

CSE 473S: Introduction to Computer Networks



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Audio/Video recordings of this lecture are available on-line at:

<http://www.cse.wustl.edu/~jain/cse473-19/>



- ❑ Why Study Computer Networking?
- ❑ Goal of This Course
- ❑ Instructor
- ❑ Grading
- ❑ Contents of the course
- ❑ Tentative Schedule

Networking = “Plumbing”

- ❑ Networking is the “plumbing” of computing
- ❑ Almost all areas of computing are network-based.
 - Distributed computing
 - Big Data
 - Cloud Computing
 - Internet of Things
 - Smart Cities
- ❑ Networking is the backbone of computing.



Networking is already great!

Networking is Fueling All Sectors of Economy

- ❑ Networking companies are among the most valued companies: Apple, AT&T, Samsung, Verizon, Microsoft, China Mobile, Alphabet, Comcast, NTT, IBM, Intel, Cisco, Amazon, Facebook, ...
⇒ All tech companies that are hiring currently are networking companies
- ❑ Note: Apple became highly valued only after it switched from computing to communications (iPhone)



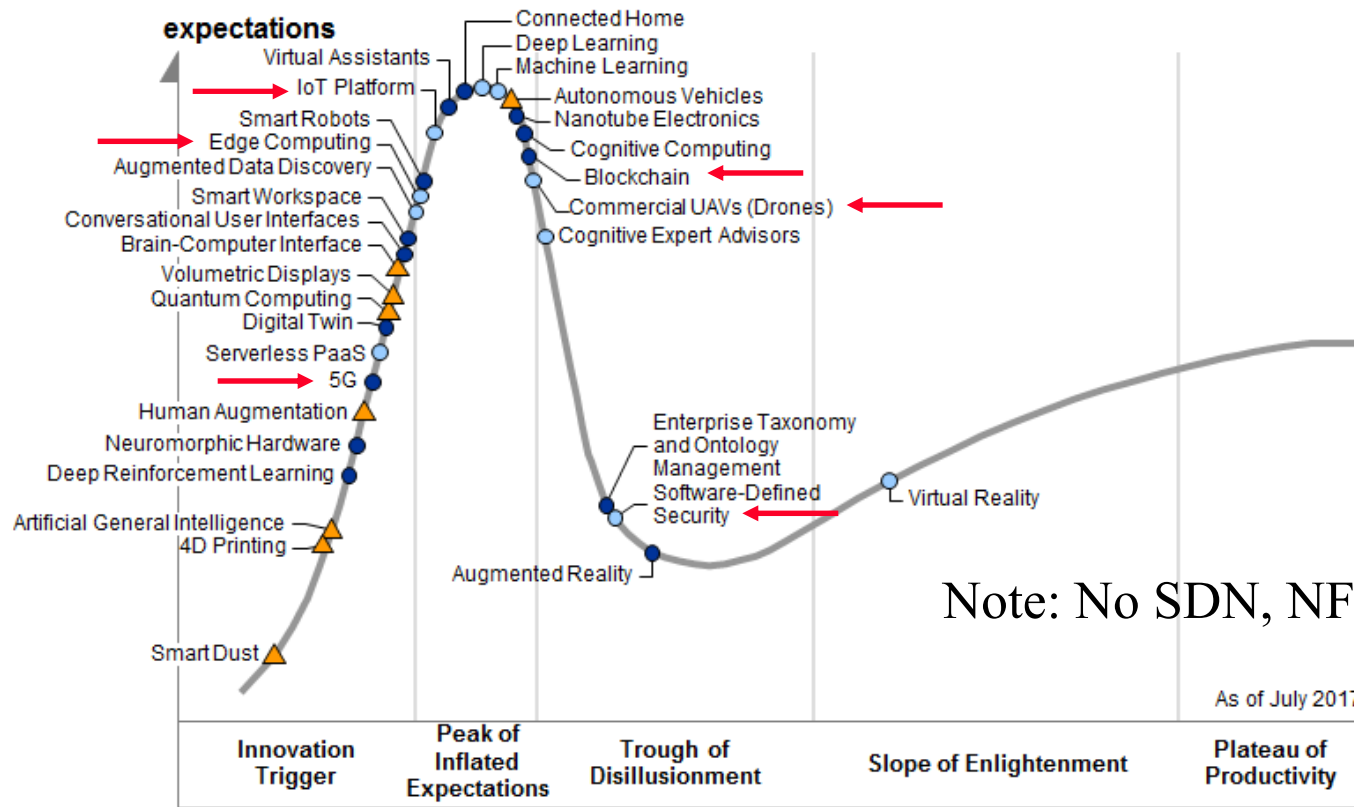
Networking = Economic Indicator

Selecting the Right Field

- ❑ Important question for **students**, academics, entrepreneurs, and companies
- ❑ Goal: To impact
- ❑ Follow the **paradigm shifts**:
 - 1980: Operating Systems
 - 1990: Performance Analysis
 - 2000: Networking
 - 2013: Multi-Cloud Computing
 - 2017: Whatever is being **hyped** this year?



