EECS 863
Network Analysis, Simulation, and Measurements

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Course Information

- Semester: Spring 2022
- Text: “Queueing Modeling Fundamentals: With Applications in Communication Networks”, 2nd Edition Chee-Hock Ng and Soong Boon-Hee, ISBN: 978-0-470-51957-8, 2008
- Alternate and Reference Texts:
  - “Computer Networks and Systems: Queueing Theory And Performance Evaluation”, 3nd ed., T. G. Robertazzi, Springer, 2000.
  - "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design Measurement, Simulation, and Modeling," R. Jain, Wiley- Interscience, New York, NY, April 1991.
  - “Queueing Systems, Volume I and II”, Leonard Kleinrock, Wiley, 1975.
  - “Internet Measurement: Infrastructure, Traffic and Applications” Mark Crovella, Balachander Krishnamurthy, Wiley, 2006
  - Simulation Modeling and Analysis 4th Edition, Averill Law, McGraw Hill, 2007.
  - Discrete Event Simulation using ExtendSim 8, Jeffrey Strickland, Lulu, 2011
  - Simulation Modeling and Analysis 5th Edition, Averill Law, 2013

Course Information

- Class Web Page:

http://www.ittc.ku.edu/~frost/EECS_863/index_Spring_2022.htm

- Office hours and Contact Information:
  - 8:00 - 9:00 & 2:30-4:00 TR
  - 2054 Eaton Hall
  - Other times by appointment
  - Phone:
    - Eaton 864-1028
    - Home 841-3244
  - e-mail: vsfrost@ku.edu

Course deliverables

- Exams: 1 in class test (open book & notes)
- Homework: problems will be assigned.
- Grading:
  - 2 - In class test; open book & notes = 20%
  - 5 - Projects (with technical reports) = 40%
  - Homework = 15%
  - Paper & Presentation = 20%
  - Class participation & attendance = 5%
  - No Final

- Produce a written review and make an oral presentation to the class of a published paper, the paper will be selected by the student. Or execute a substantial measurement/simulation project, write up the results, and make an oral presentation to the class. Or conduct measurements using an existing testbed, write up the results, and make an oral presentation to the class The paper or project must be selected and approved by March 3, 2022.

- General guidelines: Only under very extreme conditions will a make up test be given. No late homework will be accepted

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 (30 day free) version at: https://extendsim.com/products/trials
  - ExtendSim LT $50.00 [not required]
    - https://extendsim.com/academic#student
- Wolfram CDF Player
  - Interactive documents
  - Installed on all EECS Windows computers
  - http://www.wolfram.com/products/player/

Initial Grading Scale

- 90 - 100 % A
- 80 - 89 % B
- 70 - 79 % C
- 60 - 69 % D
- 0 - 59 % F
- Lower limit on these ranges maybe reduced as a function of the distribution of the final scores.
- This class will not use +/- grading

EECS 563 - Homework Rules

- I will score the homework
- Homework must be submitted by e-mail as a pdf.
- File Name specification: LastName_HW_#_EECS863, Example: Frost_HW_4_EECS863.pdf
- 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.

