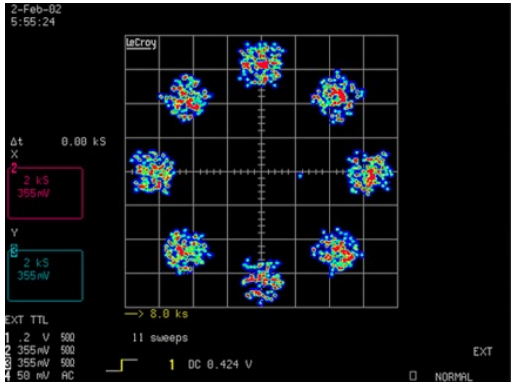
- Can we transfer even faster?

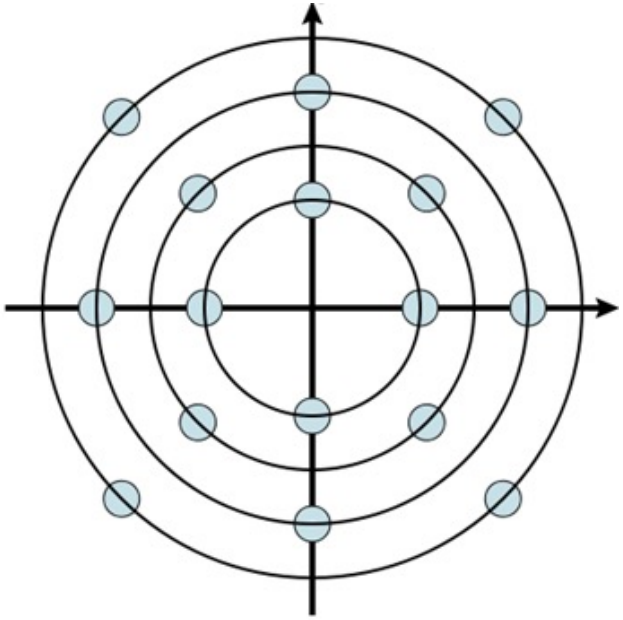
- Quadrature Amplitude Modulation (QAM) combines ASK and PSK. Many combinations are possible.
  - A signal unit in a 2^k-QAM scheme is a combination of amplitude and phase that represents k bits.
  - Baud rate is the number of signal elements (signal units) per second.
  - Bit rate is the number of bits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

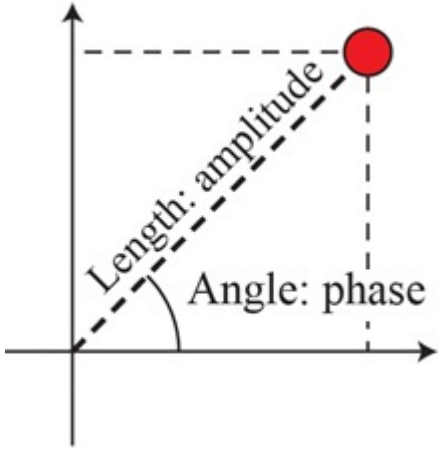
16-QAM

- 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 Meta, i.e., the *company formerly known* as 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 ☺.

Meta

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 broadcast on subnet.

  - DHCP server receives and processes this frame, starts negotiation with your PC for IP.
  - Intermediate switches learn your position when forwarding your frames.

Details in lecture 6 notes

Details in lecture 9 notes

A Day in the Life of a Web Request

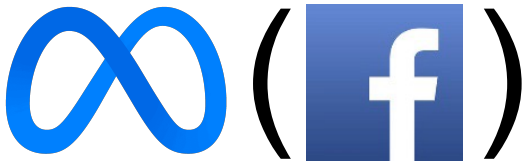
- Step 2:
  - DHCP server also tells you IP addresses of first-hop router and local DNS server.
  - After you type www.facebook.com, browser needs to know IP of this website → from local DNS server
    - To know the MAC address of local DNS server, PC broadcasts ARP query. Local DNS server replies with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

