

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/cse473-20/>



- ❑ 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.



We are in the Internet Age.

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

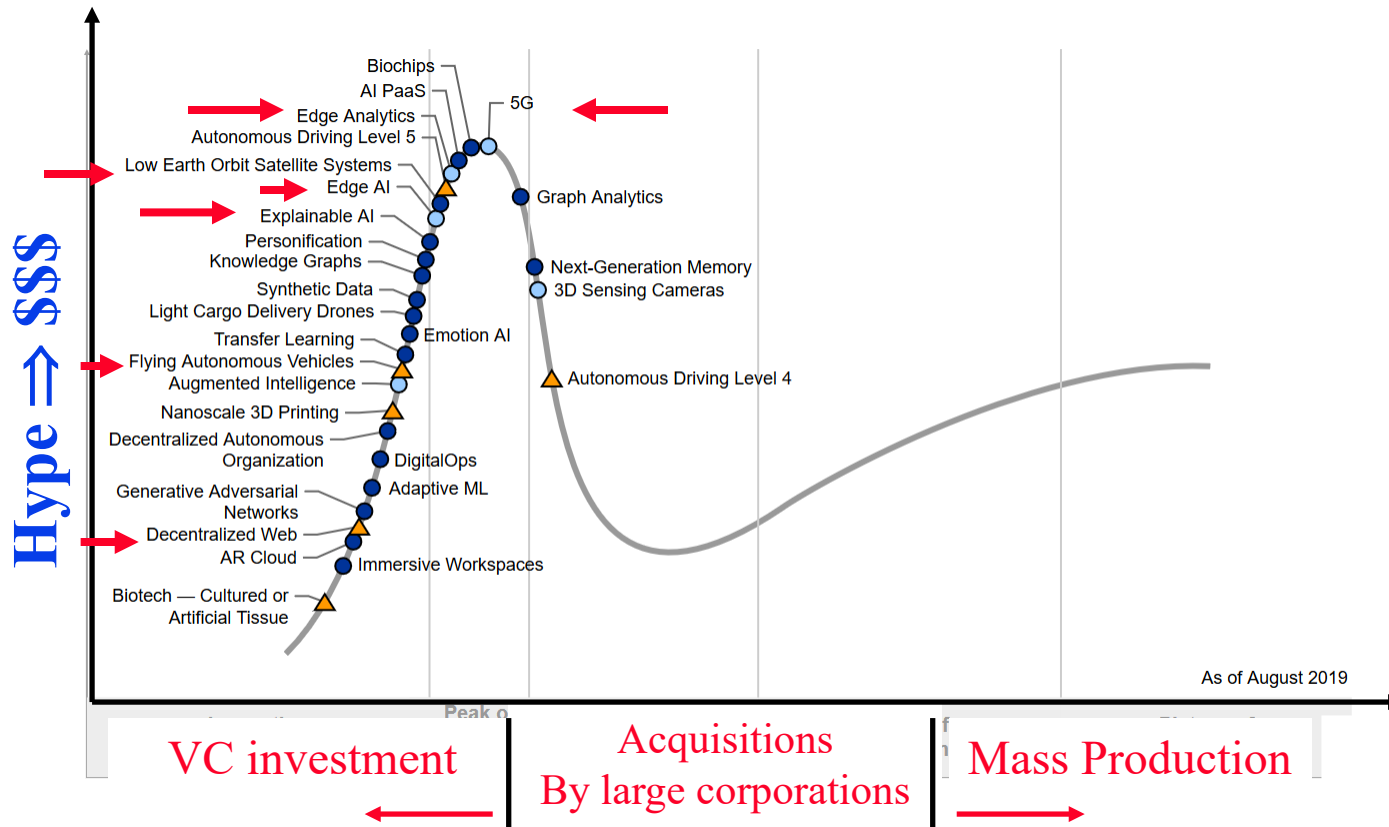
Selecting the Right Field

- ❑ Important question for **student** academics, entrepreneurs, and companies
- ❑ Goal: To impact
- ❑ Follow the **paradigm shifts**:
 - 1980: Ethernet
 - 1990: ATM Networks
 - 2000: Optical Networks
 - 2005: Wireless Networks
 - 2008: Next Generation Internet/SDN



Industries adopt by necessity.
Academics continue to develop deeper expertise on what they already know.