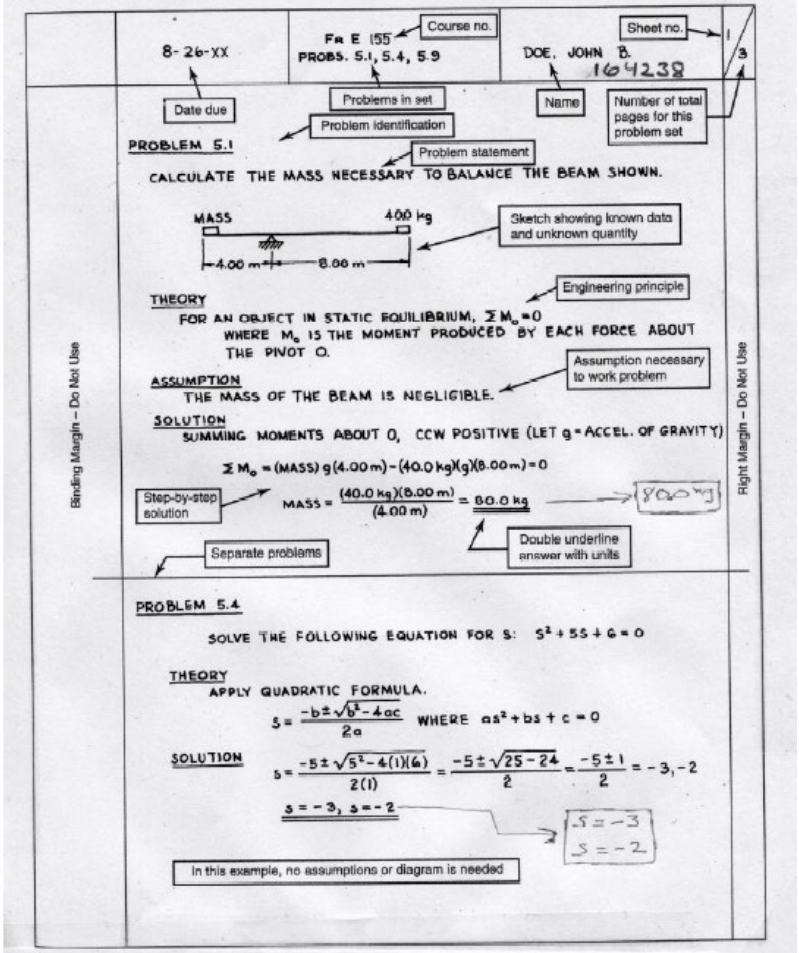
8. No part of a question should appear in any margin of the paper.

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

Figure 3.1



From: Engineering: Fundamentals and Problem Solving, A. R. Eide, et. Al. McGraw Hill, Boston, 2002

Project Report-Grading

- I will grade the projects
- Projects must be submitted by e-mail as a pdf.
- File Name specification: LastName_Project_#_EECS863, Example: Frost_Project_2_EECS863
- Grading criteria

  Demonstrating an understanding of the project goals

  Providing the correct answers to project questions

  Demonstrating an understanding of the results obtained

  Generating a professional product that is straightforward to read and understand; the provided format is a guide for writing the report.

  See: **Technical Report Format**
  http://www.ittc.ku.edu/~frost/EECS_563/Technical%20Report%20Format-2019.pdf

- Report in .pdf and the simulation model in .mox must be submitted via e-mail.

Project Report Format

1. Title page (include your name and student number)
2. Abstract
3. Table of contents (with page numbers)
4. Introduction
5. Narrative
   a) Objective
   b) Methodology: overview of methods used, including associated theory, system model, block diagrams, and/or system parameters as appropriate
   c) Discussion of results
6. Conclusions and lessons learned.
7. References
8. Appendices (if needed)

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 & Tables
  - All plots and tables included in the report must be discussed in the text.
  - 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 with units.
  - 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.
- Paper on writing technical reports: http://www.ittc.ku.edu/~frost/EECS_563/Writing%20Technical%20Reports.pdf "Writing Technical Reports" by David Dettinger, IEEE Engineering Management Review, Year: 1977, Volume: 5, Issue: 4

Electronic Submission

- Homework and projects assignments must be submitted via e-mail as pdfs for homework and project reports and .mox files for simulation models.
- Electronic submissions **must** use this file naming format.
  - Homework: LastName_HW_#_EECS863.pdf
    - For example, Frost_HW_5_EECS863.pdf
  - Project: Lastname_Project_#_EECS863.pdf
    - For example, Frost_Project_1_EECS863.pdf
- E-mail homework assignments me
- E-mail the project reports and simulation models to me at vsfrost@ku.edu

Academic Integrity and Plagiarism

- The department, school and university have very strict guidelines regarding academic misconduct. Obviously, copying is not allowed on exams. Students are expected to submit their own work on individual homework and projects. Lending or borrowing all or part of a simulation model or program from another student is not allowed. Students ARE allowed to borrow and modify any code on this class web site in their projects. Instances of cheating will result in a referral to the department chairman and the dean of engineering.
- All sources in your written work (project reports) must be properly referenced; if you use a source from the literature or the idea of another for your work you must reference it. If you quote or copy a block of text, it must be cited and included in quotation marks (if a sentence or less in length) or in block quote style (if more than a sentence in length). If you paraphrase text (reword a phrase, sentence, or paragraph), you must also quote or blockquote followed by "[paraphrased]" in addition to proper citation. Figures taken from other sources must be referenced.