Details in lecture 9 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

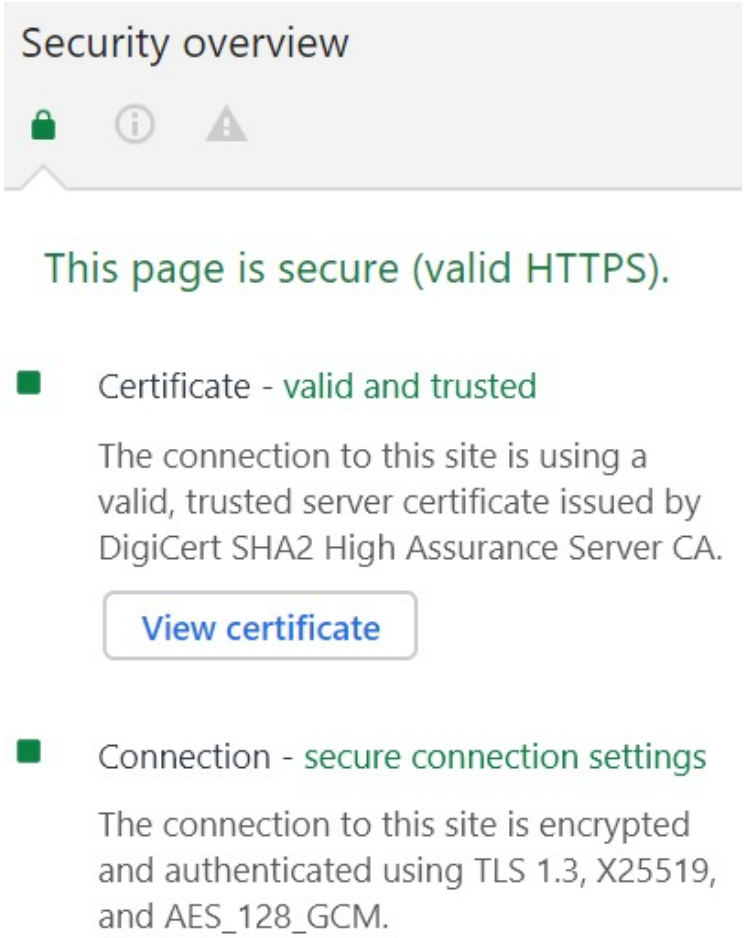
Details in lectures 2, 3 notes

Details in lecture 7 notes

A Day in the Life of a Web Request

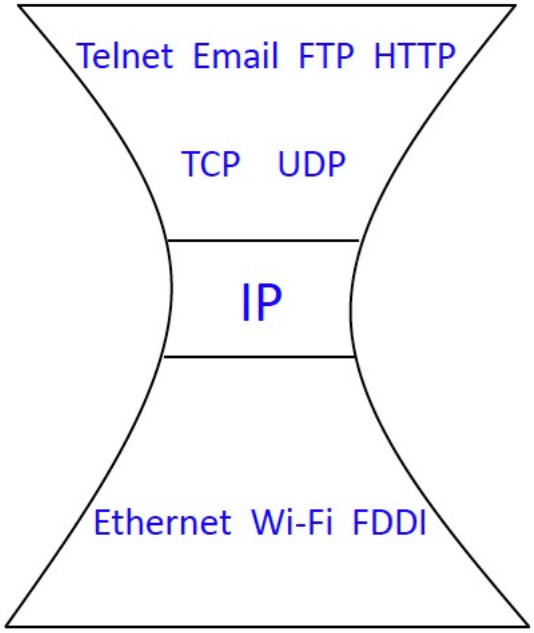
- Step 4:
  - When Facebook is contacted
    - Negotiate for secure connection.
    - HTTPS = HTTP + SSL/TLS
    - Digital certificate of Facebook verified.
    - Message encryption and authentication.

Details in lecture 11 notes



Lessons from CS2105

- Network systems are so complex!
  - There are many issues to consider, to support different applications running on a large number of hosts through different access technologies and physical media.
- To deal with complexity:
  - Separation of concerns
  - 5 protocol layers
- To deal with scalability:
  - Hierarchical systems



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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Examination Matters

1. SoC has prepared E-exam SOPs for students, please refer to the guide: https://mysoc.nus.edu.sg/academic/e-exam-sop-for-students/

Please ensure that you read through and set up what you need before the exam date.

2. You should sit for the exam in insolation in a quiet environment with all the required hardware and software. If there's any circumstances that require you to attempt your exams in campus, please email your request to socexams@comp.nus.edu.sg by **10 November 2021, Wednesday** latest.

CS2105 Final Preparation

- **Mock Final Exam**: **Online – LumiNUS Quiz**
- When: Opens this weekend (by 14 Nov), closes 21 Nov
- Duration: 1 hour (~**1/2** of real final exam)
- Marks: **0%** for taking mock exam – right/wrong answers don't count
- Scope (the same as final exam):
  - Materials from Lectures 1 to 11 (not 12) and all Tutorials

CS2105 Final Preparation

- **Consultation Session**
- When: **Zoom**, Thu 18 November 2021, 4-6 PM
- Will make announcement, with Zoom link
- All Profs. Lifeng, Jithin, and Roger

CS2105 Final Assessment

- Time: **09:00 – 11:00, Monday 29 November 2021**
- Venue: **Online – LumiNUS Quiz**
- **Open book** assessment
  - You may bring any printed and PDF materials
- iPad allowed for **viewing only**; non-programmable calculator allowed
- Scope:
  - Materials from Lectures 1 to 11 (not 12) and all Tutorials

CS2105 Final Assessment

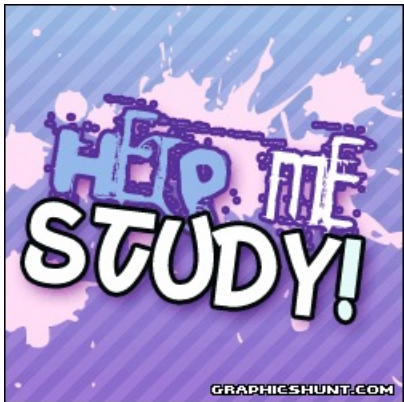
- Format (similar to Midterm) – 50 marks total
  - # of MCQs – 1 mark each
  - # of Multiple Response Questions (MRQ) – 2 marks each
  - # of Fill-in-the-Blanks Questions – 2 marks each
- In MRQ, wrong answers reduce marks. Don't randomly guess.

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.
    - Answers provided.
    - For your practice; don't post them onto the Internet.
- During exam
  - Read the instructions/questions carefully.
  - A (non-programmable) calculator is allowed and may be helpful.

Consultation

- Discuss on **LumiNUS** Forum
- Email lecturers
  - zhoulife@comp.nus.edu.sg
  - jithin@comp.nus.edu.sg
  - rogerz@comp.nus.edu.sg
- Zoom/Office consultation (Upon email appointment)
  - Office: COM2 #02-56 (Lifeng)
  - Office: AS6 #04-17 (Jithin)
  - Office: AS6 #05-05 (Roger)



Thank you!


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