Gartner Hype Cycle of Emerging Tech 2019



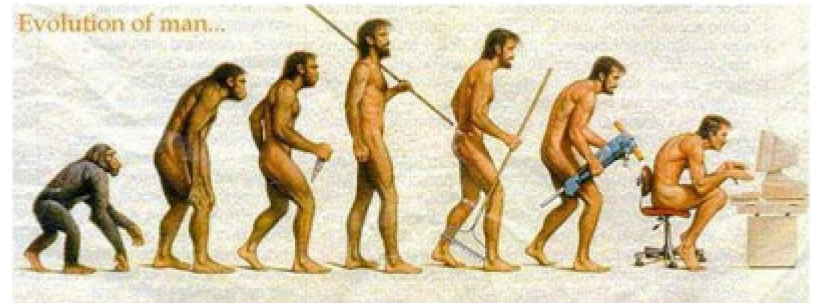
Ref: B. Burke, D. Smith, "Hype Cycle for Emerging Technologies, 2019," Gartner Report G00370466, 6 Aug. 2019, 68 pp.

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Internet Age



- ❑ Distributed Computing
- ❑ Cloud Computing
- ❑ Mobile Computing \Rightarrow Smart Phones
- ❑ Streaming Video \Rightarrow YouTube
- ❑ Social Networking \Rightarrow FaceBook
- ❑ Big Data
- ❑ Machine Learning \Rightarrow Artificial Intelligence
- ❑ Online Shopping \Rightarrow Amazon, Ebay, Google
- ❑ Most fields today – Education, Health, Environment – are advancing simply because of advances in networking

Current Hot Topics in Networking



1. Internet of Things (IoT)
2. Cybersecurity
3. Cloud Computing
4. Software Defined Networking
5. Wireless Networking
6. Streaming Media

Trend: Smart Everything



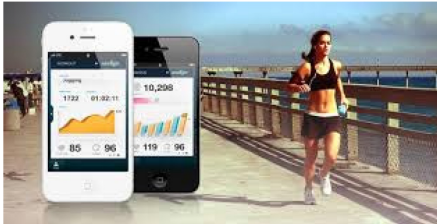
Smart Watch



Smart TV



Smart Car



Smart Health



Smart Home



Smart Kegs



Smart Space



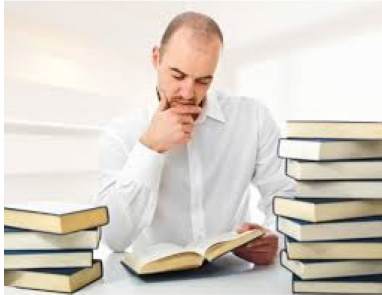
Smart Industries



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

- ❑ Smart = Apply the latest **technology** to solve problems

Trend: Smart to Intelligent



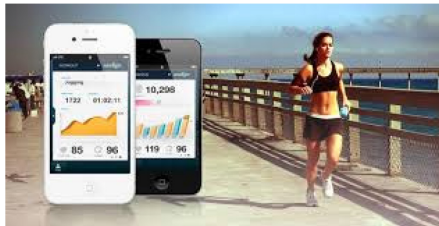
Intelligent Clock



Intelligent TV



Intelligent Car



Intelligent Health



Intelligent Home Security



Intelligent Microwave



Intelligent Light



Amazon Alexa



Google Assistant

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

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>
Washington University in St. Louis <http://www.cse.wustl.edu/~jain/cse473-20/>

DEFCON



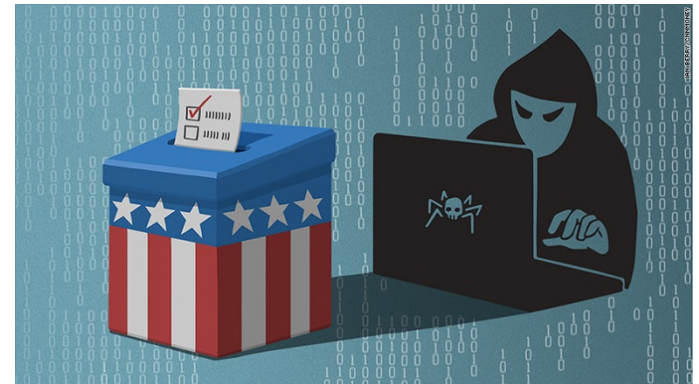
- ❑ Hacker's conference
- ❑ Held in Las Vegas every July
- ❑ 20,000+ attendees
- ❑ All anonymous

