The University of Connecticut **Spring 2017**
Dept. of ECE **KRP**

ECE 6433: Stochastic Models for the Analysis of Computer Systems and Communication Networks

General Information

Instructor:

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Office Hours: Tuesday-Thursday: 11:00 AM – 12:00 Noon

Classes: Time: Wednesday, 6PM-9PM, Location: ITE 119

Text: G. Bolch, S. Greiner, H. de Meer and K. Trivedi, "Queuing Networks and Markov Chains," 2nd Edition, Wiley, 2006.
D. P. Bertsekas and R. Gallagher, **Data Networks**, 2nd Edition, Prentice-Hall, 1992.
B. R. Haverkort, **Performance of Computer Communication Systems: A Model-based Approach**, Wiley, 1998.

Course Objective

This course is designed to provide students with a thorough understanding of the mathematical underpinnings of widely used performance and reliability models and algorithms for the analysis of complex computer systems and communication networks.

Course Outline

Lecture 1: **Introduction and Course Overview :**

- *Course Objectives*
- *How to characterize a simple queue?*
- *What are the measures of system performance?*
- *Fundamental accounting identity of queues … Little's Theorem*
- *Applications of Little's Theorem: single server queue, a closed system with a multi-server node, multi-access communication channel, Amdahl's law and problem scaling*

Lecture 2: **Discrete-time and Continuous-time Markov Chains**

- *Classification of Stochastic Processes*
- *Discrete-time Markov Chains (DTMC) and Applications*
- *Continuous-time Markov Chains (CTMC) and the Poisson Process*
- *Geometric and Exponential Distributions for characterizing the time between state changes in DTMC and CTMC*
- *Uniformization*

Lecture 3: **Birth-Death Processes, M/M/1, M/M/1/N, M/M/m, M/M/∞, M/M/m/m Queues**

- *Properties of Exponential and Geometric Distributions*
- *Properties of the Poisson Process*
- *Steady-state solutions to DTMC and CTMC*
- *State transition rate diagrams*

- *Applications to M/M/1, M/M/1/N, M/M/m, M/M/∞, M/M/m/m queues*
- *Performance Measure of* M/M/1, M/M/1/N, M/M/m, M/M/∞, M/M/m/m Queues*: Throughput, Queue Length, Utilization, Average Response Time*

Lectures 4 - 5: Control of Queues and Product-form Open Networks

- *Control of M/M/1 queues: controlled service rate, controlled arrival rate, priority assignment and the μC rule*
- *Time Reversibility, Detailed (local) balance*
- *Burke's Theorem*
- *Two-stage Tandem Network and feedforward networks*
- *Concepts of Closed, Open and Mixed Networks*
- *Jackson Networks*
- *Application to Capacity Assignment in Communication Networks*

Lectures 6 -8: Product-form Closed (Gordon-Newell) and Mixed Queuing Networks

- *Machine Repairman (also termed Multi-access Communication Channel, Time-shared Computer System) Model*
- *Central server model*
- *Single class closed queuing networks*
- *Computational Algorithms (Convolution, MVA)*
- *Applications: "what if" analysis, sliding window flow control, Optimization of Routing and Service Rate Selection*
- *Multi-class (closed, Open, and Mixed) Networks and Computational Algorithms*
- *Chandy-Herzog-Woo's (also termed Norton's) Theorem*
- *Flow Equivalence and Aggregation*
- *Approximation Methods and Applications (simultaneous resource possession, product-form equivalents of non-product form networks, hierarchical networks)*

Lecture 9: M/G/1 Queue and Queues with Vacations

- *Exponential method of stages*
- *M/G/1 Queue*
- *M/G/1 Queus with vacations*
- *Application to reservations and polling*
- *Extension to non-product form Queuing Networks with M/G/1 nodes*