Gartner Hype Cycle 2017



Note: No SDN, NFV, ...

As of July 2017

VC investment ← | Acquisitions By large corporations | → Mass Production

Current Hot Topics in Networking



1. Internet of Things (IoT)
2. Security
3. Edge Computing and Multi-Cloud
4. Blockchains
5. Drones

Trend: Smart Everything



Smart Watch



Smart TV



Smart Car



Smart Health



Smart Home



Smart Kegs



Smart Space



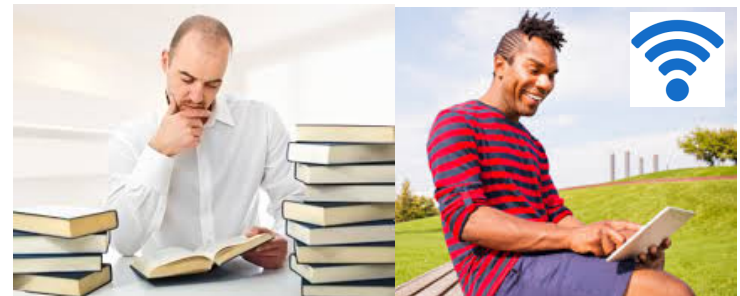
Smart Industries



Smart Cities

What's Smart?

- ❑ Old: Smart = Can think \Rightarrow Computation
= Can Recall \Rightarrow Storage
- ❑ Now: Smart = Can find quickly, Can Delegate
 \Rightarrow Communicate = Networking
- ❑ Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, ...



Not-Smart

Smart

Trend: Security & Cyber Warfare

- ❑ Security of computers, companies, smart grid, and nations
- ❑ Nation States are penetrating other nations computers
5th domain of warfare (after land, sea, air, space)
- ❑ In 2010, US set up US Cyber Command
- ❑ UK, China, Russia, Israel, North Korea have similar centers
- ❑ Many cyber wars: North Korea vs. USA, Israel vs. Syria, South Korea vs. North Korea, India vs. Pakistan, ...



Old



New

Ref: http://en.wikipedia.org/wiki/Cyber_war

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Internet of Harmful Things

Researchers at DEFCON 3, hacked a smart toilet, making it flush incessantly and closing the lid repeatedly and unexpectedly. Causing a **Denial of Service** Attack.



Ref: <http://www.computerworld.com/article/2486502/security0/worm-may-create-an-internet-of-harmful-things--says-symantec--take-note--amazon-.html>

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DEFCON



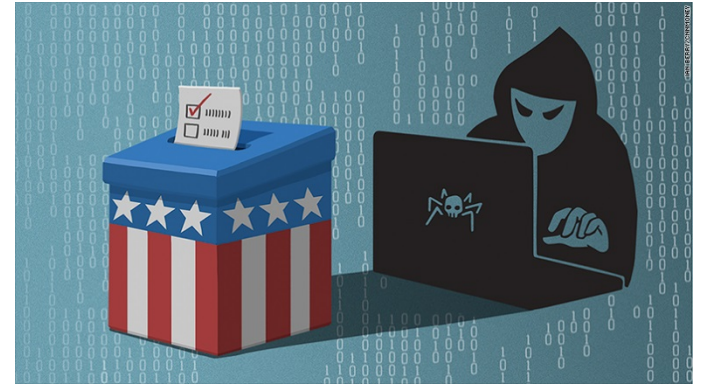
- ❑ Hacker's conference
- ❑ Held in Las Vegas every July
- ❑ 20,000+ attendees
- ❑ All anonymous

Ref: <https://www.ethicalhacker.net/features/opinions/first-timers-experience-black-hat-defcon>
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DEFCON 2017

- ❑ Hacking voting machines
- ❑ Hack connected vehicles
- ❑ Hacking the cloud
- ❑ Hacking travel routers
- ❑ Clone RFID in real time
- ❑ Breaking the Uber badge ciphers
- ❑ Counterfeit hardware security devices, RSA tokens
- ❑ Fool antivirus software using AI
- ❑ How to track government spy planes
- ❑ Break bitcoin hardware wallets
- ❑ DARPA Cyber Grand Challenge (2015, 2016)



