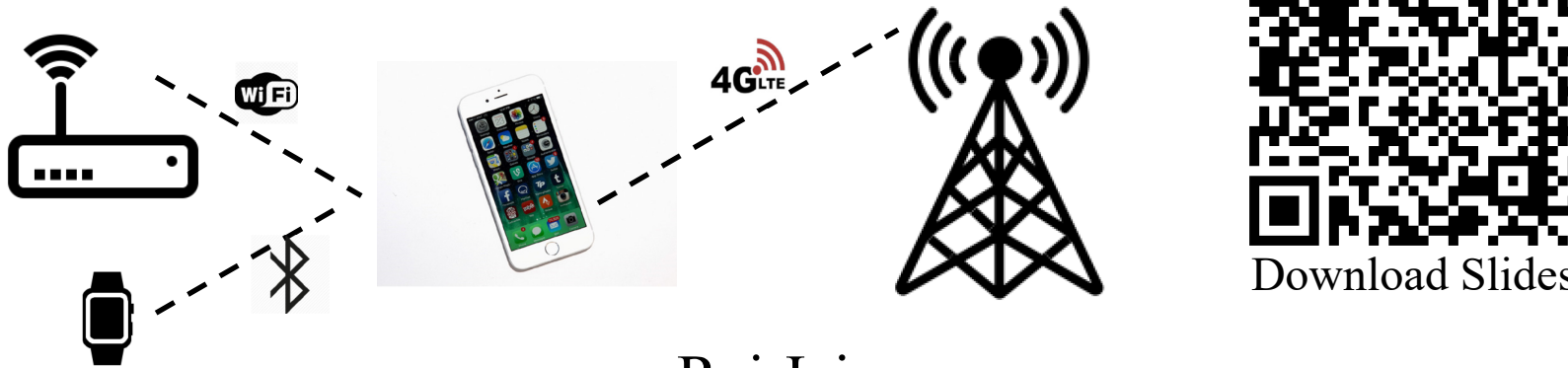


# CSE 574S: Recent Advances in Wireless and Mobile Networking



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Audio/Video recordings of this class lecture are available at:

<http://www.cse.wustl.edu/~jain/cse574-22/>

Student Questions



- ❑ Goal of this Course
- ❑ Grading
- ❑ Contents of the course
- ❑ Tentative Schedule
- ⇒ ❑ *Note: Please pay special attention to the recently changed text identified by an arrow symbol on the left margin. Ignore the recorded speech if different.*

Student Questions

# 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

Student Questions

## 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

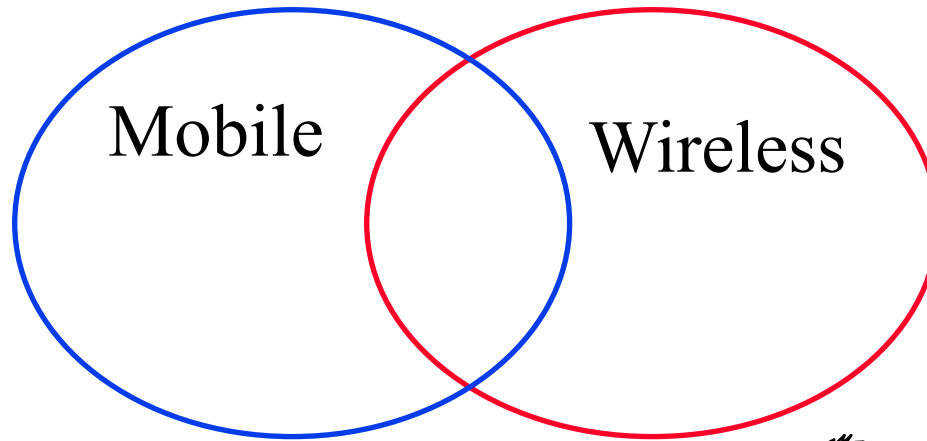
- ❑ Note: Apple became highly valued only after it switched from computing to communications (iPhone)



