Experimental Networking
ECSE-4690 (UG)
ECSE-6966 (G)

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

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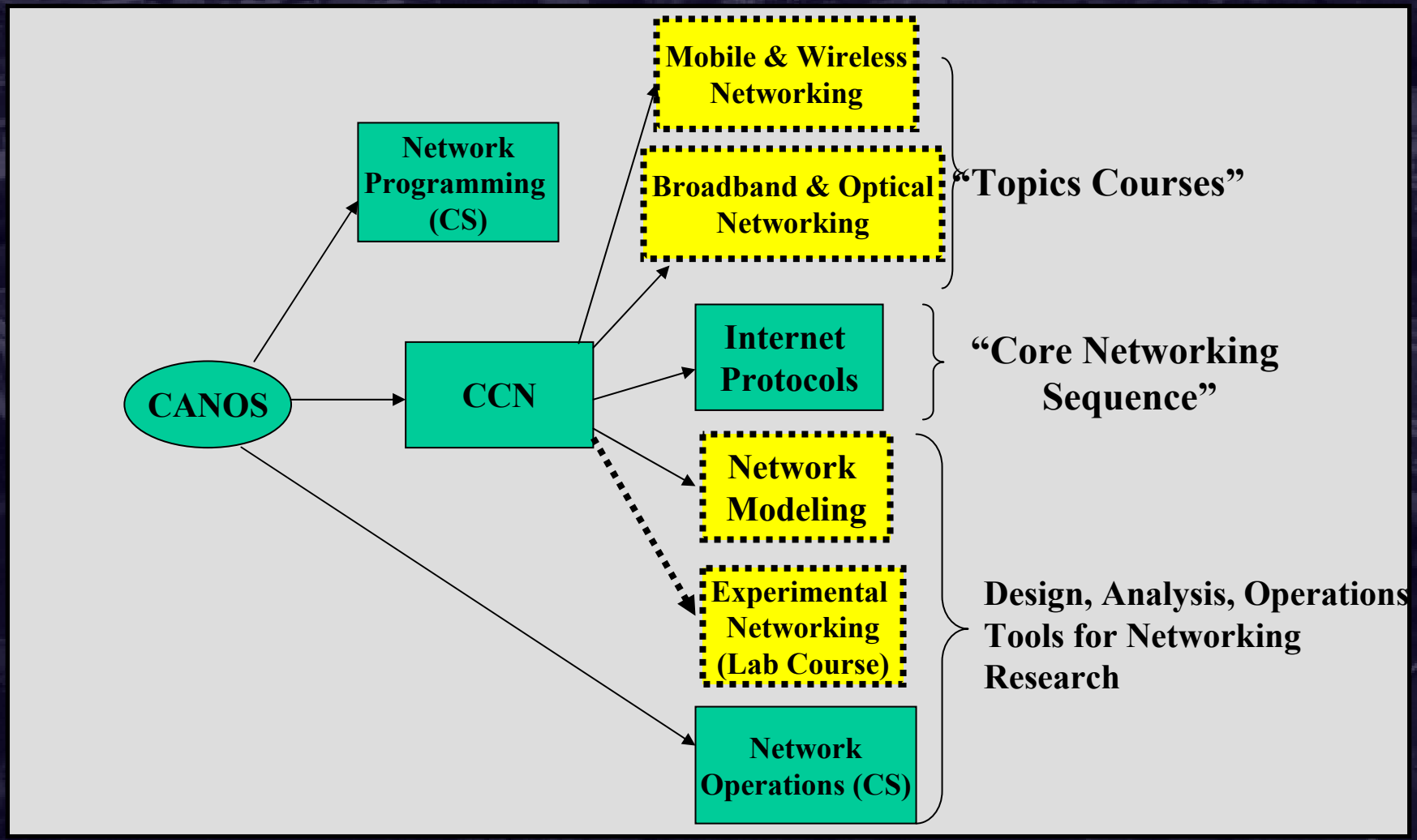
Who's Who