Trend: Cloud Computing

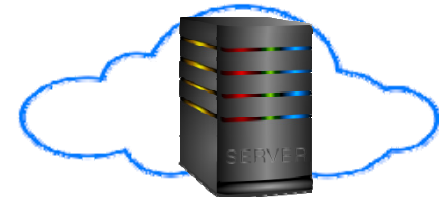
- ❑ August 25, 2006: Amazon announced EC2
⇒ Birth of Cloud Computing in reality
(Prior theoretical concepts of computing as a utility)
\$10 B in 2016, a growth rate of 49% with 17% margins, much higher than the overall Amazon business



- ❑ Cloud Computing:
 - Applications through Internet (Google Docs)
 - Computing through Internet (Amazon EC3)
 - Storage and backup through Internet (iCloud, Google Drive)

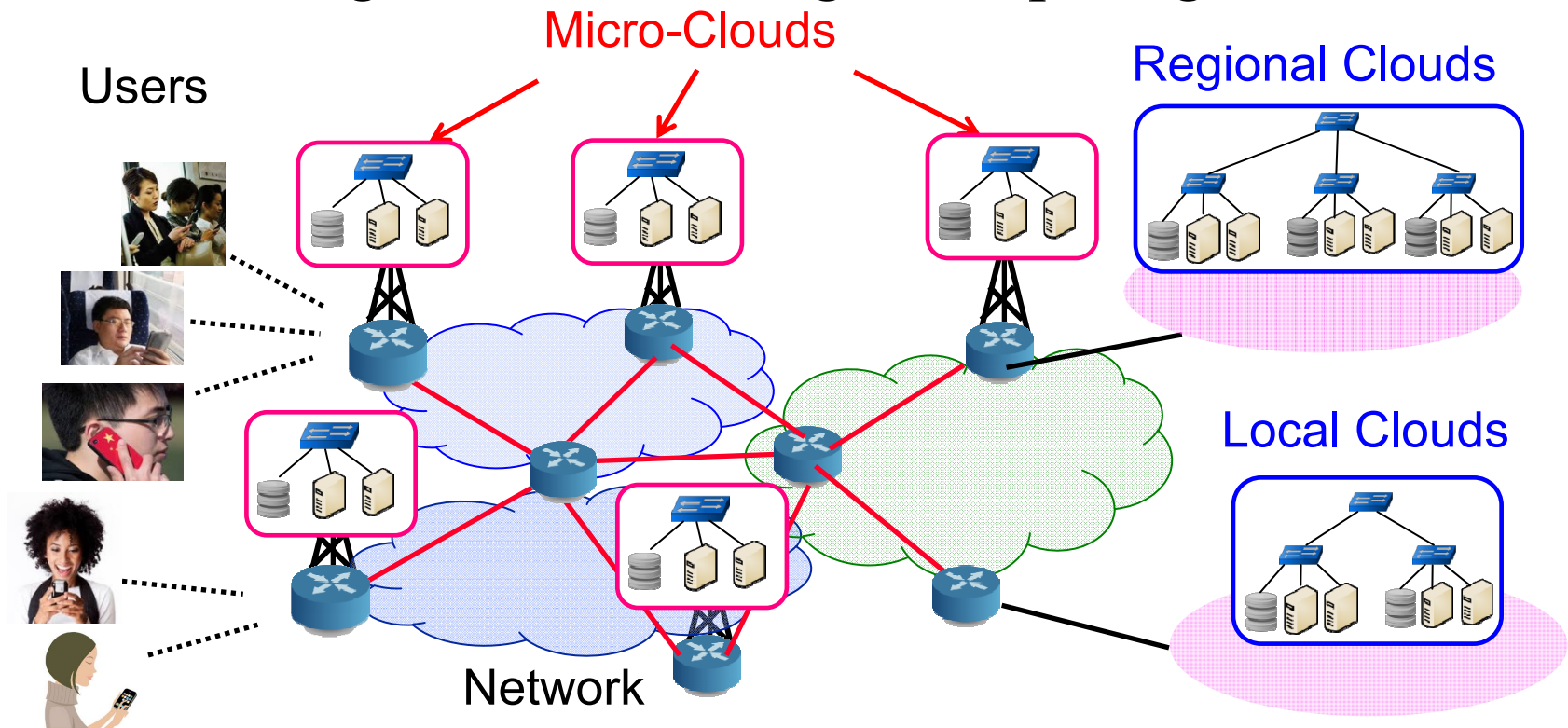
Trend: Micro-Cloud Computing

- ❑ Cloud computing was invented in 2006
- ❑ Then: Cloud = Large Data Center
Multiple VMs managed by a cloud management system (OpenStack)
- ❑ Today: Cloud = Computing using virtual resources
 - μ Cloud = Cloud in a server with multiple VMs.
 - Each VM with Multiple Containers \Rightarrow Multiple Services