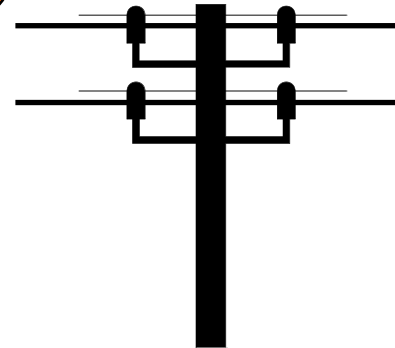
Networking = Economic Indicator

Student Questions

# Mobile vs Wireless



- ❑ Mobile vs. Stationary
- ❑ Wireless vs Wired
- ❑ Wireless  $\Rightarrow$  Media sharing issues
- ❑ Mobile  $\Rightarrow$  Routing, addressing issues



Student Questions

# Wireless Networking

## Impact of Wireless on Networking:

1. Not tied to walls/infrastructure  
⇒ Ad-hoc networking
2. Error-prone ⇒ Traffic Management
3. Frequent Disconnections  
⇒ Resource Management  
Quality of Service for multimedia
4. Battery operated  
⇒ Media access and networking while sleep  
⇒ Time synchronization
5. Broadcast ⇒ Security

Student Questions

# Mobile Networking

Impact of Mobility on Networking:

- Location
- Addressing
- Handoff

Student Questions

# Why Wireless Networking?

1. Wireless (Wi-Fi) is ubiquitous (Intel Centrino)
2. Most of the access (end user connectivity) is wireless
  - Smart phones, Tablets, and many laptops (Ultra books) have no wired Ethernet connections
3. Most of telecommunication carriers' revenue is in wireless
4. New Developments:
  - 5G: 1 Gbps Metropolitan Area Networks
  - Vehicular Networking (802.11p)



## Student Questions



# Mobile Internet

- ❑ June 29, 2007: Apple announced iPhone  
⇒ Birth of Mobile Internet, Mobile Apps
  - Almost all services are mobile apps: Google, Facebook, Bank of America, ...
- ❑ 2014 **mobile** data traffic was  $2.5 \times 10^{18}$  B/month.  
30× the size of the entire global Internet in 2000 (75 PB/month).
- ❑ Between 2016-21:
  - PC traffic will be only 1/4<sup>th</sup> compared to 1/2 in 2016.
  - **Smart phone** traffic will be 1/3<sup>rd</sup> compared to 1/8<sup>th</sup> in 2016
  - **Mobile traffic** will grow twice as fast as fixed IP traffic
- ❑ Issues: Errors, Disconnection, Limited bandwidth, Limited distance



## Student Questions

Ref: Cisco, "Cisco Visual Networking Index: Forecast and Methodology, 2016-2021," June 6, 2017,

<https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf>

Washington University in St. Louis

<http://www.cse.wustl.edu/~jain/cse574-22/>

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# Internet of Things



Smart Watch



Smart TV



Smart Car



Smart Health



Smart Home



Smart Kegs



Smart Space



Smart Industries

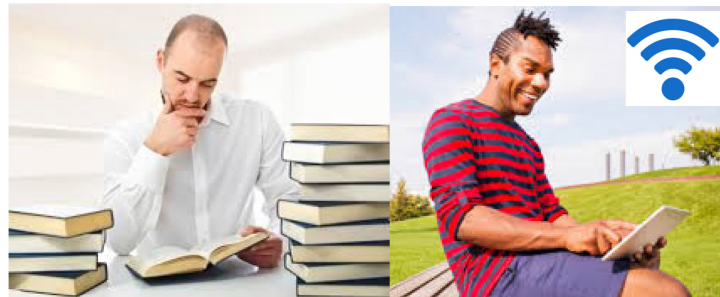


Smart Cities

## Student Questions

# 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

Student Questions

# Goal of This Course

- ❑ Comprehensive course on wireless and mobile networking
- ❑ Broad coverage of current key areas
- ❑ Topics of interest to industry
- ❑ Intro to physical layer “Wireless Communication.”
- ❑ Emphasis on lower layers: Layers 2, 3
- ❑ Emphasize both present (Industry standards and products) and near future (Research)
- ❑ Graduate course: (Advanced Topics)  
⇒ Less reliance on one textbook

