Scaling the Practical Education Experience

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Motivation

- Many tools, environments, and approaches developed for practical, hands-on experiences
  - Provide realistic, applied setting for teaching, learning and research
  - Many focus on relatively small graduate-level courses
- How to adapt and scale to larger classes and to undergraduate settings?

Position

- Practical exercises are essential for students at both undergraduate and graduate levels
  - Directly grapple with important scientific & engineering issues in networking
  - Realism counts a lot!
- We treat "Building an internet router" as a successful example with a coherent and compelling set of exercises
  - How to adapt to undergraduate institutions? Scale up? Scale out?

Building an internet router

- Goal: in one semester/term, build a functional IPv4 router and design and implement some advanced router functionality
  - Project-based course with groups of students (2)
    - Hardware (Verilog) and software components
    - Based around NetFPGA and VNS
- Many networking and software development skills addressed
  - Algorithms, data structures, concurrency, version control, testing
  - Routing, forwarding, ICMP and ARP processing, interoperability
- Highly compelling and rewarding

Undergraduate approaches and constraints

- Two basic approaches
  - Simulation and trace-based approaches
  - Laboratory and emulation-based approaches
- Constraints
  - Instructor overhead, laboratory setup and maintenance
  - Depth of student background
  - Larger course sizes
    - Assessment and grading
    - Open-ended versus more constrained exercises

Challenges in scaling

- Laboratory setup and maintenance
  - Cost, space, instructor overhead
  - Shared and openly available testbeds can help
- Assessment and grading
- Need appropriate scaffolding and support for undergraduates
  - Smaller departments can only offer a limited range of systems courses
  - Requires a variety of exercises to address different levels of understanding

Looking ahead

- Goal: develop a range of activities based on BIR that address multiple levels Bloom's taxonomy
  - Current BIR activities are somewhat open-ended
  - Address highest levels of learning
- Examples of possible projects that could be developed
  - Observation: simulation and visualization of a congested queue
  - Constrained: develop and test IP longest prefix match lookup
  - Loosely constrained: develop novel built-in router support for traffic measurement