Experimental Networking
ECSE-4963

I hear and I forget.
I see and I remember.
I do and I understand.
-- Chinese Proverb

Shivkumar Kalyanaraman
Rensselaer Polytechnic Institute
shivkuma@ecse.rpi.edu
http://www.ecse.rpi.edu/Homepages/shivkuma/
Who’s Who

- **Instructor:** Shiv Kalyanaraman; kalyas@rpi.edu
  - Room: JEC 6042, Phone: x8979
- **Course secretary:** (on-campus)
  - Jeanne Denue-Grady; denuej@rpi.edu
  - Room: JEC 6049, Phone: x6313
- **TA:**
  - Yong Xia; xiay@rpi.edu
  - Room: JEC 6037, Phone: x8231
- Other research students will help from time to time
Networking Courses @ RPI

- CANOS
  - Network Programming (CS)
- CCN
  - Internet Protocols
  - Network Modeling
  - Experimental Networking (Lab Course)
- Mobile & Wireless Networking
- “Topics Courses”
- “Core Networking Sequence”
  - Network Operations (CS)

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Prerequisites

- **Required** *(no exceptions):*
  - ESCE-4670 Computer Communication Networks or equivalent
  - Probability Class (usually required for CCN)
  - VERY GOOD C programming knowledge

- **Desirable:**
  - Operating Systems
  - Computer Architecture (ECSE-4730 or equivalent)
  - Basic ideas of statistics

- If you **do not have the required prerequisites**, you **must drop the course** and take it later (next year).
Course/Grading Format

- **Lab time**: 1 hr Lecture + 2.5 hr Lab Work
  - Lab Report for Each Day (groups of 2) submit via WebCT
  - Solutions/grading policy will be posted and you will self-grade and submit your graded copy to TA
  - WebCT bulletin board: Post your questions!

- **1 term project** in the last month (complete design exercise)

- **2 exams**: mid-term and final, on concepts, theory, etc.
  - Term project and exams will be graded by TA/instructor

- **Grading**:
  - Lab Work/Reports: Self-Grading {50 pts}
  - Term Project: {20 pts}
  - Mid-Term and Final Exam: {30 pts}
I do and I understand…

- **What** to do?
  - **Play** around with **real & messy stuff**: wires, routers, real networking code: builds character!
  - **Simulate/animate** it: avoid the mess, focus on basic understanding of a subset of properties
  - **Poke/Peek around** the network: peek at packets, measure n/w performance, collect/analyze traces/routing tables etc
  - Structure a **large set** of above activities to maximize information derived with minimum effort

- **Why**?
  - Semantic behavior of protocols/networks: *how does it work?*
  - Performance behavior of protocols/networks: *how good is it?*
  - Use such techniques in the design process: **design your own new protocols/networks!**
Course Objectives

- **Hands-on networking**: “do networking” at the hardware, software, simulation, configuration (a.k.a. messy!) levels

- **Experimental Method**: How to correctly use a variety of abstract tools (measurement, simulation, animation, experiment) for design and analysis of computer/network systems

- **Tools**: specific tools/platforms useful for networking research and advanced development
Network-in-a-Box Model

Parameters → Network System → Metrics

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Course Description Highlights

1. **Simulation and animation tools**: understand complex networking concepts by viewing the system as a **black box**
   - Vary *external* “knobs” (parameters)
   - Someone else has designed the system!
   - Why? Limited views of protocols allows a self-paced, visual understanding…

2. **Simulation development**: develop the networking protocol code, in a controlled environment, the simulator.
   - Run simulations and vary parameters to **incrementally refine** design.
   - **You** are designing & building the system!
   - Why? Understand what it takes to *embed your idea* in an existing event-driven system.
Course Description Highlights

3. **Experiment design**: one simulation does not give you the answer (i.e. characterize system behavior)
   - Systematic design of a *set of experiments* to maximize information extracted
   - Fit regression or other functional models to correlate parameters to observed metrics.
   
   [Some applied probability, statistics and simulation theory will be covered as necessary.]

4. **Linux-based protocol development**: Develop variants of protocols on a real OS platform (Linux)
   - Set up experiments to instrument, measure and visualize system behavior.
Course Description Highlights

5. **Measure, Model and Analyze the Internet:**
   - Understand tools to observe and measure network/protocol properties
   - Develop and analyze measurement archives to understand protocol and network behavior

6. **Experimentation with a combination of Linux and Cisco routers:**
   - Learn how to create experimental scenarios with a combination of customized/prototyped systems and off-the-shelf networking equipment.
Course Description Highlights

7. **Development on modular platforms (Click router and Intel IXA):**
   - Recent developments include modular code development inside the OS kernel (Click), and network processor platforms (Intel IXA)
   - Powerful, realistic prototypes can be created rapidly!

8. **Term project:** Take a problem and use a mix of relevant tools to incrementally design, prototype, test and validate solutions
   - Students are welcome to define a project of their own; and should get a written project definition approved by the instructor. Approval will require a critical mix of key ingredients to be present.
Schedule

Every Thursday 4pm – 8pm in Fall’02, Aug 29 ~ Dec 5

Basic Labs: Tools and Techniques

**Week 1** Aug 29
Lab 1, Networking commands and socket programming

**Week 2-5** Sept 5, 12, 19, 26
Lab 2, Network simulator NS2 (and NAM)
Lab 3, TCP Tahoe, Reno, and SACK comparisons in simulation
Lab 4, Experiment design
Lab 5, Active queue management (AQM): RED scheme

**Week 6** Oct 3
Lab 6, TCP traffic experiment: how to encode/setup/measure real TCP dynamics

**Week 7-8** Oct 10, 17
Lab 7, Routing protocols (RIP, OSPF, BGP etc.)
Lab 8, BGP routing table analysis, Internet Mapping

[ MID-TERM EXAM: Oct 17th ]

**Week 9-10** Oct 24, 31
Lab 9, MIT Click modular router, Linux kernel programming, Intel IXA Network Processor Platform, Introduction to the Utah Emulab facility
Term Project Ideas

**Week 11-14** Nov 7, 14, 21, 28

1. Design and Comparison of Active queue management (AQM) approaches: e.g.: ARED, BLUE, AVQ, REM...
2. TCP+AQM traffic dynamics: Various Flavors of TCP/Binomial/Uncooperative End-system schemes w/ AQM: (RED, ARED, REM, AVQ)
3. Implementation and experimentation of routing/AQM etc on Intel IXA platform project
4. Cisco routing configuration and mix of Linux/Cisco equipment to design new routing/traffic engineering algorithms
5. Using SSFNet to test a mix of new OSPF/BGP related concepts and perform larger scale simulation experiments
6. Multimedia Streaming: understanding effect of various system components
7. Mixed Wireless (802.11) and Internet Experiments/Simulations
8. Large-scale Internet Measurement Studies: TCP Latency/Bandwidth, Internet Mapping, Feeding online measurement and models into design

Other ideas welcome!

**[FINAL EXAM: Nov 28th; Submission of Project Reports]**

**Week 15** Dec 5

**Presentations: Sharing Ideas, Experiences and Frustrations 😊**
Caveat!

- This is the first offering of the class.
- A lot of lab development has been done and labs have been tested.
- Things could go wrong, and you may have to discover things on your own at times.
  - We will try to provide maximum help.
  - Grading will be sensitive to such issues.

- Be prepared to live with some uncertainty; try out some realistic hacking; and spend a larger-than-average effort on the class…