## Student Questions

# What Will You Learn?

1. How is wireless different from wired communication?
2. How does Wi-Fi work?
  1. How is the speed of Wi-Fi increasing from 10 Mbps to 10 Gbps?
  2. What is the difference between a/b/g/n/ac/ad/...
3. How is Bluetooth different from Wi-Fi?
4. How is ZigBee different from Wi-Fi?
5. What are the protocols that are used in IoT?
6. Why do we need new protocols for IoT?
7. What is the fundamental difference between 1G/2G/3G/4G/5G
8. What new features came in with 4G?
9. What new techniques enabled 5G?
10. What about 6G? When and how?

## Student Questions

# Tentative Schedule

#	Date	Topic
1	8/29/22	Course Overview
2	8/31/22	Wireless Trends+Wireless Coding and Modulation (Part 1)
3	9/5/22	Wireless Coding and Modulation (Part 2)
4	9/7/22	Wireless Signal Propagation
5	9/12/22	IEEE 802.11 Wireless LANs. Part I:Basics
6	9/14/22	Wireless LANs Part II: 802.11a/b/g/n/ac (Part 1)
7	9/19/22	Wireless LANs Part II: 802.11a/b/g/n/ac (Part 2)
8	9/26/22	Exam 1 Review
9	<b>9/28/22</b>	<b>Mid-Term Exam 1</b>

Student Questions

# Tentative Schedule (Cont)

#	Date	Topic
10	9/30/22	60 GHz Millimeter Wave Gigabit Wireless Networks
11	10/3/22	Vehicular Wireless Networks + Wireless in White Spaces
12	10/5/22	IoT+Bluetooth and Bluetooth Smart (Part 1)
	10/10/22	<i>Fall Break</i>
13	10/12/22	Bluetooth and Bluetooth Smart (Part 2)
14	10/17/22	IEEE 802.15.4 WPAN
15	10/19/22	Low Power WAN Protocols for IoT
16	10/24/22	Introduction to 6LowPAN and RPL
17	10/26/22	Exam 2 Review
<b>18</b>	<b>10/31/22</b>	<b>Mid-Term Exam 2</b>

Student Questions

## Tentative Schedule (Cont)

#	Date	Topic
19	11/2/22	Cellular Networks: 1G/2G/3G
20	11/7/22	LTE
21	11/9/22	4G/LTE-Advanced (4G)
22	11/11/22	LTE Advanced Pro (4.5G)
23	11/16/22	5G (Part 1)
24	11/18/22	5G (Part 2)
	11/23/22	<i>Thanksgiving Break</i>
	11/25/22	<i>Thanksgiving Break</i>
25	11/30/22	TBD
26	12/2/22	Exam 3 Review
27	<b>12/7/22</b>	<b>Exam 3</b>

Student Questions



# Prerequisite: CSE473S

- ❑ Protocol Layers: ISO/OSI reference model
- ❑ TCP/IP protocol stack
- ❑ LAN Addressing: Unicast vs. multicast, Local vs. Global
- ❑ Extended LANs: Hubs vs. Bridges vs. Routers vs. Switches
- ❑ IPv4 and IPv6 Address: Public vs. Private Addresses
- ❑ Subnets
- ❑ Address Resolution Protocol (ARP)
- ❑ TCP connection setup, Checksum (pseudo-header), Slow start
- ❑ TCP vs. UDP

## Student Questions

# Text Book

- ❑ No one book covers the the breadth of the material in this course
- ❑ There will be a reading list with each lecture.  
The list may include some books, websites, and Wikipedia links
- ❑ Mostly, books available as “Safari Books” will be used.
- ❑ WUSTL has a subscription to Safari Books  
⇒ All WUSTL students and faculty have free online access.

