CSE 574S
Wireless and Mobile Networking

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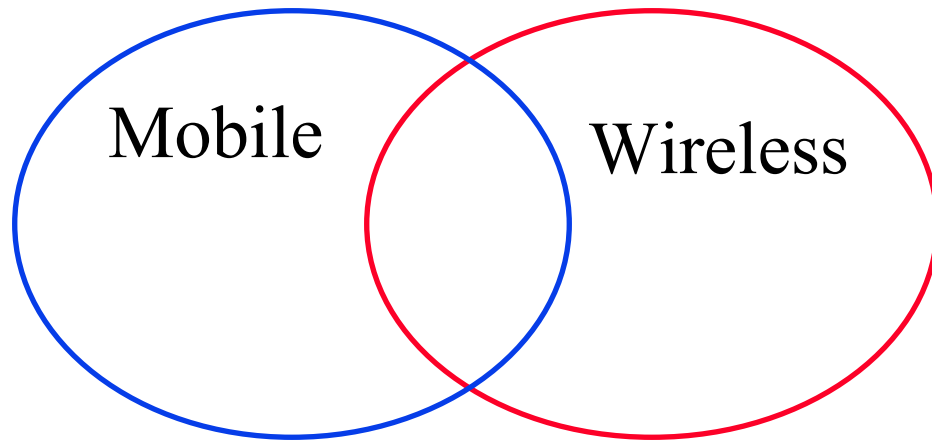
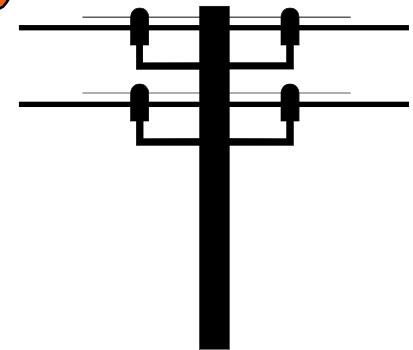Audio/Video recordings of this class lecture are available at:

http://www.cse.wustl.edu/~jain/cse574-16/
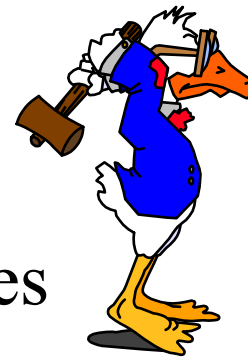
Overview

❑ Goal of this Course

❑ Grading

❑ Contents of the course

❑ Tentative Schedule

Mobile vs Wireless

Mobile   Wireless

- ❑ Mobile vs Stationary
- ❑ Wireless vs Wired
- ❑ Wireless ↻ Media sharing issues
- ❑ Mobile ↻ Routing, addressing issues

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

Mobile Networking

Impact of Mobility on Networking:

❑ Location

❑ Addressing

❑ Handoff

Goal of This Course

❑ Comprehensive course on wireless and mobile networking

❑ Broad coverage of current key areas

❑ Intro to physical layer "Wireless Communication"

❑ Emphasis on Higher layers: Layers 2, 3

❑ Emphasize both present (Industry standards and products) and near future (Research)

❑ Graduate course: (Advanced Topics)
  ↻ Less reliance on one textbook
  ↻ Lot of independent reading and writing
  ↻ Survey paper (Research techniques)
  ↻ Peer-Reviews

Why Wireless Networking?

1. Wireless (WiFi) is ubiquitous (Intel Centrino)

2. Most of the access (end user connectivity) is wireless

    ➢ Smart phones, Tablets, and many laptops (Ultrabooks) have no wired Ethernet connections

3. Most of telecommunication carriers' revenue is in wireless

4. New Developments:

    ➢ 5G: 1Gbps Metropolitan Area Networks (LTE-Advanced)

    ➢ Vehicular Networking (802.11p)

    ➢ Cognitive networks: Sharing unused spectrum

Wireless storage

Wired

Wireless Display

Mobile Internet

❑ June 29, 2007: Apple announced iPhone
  ↻ Birth of Mobile Internet, Mobile Apps
  ➢ Almost all services are now mobile apps: Google, Facebook, Bank of America, …

❑ 2014 **mobile** data traffic was 2.5×10^{18} B/month. 30× the size of the entire global Internet in 2000 (75 PB/mth).

