Teaching Networking on Testbeds

Experiences with GENI

Fraida Fund

ffund@nyu.edu

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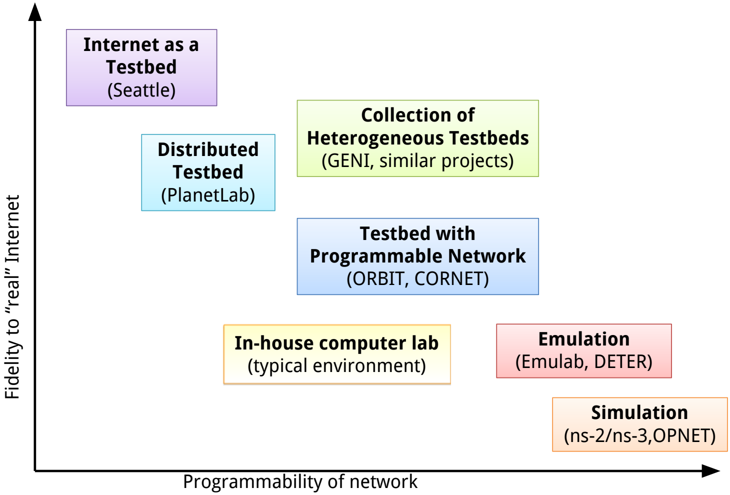
- GENI wireless testbed administrator
- developer of educational materials for GENI testbeds
- TA/lab instructor in courses using GENI lab materials

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?


Internet as a Testbed
(Seattle)
Collection of Heterogeneous Testbeds
(GENI, similar projects)
Distributed Testbed
(PlanetLab)
Testbed with Programmable Network
(ORBIT, CORNET)
In-house computer lab
(typical environment)
Emulation
(Emulab, DETER)
Simulation
(ns-2/ns-3,OPNET)
Fidelity to "real" Internet
Programmability of network

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

NYU·poly POLYTECHNIC INSTITUTE OF NYU **Spring 2013:** **Wireless information systems**	ASU **Fall 2013:** **Computer networks**	UNIVERSITY OF THESSALY **Fall 2013:** **Advanced topics in networks**
UNIVERSITY OF THESSALY **Spring 2014:** **Wireless communications**	NYU **Spring 2014:** **Communication networks**	Clarkson UNIVERSITY **Fall 2014:** **Computer networks**
BUE The British University in Egypt الجامعة البريطانية فى مصر **Fall 2014:** **Wireless networks**	UNIVERSITY OF THESSALY **Fall 2014:** **Advanced topics in networks**	ASU **Fall 2014:** **Computer networks**

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

Motivation

Key Terms:

- Cognitive radio
- Software radio

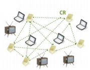
Cognitive radios can effectively share the scarce free spectrum.

U.S. Frequency Allocation Chart

Problem

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

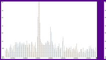
Centralized



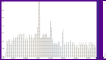
Decentralized

For the best and most accurate communication in an unknown environment, we need to self-tune certain settings:

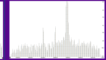
- Modulation
- Frequency
- Bit rate
- Amplitude
- Gain



Default Gain



Receiver Gain



Transmitter Gain

Tools

- Wireless testbed at NYU

- USRP software radios with GNU Radio Software Platform

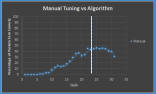
Algorithm

- 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



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

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

NYU POLYTECHNIC SCHOOL OF ENGINEERING

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CENTER FOR ADVANCED TECHNOLOGY IN TELECOMMUNICATIONS

Results

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.

GENI

Course Started - Oct 21, 2014

GENI105 Internet Routing

View Course

Unregister

GENI

Course Starts - Jan 22, 2015

GENI101 Adaptive Video Streaming

View Course

Unregister

NEW

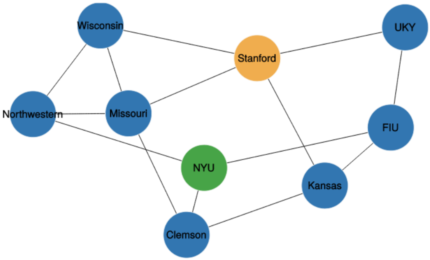
GENI102 Internet Security and Cryptography

NEW

GENI103 Network Neutrality

NEW

GENI104 Bitcoin & Consensus in Distributed Systems



Step	STANFORD	CLEMSON	FIU	KANSAS	MISSOURI	NW	NYU	UKY	WI
1	0	∞	∞	∞	94.221ms STANFORD	∞	∞	95.553ms STANFORD	93.051ms STANFORD
2	0	∞	∞	∞	94.221ms STANFORD	124.13ms WISCONSIN	∞	95.553ms STANFORD	93.051ms STANFORD
3	0	529.248ms MISSOURI	∞	∞	94.221ms STANFORD	124.13ms WISCONSIN	∞	95.553ms STANFORD	93.051ms STANFORD
4	0	529.248ms MISSOURI	139.877ms UKY	∞	94.221ms STANFORD	124.13ms WISCONSIN	∞	95.553ms STANFORD	93.051ms STANFORD

Internet routing (open now)

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

Thanks