## Student Questions

# Projects

- ❑ Hands-on project or a survey paper related to the topics of the course
- ❑ Most survey topics will be assigned.  
You can suggest hands-on projects for approval.
- ❑ Average 6 Hrs./week/person on project + 9 Hrs./week/person on class
- ❑ Recent Developments: Last 2 to 4 years  
⇒ Not in books
- ❑ Will be published on my website,  
Better ones may be submitted to magazines or journals.

Student Questions

# Examples of Projects

- ❑ Implementation of a Mobile Aerial Wireless Network
- ❑ A Survey of Bio-Inspired Wireless Communication
- ❑ Cloud RAN: Basics, Advances and Challenges
- ❑ A Survey of Distributed Radio Systems
- ❑ Energy Efficient Wireless Communication Survey
- ❑ Long Range Low Power (LRLP) Wireless Network
- ❑ LTE-A for Device to Device and Machine-to-Machine Comm
- ❑ M2M Communication Scheduling using LTE/LTE-A
- ❑ Emerging MIMO Technologies
- ❑ Network Coding for Wireless Applications: A review
- ❑ A Survey of Self-Organizing Networks

## Student Questions

Ref: Raj Jain, "Wireless and Mobile Networking (Spring 2016)," <http://www.cse.wustl.edu/~jain/cse574-16/index.html>

# Examples of Projects

- ❑ Voice over LTE: Status and Migration Trends
- ❑ A Survey of Software-Defined Wireless Networks
- ❑ Virtualization in Wireless Networks
- ❑ Energy Efficiency in Wireless Networking Protocols
- ❑ Wireless Power Transfer – Concepts and Applications
- ❑ Survey of Low Altitude Unmanned Aerial Vehicles
- ❑ Security and Privacy Issues in the Internet of Things
- ❑ Wireless Networks for Disaster Relief
- ❑ Survey of Wireless Based Indoor Localization Technologies
- ❑ Recent Advances in Broadband Wireless Access Networks
- ❑ Recent Advances in Cognitive Radios
- ❑ Constrained Application Protocol for Internet of Things

Student Questions

# Project Requirements

- ❑ Recent Developments: Last 3 to 5 years
    - Generally not in books
  - ❑ Comprehensive Survey:  
Technical Papers, Industry Standards, Products
  - ❑ Will be published on my website,  
Better ones may be submitted to magazines or journals
  - ❑ No copyright violations:
    - ⇒ You need to re-draw all figures
    - ⇒ You need to summarize all ideas in your **\*own\*** words
    - ⇒ Cannot copy any part of text or figure unmodified
    - ⇒ Short quotes ok
    - ⇒ Any unmodified figures need permissions
- Any infringement will result in forfeiture of grades even after graduation.

Student Questions

# Grading

- ❑ Exams (Best 2 of 3 Exams) 60%
- ❑ Video Reviews 10%
- ❑ Homework/Class Quizzes 10%
- ⇒ ❑ Project 15%
- ❑ Class Participation 5%
  
- ⇒ ❑ **Pass/Fail:** 60 points

## Student Questions

- ❑ Do homeworks include programming and/or Research?

*Labs do have some programming.*

*Some students may do projects that require programming.*

---

# Project Schedule and Point Weights

Day	Date	Due	Points
Wednesday	9/7/2022	Search	0.5
Monday	10/3/2022	HTML Sample	0.5
Monday	10/10/2022	Topic	
Monday	10/17/2022	References	1
Monday	10/24/2022	Outline	1
Monday	11/7/2022	Draft Paper	4
Monday	11/14/2022	Reviews	1
Monday	11/21/2022	HTML	2
		Final Paper	5
		Total	15