Trend: Mobile Edge Computing

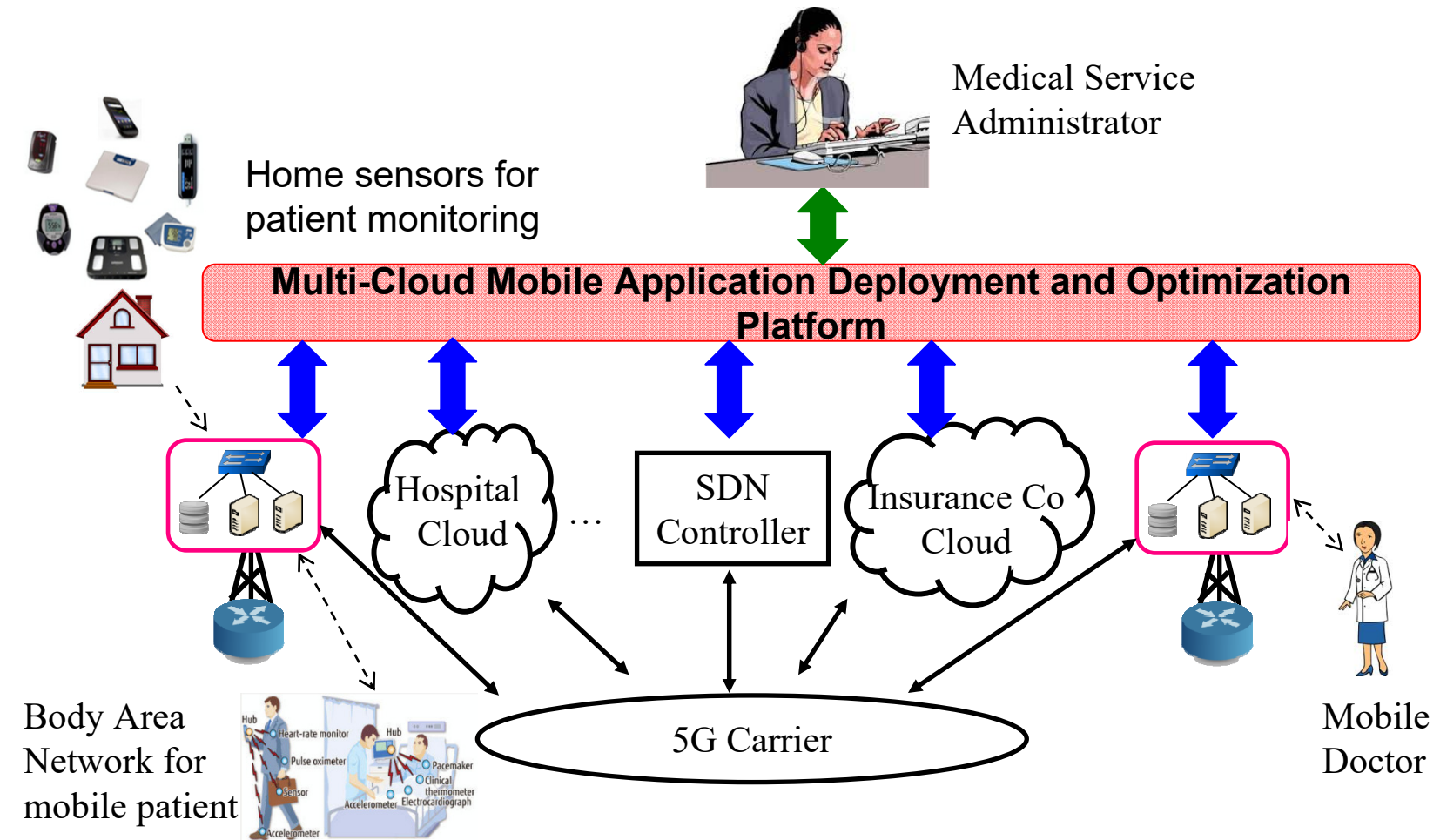
- To service mobile users/IoT, the computation needs to come to edge \Rightarrow Mobile Edge Computing



Ref: Lav Gupta, Raj Jain, H. Anthony Chan, "Mobile Edge Computing - an important ingredient of 5G Networks," IEEE Softwarization Newsletter, March 2016, <http://www.cse.wustl.edu/~jain/papers/mec16.htm>
Washington University in St. Louis <http://www.cse.wustl.edu/~jain/cse473-19/>