- I recommend that you take intermediate notes from which you write your own words. I strongly recommend that you not write in one window while displaying the work of others in another window; this is asking for trouble. "Unintentional" paraphrasing is also not an acceptable excuse for academic misconduct.

- Modified with permission from James P.G. Sterbenz http://www.ittc.ku.edu/~jpgs/courses/eecs800/ and John Gauch http://www.ittc.ku.edu/~jgauch/teaching/258.f03/syllabus.html

Use of EdTech Services

- Professors and instructors at the KU School of Engineering are aware that some students are actively posting homework, laboratory, and exam questions and responses to EdTech services (e.g., Chegg) even during exam time frames.
- Keep in mind that when a person signs up to participate by either uploading, and/or downloading, and/or using posted material from these sites, the “terms of service” that are agreed to do not protect the person when KU and/or the School of Engineering decide to conduct investigations related to academic misconduct (e.g., plagiarism and/or cheating).
- In fact, EdTech services, like Chegg, retain contact information of students who use their services and will release that information, which is traceable, upon request. Using these services constitutes academic misconduct, which is not tolerated in the School of Engineering. It violates Article 3r, Section 6 of its Rules & Regulations, and may lead to grades of F in compromised course(s), transcript citations of academic misconduct, and expulsion from the University of Kansas.
- If unsure about assignments, it is important that students use the allowable available resources, such as instructor office hours, graduate teaching assistants, and/or tutoring. The School of Engineering wants students to be successful; cheating is not the way to attain that success.

Use of smartphones, tablets, and laptops in class

- Smartphones, tablets, and laptops may **only** be used in direct support of class activities.
- Texting, general web browsing, checking of e-mail is **NOT** permitted during class.
- Video and audio recording of the EECS 563 class lectures is prohibited.

Why Do Performance Analysis?

- System design
- Understand system behavior
- Understand system trade-offs
  - Cost vs Performance
- System management
  - “you can only manage what you can measure” Tom Peters
- Guide system evolution

Role of Models

- Models are abstract descriptions of the physical world.
- Models are used to predict future system behavior.

