Performance Evaluation for Network Engineering
IK2219

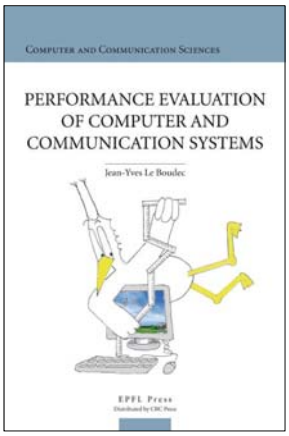
Jeong-woo Cho
KTH - ICT School - COS - NSLab

21st of January, 2015

This course covers

General-Purpose Theoretical Subjects in Networking Field

- **Confidence Intervals** (Ch. 2)
- **Simulation** (Ch. 6)
- **Queuing Theory & Networks** (Ch. 8)
- **Palm Calculus** (Ch. 7)
  - Higher-level reinterpretation of queuing theory
- **Model Fitting** (Ch. 3)
- ~~**Tests** (Ch. 4)~~



Organization: *Combinatorial Assessment!*

9 Lectures + 1 Question Session (7%)

4 Homeworks (35%), Mini-Project (28%)

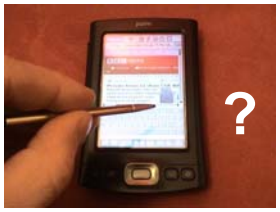
Final exam (30%) from textbook examples

More information: ***http://web.ict.kth.se/~jwcho/IK2219-Course-Plan.pdf***

Bespoke course for master students

- **More essential parts** of its doctoral version, IK3506, will be covered
  - Advanced theoretical results will be skipped.
- **Higher weight** on homeworks
  - Rather than on mini-projects which is more for research activities
  - Students may select **easier papers** for mini-projects

Palm Calculus ???



Palm Calculus

- The pinnacle of this course, *Palm Calculus*, was named after
  - **Conrad "Conny" Palm** (1907-1951), Swedish statistician
    - studied at KTH
    - laid a foundation for **elegant** unification of queuing theory and point process

Why Theory? : Common Language

Fairness in general networks

Proportional Fairness | **Max-Min Fairness**

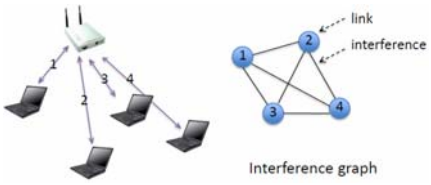
Unification under optimization theoretic framework in 2000 [MO00]

Max-Min Fairness | **Proportional Fairness** | **Other Fairness Concepts in Microeconomics**

Re-Unification under axiomatic framework in 2013 [JOE13]

[MO00] J. Mo and J. Walrand, "Fair end-to-end window-based congestion control", **IEEE/ACM Transactions on Networking**, October 2000.
[JOE13] C. Joe-Wong, S. Sen, T. Lan, and M. Chiang, "Multi-resource allocation: Fairness-efficiency tradeoffs in a unifying framework", **IEEE/ACM Transactions on Networking**, December 2013.

Why Theory? : Profundity



A key formula in Wi-Fi networks:
Collision probability <-> Number of nodes

Bianchi [BIA00] proved the formula in 2000 under decoupling assumption.

This assumption has been validated only recently through a few theoretical results [BOR10] derived from mean field theory.

[BIA00] G. Bianchi. "Performance analysis of the IEEE 802.11 distributed coordination function", **IEEE Journal on Selected Areas in Communications**, March 2000. (Total citation counts: 6585)
[BOR10] C. Bordenave, D. McDonald, and A. Proutiere. "A particle system in interaction with a rapidly varying environment: Mean field limits and applications", **Networks and Heterogeneous Media**, March 2010.

Why Theory? : Simply Indispensable

Example:
Suppose you sample inter-arrival times of a bus for a very long time and found out that the average is m=10 minutes with standard deviation σ=5 minutes.

On the next day, you are waiting for the same bus at the same station.
How long are you expected to wait on average?
~~Wrong answer: 5 minutes~~
Correct answer: 6 minutes and 15 seconds

Feller's Paradox
Seemingly simplistic questions just can't be answered without theory.

IK2219/IK3506 Performance Evaluation for Network Engineering

Credits: 7.5 hp
Education Level: 2nd Cycle (IK2219), 3rd Cycle (IK3506)
Grading scale: A-F (IK2219), Pass / Fail (IK3506)
Language: English
Period: 1st Period

Prerequisites

Required: Basic knowledge in probability (e.g., taking expectation and conditional probability)
Recommended: Basic Knowledge in communication networks, e.g., IK1550, IK1551, IK2215, IK2217

Course Literature: Available online at http://perfeval.epfl.ch/

Jean-Yves Le Boudec, "Performance Evaluation of Computer and Communication Systems", 2010, 1st edition, EPFL Press. ISBN: 978-2-940222-40-7.

Course Webpage: https://moodle.ssvl.kth.se

Learning Outcomes

Rather than cramming students with the vast volume of baroque queuing theory, this course intends to address more common analytical problems arising in the field of communication networking: (i) how to process simulation and experimental data in a scientific way?; (ii) how to model a communication network system and to analyse its performance metrics?