- **Instructor:** Shiv Kalyanaraman, kalyas@rpi.edu
  - Room: JEC 6042, Phone: x8979
- **TA:**
  - Neeraj Jaggi, jaggin@rpi.edu
  - Room: JEC 6213, Phone: x8289
  - Other research students (esp. Yufeng Shan, Su Yi) will help from time to time

Networking Courses @ RPI



Prerequisites

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

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 graded by 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** **{50 pts}**
  - **Term Project:** **{20 pts}**
  - **Mid-Term and Final Exam:** **{30 pts}**

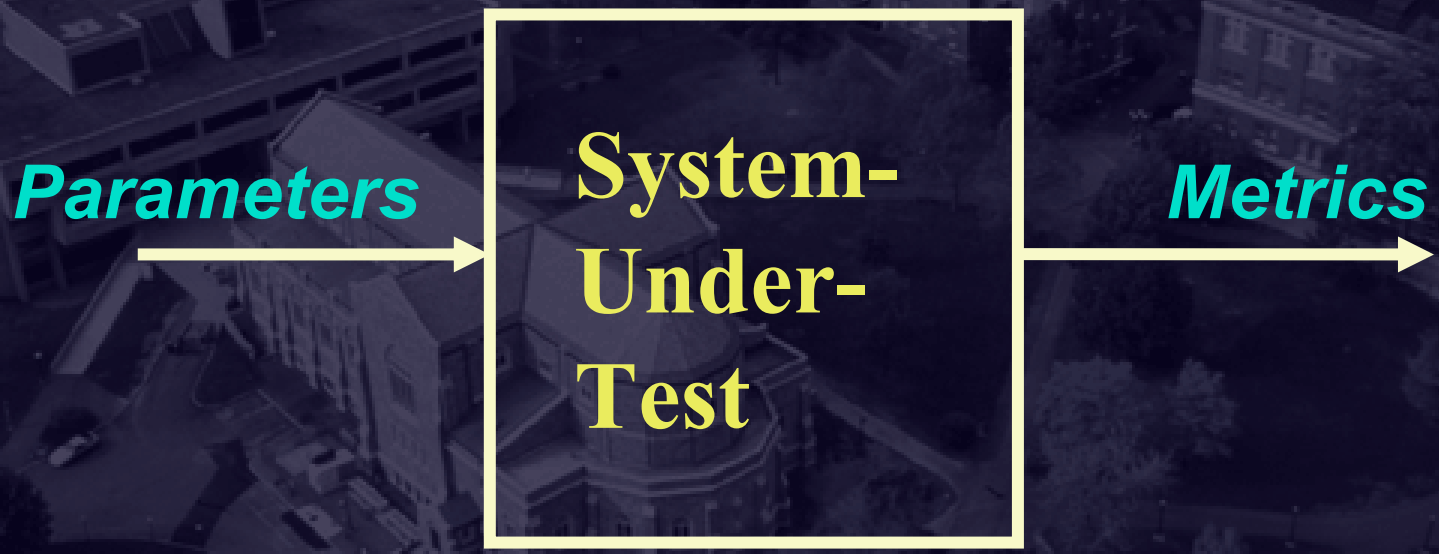
I do and I understand…

- ***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 ***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

System-Under-Test Model



Subject system to a set of tests (workloads/conditions)

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. **Systematic Tracing, Graphing, Profiling:**
  - Define *parameters* (input) and *metrics* (output)
  - **Parameter** criteria: all params that have performance impact (or a subset relevant to the performance "view")
  - **Metric** criteria: must capture the relevant tradeoffs
    - Time series graphs vs point estimates
    - Examples of good, poor graphs;
  - **Workloads**: must stress test the system, capture relevant aspects of reality (in stages)
    - Issues with randomness: confidence intervals etc
  - **Profiling**: accounting for performance: contributions of components. Does it add up? Apply amdahl's law to decide where to make changes
  - **Tracing**: at different degrees of resolution (low pass, high pass): helps in design debugging

Course Description Highlights

4. **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*.
   - Why? A practical tool for incremental design and performance analysis. Understand the nature of protocols in-depth.

   [Some applied probability, statistics and simulation theory will be covered as necessary.]