Ref: <https://www.ethicalhacker.net/features/opinions/first-timers-experience-black-hat-defcon>
Washington University in St. Louis <http://www.cse.wustl.edu/~jain/cse473-20/>

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Recent DEFCON Topics

- ❑ 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

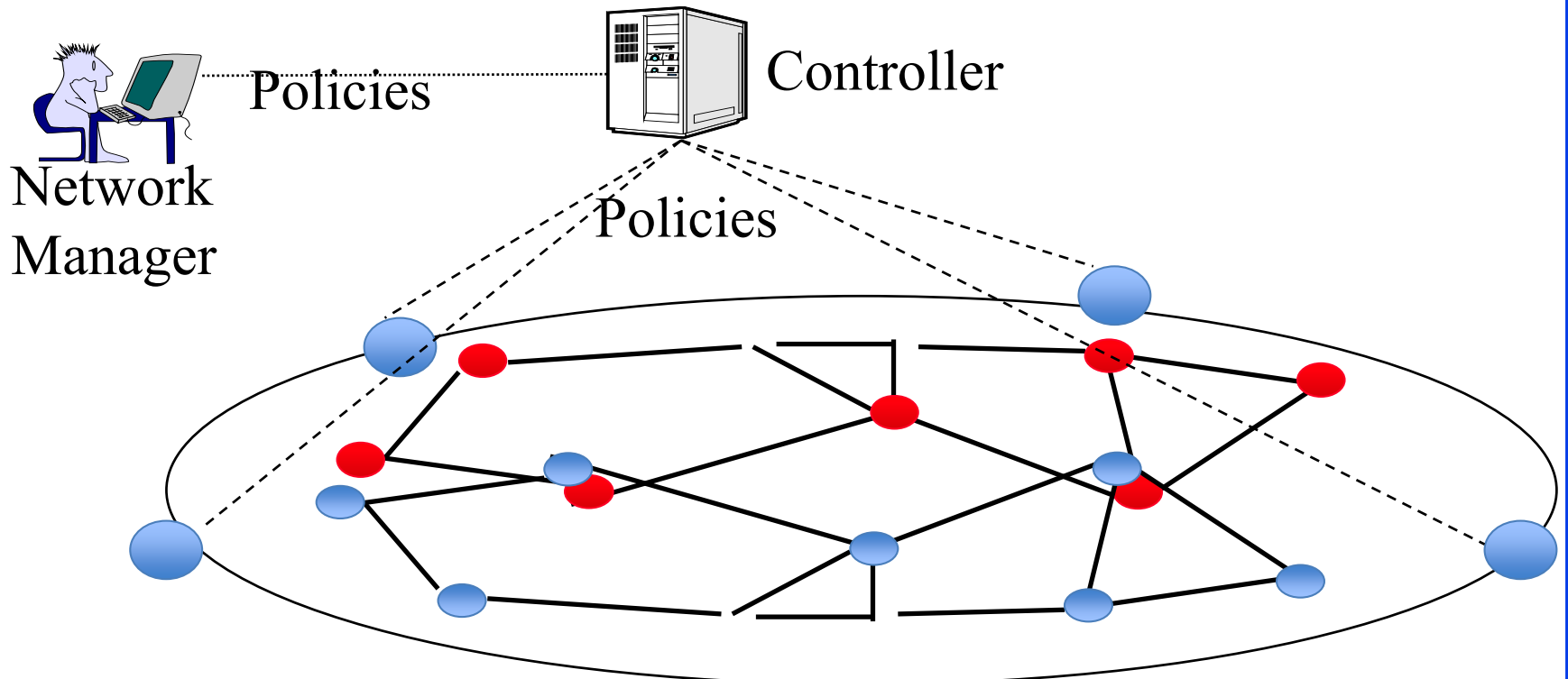
- ❑ August 25, 2006: Amazon announced EC2
⇒ Birth of Cloud Computing in reality
(Prior theoretical concepts of computing as a utility)
\$10 B in 2016, a growth rate of 49% with 17% margins, much higher than the overall Amazon business



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

Software Defined Networking

- Using standard networking hardware
⇒ Allows managing large networks using software



