## EECS 563 Fall 2013

# Introduction
# to
# Communications Networks

Victor S. Frost
Dan F. Servey Distinguished Professor
Electrical Engineering and Computer Science
University of Kansas
2335 Irving Hill Dr.
Lawrence, Kansas 66045
Phone: (785) 864-4833
e-mail: frost@eecs.ku.edu
http://www.ittc.ku.edu/

Introduction      1

---

# EECS 563-Book

■ Main Text: Computer Networks, A Systems Approach 5th Edition, Larry L. Peterson and Bruce S. Davie
  ➢ Book Web Site: http://booksite.mkp.com/9780123850591/
    – Glossary Flashcards
    – Learning Assessment
■ Alternate texts:
    – Communication Networks: Fundamentals Concepts and Key Architectures, A. Leon-Garcia and I. Widjaja
    – Computer Networks, 4th Edition, A. Tanenbaum
    – Computer Networking: A Top-Down Approach, 5th Edition, J. Kurose and K. Ross
■ Look to the Web, search on networking terms to answer your questions

Introduction      2

# EECS 563 - Class Web Site

- The class will follow notes on the Class Web site:

  http://www.ittc.ku.edu/~frost/EECS_563/index-Fall_2013.html

  - Class notes content = instructors notes + material from the main
    + material alternate texts + material other sources
  - Homework assignments
    - All homework assignments will be posted on the class web page
    - Solution will not be posted, problems will be worked in class or during office hours upon request.
  - Projects assignments
  - Lecture summaries
  - Useful links
  - Class will use interactive graphs using the Wolfram CDF Player
    - Download Wolfram CDF Player
  - **Academic Integrity and Plagiarism** (See class web page)

# EECS 563 - Contact Info

- Contact Information
  - e-mail: frost@eecs.ku.edu
  - Home: Phone 841-3244
  - Nichols Hall: 864-4833

- Office hours:
  - In 3016 Eaton Hall:
    - TR 8:15-9:15 & 11:00 – ~12:00 (before and after class)
    - Wed 1:30 – 4:00
  - Some times in Nichols Hall rm 224
  - Outside of office hours call or e-mail to insure that I am available, especially before going over the Nichols Hall

# EECS 563 - Deliverables

- Homework
  - Problems will be assigned and graded
  - Homework will be posted on the class web site
    - pdf
    - CDF
- Two in class tests
- Two network analysis and design projects
- Final

# EECS 563 - Grading

- Tests (2)          = 40%
- Projects (2)        = 20%
- Final             = 30%
- Homework          = 10%
  - Homework on Performance Analysis of Networks     = 4%
  - Total for other assignments    = 6%

# EECS 563: Grading

- Initial grading scale:
  - 90 - 100 A
  - 80 - 89 B
  - 70 - 79 C
  - 60 - 69 D

# EECS 563: Grading

- Only under **VERY** extreme conditions will make up tests be given.
- I **MUST** be notified BEFORE you miss a test otherwise you **WILL** get a 0.
- No late homework will be accepted.
- No make up quizzes will be given

# Tools Used for Class Assignments

- Wireshark
  - http://www.wireshark.org/
  - Free software at http://www.wireshark.org/
  - Install on your own machine, need to install and run as administrator
- Simulation: ExtendSim
  - Installed on all EECS Windows computers ← Suggest you use
  - http://www.extendsim.com/
  - Limited free version at:
    http://www.extendsim.com/prods_demo.html
    - Can not save & print models
  - ExtendSim LT $50.00 [not required]
- Wolfram CDF Player
  - Interactive documents
  - Installed on all EECS Windows computers
  - http://www.wolfram.com/products/player/

# EECS 563 - Homework Rules

- The class grader will score the homework
- Homework can be submitted by e-mail, send it to the grader and cc to me.
- All work containing more than one page must be stapled - no paper clips and no folded corners. In order to facilitate grading of homework problems, homework shall meet the following specifications:

  1. Hand written or typed single-sided on 8.5"x11" paper.

  2. If not typed then for text and equations, use an HB or No. 2 pencil (or darker), or blue or black ink. (Pencil is preferred.) No other colors please, except in diagrams or graphs.

  3. All pages should be numbered i/j in top right hand corner, with your name appearing at the top of each page. It is O.K. to use your initials after the first page.

  4. All work must be shown for full grade - be as thorough as possible.

  5. Writing should be legible and literate - if the grader cannot read your handwriting, you will receive no credit for the problem.