Though the ever-dizzying variety of theories in the field makes it very hard to distinguish the common set of widely applicable theories, the textbook of the course brings a concise set of such theories together in order to answer the above two questions, a part of which has been rarely introduced in the classical books and made accessible only through this textbook. More importantly, it is unethical to make a wrong and hasty conclusion only because of the ignorance of suitable analytical techniques.

This course covers a practical collection of theories and techniques which have been widely applied in the field over the past decades. It is no surprise that the subject matter stretches over multiple theories. Upon completion of the course, students are expected to learn how to:

Useful Modern Statistics (Chapters 1-4)

- ***Compute*** confidence interval and prediction interval
- ***Fit*** a suitable model or curve to your measurement data
- ~~***Make*** assertions on your model in a mathematical manner~~ (Will not be covered for the time being)

Basic Theory for Simulation (Chapter 6)

- ***Internalize*** theoretical framework in order to run simulations correctly

Palm Calculus: the Importance of Viewpoints (Chapter 7)

- ***Explain*** why other queues are always faster when you are shopping

Queuing Theory: Through the Lens of Palm Calculus (Chapter 8)

- ***Comprehend*** useful topics in queuing theory from a fresh angle

Throughout the course, students will learn how to utilize various software packages in conducting simulations and validating analyses.

Will this course come useful to you?

One of the artistic aspects of performance evaluation lies in that seemingly trivial questions in everyday life are directly related to those encountered in the field. For instance, the following questions will turn out to be not only exquisitely relevant to engineering problems in networking but also crucial for avoiding common repetitious pitfalls in the field:

"Why do we feel that we wait relatively longer than others when shopping in ICA or COOP?" (Palm Calculus)

"Can we validate the ad for a ski resort, 'capacity doubled, waiting time halved'?" (Queuing Theory)

Some more specific problems you may encounter while conducting research or development are as follows:

"If the data is not normal, what kind of method can be used for computing a confidence interval for an arbitrary performance metric?" (Confidence Interval)

"It is well-known that determining whether truncated data follow power-law or not is an intricate problem. How can we test and quantify the goodness of a certain distribution to the data?" (Tests)

"It takes months to estimate by simulation the probability of a very rare event, e.g., a bit error rate of 10^{-10}. Is there any other way around this?" (Discrete Event Simulation)

Answers to all the aforementioned questions and their implications will be taught in the course. Note also that some people complain about or even reject your idea or paper simply because you have not provided confidence intervals for the data.

Main content

This course focuses on broadly applicable methodologies in the field of communication networks, putting special emphasis upon the evaluation of performance therein. A distinctive feature of this course lies in its combination of questions in everyday life and practical problems in communication networks with selected topics in methodologies. In order to help students to gain a better understanding of the methodologies and its applications, the course also contains a set of homework assignments and a project. The textbook can be referred to throughout the academic and industrial careers of students for tackling out various problems in both fields.

- **Content of Lectures (90-minute lecture × 12)**

In order to achieve the abovementioned learning outcomes, there will be about 12 lectures primarily based on the main textbook. The lectures will cover various topics in performance evaluation of

communication networks: Summarizing Data (Topic 1), Model Fitting (Topic 2), Discrete Event Simulation (Topic 3), Palm Calculus (Topic 4), Queuing Theory for Dummies (Topic 5).

- **Review Question Session**

Each group of students will present how to solve a few (2-4) selected review questions within a short time (no more than 5 minutes). All review questions and their complete solutions for each topic will be provided by the examiner. There will be about 5-6 review question sessions, depending on the number of students.

- **Homework Assignments**

Assignment 1 – (Introductory) Performance Data Summarizations (**Topic 1**)
Assignment 2 – Random Waypoint Simulation (**Topics 3 & 4**)
Assignment 3 – Queuing Theory from Palm Viewpoint (**Topics 4, 5 & 3**)
Assignment 4 – Web Server Simulation (Queuing Network) (**Topics 5 & 3**)

- **Project Assignment (Group work) for IK2219**

Each group will define a performance evaluation problem in their thesis projects or ongoing research projects and apply methodologies in the course to analyse the problem. If it is impossible for a group to find an appropriate problem, the group will give a talk about a topic or a research paper closely related to performance evaluation in networking.

- **Project Assignment (Group work) for IK3506**

Each group will define a performance evaluation problem in their ongoing research projects and apply methodologies in the course to analyse the problem. The outcome of this project assignment should be excellent enough to be publishable in academic venues (conference & journal). If it is impossible for a group to find an appropriate problem, each student will give a talk about a topic or a research paper closely related to performance evaluation in networking.

Course disposition

Examination for IK2219

Review Question Session: 7%, Homework Assignments: 35%, Project Assignment: 28%, Written Final Exam: 30%, Grade scale: A-F

Examination for IK3506

Review Question Session: 10%, Homework Assignments: 40%, Project Assignment: 50%, Grade scale: Pass/Fail

Requirements for final grade for IK2219

The final grade is based on the weighted average of the three examination parts when each part has received a passing grade: review question session (0.07), homework assignment (0.35), project assignment (0.28), and closed exam (0.30).

Requirements for final grade for IK3506

The final grade is based on the weighted average of the two examination parts when each part has received a passing grade: review question session (0.10), homework assignment (0.40), and project assignment (0.50).