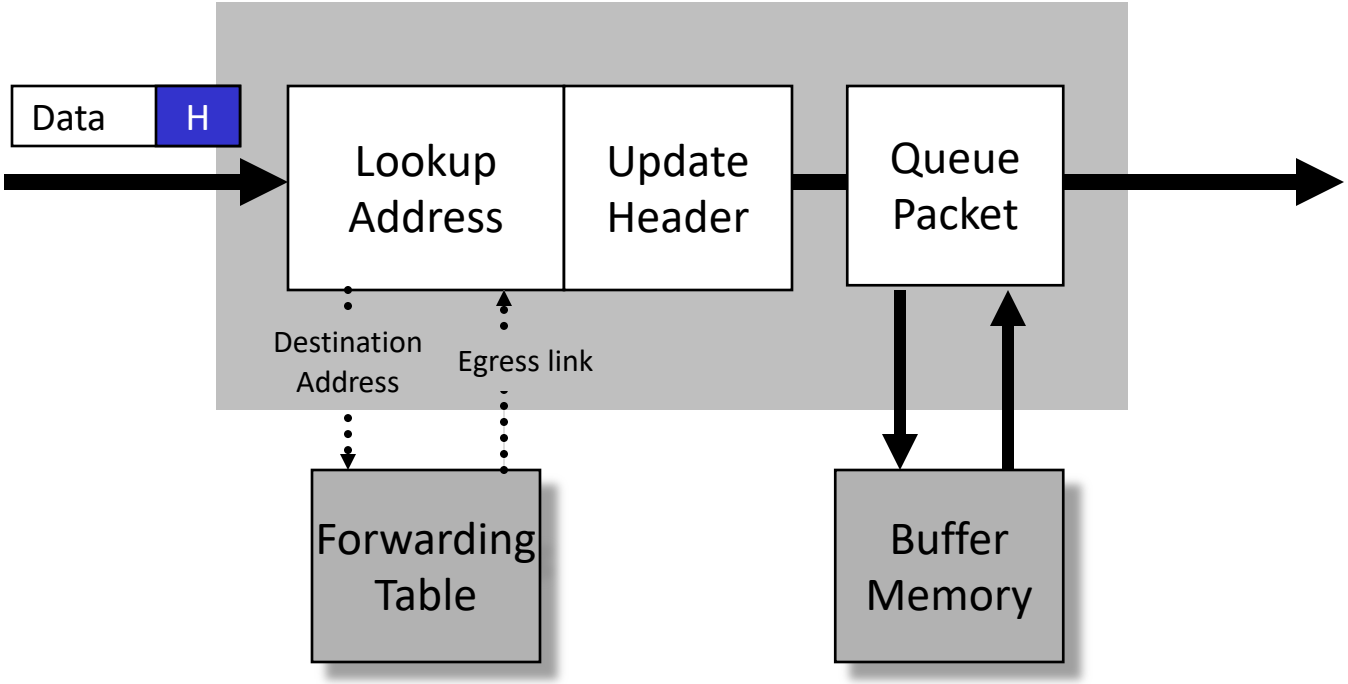
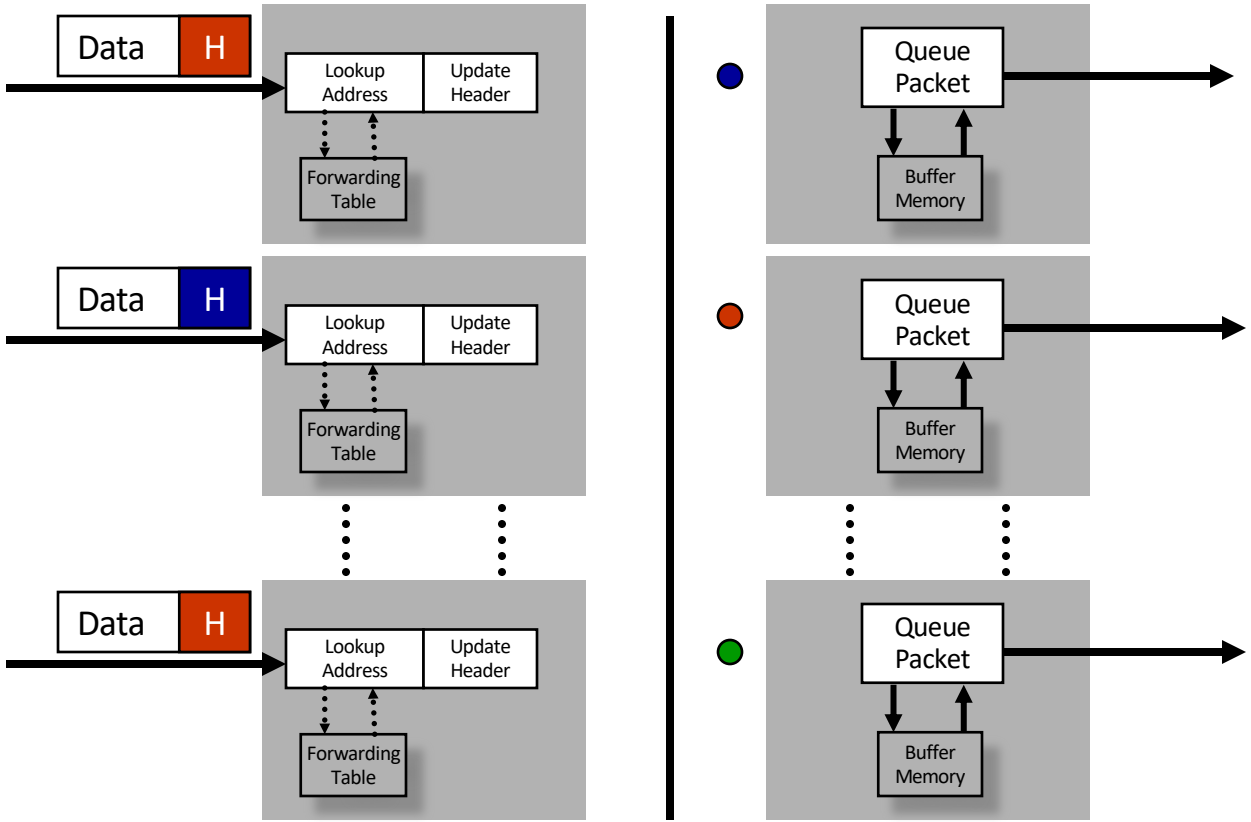
CS344 - Build an Internet Router