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Mobile Healthcare Use Case



Trend: Blockchains

- ❑ Blockchain is the technology that made Bitcoin secure
- ❑ Blockchain was invented by the inventor of Bitcoin
- ❑ After Bitcoin became successful, people started looking into the technology behind Bitcoin and found:
 - Blockchain is the key for its success
 - Two complete strangers can complete a transaction without a third party

Example of a Contract: Wedding



Wedding (Cont)

❑ Centralized



- ❑ Centralized registry
- ❑ Single point of failure
- ❑ Easier to hacked

❑ Decentralized



- ❑ Decentralized
- ❑ No single point of failure
- ❑ Very difficult to hack

Trend: Centralized to Decentralized

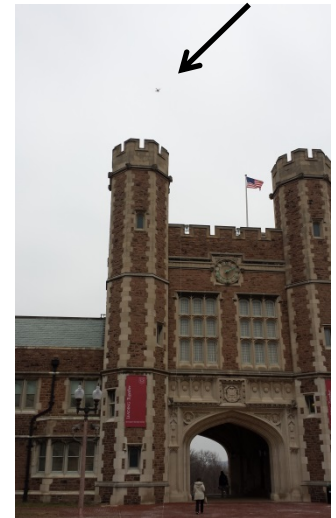
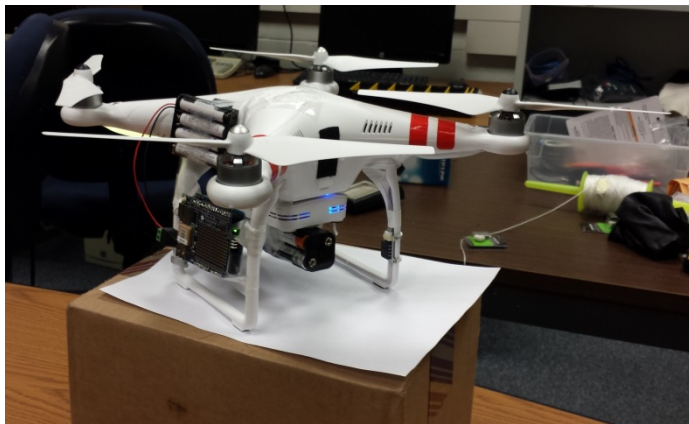
- ❑ **Trend:** Make everything decentralized with no central point of control
- ❑ Two perfect strangers can exchange money, make a contract without a trusted third party
- ❑ Decentralized systems are
 1. More reliable: Fault tolerant
 2. More secure: Attack tolerant
 3. No single bottleneck \Rightarrow Fast
 4. No single point of control \Rightarrow No monopoly
- ❑ Blockchain is one way to do this among **untrusted multi-domain** systems.

Time is a cycle: Distributed vs. Centralized debate

Examples of Centralized Systems

- ❑ **Banks:** Allow money transfer between two accounts
- ❑ **Currency:** Printed and controlled by the government
- ❑ **Stock Exchanges:** Needed to buy and sell stocks
- ❑ **Networks:** Certificate Authorities, DNS
- ❑ In all cases:
 1. There is a central third party to be trusted
 2. Central party maintains a large database of information \Rightarrow Attracts Hackers
 3. Central party may be hacked \Rightarrow affects millions
 4. Central party is a single point of failure.
Can malfunction or be bribed.

Trend: Drones



Goal of This Course

- ❑ First course in networking
- ❑ Fundamentals
- ❑ Broad coverage of key areas of networking
- ❑ Networking background for networking applications in other areas of computing
- ❑ This is a course on Networking Architecture
- ❑ This is not a course on network building or usage
- ❑ You will be able to understand protocols
- ❑ An example of the difference between architecture and implementation is the computer architecture course and a course on Intel Pentium Chip.
- ❑ This is the first course on networking.
- ❑ Basis for more advanced networking courses

What Will You Learn?

1. What messages and messages are exchanged when you fetch a web page?
2. What messages are used to send/receive emails?
3. How the names such as www.google.com gets translated to IP addresses such as 74.125.73.104?
4. What is done to avoid congestion under overload?
5. How is the path in the Internet determined?
6. What happens if bits in a packet get corrupted?
7. How WiFi or Ethernet works?
8. What is the difference between WiFi, Ethernet, IP, and TCP?
9. What is done to handle audio/video on the Internet?
10. How can you guarantee security on the Internet?