Student Questions



# Exams

- ❑ Exams consist of numerical, fill-in-the-blank, and multiple-choice (true-false) questions.
- ❑ There is negative grading on incorrect multiple-choice questions. Grade: +1 for correct.  $-1/(n-1)$  for incorrect.  
⇒ For True-False: +1 for Correct, -1 for Incorrect  
This ensures that random marking will produce an average of zero.
- ❑ Everyone, including the graduating students, is graded the same way.
- ⇒ ❑ *Everyone's grade is scaled up so that the highest score becomes 100% for that exam. This eliminates the effect of the difficulty level of different exams and makes them comparable and combinable.*

## Student Questions

## Exams (Cont)

- ❑ All exams are a closed book.  
One 8.5" X11" cheat sheet with your notes on both sides is allowed.
- ❑ No smartphones allowed. Only a simple TI-30 or equivalent calculator allowed for calculations.
- ❑ Exam dates are fixed, and there are no substitute exams
  - ▷ Plan your travel accordingly.
- ❑ Best two of the three exams are used.
- ❑ *Everyone should take the first two exams. The third is optional. The exams will be in person in the classroom.*
- ❑ ~~Respondus will be used to monitor the exam.~~
- ❑ ~~You will need a webcam separate from the one on your laptop for Respondus. Also, get a good headset with a microphone.~~

Student Questions

# Homework Submission

- ❑ All homework is due the following Monday, just before the beginning of the class, unless specified otherwise. This gives you the weekend to work on the homework.
- ❑ Late submissions will *\*always\** have a penalty.
- ❑ *The penalty is 10% per day ⇒ You have a maximum of 9 days to submit late homework with a penalty.*
- ❑ All homework should be submitted on canvas
- ❑ The class handout number identifies all homework.
- ❑ All homework should be in a separate file.
- ❑ Homework has Due Date/time and Until Date/time. Please try to do the homework before the due date. Submissions will be allowed up to the “until date/time” *with* a penalty. Canvas will not accept submissions after the “until date/time.”

## Student Questions

# 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 a page. (See Page Setup)
- ❑ **Quizzes:** There may be questions or quizzes during the class to check if you have understood the material.

Student Questions

# Questions

- ⇒  During the class, I may ask some questions to ensure that you have understood the topics.

Student Questions

# Academic Integrity

- ❑ Academic integrity is expected in homework, quizzes, and exams.
- ❑ All solutions submitted are expected to be yours and not copied from others or solution manuals, or from the Internet
- ❑ School requires us to report all integrity violations to the department

Student Questions

# Class Discussions

- ❑ We will use Piazza for class discussion.
- ❑ Find our class page at:
- ❑ <https://piazza.com/wustl/fall2022/cse574s>

Student Questions

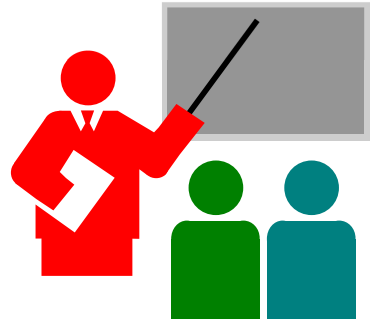
# Office Hours

- ❑ Office Hours: On Zoom, by appointment
- ❑ **Teaching Assistant:** Zebo Yang Zebo at wustl.edu
  - Office Hours on Zoom: Friday 1:30-2:30 PM  
Sunday 1:30-2:30 PM
- ❑ Please write **CSE574** in the subject field of all emails related to this course.
- ❑ Use the words “**Homework xx**” in the subject field on emails related to homework xx. Remember to indicate the homework number.
- ❑ *Resolve your grading issue with the TA first before approaching the instructor.*

Student Questions



# Summary



- ❑ We are living in the Internet age. Most activities, including work and play, require the Internet.
- ❑ Networking companies are among the most valued companies in the world.
- ❑ Wireless networking is taking over the edge, fueled by smartphones and smart devices (IoT).
- ❑ Goals of this course:
  - To prepare you for the current job market in networking
  - To teach you how to keep up with the latest in wireless and mobile networking