Lecture 10: Priority Queuing, Batch Arrivals and G/G/1 Queues

- *M/G/1 Queue with non-preemptive priority queuing disciplines*
- *M/G/1 Queue with preempt-resume priority queuing discipline*
- *Extensions to Multi-class Queuing Networks*
- *Batch Arrivals*
- *G/G/1 Queue*
- *Approximation Methods for Non-product form Queuing Networks*

Lectures 11-12: Random Access Networks

- *Pure and slotted Aloha, stability issues*
- *Stabilization of slotted Aloha*
- *Splitting algorithms*
- *Slotted CSMA and stability: Pseudo Bayesian Algorithm*
- *Unslotted and Slotted CSMA/CD*
- *Multi-access Reservations*

Lecture 13: Reliability Analysis

- *Structure and coherent functions*

- *Series-parallel and m-out-of-n systems*
- *Path and cut sets*
- *Sum of disjoint products algorithms*

Lecture 14: **Performability Analysis**

- *What is performability?*
- *Hyperbolic PDEs*
- *Moment Equations*
- *Applications*

Grading:

Homework/Project Assignments	60%
Review Paper Presentation	10%
Term Project	30%
Total	100%

Additional Information:

- Starting with March 17 Lecture, each lecture will be divided into two parts. The first 2.5 hours will be used to present course materials, and the remaining 0.5-hour will be used for students to present reviews of recent journal publications.

- Paper reviews should be based on relevant and recent (2007 and up) journal articles from, e.g., IEEE Trans. On Reliability, IEEE Trans. On Computers, Operations Research, Reliability and Safety Engineering.

- Term projects can be performed in teams of two students on relevant neural networks topics. Topics could be related to research, or based on at least two recent journal articles. **Numerical implementation** and **testing** are a must.

- Term project **proposals** are due on **Wednesday March 17**, presentations are scheduled on **Wednesday May 5** from 6 PM to 9 PM, and final reports are due on **Friday May 7**.

- Programming can be done in any language.

References:

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[BAK74] Baker, K.R., Introduction to Sequencing and Scheduling, Wiley, 1974.
[BAR75] Barlow,R.E. and Proschan, F., Statistical Theory of Reliability and Life Testing, Holt, Rinehart and Winston, 1975.
[BLO98] Bolch, G., Greiner, S., de Meer, H. and Trivedi, K.S., Queueing Networks and Markov Chains: Modeling and Performance Evaluation with Computer Science Applications, Wiley, 1998.
[BUZ93] Buzacott, J.A.and Shantikumar, J.G., Stochastic Models of Manufacturing Systems, Wiley, 1993. [Coo81] Cooper, R.B., Introduction to Queuing Theory, North Holland, 1981.
[CHA00] Chan, W.C., Performance Analysis of Telecommunications and Local Area Networks, Kluwer, 2000.
[CHE13] H. Chen and D. Yao, **Fundamentals of Queuing Networks,** Springer 2013
[CON67] Conway, R.W., Maxwell, W.L., and Miller, L.W., Theory of Scheduling, Addison-Wesley, 1967.
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[HAR93] Harrison, P.G., and Patel, N.M., Performance Modelling of Communication Networks and Computer Architectures, Addison Wesley, 1993.
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[JAI91] Jain, R., The Art of Computer Systems Performance Analysis, Wiley, 1991.
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[KLE76] Kleinrock, L., Queuing Systems: Vol 2: Computer Applications, Wiley, 1976.
[KOB78] Kobayashi, H., Modeling and Analysis: An Introduction to System Performance Evaluation Methodology, Addision-Wesley, 1978.
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[LIL00] Lilja, D.J., Measuring Computer Performance, Camridge University Press, 2000.
[LIN98] Lindemann, L., Performance Modeling with Deterministic and Stochastic Petri Nets, Wiley, 1998.
[MAR95] Marsen, M.A., Balbo, G., Conte, G., Donatelli, S., Franceschinis, G., Modelling with Generalized Stochastic Petri Nets, Wiley, 1995.
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Website links for software:

http://www.lehigh.edu/~amr5/q/software.html
http://www2.uwindsor.ca/~hlynka/qsoft.html