Networking Courses at WUSTL

1. **CSE 473: Introduction To Computer Networks**
(Spring 2019) – Prerequisite for all other networking classes
2. CSE 521S: Wireless Sensor Networks
3. CSE 537S: Mobile Computing
4. **CSE 570S: Advanced Networking:**
Clouds, Big Data, SDN, IoT (Spring 2018)
5. **CSE 574S: Wireless and Mobile Networking** (Fall 2018)
6. **CSE 571S: Network Security**
7. CSE 7700: Research Seminar On Networking and Communications



Networking Foundation

CSE 521S: Wireless Sensor Networks

CSE 537S: Mobile Computing

CSE 570: Advanced Networking

CSE 571: Network Security

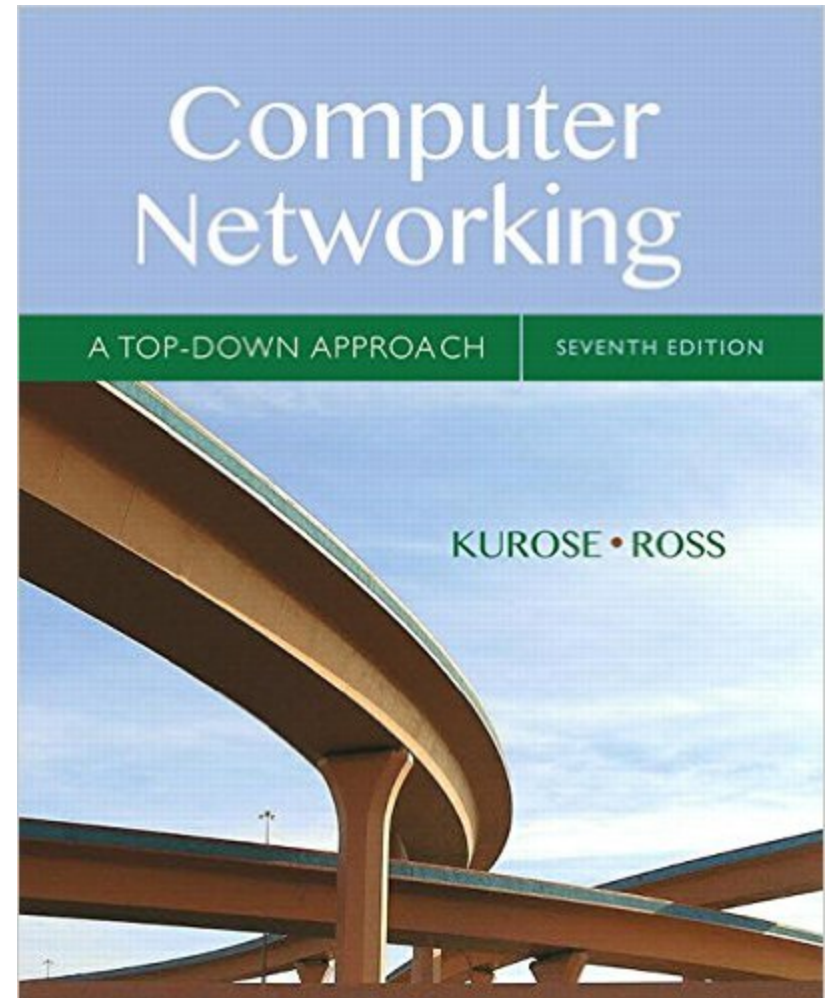
CSE 574S: Wireless and Mobile Networking

CSE 7700: Res Seminar On Networking

CSE 473S: Introduction to Networking

Textbook

- ❑ J.F. Kurose and K.W. Ross, “Computer Networking” 7th Edition, Addison-Wesley, 2017, ISBN: 9780133594140 or 9780134296135, 864 pp. **Required.**
- ❑ Get the latest edition. Do not use older editions. If you use international edition, it should be dated later than 2016, should have 864 pages.



Textbook (Cont)

- ❑ It is recommended that you read the relevant chapter of the book chapter before coming to the class
⇒ Class time will be used for discussing and clarifying key concepts
- ❑ Only key concepts will be covered in the class.
You are expected to read the rest from the book.
- ❑ Please ask questions in the next class about any concepts that are not clear to you
- ❑ Material covered in the class will include some concepts from other textbooks. Please pay attention to the class lecture.

