L50: Introduction to networking and systems measurements Syllabus

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Code: L50
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Prerequisites: Undergraduate courses in digital communication; please see below for further details
Structure: Six 1-hour lectures; five 2-hour labs

1 Aims

Systems research refers to the study of a broad range of behaviours arising from complex system design, including: resource sharing and scheduling; interactions between hardware and software; network topology, protocol and device design and implementation; low-level operating systems; Interconnect, storage and more. This module will:

- Teach performance characteristics and performance measurement methodology and practice through profiling experiments;
- Expose students to real-world systems artefacts evident through different measurement tools;
- Develop scientific writing skills through a series of laboratory reports;
- Provide research skills for characterization and modelling of systems and networks using measurements.

2 Prerequisites

It is strongly recommended that students have previously (and successfully) completed an undergraduate networking course – or have equivalent experience through project or open-source work.

3 Lectures, Labs, and Lab Reports

3.1 Lectures

Lecture 1: Introduction to performance measurements, performance characteristics.
This lecture will introduce students to system and network measurements, starting at the motivation for measurements and a brief history. We will discuss types of measurements, and in particular performance measurements. Different performance metrics will be introduces and compared. The lecture will conclude with a discussion of passive and active measurements.
Lectures 2: Basic performance measurements tools and techniques.
This lecture will focus on basic performance measurements and techniques. The it will consider topology measurements and latency measurements, and discuss the limitations of tools and enhancements developed over time. We will explore measurement projects and databases openly available. Next, the lecture will focus on hardware-aided latency measurement tools.
Lectures 3: Advanced performance measurements tools and techniques.
In this lecture we will continue the discussion of latency, and discuss performance metrics such as flow completion time. Next, we will consider bandwidth measurement tools, both open source and commercial, and discuss their limitations. Traffic control measurement techniques will also be covered.

Lecture 4: Common pitfalls in measurements.
This lecture will explore common problems and errors in performance measurements. It will cover aspects such as hidden assumptions, tool limitations, bottlenecks and vantage points, and extend on analysis and how to critically analyse results. Part of the discussion will be assigned to performance metrics discussed in the previous lectures.
Lecture 5: Device and system characterisation.
This lecture will discuss device and system characterisation. It wil begin with the setting of goals and building the characterisation plan. We will discuss aspects such as workloads, metrics and tool selection. The lecture will explore the differences between device, platform, system and network characterization and cover considerations such as synchronization.
Lecture 6: Reproducible experiments.
In the last lecture, we will explore measurements reproducibility, starting with the motivation for reproducible experiments and where it has failed in the past. The lecture will cover practical aspects of experimental design for reproducibility and recommended practices. We will discuss potential pitfalls and reproducing papers. Finally, we will summarize the course.

3.2 Labs and Lab Reports

Lab 1: Basic network measurement tools.
This lab will explore simple software based measurement tools, such as ping, traceroute and iperf, and their limitations. The lab will be based on material taught in Lecture 2.
Lab 2: Traffic generation tools.
This lab will explore software and hardware based traffic generation tools and their limitation. It will cover metrics such bandwidth, pps, inter-arrival time and inter packet gap. The lab will be based on material taught in Lectures 2 and 3.
Lab 3: Traffic capture tools.
This lab will explore software and hardware based traffic capture tools and their limitation. It will cover metrics such as latency, RTT, propagation delay, and concept such as precision and accuracy. The lab will be based on material taught in Lectures 2 and 3.
This lab will be followed by a lab report summarizing the first three labs.
Lab 4: Device characterization.
In this lab, each group of students will receiver an object (a device, platform or system) and will need to characterise it. This will include building and executing a characterization plan, using the previously taught tools and techniques. The experiment will need to be reproducible. **Lab 5: Reproducibility.**
In the concluding lab, students will reproduce the experiment of other teams, executed as part of Lab 4. They will need to explore aspects of reproducibility, measurement pitfalls and extending measurement plans. A final report, summarizing both Lab 4 and Lab 5 will follow this lab.
Deliverables: Lab report 1 will be summarise Labs 1 through 3, Lab report 2 will summarize Labs 4 and 5.

4 Objectives

On completion of this module, students should:

- Describe the objectives of measurements, and what they can achieve;
- Characterise and model a system using measurements;
- Perform reproducible measurements experiments;
- Evaluate the performance of a system using measurements;
- Operate measurements tools and be aware of their limitations;
- Detect anomalies in the network and avoid common measurements pitfalls;
- Write system-style performance evaluations.

5 Coursework

Five 2-hour in-classroom labs will ask students to develop and use skills in performance measurements as applied to real-world systems and networking artefacts. Results from these labs (and follow-up work by students outside of the classroom) will by the primary input to lab reports.
The first three labs will provide an introduction and hands on experience with measurement tools and measurements methodologies, while the last two labs will focus on practical measurements and evaluation of specific platforms. Students may find it useful to work in pairs within the lab, but must prepare lab reports independently. The module lecturer will give a short introductory at the start of each lab, and instructors will be on-hand throughout labs to provide assistance.
Lab participation is not directly included in the final mark, but lab work is a key input to lab reports that are assessed.

6 Assessment

Each student will write two lab reports. The first lab report will summarise the experiments done in the first three labs (20%). The second will be a lab report (5000 words) summarising the evaluation of a device or a system (80%).

7 Recommended Reading

The following list provides some background to the course materials, but is not mandatory. A reading list, including research papers, will be provided in the course materials.

- George Varghese. Network algorithmics. Chapman & Hall/CRC, 2010.
- Mark Crovella and Balachander Krishnamurthy. Internet measurement: infrastructure, traffic and applications. John Wiley & Sons, Inc., 2006.
- Brendan Gregg. Systems Performance: Enterprise and the Cloud, Prentice Hall Press, Upper Saddle River, NJ, USA, October 2013.
- Raj Jain, The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling, Wiley - Interscience, New York, NY, USA, April 1991.