❑ Mobile **video** traffic was more than 55% of the mobile traffic in 2014.

❑ Issues: Errors, Disconnection, Limited bandwidth, Limited distance

Ref: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2014–2019, Feb 3, 2015, http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.pdf

http://www.cse.wustl.edu/~jain/cse574-16/

Internet of Things

Smart Watch	Smart TV	Smart Car
Smart Health	Smart Home	Smart Kegs
Smart Space	Smart Industries	Smart Cities

Tentative Schedule

#	Date	Topic
1	1/20/2016	Course Overview
2	1/25/2016	Wireless and Mobile Networking: Facts,Statistics,and Trends
3	1/27/2016	Introduction to Wireless Coding and Modulation
		Project Guidelines
4	2/1/2016	Introduction to Wireless Signal Propagation
5	2/3/2016	Introduction to IEEE 802.11 Wireless LANs
6	2/8/2016	Wireless LANs Part II: 802.11a/b/g/n/ac (Part 1)
7	2/10/2016	Wireless LANs Part II: 802.11a/b/g/n/ac (Part 2)
8	2/15/2016	Introduction to 60 GHz Millimeter Wave Gigabit Wireless Networks (Part 1)
9	2/17/2016	Introduction to 60 GHz Millimeter Wave Gigabit Wireless Networks (Part 2)
10	2/22/2016	Mid-Term Exam 1

Tentative Schedule (Cont)

#	Date	Topic
11	2/24/2016	Introduction to Vehicular Wireless Networks
12	2/29/2016	Wireless Networking in White Spaces (Part 1)
13	3/2/2016	Wireless Networking in White Spaces (Part 2)
14	3/7/2016	IEEE 802.22 Regional Area Network (Part 1)
15	3/9/2016	IEEE 802.22 Regional Area Network (Part 2)
	3/14/2016	*Spring Break (No Class)*
	3/16/2016	*Spring Break (No Class)*
16	3/21/2016	Bluetooth and Bluetooth Smart
17	3/23/2016	Wireless Personal Area Networks
18	3/28/2016	Mid-Term Exam 2

Tentative Schedule (Cont)

#	Date	Topic
19	3/30/2016	Wireless Protocols for IoT (Part 1)
20	4/4/2016	Wireless Protocols for IoT (Part 2)
21	4/6/2016	Introduction to Cellular Networks: 1G/2G/3G(Part 1)
22	4/11/2016	Introduction to Cellular Networks: 1G/2G/3G (Part 2)
23	4/13/2016	Introduction to LTE
24	4/18/2016	Introduction to LTE-Advanced
25	4/20/2016	Introduction to 5G (Part 1)
26	4/25/2016	Introduction to 5G (Part 2)
27	4/27/2016	Final Exam

Prerequisite: CSE473S

❑ Protocol Layers: ISO/OSI reference model

❑ Physical Layer: Nyquist/Shannon theorems, Coding, Manchester

❑ Transmission Media: UTP, Cat 5, Microwave, Radio

❑ Data Communication: Asynchronous vs synchronous, Baud, bit, and Hz, Half-Duplex vs Full-duplex, Modulation/Demodulation

❑ Packet Transmissions: Framing, Bit stuffing, byte stuffing

❑ Flow Control: On-Off, Window

❑ Error Detection: Parity, Checksum, Cyclic Redundancy Check

Prerequisites (Cont)

❑ Error Recovery: Start and Stop, Go back *n*, Selective Reject

❑ LANs: Aloha, CSMA/CD, Ethernet, IEEE 802.3

❑ LAN Addressing: Unicast vs multicast, Local vs Global

❑ LAN wiring: 10Base5, 10Base2, 10Base-T, 100Base-T4, 100Base-TX, 100Base-FX

❑ Extended LANs: Hubs, Bridges, Routers, Switches

❑ Routing: Distance Vector vs Link State, Spanning tree, source routing

❑ Network Layer: Connectionless vs connection oriented

http://www.cse.wustl.edu/~jain/cse574-16/

Text Book

❑ There is no one book that covers the breadth of the material in this course

❑ There will be a reading list with each lecture. The list will include some books, web sites, 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

Project

❑ A survey paper on a recent topic.
   A list of topics will be provided in the class.

❑ A hands-on (implementation or measurement) project of your choice approved by the instructor.