5. **Linux-based protocol development:** Develop variants of protocols on a real OS platform (Linux)
   - Set up experiments to instrument, measure and visualize system behavior.
   - Introduction to advanced community platforms: **Emulab, Planetlab**

Course Description Highlights

6. **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!
   - Introduction to advanced community platforms: **Emulab, Planetlab**

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.
   - Graduate students should choose a challenging research-driven project. Topics from their current research are welcome.
   - Measurement projects or projects using Emulab/Planetlab/Intel IXA platforms are also welcome. The instructor will do his best to facilitate them.

Schedule

Every Wednesday 3pm – 8pm in Fall'05, Aug 31 ~ Dec 7

Basic Labs: Tools and Techniques

Week 1 Aug 31
Lab 1, Networking commands and socket programming
Week 2-5 Sept 7,14,21,28
Lab 2, Network simulator NS2 (and NAM)
Lab 3, TCP Tahoe, Reno, and SACK comparisons in simulation
Lab 4, Perf. Analysis methods: Metrics, Tracing, Experiment design
Lab 5, Active queue management (AQM): RED scheme
Week 6 Oct 5
Lab 6, TCP traffic experiment: how to encode/setup/measure real TCP dynamics

[MID-TERM EXAM: Oct 12th]

Week 7-8 Oct 12, 19
Lab 7, Routing protocols (RIP, OSPF, BGP etc.): *may skip this* …
Lab 8, BGP routing table analysis, Internet Mapping, Measurement projects

Week 9-10 Oct 26, Nov 2nd
Lab 9, MIT Click modular router, Linux kernel programming, Intel IXA Network Processor Platform, Introduction to the Utah Emulab facility, Planetlab

Term Project

Week 11-14 Nov 2, 9, 16, 23:
1-month term project.
Project proposals due on Oct 26th, approved by Nov 2.
Mid-project written updates due on Nov 16th.

Week 15: Nov 30th

Presentations [7 min/group]: Sharing Ideas, Experiences and Frustrations ☺

PPTs due before class.

[FINAL EXAM: DECEMBER 7th; Submission of Written Project Reports]

Term Project Ideas

- **1.** Design and Comparison of Active queue management (AQM) approaches: e.g.: ARED, BLUE, AVQ, REM…
  - Architectural twists: virtual AQM, edge-based policing
- **2.** TCP+AQM traffic dynamics: Various Flavors of TCP/Binomial/Uncooperative End-system schemes w/ AQM: (RED, ARED, REM, AVQ)
- **3.** TCP enhancements for high-bandwidth delay product and wireless networks (VCP, LT-TCP): evaluate, implement
- **4.** Performance and implementation of mesh wireless routing and name-resolution algorithms (eg: GHTs, coordinate space routing, location systems)
- **5.** Measurement study of 802.11 on campus (understanding performance problems)
- **6.** Measurement and inference problems using overlays on the Internet (using Planetlab)
- **7.** Implementation and experimentation of routing/AQM and new hybrid FEC techniques etc on Intel IXA platform

Term Project Ideas

- **8.** Using SSFNet to test a mix of new OSPF/BGP related concepts and perform larger scale simulation experiments
- **9.** Multimedia Streaming: understanding effect of various system components, joint source-network coding
- **10.** Delay tolerant networks: evaluation of various routing mechanisms
- **11.** Mixed Wireless (802.11) and Internet Experiments/Simulations
- **12.** Large-scale Internet Measurement Studies: TCP Latency/Bandwidth, Internet Mapping, Feeding online measurement and models into design
- Other ideas welcome!

Caveat!

- 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

- If you cannot live with some uncertainty; trying out some realistic hacking; and/or do not have the time to spend a larger-than-average effort on the class…
  - Please drop the class!

Logistics

- Restart machine to Linux when you come
  - Username: net
  - Password: netnet
- Restart machine to Windows before you leave
- Openshop hours: Everyday (except Wednesday) after 4 pm
  - (Neeraj will be there Mon 4-6pm)
- Every week's Assignment due: Sunday 11:55pm