Model Inputs

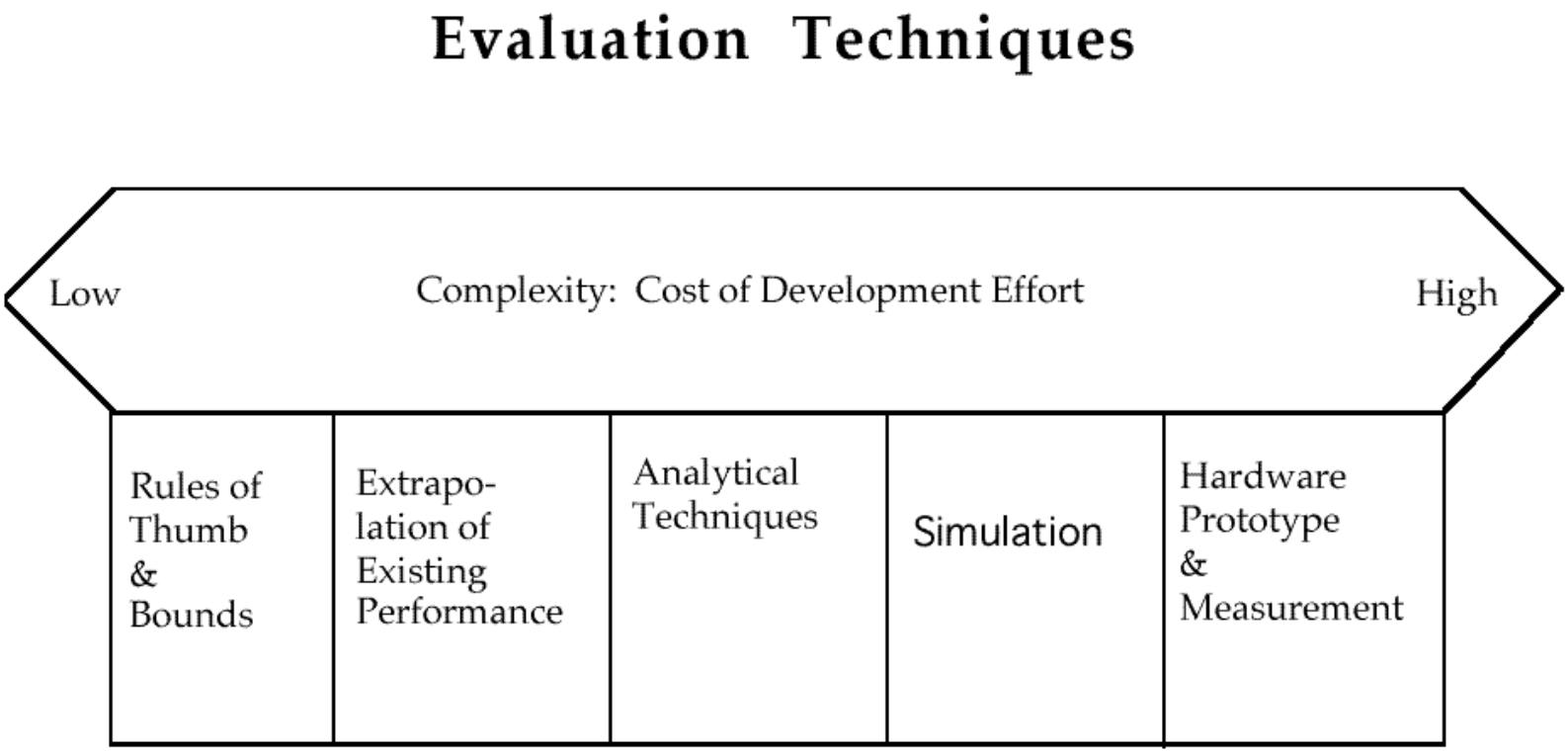
- Inputs
  - Controllable system parameters
    - Min/max packet size
    - Maximum burst size
    - Link capacities
    - Buffer size
    - Queue service disciplines
    - Queue priorities
    - Routing
    - Window size
    - Transmit signal power
    - Receiver sensitivity
    - …….
  - Traffic (workload)
    - Number of traffic sources
    - Packet size pdf
    - Packet interarrival time pdf
    - Geographical distribution of traffic sources
    - Motion of traffic sources
    - …….
  - Environmental parameters
    - Noise environment
    - Fading environment
    - ……

Model Outputs

- Outputs
  - Throughput
    - b/s
    - Packets/sec
    - Normalized throughput, S
  - Delay
    - Average Delay
    - Variance (SD)
    - pdf of delay
  - Loss
  - Others…..

Modeling Approaches

- Closed form mathematical models (analytical)
- Simulation
- Measurement- Empirical



Steps in Performance Analysis

- Understand who is the customer and what is their expectation
- Clearly define goals for the analysis, what is the question to be answered
- Define the system
- Articulate the outcomes of the analysis
- Select metrics (outputs)
- Select fixed system parameters
- Select system variables (factors) to study (define the x-y axis on output performance plots)
- Select environmental parameters
- Select traffic model (workload)
- Select modeling approach (evaluation technique)
- Clearly state and understand modeling assumptions
- Design and execute the analysis, e.g., simulation experiments
- Analyze and interpret data
- Present results
- Plan for success, the customer will say, “that is informative, but can you answer this related question…..”

Modified From: R. Jain, "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design Measurement, Simulation, and Modeling," Wiley- Interscience, New York, NY, April 1991.

