Teaching Networking on Testbeds
Experiences with GENI

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- GENI wireless testbed administrator
- developer of educational materials for GENI testbeds
- TA/lab instructor in courses using GENI lab materials
In this talk

Experiences with **three separate educational efforts:**
- Classroom-as-a-service: prepared lab exercises on GENI
- Design and project courses on GENI
- Educating the masses with a GENI MOOC
Why do I teach with GENI?
Fidelity to “real” Internet
Programmability of network
Simulation 
(ns-2/ns-3, OPNET)
Emulation 
(Emulab, DETER)

Collection of Heterogeneous Testbeds 
(GENI, similar projects)
Testbed with Programmable Network 
(ORBIT, CORNET)
In-house computer lab 
(typical environment)

Emulation 
(Emulab, DETER)

Simulation 
(ns-2/ns-3, OPNET)
When to teach with GENI?

- Cost of in-house lab is high
- Cost of developing new materials is high
- For repeatable exercises with predictable results, that highlight realistic Internet conditions.
Classroom-as-a-service: Issues in contemporary networks
The idea

- Supplements standard courses in computer networks
- Exposes students to practical problems in contemporary networks
- Disabuse students of the lies they believe
Fallacies of distributed computing

- The network is reliable.
- Latency is zero.
- Bandwidth is infinite.
- The network is secure.
- Topology doesn’t change.
- There is one administrator.
- Transport cost is zero.
- The network is homogeneous.

(Peter Deutsch, 1994)
Wireless assumptions

- The world is flat.
- A radios transmission area is circular.
- All radios have equal range.
- If I can hear you, you can hear me (symmetry).
- If I can hear you at all, I can hear you perfectly.
- Signal strength is a simple function of distance.

(D. Kotz, C. Newport, R. S. Gray, J. Liu, Y. Yuan, and C. Elliott, 2004)
The format

Background reading, lab instructions, computer- and human-graded assessments, instructor visibility tools, all in one testbed-hosted package.
Coverage

For a course in computer networks:

- **Application layer:** Adaptive video streaming
- **IP layer:** Mobility and vertical handover
- **Transport layer:** New TCP congestion control variants
- **Transport layer:** SCTP as an alternative transport layer
- **MAC layer:** QoS of wireless networks (cellular, WiFi)
- **Physical layer:** Link adaptation in cellular systems
Coverage

For a course on wireless:

- **Signal propagation**: Outdoor (for on-site students) or indoor (off-site students) wireless signal propagation
- **QoS**: QoS performance of cellular and WiFi MACs for real-time applications
- **Link adaptation**: Adaptive modulation and coding in cellular systems
- **Wireless signal processing**: Artefacts caused by hardware impairments in software defined radios
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<thead>
<tr>
<th>Spring 2013:</th>
<th>Fall 2013:</th>
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<tbody>
<tr>
<td>Wireless information systems</td>
<td>Computer networks</td>
<td>Advanced topics in networks</td>
</tr>
<tr>
<td>Spring 2014:</td>
<td>Spring 2014:</td>
<td>Fall 2014:</td>
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<td>Communication networks</td>
<td>Computer networks</td>
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The good

From student course evaluations:
“Labs were fun, accessible, and allowed for a better understanding of material.”

From student feedback form:
“I really like how the lab relates to material that almost everyone is interested in.”
The good

Student learning:
Given “lab question” on midterm and final exams, average grade was much higher than expected.

Student learning:
Pre- and post-lab questions show how students’ understanding changes.

From student feedback form:
“I loved the fact that it was an easy to understand way of explaining video buffering because this is a topic that I always felt that I understood but didn’t know how to explain it to others.”
The infrastructure

From student feedback form:
“Everything worked smoothly. Pretty rare from a lab it seems.”

