ACM SIGCOMM Education Workshop
Graduate Curriculum Panel

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What have I found about incoming graduates ..

• Confusing networking with ....
  – client-server programming
  – CLI-based router configuration
  – Survey of research papers, telecomm standards
• Little or no *hands on* experience
  – Building experimental systems
  – background in performance evaluation and traffic characterization
    – Concepts behind discrete-event simulation
• Lack of understanding of networking system design and architecture
  – An analogy with computer architecture or OS architecture
  – Distributed architecture with backplanes, switch fabrics, blades, etc
Networking background requires ..

- Basics of efficient protocol design
  - multiple access, distributed state/stateless, fault tolerance
- Network security as a *first class object* (an integral part)
  - NAT/firewall, DDOS, authentication, encryption
- Performance analysis and evaluation
  - Traffic characterization, simulation, quantitative analysis
- **Network system architecture and design**
  - Move beyond a BSD PC-based router
  - Distributed router with switch fabric, backplane, etc
  - Solid grasp of algorithm/data structure design and analysis
    - Hashing/lookups, queuing efficient data structures for handling large no of queues, timers, etc
Graduate-level course(s)

• Must assume students have had an undergrad class
  – 7-layer model, encap/decap, error detection, ARQ, flow control known
  – Client-server model and socket programming

• Graduate core consisting of two courses
Graduate Course contents

- Focus on protocol design concepts
  - A variety of link and physical layers and implications
  - Detailed example of a protocol design and evaluation
- Include basics of network security
  - E.g., avoid DOS in protocol or algorithm design
- Detailed study of..
  - Routing algorithms, scalable network design
  - Flow and congestion control alternatives with simulation
  - Performance evaluation and traffic characterization
  - Packet processing stages at a node
    - Packet classification algorithms, media and switch fabric I/O
    - Traffic scheduling and queuing disciplines
    - Protocol conversion (IPv4-IPv6, IP/ATM/POS, etc)
- Architecture and design of a distributed router
  - Centralized vs distributed control plane, line card design tradeoffs, switch fabric choices and implications
Graduate Course contents (contd.)

- Concepts supplemented with classic papers
  - Congestion avoidance/control
  - Traffic scheduling disciplines
  - Unicast vs multicast routing

- Hands-on projects a *must* component
  - An experimental project to build a networking system
    - Switch/router with QoS, firewall, NAT, IDS
    - *What-if* scenarios with different scheduling, congestion control policies (e.g., RED vs Blue)
    - NS-2 as a traffic generator for the experimental platform
  - At least one NS-2 based simulation project to reproduce results from classic papers
    - Interactions across multiple nodes
How can we help?

• **Network processors as an open, experimental platform**
  - Equivalent of BSD kernel, a better tool to understand system design and architecture tradeoffs

• **Intel’s IXA University program**
  - Over 30 schools funded worldwide
  - A community of educators and researchers

Open issues

- What should you *not* be teaching?
- How to incorporate *network security* as a basic building block
- A separate inter-disciplinary course on “network ethics”
  - Integrity, ethics, etc
  - Demonstrated perils of hacking (“traffic school”)
  - Must be offered jointly with socialists
  - *Not* specific to networking
Backup
What do we need?

• A sequence of Solid grasp of concepts in following areas
  – Algorithm design and analysis
    – Hashing, CRC, p-tree, lookups, efficient data structures for handling large no of queues, timers, etc
    – Routing, queuing, congestion control algorithms
  – Basics of Protocol design
    – Address new link-layer issues
    – Design an efficient protocol, etc
  – Network security as a *first class object*
    – NAT/firewall, authentication, encryption
  – Performance analysis and evaluation
    – Traffic characterization, simulation, quantitative analysis
  – Network system architecture and design
    – Move beyond a BSD PC-based router
• Hands-on experience with a non-trivial exercise
Notes from the breakout session

• What are foundational courses (concepts?) that prepare students for research or industry career in networking?
  – Graph theory, queuing theory, random processes
  – Experimental methodology incl simulation, experience building a system incl design tradeoffs and perf characterization
  – Theory of protocol design
  – Modeling a system (abstract vs concrete?)

• Case studies
  – Study RFP, RFP responses, evaluation
  – E.g. “state of KS chooses telecom switches”