## Student Questions

# Google Search Modifiers

- ❑ filetype:pdf, doc, ppt, pptx
- ❑ site:wustl.com
- ❑ intitle:trend
- ❑ inurl:trend
- ❑ allintitle:Networking Trends
- ❑ Allinurl:
- ❑ “ “ $\Rightarrow$  Exact Phrase
- ❑ OR
- ❑ AND
- ❑ +  $\Rightarrow$  Must include
- ❑ -  $\Rightarrow$  Not include
- ❑ ~X  $\Rightarrow$  X or similar
- ❑ \*  $\Rightarrow$  Wildcard

## Student Questions

# Project Homework 1

- ❑ Search web pages, books, and journal articles from IEEE Xplore, ACM Digital Library, **MOBIUS**, **Safari books**, **ILLIAD** at Olin Library for one of the following topics:
  1. Wireless Networking Trends
  2. Mobile Networking Trends
  3. Internet of Things
- ❑ On the web, try the following search points:
  - <http://library.wustl.edu/findart.html>
  - <http://library.wustl.edu/fulltext/>
  - <http://scholar.google.com>
  - <http://books.google.com>
  - <http://dl.acm.org/>
  - <http://ieeexplore.ieee.org/Xplore/home.jsp>

Student Questions

# Project Homework 1 (Cont)

- Ignore all entries dated 2017 or before. Also ignore all entries that do not indicate the topic or similar words in the title. List others in the following format (5 each):
  - Author, “Title,” publisher, year, ISBN. (for five books)
  - “Title,” URL [One line description] (for five webpages)
  - Author, “Title,” source (for five technical/magazine articles)
- For the books, including whether the book is available at WUSTL, MOBIUS, Safari, or ILLiad
- Serially number the references and submit them electronically to canvas.
- Make a list of other interesting search points and share them in class.

Student Questions

# Common Mistakes in Project Homework #1

- ❑ Not indicating where the book can be found in WUSTL
- ❑ Listing books/Magazines/journals that have little to do with the topic – may show up in search engines because of a minor mention of the topic or words
- ❑ Web Pages – No one line descriptions
- ❑ Incomplete bibliographic data for journal articles. Need volume, issue, year, pages.
- ❑ Missing journals. Need names of journals dealing with the topic chosen.

Student Questions

# Quiz 0: Prerequisites

True or False?

T F

1.   Datalink refers to the 2nd layer in the ISO/OSI reference model
2.   HTTP is an example of an application layer protocol
3.   Finding a path from one node to another in a large network is a transport layer function.
4.   CRC is used for error detection
5.   MAC address of a node changes as it changes its location.
6.   For long delay paths, on-off flow control is better than window flow control.
7.   Ethernet uses a CSMA/CD access method.
8.   All Ethernet packets are acknowledged.
9.   The packets sent in a connection-oriented network are called datagrams.
10.   Spanning tree algorithm finds a loop-free path in a network.

Marks = Correct Answers \_\_\_\_ - Incorrect Answers \_\_\_\_ = \_\_\_\_\_

## Student Questions

Answers to this quiz will be provided in the class for you to check your answers privately. Next 4 slides will also be covered in the class.

# Remote Classes

- ❑ **All** classes of this course throughout this semester will be remote using Zoom.
- ❑ The class is **flipped**: you review the material in the video before the class and submit your questions on a form.
- ❑ Class time will be used to answer those and any additional questions.
- ❑ *Everyone should have their camera on. Your facial expression during class discussion indicates your level of understanding and attentiveness as in a physical class.*
- ❑ All questions during the class will be via “Zoom chat” *or microphone* and broadcast/visible/audible to all students.

Student Questions

# Class Participation

- *The following activities count towards your class participation:*
  - *Answering instructor questions in the class*
  - *Answering other students' questions on Piazza*
  - *Being present and attentive in the class*
- Keep track of your participation. You may be asked at the end.*
- Asking questions on Piazza does not count*
- Zoom reports include the time you join and leave and how much “attention” you paid to the session. Multiple monitors and unnecessary keyboard and mouse activities on other applications are counted as a lack of attention.
- Students should join with their full name and email. That way, I can associate your participation.