Andrew Moore (Guest)
Steve Ibanez (TF), Sarah Tollman (CA)

Generic Packet Switch



Generic Packet Switch



Ethernet Switch

1. Examine the header of each arriving frame.
2. If the Ethernet DA is in the forwarding table, forward the frame to the correct output port(s).
3. If the Ethernet DA is not in the table, broadcast the frame to all ports (except the one through which the frame arrived).
4. Entries in the table are learned by examining the Ethernet SA of arriving packets.

Internet Router

1. If the Ethernet DA of the arriving frame belongs to the router, accept the frame. Else drop it.
2. Examine the IP version number and length of the datagram.
3. Decrement the TTL, update the IP header checksum.
4. Check to see if TTL == 0.
5. If the IP DA is in the forwarding table, forward to the correct egress port(s) for the next hop.
6. Find the Ethernet DA for the next hop router.
7. Create a new Ethernet frame and send it.

Basic Operations

1. Lookup Address: How is the address looked up in the forwarding table?
2. Switching: How is the packet sent to the correct output port?

Lookup Address: Ethernet

Ethernet addresses (in a switch)

Match	Action
Ethernet DA = 0xA8B72340E678	Forward to port 7
Ethernet DA = 0xB3D22571053B	Forward to port 3
…	…

Methods

- Store addresses in hash table (maybe 2-way hash)
- Look for exact match in hash table