Prerequisite

- ❑ General knowledge of computer systems organization
 - Memory
 - System bus
 - Interrupt
 - CPU
 - Binary, decimal, hexadecimal representations
 - Bits, bytes
 - Storage: Memory and disk

- ❑ CSE 131: Computer Science I or equivalent

Tentative Schedule

Class	Date	Topic	Chapter
1	1/14	Course Overview	
2	1/16	Internet: Core and Edge,History (Part 1)	1
	<i>1/21</i>	<i>Martin Luther King Holiday</i>	
3	1/23	Internet: Core and Edge,History (Part 2)	1
4	1/28	Application Layer (Part 1): HTTP	2
5	1/30	Application Layer (Part 2): SMTP,DNS,P2P	2
6	2/4	Transport Layer (Part 1): Design Issues	3
7	2/6	Transport Layer (Part 2): UDP,Flow Control	3
8	2/11	Transport Layer (Part 3): TCP, TCP Congestion Control	3
9	2/13	The Network Layer: Data Plane (Part 1: Network Layer Basics)	4
10	2/18	Mid-Term Exam 1	4

Tentative Schedule (Cont)

Class	Date	Topic	Chapter
11	2/20	Network Layer Data Plane (Part 2: IP Datagram)	4
12	2/25	Network Layer Data Plane (Part 3: NAT,UPNP)	4
13	2/27	Network Layer Data Plane (Part 4: DHCP,SDN)	4
14	3/4	The Network Layer: Control Plane Part 1: Routing Algorithms,OSPF,BGP	
15	3/6	The Network Layer: Control Plane Part 2: SDN Controller + ICMP + SNMP	6
	3/11	<i>Spring Break</i>	
	3/13	<i>Spring Break</i>	
16	3/18	The Link Layer and LANs (Part 1): Functions,CRC	6
17	3/20	The Link Layer and LANs (Part 2): Multiple Access, Ethernet,VLANS	
18	3/25	Mid-Term Exam 2	6

Tentative Schedule (Cont)

Class	Date	Topic	Chapter
20	3/27	The Link Layer and LANs (Part 3): MPLS, Data Centers	7
21	4/1	Wireless and Mobile Networks (Part 1): Wireless Characteristics, LANs and PANs	7
22	4/3	<i>Wireless and Mobile Networks (Part 2): Mobility Management</i>	8
23	4/8	Security in Computer Networks: Cryptography (Part 1)	8
	4/10	Security in Computer Networks (Part 2)	9
24	4/15	Multimedia Networking (Part 1: Basic concepts)	9
25	4/17	Multimedia Networking (Part 2: VOIP, RTP, SIP)	9
26	4/22	Multimedia Networking (Part 3: DiffServ)	9
28	4/24	Final Exam	

- **Note that the final exam is on April 24, 2019.
The dates for all exams are fixed. No substitute exams.**

Grading

❑ Mid-Term Exams (Best of 2)	30%
❑ Final Exam	30%
❑ Class participation	5%
❑ Homeworks	20%
❑ Labs	15%

Exams

- ❑ There are two mid-terms and one final exam.
- ❑ All exams are 1 hour long. One note sheet of 8.5”x11” (both sides) is allowed along with a simple calculator (TI-30).
- ❑ Exams consist of numerical as well as multiple-choice (true-false) questions.
- ❑ There is a negative grading on incorrect multiple-choice questions. Grade: +1 for correct. $-1/(n-1)$ for incorrect.
- ❑ Everyone including the graduating seniors are graded the same way.
- ❑ Your grade depends upon the performance of the rest of the class.

Lab Exercises

- ❑ Most modules will have a lab component
- ❑ Labs require writing a short program to do what the protocol would do
- ❑ You should be able to do most labs on your own computer

Homework Submission

- ❑ All homeworks are due on the following Monday at the beginning of the class unless specified otherwise.
- ❑ Any late submissions, if allowed, will **always** have a penalty.
- ❑ We are working on canvas for online homework submission. Until then all homeworks should be submitted in hardcopy unless specified otherwise
- ❑ All homeworks are identified by the class handout number.
- ❑ All homeworks should be on a separate sheet. Your name should be on every page.
- ❑ Please write CSE473 in the subject field of all emails related to this course.
- ❑ Use word “Homework” in the subject field on emails related homework. Also indicate the homework number.

Homework Grading

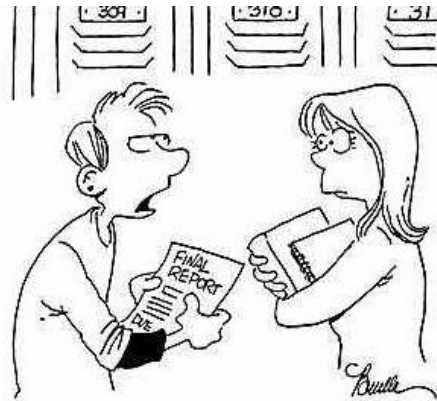
- ❑ Grading basis: Method + Correct answer
- ❑ Show how you got your answer
 - Show intermediate calculations.
 - Show equations or formulas used.
 - If you use a spreadsheet, a statistical package, or write a program, print it out and turn it in with the homework.
 - For Excel, set the print area and scale the page accordingly to fit to a page. (See Page Setup)

Quizzes

- ❑ There may be a short 5-minute quiz at the beginning of some classes to check if you have read the topics covered in the previous class.