From student feedback form:
“I had to run the experiment six times before I got usable results (errored out the other times). This seems ridiculous.”
Design/project courses
**The good**

**Advantage of GENI for design and project courses:**
Instructor can provide structure, allow students to pursue more sophisticated designs.
The bad

Disadvantage of GENI for design and project courses:
Learning curve (especially if instructor doesn’t provide structure).
Projects in computer networks

- **When:** Fall 2013
- **Who:** Thanasis Korakis
- **Where:** University of Thessaly, Greece
- **What:** Undergraduate/M.S. special topics in computer networks.
Curriculum

1. Prepared lab exercises from the “Contemporary issues” curriculum.
2. Students design, implement, and critically evaluate an extension of one of prepared labs.
Results

Instructor’s perspective:

The most impressive part of the class is that I assigned to students an implementation-based project based on Poly’s testbed. The most impressive part of the whole process was the outcomes of these projects. The students came up with very interesting schemes to implement, insured by the hands-on labs of the class. I was inspired to see them implementing their cool ideas and presenting experimentation results that in many cases would be worth being published.
Results

Student project abstracts are available online: http://tinyurl.com/uth-projects
Adaptive video policy design challenge

- **When:** Fall 2014
- **Who:** Violet Syrotiuk
- **Where:** Arizona State University
- **What:** Supplements undergraduate course in computer networks
Curriculum

Supplements standard course in computer networks:

1. Prepared lab exercise on adaptive video
2. Extend the software to design, implement, and evaluate their own adaptive video delivery policy
3. **Friendly competition**: Students’ designs ranked on leaderboard
CogRadio design challenge

- **When:** Fall 2014
- **Who:** Thanasis Korakis
- **Where:** University of Thessaly, Greece
- **What:** Undergraduate/M.S. special topics in computer networks.
Curriculum

Modeled after DARPA Spectrum Challenge

1. Lectures on wireless signal processing and prepared lab exercises on software radio
2. Students design software radios in teams
3. **Friendly competition:** Students’ radios go head-to-head in a tournament
Designing and Implementing a Self-Optimizing Software Radio Receiver

Jason Shin, Sharri Glloxhani
Fraida Fund, George Kyriakou, Sanjay Goyal, and Prof. Shivendra Panwar

Department of Electrical and Computer Engineering
NYU Polytechnic School of Engineering

Motivation

Key Terms:
- Cognitive radio
- Software radio

Cognitive radios can effectively share the scarce free spectrum.

Problem

Cognitive radio systems don’t have a centralized infrastructure to tell them what settings to use.

For the best and most accurate communication in an unknown environment, we need to self-tune certain settings:
- Modulation
- Frequency
- Bit rate
- Amplitude
- Gain

Tools

- Wireless testbed at NYU
- USRP software radios with GNU Radio Software Platform

Algorithm

- Compares a group of 100 packets to another group
- Gain of packets differs by 1, starts at 0.
- If amount correct of higher gain value > amount correct of lower value by insignificant amount, the minimum optimal gain has been reached.
- If not, repeat with higher gain

Evaluation

- Algorithm finds minimum “best” gain value
- Manually check all gain values, see if algorithm found the right ones
- Control tests so that results are fair comparison

Results

- Transmitter Gain
- Receiver Gain

Future Work

- Implement control channel so we can optimize other parameters in a similar way
- Design decentralized architecture to replace current cell phones with cognitive radios

Acknowledgements:

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Classes of Communication

Centralized

Decentralized

U.S. Frequency Allocation Chart

29 / 36
Instructor’s perspective:

It is great to see students learning about the difficult concepts of wireless signal processing, by building a real communication system from scratch coming up with innovative communication modules in order to compete with their schoolmates on the best implementation. It is impossible to give to students such knowledge through a traditional teaching approach.
GENI MOOC
The idea

User-friendly, low-barrier-to-entry, experiments that run on GENI and are open to anybody with a browser.
Internet routing (open now)

Try it at
http://hyperion.poly.edu/
Thanks