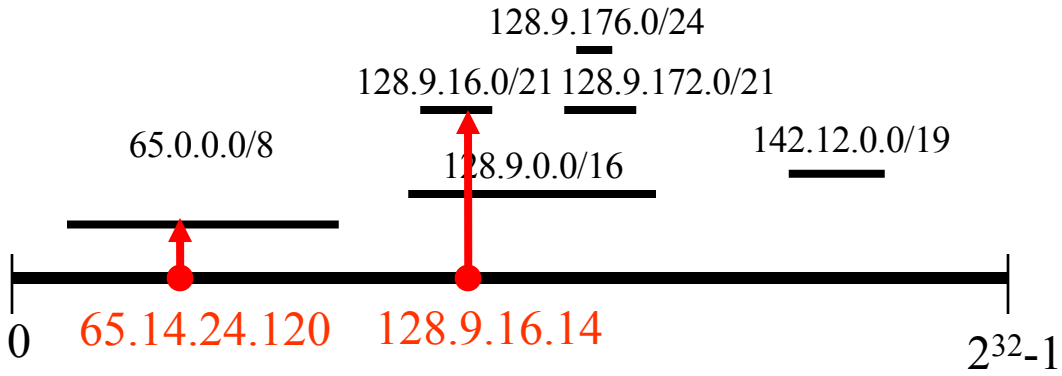
Lookup Address: IP

IP addresses (in a router)

Match	Action
IP DA = 127.43.57.99	Forward to 56.99.32.16
IP DA = 123.66.44.X	Forward to 22.45.21.126
IP DA = 76.9.X.X	Forward to 56.99.32.16
…	…