# EECS 563 Homework Format

6. Answers are to be boxed and right justified, with the variables, values (if any) and units (if any), included in the box. Right justified means placed on the right side of the page.

7. Leave half an inch between consecutive parts of a question, and draw a line across the page at the end of each complete question.

8. No part of a question should appear in any margin of the paper.

9. Diagrams and graphs should be of a good size (say at least 3x5 sq. inch), and may contain colors. Diagrams and graphs must be titled, labeled, and clearly drawn. Tables should also be titled.

10. Graphs should be scaled (put number on axes), labeled (put names /units on axes), and titled at the bottom of the graph. Any graph which occupies an area of less than 3x5 sq. inch and which is not titled will not be graded.

11. Where possible use conventional units such as bits/sec, Hz and km
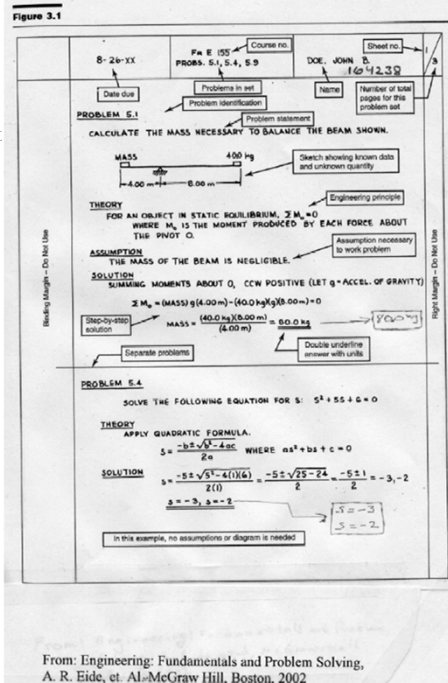
From: Engineering: Fundamentals and Problem Solving,
A. R. Eide, et. Al. McGraw Hill, Boston, 2002

# Project Report-Grading

- I will grade the projects
- Grading criteria
  - Demonstration of understanding of the project goals
  - Providing the correct answers to project questions
  - Demonstration of understanding of the results obtained
  - Generating a professional product that is straightforward to understand; the provided format is a guide for writing the report.
- Report and simulation model will be submitted

# Project Report Format

- See class web page for Project Report Format
- Brief statement of objective of the project.
- Brief overview of system model, appropriate block diagrams and parameters.
- Discussion of results, all plots and tables included must be discussed in the text.
- Conclusions and lessons learned.
- DO NOT PAD THE REPORT! YOU WILL LOSE POINTS FOR INCLUDING MATERIAL NOT DISCUSSED IN THE TEXT OR NOT DIRECTLY RELATED TO THE ASSIGNMENT.

# Project Report Format

- Figures
  - Each figure/table should be placed as close to the first reference to it in the text as possible. Placing the figure/table on a separate page following the first reference to it in the text is permissible.
  - Each figure/table must have a title.
  - All axis on graphs must be labeled.
  - Each figure/table should be self contained, that is, the title, axis labels, and other information in the figure/table should provide the reader enough information to interpret the item.

# Electronic Submission

- Electronic submission of assignments is permitted.
- Electronic submissions **must** be in pdf format
- Electronic submissions **must** use this file naming format.
  - Homework: HW#_LastName.pdf
    - For example, HW5_Frost.pdf
  - Project: Project#_Lastname.pdf
    - For example, Project1_Frost.pdf
- E-mail assignments to the grader and me

# Course Outline

- Network Evolution, Standards, and Layered Architectures
- Network Switching Technologies, Impairments, and Metrics
  - Network technologies
    - Circuit switching
    - Message switching
    - Packet switching  (Statistical multiplexing)
    - Virtual Circuit Packet Switching
  - Network impairments
  - Network metrics
- Internet Protocols (IP)
  -----------------------------------> Test 1 Likely Here

---

# Course Outline

- Network traffic
- Network design, performance evaluation, and simulation
  (simulation not on tests or final: <u>covered in homework & projects</u>)
- Media Access Control
- Data Link Control
- Transport Protocols
  -----------------------------------> Test 2 Likely Here

# Course Outline

- Network Security (Chapter 11)
- Signaling, TDM Hierarchies/SONET and Switching (Chapter 4)
  - - - - - - - - - - - - - - - - - - - - - - - - - → Final