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

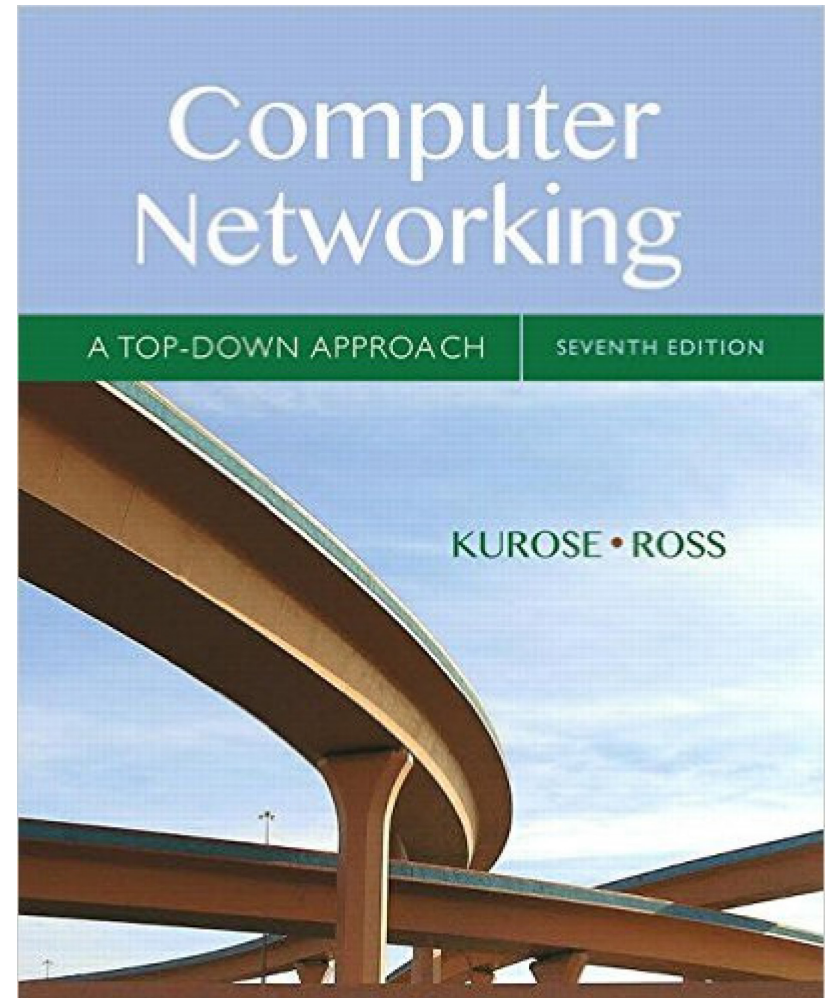
CSE 574S: Wireless and Mobile Networking

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	1/13	Course Overview	
2	1/15	Internet: Core and Edge,History (Part 1)	1
	1/20	Martin Luther King Holiday	
3	1/22	Internet: Core and Edge,History (Part 2)	1
		Application Layer (Part 1): Architecture	2
4	1/27	Application Layer (Part 2): HTTP	2
5	1/29	Application Layer (Part 3): SMTP,DNS,P2P	2
		Transport Layer (Part 1): Design Issues	3
6	2/3	Transport Layer (Part 2): Design Issues	3
7	2/5	Transport Layer (Part 3): UDP,Flow Control	3
8	2/10	Transport Layer (Part 4): TCP,TCP Congestion Control	3
		The Network Layer: Data Plane (Part 1: Network Layer Basics)	4
9	2/12	Network Layer Data Plane (Part 2: IP Datagram,NAT,UPNP)	4
10	2/17	Network Layer Data Plane (Part 3: DHCP,SDN)	5
11	2/19	Mid-Term Exam 1	3

Tentative Schedule (Cont)

Class	Date	Topic	Chapter
12	2/24	The Network Layer: Control Plane (Part 1: Routing Algorithms, OSPF, BGP)	5
13	2/26	The Network Layer: Control Plane (Part 2: SDN Controller + ICMP + SNMP)	5
14	3/2	The Link Layer and LANs (Part 1): Functions, CRC	6
15	3/4	The Link Layer and LANs (Part 2): Multiple Access, Ethernet	6
	3/9	Spring Break	
	3/11	Spring Break	
16	3/16	The Link Layer and LANs (Part 3): VLANs	6
17	3/18	The Link Layer and LANs (Part 4): MPLS, Data Centers	6
18	3/23	Mid-Term Exam 2	6

Tentative Schedule (Cont)