Lookup is a longest prefix match, not an exact match

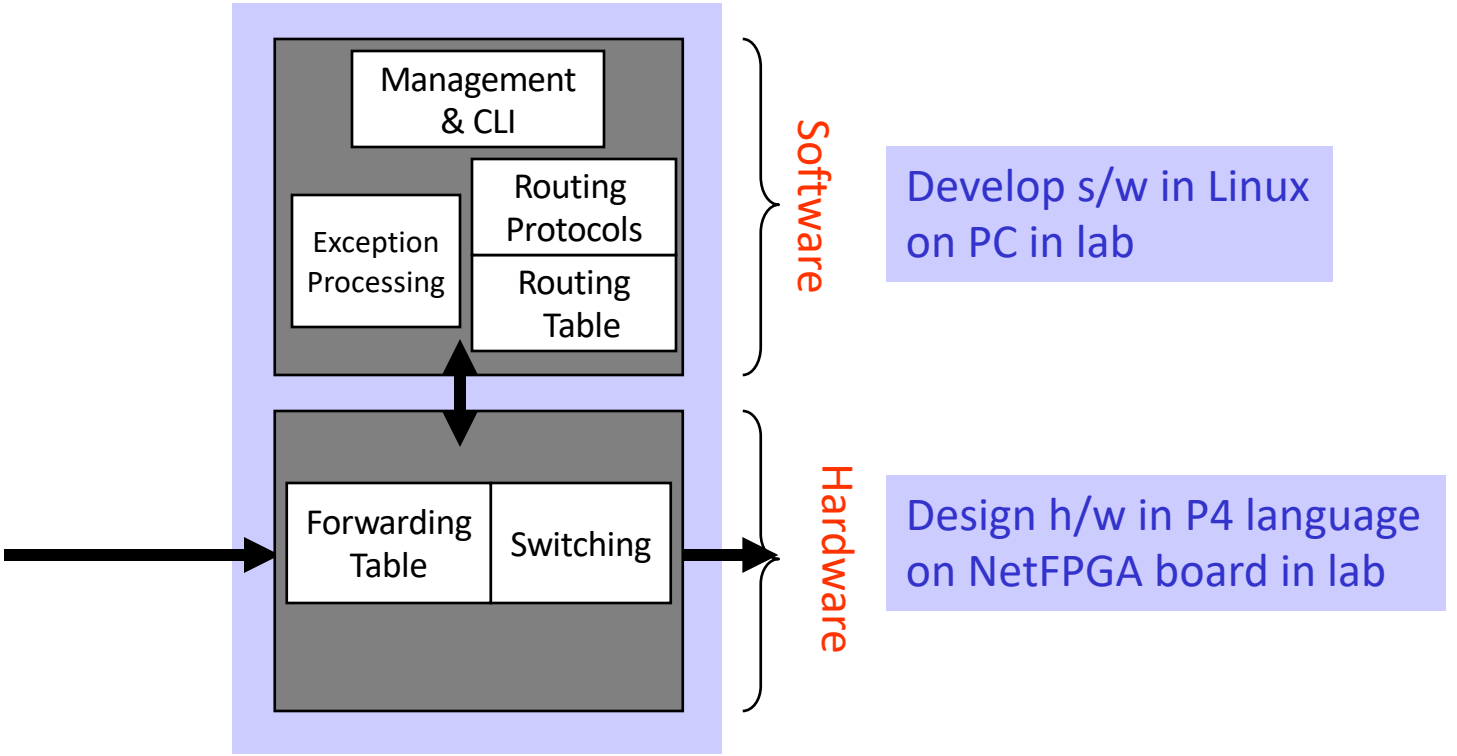
Longest prefix match



Routing lookup: Find the longest matching prefix (aka the most specific route) among all prefixes that match the destination address.

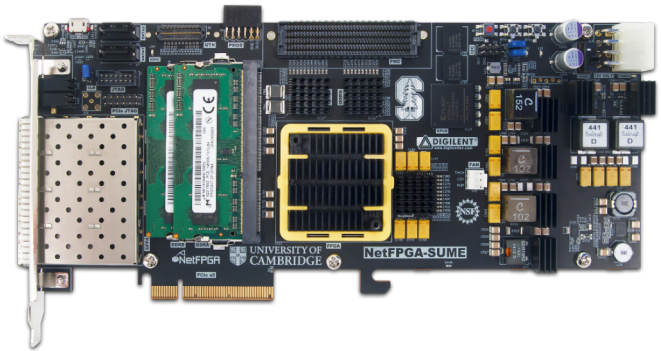
The CS344 Project:

Build a 4-port 10GE IPv4 Router



NetFPGA = Networked FPGA

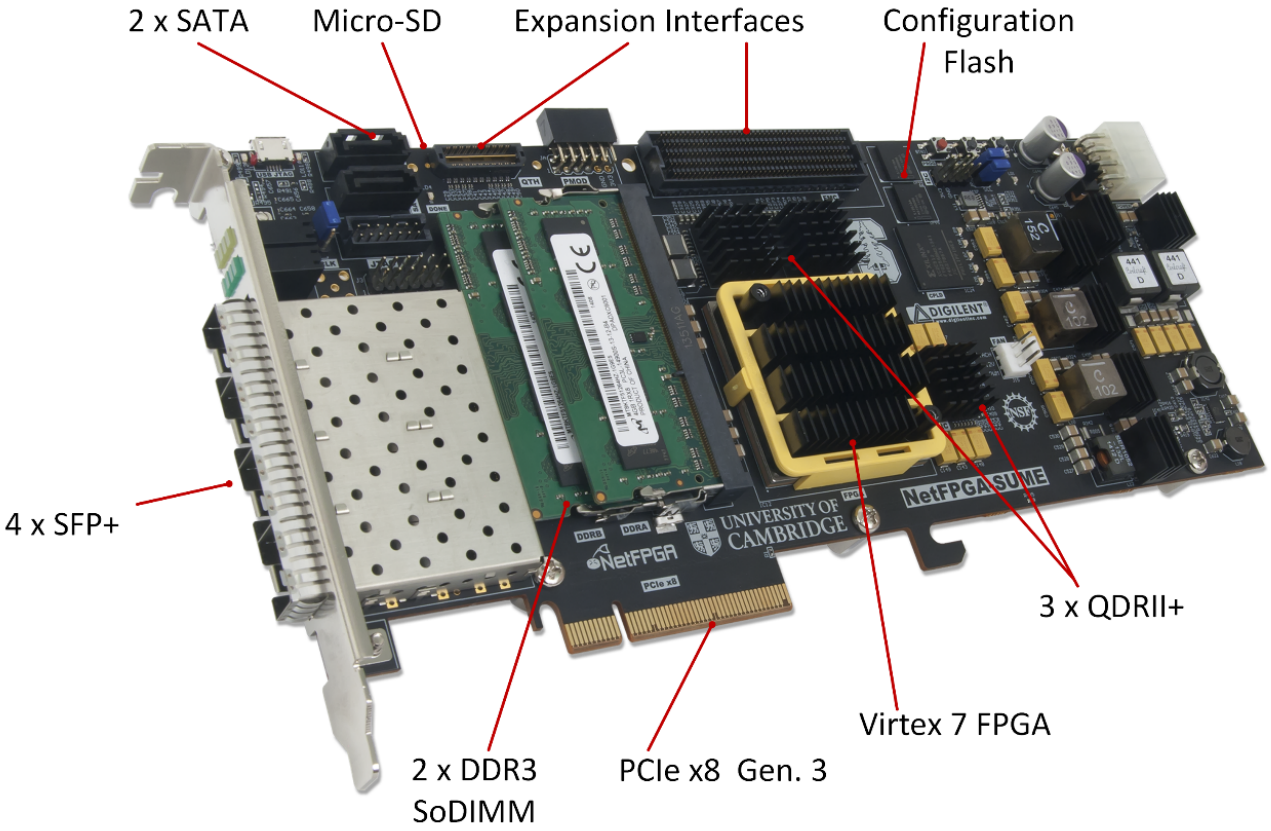
- A line-rate, flexible, open networking platform for teaching and research