❑ Teams of 2 allowed for hands-on project.

❑ Stages:
   ➢ Literature search
      ❑ CD ROMs:Compendex, Books in Print, WWW
   ➢ Reading
   ➢ Writing

❑ Average 6 Hrs/week/person on project

❑ Average 9 Hrs/week/person on class

Examples of Projects

2014:

- 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

Examples of Projects (Cont)

2010:

- 802.16m and WiMAX Release 2.0
- Current Status and Overview of the CAPWAP Protocol
- Femtocell: Indoor Cellular Communication Redefined
- Long Term Evolution (LTE)
- An Overview of Long Term Evolution Advanced (LTE-Advanced)
- Mobile Based Augmented Reality
- Mobile Cloud Computing
- Smart Grid
- Smart Grid: Trends in Power Market
- The Future of Networking: The Green Movement

Examples of Project (Cont)

2008:

❑ Body Area Networks (BAN)

❑ OSPF Extensions for Mobile Ad-hoc Networks

❑ 4G Wireless and International Mobile Telecommunication (IMT) - Advanced

❑ The 700 MHz Band: Recent Developments and Future Plans

❑ Wireless Options for Providing Internet Services to Rural America

❑ Long Term Evolution (LTE) & Ultra-Mobile Broadband (UMB) Technologies for Broadband Wireless Access

❑ Medical Applications of Ultra-Wideband (UWB)

❑ Medical Applications of Wireless Networks

❑ New and Emerging Energy Efficient Wireless Protocols

❑ Applications of Recent Wireless Standards in Satellite Networking

Examples of Projects (Cont)

2006:

❑ Metropolitan and Regional Wireless Networks: 802.16, 802.20 and 802.22

❑ Wireless Personal Area Networks

❑ RFID

❑ Recent Advances in the Wireless Physical Layer

❑ Location Management in Wireless Data Networks

❑ Location Management in Wireless Cellular Networks

❑ Time Synchronization in Wireless Networks

❑ Power Management in Wireless Networks

❑ Energy Efficient Routing in Wireless Networks

❑ Mobile IP

❑ Network Mobility

❑ Network Architectures for Mobility

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.

Project Schedule

#	Day	Date	Project	Points
3	Monday	1/25/2016	Search Sample Due	1
6	Monday	2/1/2016	HTML Sample Due	1
8	Monday	2/8/2016	Topic Selection Due	
11	Monday	2/15/2016	References Due	1
14	Monday	3/7/2016	Outline Due	2
20	Monday	4/4/2016	Final Report Due	5
22	Monday	4/11/2016	Reviews Due	1
24	Monday	4/18/2016	Revised Report Due	7
			HTML	2
			Total	20

Grading

❑ Exams (Best of 2 mid terms + Final) 60%

❑ Class participation   5%

❑ Homeworks   15%

❑ Project   20%

Frequently Asked Questions

❑ Yes, I do use "curve". Your grade depends upon the performance of the rest of the class.

❑ One 8.4x11 sheet allowed in the exam. Class handouts, books not allowed. Time limited.

❑ Exams consist of numerical as well as multiple-choice (true-false) questions.

❑ There is negative grading on incorrect multiple-choice questions. Grade: +1 for correct. -1/(n-1) for incorrect.

❑ Everyone including the graduating students are graded the same way.

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 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 CSE574 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)

http://www.cse.wustl.edu/~jain/cse574-16/

Quizzes

❏ There may be a short 5-minute quiz at the beginning of each class to check if you have read the topics covered in the last class.

Office Hours

❑ Monday: 11:00 to 12:00 noon
  Wednesday: 11:00 to 12:00 noon

❑ Office: Bryan 523

❑ **Teaching Assistant**: Siddhant Sirohi, Bryan 516,
                          s.sirohi (at) wustl.edu
                          Office Hours: Friday 1:00-2:00PM
                                        Sunday 1:00-2:00PM