Common Mistakes in Evaluation

- No goals, question is not well defined
- Biased goals: ``to show that OUR system is better than THEIRS''
- Lack of in-depth understanding of the system
- Selection of wrong evaluation technique
- Analysis without understanding the problem
- Selection of inappropriate performance metrics
- Selection of inappropriate traffic models
- Overlook important system or environmental parameters
- Focus on insignificant factors while missing important ones
- Inappropriate experimental design – you are an explorer; exploring the design space

Modified From: R. Jain, "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design Measurement, Simulation, and Modeling," Wiley- Interscience, New York, NY, April 1991.

Common Mistakes in Evaluation

- Inappropriate level of modeling detail
- Flawed analysis
- Ignores system sensitivity to changes in factors
- Errors in specification of input parameters and range of factor values – Exploring wrong part of the design space
- Improper treatment of outliers
- No consideration of system evolution
- Lack of understanding the impact of assumptions and limitations of the evaluation methodology
- Poor and/or improper presentation of results

Modified From: R. Jain, "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design Measurement, Simulation, and Modeling," Wiley- Interscience, New York, NY, April 1991.

Checklist for Avoiding Common Mistakes

- Is the system correctly defined and the goals clearly stated?
- Are the goals stated in an unbiased manner?
- Is the problem clearly understood before analyzing it?
- Have all the steps of the analysis followed systematically?
- Are the performance metrics relevant for this problem?
- Is the traffic model correct for this problem?
- Is the evaluation technique appropriate?
- Is the list of parameters that affect performance complete?
- Have all the important factors been identified?

Modified From: R. Jain, "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design Measurement, Simulation, and Modeling," Wiley- Interscience, New York, NY, April 1991.

Checklist for Avoiding Common Mistakes

- Is the experimental design efficient in terms of time and results?
- Is the level of detail proper?
- Is the measured data presented with analysis and interpretation?
- Is the analysis statistically correct?
- Has the sensitivity analysis been done?
- Would errors in the input cause an insignificant change in the
- results?
- Have the outliers in the input or output been treated properly?
- Has the evolution of the system and traffic been considered?
- Has the variance of input been taken into account?

Modified From: R. Jain, "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design Measurement, Simulation, and Modeling," Wiley- Interscience, New York, NY, April 1991.

Checklist for Avoiding Common Mistakes

- Has the variance of the results been analyzed?
- Is the analysis easy to explain?
- Is the presentation style suitable for its audience?
- Have the results been presented graphically as much as possible?
- Are the assumptions and limitations of the analysis clearly documented?

Modified From: R. Jain, "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design Measurement, Simulation, and Modeling," Wiley- Interscience, New York, NY, April 1991.

Course Outline

- Introduction
- Theoretical Background: Markov Processes
  - Obtain understanding of key assumptions
  - Learn terminology of Markov chains
  - Develop techniques to solve Markov systems
- Application of Markov Processes to Queueing and Blocking Systems
  - Delay analysis of queueing systems with Markov service process
  - M/M/1
  - M/M/1/K
  - M/M/K/K
  - Finite population systems
  - Little's Result
- Traffic Modeling
- Simulation of Communication Networks
  - Building simulation models
  - Verification and validation of communication network simulation models
  - Deriving statistically significant results from simulation models

Tentative Exam

Course Outline

- Application of Markov Process to systems with arbitrary service process
  - M/G/1 analysis
  - Develop the concept of Residual Life
  - Analyze M/G/1 systems with vacations
  - Analyze Priority Systems
  - Scheduling Algorithms
- Analysis of MAC protocols
- Scheduling
- Analysis of Networks of Queues
  - Analysis of open networks
  - Analysis of closed networks and application to analysis of window flow control techniques

Tentative Exam

Course Outline

- Network Measurements
  - Role of Measurements
  - What to Measure
  - How to Measure
    - Passive
    - Active
    - Role of time
  - Bandwidth measurements
  - How to plan for measurements
  - Measurement repositories
- Design of Simulation Experiments