---

# At the conclusion of this class the students are expected to:

- Understand the basics of multiplexing
- Understand the layered structure of protocols
- Understand the importance of standards and who sets them
- <u>Understand the basics of network protocols, including, datagram/virtual circuit switching, forwarding, access control, data link control, IP, routing, transport protocols. Resulting in an understanding of how the Internet works.</u>
- Understand the tradeoffs involved in network design in a variety of environments - LAN and WAN, diverse link rates, and varied error and delay conditions

## At the conclusion of this class the students are expected to:

- Perform simple analytic performance and design trade-off studies
- Perform simulation-based performance and design trade-off studies
- Understand the basics of network security, including public/private key systems, digital signatures, key distribution systems, and certificate authorities
- Use network analysis tools, e.g., Wireshark, traceroute, ping, and simulation
- Be fluent in the language of communication networks, i.e., understand the meaning of networking terms and abbreviations

## Communications Landscape

- Voice
- Data: E-mail, Web, Network based applications, image
- Video, Broadcast, Video on Demand, Video Over the Web, Mobile
- Wired & wireless (Mobility)
- Some  separate Voice/Internet/Video networks remain
- Rapidly converging to:
  **An integrated packet network**
- Triple Play→ Voice/Internet/Video
- Mobility

# Drivers: Customer Expectations

- Sense of always connected
- Instant response, high bandwidth
- Ubiquitous connectivity
- Multimedia support
- Conferencing (simultaneous communications with multiple users)

# Drivers: Customer Expectations

- Mobility support
- Personalized information services
- Context sensitive information services
- Absolutely secure
- Low-cost

# The Value of the Net

- Metcalf's Law: The value of a network increases as the square of the number of connected users [some say nlog(n)]
- The value of a network increases as the square of the access bandwidth
- The value of a network increases as the square of computing power of end device
- Number of connected users, bandwidth/user and device capabilities are increasing → Value of the Net ↑
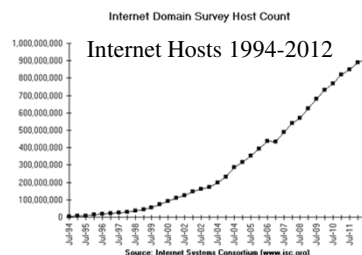
# Drivers: Technology
## Traffic Growth

- Internet still growing

Internet Domain Survey Host Count

Internet Hosts 1994-2012

Source: Internet Systems Consortium (www.isc.org)

- Access rates increasing
  - Modem ~ 50kb/s
  - Cable/DSL ~ 10's-100 Mb/s
  - FTTH ~100's to 1 Gb/s
  - Wireless → Gb/s
- See http://navigators.com/stats.html

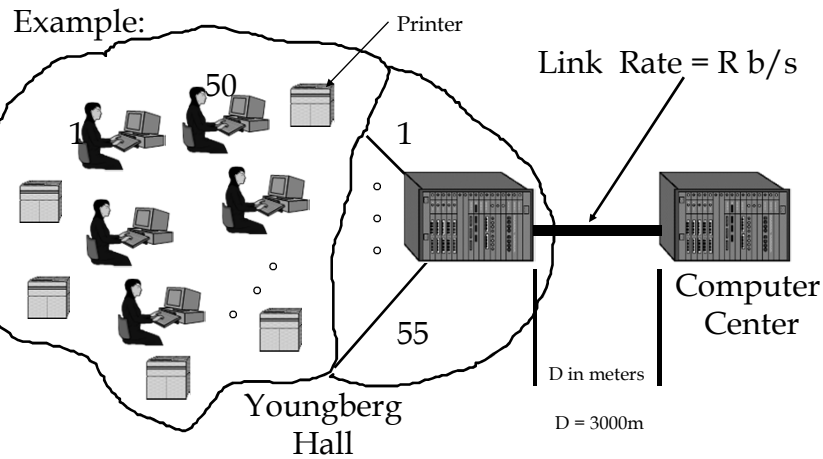Source data: M. Lottor, Internet Software Consortium <www.isc.org>

# Drivers: Technology

- Moore's Law
  - Processing power doubles every 18 months
  - Moore's Law has been true for the past 20 years
- Gilder's Law (The Law of Telecoms)
  - Total telecommunications system capacity (b/s) triples every three years

# Drivers: Others

- Economic
- Privacy/Security
- Public Policy/Regulatory
  - FCC opening of "White Space"
  - Network Neutrality
- Local Culture

# Issues in Networking: Sharing

Example:

Printer

50

1

1

55

Youngberg
Hall

Link Rate = R b/s

Computer
Center

D in meters

D = 3000m

---

# Issues in Networking: Sharing

- What is shared:
  - Link capacity
  - Common address space

# Issues in Networking: Sharing

- R = Peak rate (link capacity) b/s
- L=Message Length (Bytes)
- Packet clocking (serving) time (sec)
  $$= L*8 \text{ (bits)}/R \text{ (bits/sec)}$$
- One way propagation time (sec)
  $$= D \text{ (meters)}/c \text{ (meters/sec)} = \tau$$
  - c = speed of light = $3\times10^8$ meters/sec (in free space)
- For L=9000 & R=100Mb/s →Packet clocking time
  = 0.72 ms
- For D = 3km→ One way propagation time = 10 us
- Round trip time (RTT) = $2\tau$ (Not including switching, routing, and processing times)

---

# Issues in Networking: Sharing

- Assume each customer and printer is connected using Ethernet, i.e. at 1 Gb/s
- How fast does the link between Youngberg and the computer center have to be to **guarantee** all the customers can use the 1 Gb/s.
- R= Rate = 55 Gb/s
- Too expensive

# Issues in Networking: Sharing

- Solution: Gamble
- Assume:
  - Each host computer breaks up messages into 'smallish' units called *packets*
  - Packets from each customer are sent to a waiting line, buffer, to wait their turn to use the link
  - Packets arriving to a full buffer are discarded
  - Discarded packets are retransmitted later
- Customer information now experiences:
  - Delay, waiting in line
  - Loss
- Many network resources are shared, e.g.,
  - Transmission capacity
  - Addresses

# Issues in Networking: Sharing

- Customer performance requirements: } Quality of Service Specifications
  - Delay < 100ms and Loss < 10%
- Assume customer traffic:
  - L (bytes) =Average packet length = 9000 bytes
  - $\lambda$ (packets/sec/device) = } Input Traffic Specification
    Packets are generated at a rate of 2 per second/device
- Using basic queueing theory } System Design
  - R = 8.6 Mb/s << 55 Gb/s
  - System size > 7 packets

What happens when you lose your gamble:
- Packet Loss
- Delay

See the current Internet performance @
http://www.internetpulse.net/
and
http://www-iepm.slac.stanford.edu/pinger/

# Issues in Networking: Protocols

- Protocols are the rules, algorithms that govern the interactions between network elements, e.g.,
    - Routing
    - Media Access
    - Resource allocation
- Protocols are algorithms implemented software or hardware
- Protocols must run in "real time"
    - Assume R = 40 Gb/s and L = 1500 Bytes
        - Router must process a packet in 0.3 μs

# Issues in Networking: Protocols

- Peer protocols
    - Executed at both ends of the connection
    - Run on geographically distributed network elements
    - Use memory to save state
    - Packet events (arrival) to change state based on data in packet headers
- Protocols must work with inaccurate or imperfect knowledge
    - Packets are lost due to bit errors or traffic congestion
    - Instantaneous demands for network resources are unknown
    - Out-of date information due to finite propagation delay
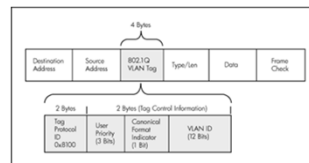- Protocols must be standardized

# Issues in Networking:

- Routing → finding path from source to destination
- Resource Allocation
  - Call admission control (CAC)
  - Congestion control
  - Flow control
- Time scales: Control network resources at time scales ranging from $10^{-6}$ sec to months
- Management, e.g.,
  - ISP need to add/delete users
  - Carriers need to administer their equipment
- Need for cooperation among competing companies

# Issues in Networks

- Specific Protocols and Acronyms
  - E.g., TDM, FDM, IP, TCP, ARP, DNS, DHCP, ICMP, IPv6…..
- Header Formats…. →
- Boxes
  - E.g., Router, switch, repeater, firewalls, headend, base station….
- Tools,
  - E.g., Ping, traceroute, wireshark,….

# Networks

- Real time distributed systems
- Owned by different companies, governments, government agencies, enterprises…..
- Must meet constraints, e.g.,
  - Quality of Experience (QoE),
  - Security,
  - Privacy,
- Large scale, e.g.,
  - Geographic
  - Number of devices (Internet of Things)
  - Range of data rates
- Must cope with a wide variety of impairments
- Must cope with imperfect knowledge