Summary
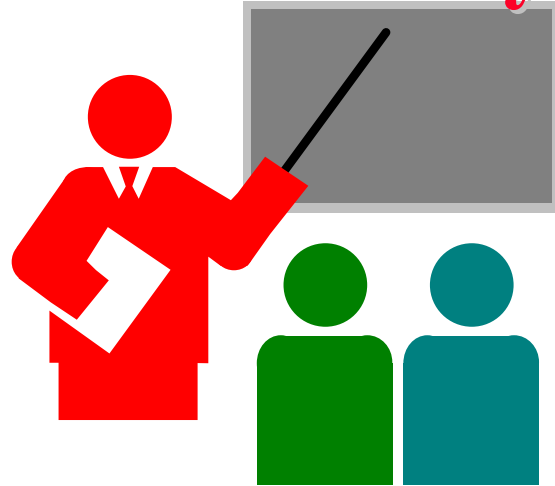
- Goal: To prepare you for the current job market in networking
- Teach you how to keep up with the latest in networking
- There will be a significant amount of self-reading and writing
- Get ready to work hard

Google Search Modifiers

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

Project Homework 1

❑ Search web pages, books, and journal articles from IEEE XPlorer, 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

Project Homework 1 (Cont)

❑ Ignore all entries dated 2011 or before. Also ignore all entries that do not indicate topic or similar words in the title. List others in the following format (5 each):
  ➢ Author, "Title," publisher, year, ISBN. (for 5 books)
  ➢ "Title," URL [One line description] (for 5 web pages)
  ➢ Author, "Title," source (for 5 technical/magazine articles)
❑ For the books, include whether the book is available at WUSTL, MOBIUS, Safari, or ILLiad
❑ Serially number the references and submit electronically to jain@wustl.edu. The mail should have a subject field of "CSE 574 Project Homework 1" (Please note the subject carefully. Do not any other characters in the subject). Your answers should be the content of the message and not in an attachment.
❑ Make a list of other interesting search points and share in class.

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.

Quiz 0: Prerequisites

True or False?

T F

1. □ □ Datalink refers to the 2nd layer in the ISO/OSI reference model
2. □ □ Cat 5 unshielded twisted pair cable is better than Cat 3 cable.
3. □ □ Finding path from one node to another in a large network is a transport layer function.
4. □ □ It is impossible to send 3000 bits/second through a wire which has a bandwidth of 1000 Hz.
5. □ □ Bit stuffing is used so that characters used for framing do not occur in the data part of the frame.
6. □ □ For long delay paths, on-off flow control is better than window flow control.
7. □ □ Ethernet uses a CSMA/CD access method.
8. □ □ 10Base2 runs at 2 Mbps.
9. □ □ The packets sent in a connection-oriented network are called datagrams.
10. □ □ Spanning tree algorithm is used to find a loop free path in a network.

Marks = Correct Answers ___ - Incorrect Answers __ = _____

Acronyms

- BAN   Body Area Networks
- CAPWAP   Protocol
- 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
- LTE   Long-Term Evolution
- MAC   Media Access Control
- MHz   Mega Hertz
- OSI   Open System Interconnection
- OSPF   Open Shortest Path First
- QoS   Quality of Service

Acronyms (Cont)

- RF   Radio Frequency
- RFID   Radio Frequency Identification
- TCP   Transmission Control Protocol
- UMB   Ultra-Mobile Broadband
- URL   Uniform Resource Locator
- UTP   Unshielded Twisted Pair
- UWB   Ultra-Wideband
- VoIP   Voice over IP
- WAP   Wireless Access Protocol
- WiFi   Wireless Fidelity
- WiMAX   Wireless Micro-wave Access
- WUSTL   Washington University in Saint Louis
- WWW   World-Wide Web

Student Questionnaire

- Name: _____

- Email: _____

- Phone: _____

- Degree: _____ Expected Date:_____

- Technical Interest Areas:

  _____

  _____

- Prior networking related courses/activities:

  _____

  _____

- Prior wireless networking related courses/activities:

  _____

  _____

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Related Modules

Introduction to 5G,
http://www.cse.wustl.edu/~jain/cse574-16/j_195g.htm

Low Power WAN Protocols for IoT,
http://www.cse.wustl.edu/~jain/cse574-16/j_14ahl.htm

Introduction to Vehicular Wireless Networks,
http://www.cse.wustl.edu/~jain/cse574-16/j_08vwn.htm

Internet of Things,
http://www.cse.wustl.edu/~jain/cse574-16/j_10iot.htm

Audio/Video Recordings and Podcasts of
Professor Raj Jain's Lectures,
https://www.youtube.com/channel/UCN4-5wzNP9-ruOzQMs-8NUw