

## ECE1549 Stochastic Networks (Spring 2018)

An introduction to analysis and optimization in communication networks using stochastic models. We cover both classical queueing networks and recent advances in stochastic network modeling. Topics include Jackson and Whittle networks, reversible network processes, Palm probabilities, space-time Poisson models, stochastic geometry, network utility maximization, and stochastic network optimization. Pre-requisite: ECE1500/ECE537 or equivalent with continuous-time Markov chains.

### *Instructor:*

Ben Liang (<http://www.comm.utoronto.ca/~liang>)

### *Lectures:*

Tuesdays 2 – 5 pm, BA3014

### *Approximate Schedule:*

#### Part I: Markovian Network Processes

- Preliminaries: network processes, Poisson processes, continuous-time Markov chains, Law of Large Numbers for Markov reward processes, reversible Markov chains
- Jackson and Whittle networks, invariant measure of Whittle processes, stationary distribution of Jackson processes
- Phi-balance and reversibility, sector-dependent service rates, throughput in Whittle networks, reversible Markov chains, Kolmogorov criterion for reversibility, invariant measure of reversible Markov chains
- Kolmogorov criterion for Phi-balance, computation of Phi, truncating and merging of reversible processes, blocking in Erlang queueing networks
- Whittle networks with multiple types of units, Kelly and BCMP networks, networks with generally distributed service times

#### Part II: Point Processes and Palm Probabilities

- Point processes, point processes in Markov chains, Levy's formula, Poisson transitions in Markov chains, Poisson flows in Whittle networks
- Palm probabilities in Markov chains, sojourn and travel times in Markov chains, Palm probabilities in Whittle networks, PASTA and MUSTA properties
- Palm probabilities in stationary processes, stationary functionals, stationarity under Palm probability, Campbell-Mecke formula, marked point processes, inversion formula, random observer's paradox
- Stochastic geometry, Poisson point processes, Laplace functional, Slivnyak theorem, strong Markov property of Poisson point processes, marked Poisson point processes
- Short-noise and interference, Matern hardcore model, connectivity in Boolean model, Voronoi tessellation, Neveu's exchange formula

#### Part III: Network Control and Optimization

- Network utility optimization, alpha-fairness, Chiu-Jain distributed control, Lyapunov stability, primal algorithm with penalty, Adaptive Virtual Queue algorithm, dual algorithm, primal-dual algorithm, VCG and Kelly mechanisms
- Stochastic network optimization, stability criteria, queue-oblivious algorithm, Lyapunov drift control algorithm, maximum weighted matching algorithm, drift-plus-penalty algorithm

*Grading:*

Homework assignment (50%) and one survey report and presentation (50%).

*Main References:*

- R. Serfozo, *Introduction to Stochastic Networks*, Springer, 1999.
- R. Mazumdar, *Performance Modeling, Stochastic Networks, and Statistical Multiplexing*, 2nd Ed, Morgan & Claypool, 2013.
- F. Kelly, *Reversibility and Stochastic Networks*, Wiley, 1979.
- F. Baccelli and B. Blaszczyszyn, “Stochastic Geometry and Wireless Networks Volume I: Theory,” *Foundations and Trends in Networking*, vol. 3, no. 3-4, pp. 249 – 449, 2010.
- F. Baccelli and B. Blaszczyszyn, “Stochastic Geometry and Wireless Networks Volume II: Applications,” *Foundations and Trends in Networking*, vol. 4, no. 1-2, pp. 1 – 312, 2010.
- M. Haenggi, *Stochastic Geometry for Wireless Networks*, Cambridge University Press, 2012.
- R. Srikant, *The Mathematics of Internet Congestion Control*, Birkhauser, 2003.
- S. Shakkottai and R. Srikant, “Network optimization and control,” *Foundations and Trends in Networking*, vol. 2, no. 3, 2007, pp. 271 – 379.
- M. J. Neely, *Stochastic Network Optimization with Application to Communication and Queueing Systems*, Morgan & Claypool, 2010
- L. Georgiadis, M. J. Neely, and L. Tassiulas, “Resource allocation and cross-layer control in wireless networks,” *Foundations and Trends in Networking*, vol. 1, no. 1, 2006, pp. 1 – 144.