Academic Integrity

- ❑ Academic integrity is expected in home works
- ❑ All solutions submitted are expected to be yours and not copied from others or from solution manuals or from Internet
- ❑ All integrity violations will be reported to the department and action taken



"I don't know what plagiarizing is, so I'm gonna take the easy way out and just copy something off the internet."

Office Hours

□ By Appointment:

- Monday: 11:00AM to 12:00 noon
- Wednesday: 11:00AM to 12:00noon
- Office: Jolly 208

□ Teaching Assistants:

- TBD

□ All meetings with TA will be at:

- Networking Lab: Jolley 323

Class Discussions

- ❑ We will use Piazza for class discussion.
- ❑ Find our class page at:
<http://piazza.com/wustl/spring2019/cse473s>

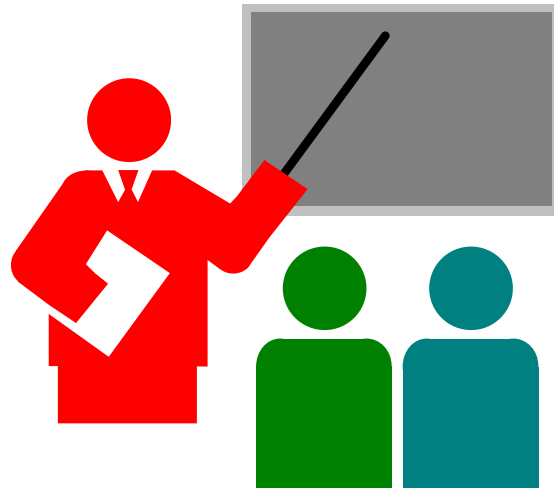


Class Attendance

- ❑ Attendance on arkaive.com
- ❑ Download the mobile app
- ❑ Free version allows checking in



Summary



- ❑ Computer networking is important for all areas of computing
- ❑ First course in computer networking
- ❑ Goal: To prepare you for a career in networking
- ❑ Get ready to work hard

Reading

- Read Chapter 1 of Kurose and Ross

Quiz 0: Prerequisites

True or False?

T F

1. Transmitting 100 bytes @ 800 bit/sec will take 1 sec.
2. A system with 32kB memory can hold only 16000 ASCII characters
3. A system with 2GB memory is same as that with 2GB disk.
4. Interrupts are used by CPU to stop an ongoing I/O.
5. Binary representation of 9 is 1001
6. 0A in Hexadecimal is 11 in decimal system.
7. For $I = A \sin(2\pi ft + \phi)$, the frequency is f .
8. 5 modulo 2 is 1
9. Two entries "P" and "Q" are pushed sequentially on a stack. A "pop" operation on the stack will produce P.
10. If x is 0, then after $x++$, x will be 1.

Marks = Correct Answers _____ - Incorrect Answers _____ = _____

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Raj Jain

<http://rajjain.com>

http://www.cse.wustl.edu/~jain/cse473-19/i_0int.htm

Related Modules



CSE 567: The Art of Computer Systems Performance Analysis

https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof

CSE473S: Introduction to Computer Networks (Fall 2011),

https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcg5e_10TiDw



CSE 570: Recent Advances in Networking (Spring 2013)

<https://www.youtube.com/playlist?list=PLjGG94etKypLHyBN8mOgwJLHD2FFIMGq5>

CSE571S: Network Security (Spring 2011),

<https://www.youtube.com/playlist?list=PLjGG94etKypKvzfVtutHcPFJXumyyg93u>



Video Podcasts of Prof. Raj Jain's Lectures,

<https://www.youtube.com/channel/UCN4-5wzNP9-ruOzQMs-8NUw>

TA

- ❑ Josh Serota, e.serota@wustl.edu
- ❑ Robert Esswein, resswein@wustl.edu
- ❑ Elaine Cole, elainemcole@wustl.edu (Tu 3-6, F 10-1, S 12-3)
- ❑ Xin Yan, yan.x@wustl.edu
- ❑ Tyler Orden (?)
- ❑ Zhanglong Peng (?) – considering. Substitute class
- ❑ Gong Chengyue (?) - considering