Class	Date	Topic	Chapter
19	3/25	Wireless and Mobile Networks (Part 1): Wireless Characteristics, LANs and PANs	7
20	3/30	Wireless and Mobile Networks (Part 2): Mobility Management	7
21	4/1	Wireless and Mobile Networks (Part 3): Mobility Management	7
22	4/6	Security in Computer Networks: Cryptography (Part 1)	8
23	4/8	Security in Computer Networks (Part 2)	8
24	4/13	Multimedia Networking (Part 1: Basic concepts)	9
25	4/15	Multimedia Networking (Part 2: VOIP, RTP, SIP)	9
26	4/20	Multimedia Networking (Part 3: DiffServ)	9
27	4/22	Final Exam	

- **Note that the final exam is on April 22, 2020.**
- **The dates for all exams are fixed. No substitute exams.**
- **Every one has to take all exams.**

Grading

- ❑ Exams (Best 2 of 3) 60%
- ❑ Class participation 5%
- ❑ Homeworks 20%
- ❑ Labs 15%

Exams

- ❑ There are three exams.
- ❑ All exams are 50 minutes 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
- ❑ Some 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.
- ❑ All homeworks should be submitted to Canvas 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

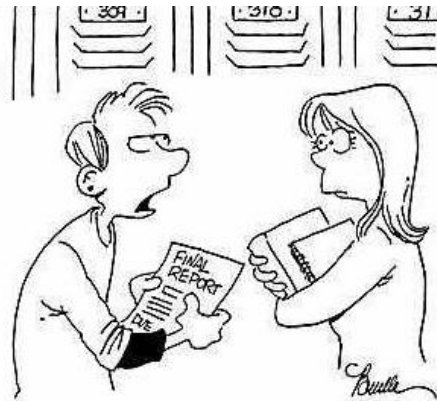
- ❑ Grading basis: Method + Correct answer
- ❑ Show how you got your answer
 - Show intermediate calculations.
 - Show equations or formulas used.
 - If you use a spreadsheet, a statistical package, or write a program, print it out and turn it in with the homework.
 - For Excel, set the print area and 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: Office: Jolly 208
- ❑ Teaching Assistants:
 - Fan Wu, fan.wu at wustl.edu
 - ❑ Sunday 3:00- 4:00 PM
 - ❑ Wednesday 11:30PM-12:30 PM
 - ❑ Thursday 4:00-5:00 PM
 - Haiyu Wang, haiyu.wang at wustl.edu
 - ❑ Monday 11:30PM-12:30 PM
 - ❑ Friday 3:00 – 4:00 PM
 - ❑ Saturday 3:00-4:00 PM
- ❑ All meetings with TA will be in the meeting area outside the Networking Lab: Jolley 323

Class Discussions

- ❑ We will use Piazza for in-between class urgent questions.
- ❑ No participation points for questions on Piazza
- ❑ If a question is not urgent and can wait till the next class, please bring it up in the class ⇒ Get points
- ❑ Find our class page at:

<http://piazza.com/wustl/jain/cse473s>



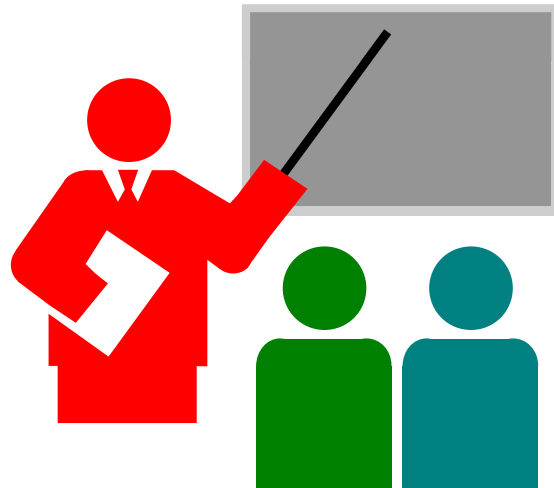
Class Attendance

- ❑ Attendance on arkaive.com
- ❑ Download the mobile app
- ❑ Free version allows checking in
- ❑ App does not work 15 minutes after the beginning of class.
- ❑ Manual attendance will get you only 0.5 for the day



GYSR

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/cse473-20/i_0int.htm

Related Modules



CSE567M: Computer Systems Analysis (Spring 2013),

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

CSE473S: Introduction to Computer Networks (Fall 2011),

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



Wireless and Mobile Networking (Spring 2016),

https://www.youtube.com/playlist?list=PLjGG94etKypKeb0nzyN9tSs_HCd5c4wXF

CSE571S: Network Security (Fall 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>