Student Questions



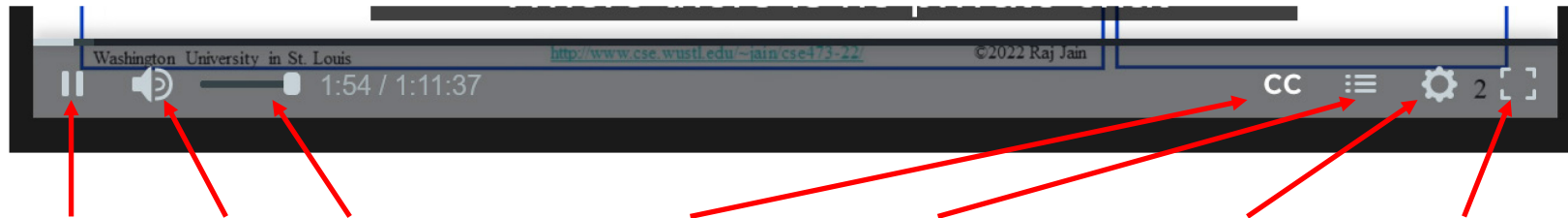
# Video Review Task

- *Video Review question form closes at midnight before the class so the questions can be incorporated into the class presentation. This is the deadline (Due Date). The allowable deadline (Until Date) is ten days after with a 10% penalty/day.*
- During each video review, please answer the quiz questions on Canvas. These questions are simple and have 10-grade points.*
- Also, remember to write your questions about each slide on the Google form. Submission of the form is required.*
- If you do not have any questions on a slide, you should leave it blank.*
- *Everyone should ask at least one question.*

## Student Questions

## *Video Play Menu*

- ❑ *When you mouse over the bottom of the play area, several controls show up, as shown below.*



Start/Stop Mute Volume Closed Captions Table of Contents Settings Full Screen

- ❑ *These features are available only on recordings played directly from the course website or Canvas. Not available on YouTube.*
- ❑ *Press CC to enable and disable the display of “Closed Captions.” with transcription of the speech.*
- ❑ *Table of contents lists each slide’s title. This allows you to jump to the particular slide in the video.*

## Student Questions

# Acronyms

- ❑ BAN Body Area Networks
- ❑ CSMA/CD Carrier Sense Multiple Access with Collision Detection
- ❑ IEEE Institution of Electrical and Electronic Engineers
- ❑ ILLIAD Inter-Library Loan
- ❑ IMT International Mobile Telecommunication
- ❑ IPv4 Internet Protocol Version 4
- ❑ IPv6 Internet Protocol Version 6
- ❑ ISO International Standards Organization
- ❑ LAN Local Area Network
- ❑ LRLP Long Range Low Power
- ❑ LTE Long-Term Evolution
- ❑ MAC Media Access Control
- ❑ OSI Open System Interconnection
- ❑ OSPF Open Shortest Path First

## Student Questions

## Acronyms (Cont)

- ❑ RFID Radio Frequency Identification
- ❑ TCP Transmission Control Protocol
- ❑ TV Television
- ❑ UMB Ultra-Mobile Broadband
- ❑ URL Uniform Resource Locator
- ❑ UWB Ultra-Wideband
- ❑ VoIP Voice over IP
- ❑ Wi-Fi Wireless Fidelity
- ❑ WUSTL Washington University in Saint Louis
- ❑ WWW World-Wide Web

Student Questions

**Scan This to Download These Slides**



Raj Jain

<http://rajjain.com>

[http://www.cse.wustl.edu/~jain/cse574-22/j\\_01int.htm](http://www.cse.wustl.edu/~jain/cse574-22/j_01int.htm)

Student Questions

# Related Modules



CSE567M: Computer Systems Analysis (Spring 2013),  
[https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n\\_1X0bWWNyZcof](https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof)

CSE473S: Introduction to Computer Networks (Fall 2011),  
[https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcg5e\\_10TiDw](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 (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>

## Student Questions