=

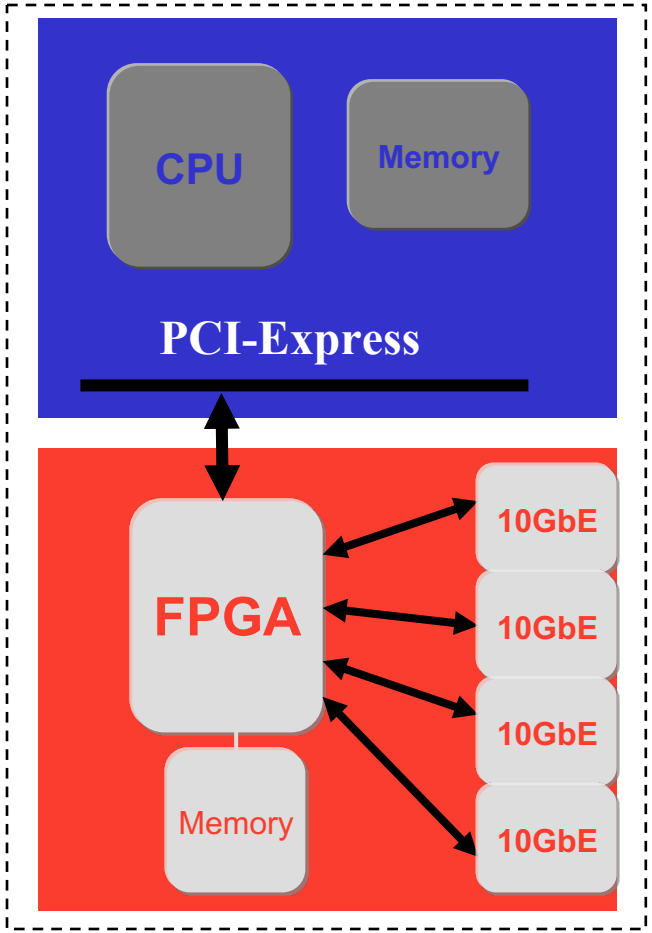
- Network Interface Card
- Hardware Accelerated Linux Router
- IPv4 Reference Router
- Traffic Generator
- Openflow Switch
- More Projects
- Add Your Project

NetFPGA-SUME



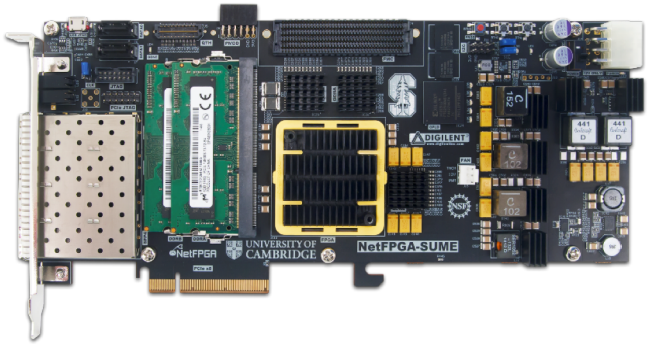
NetFPGA board

Networking Software running on a standard PC



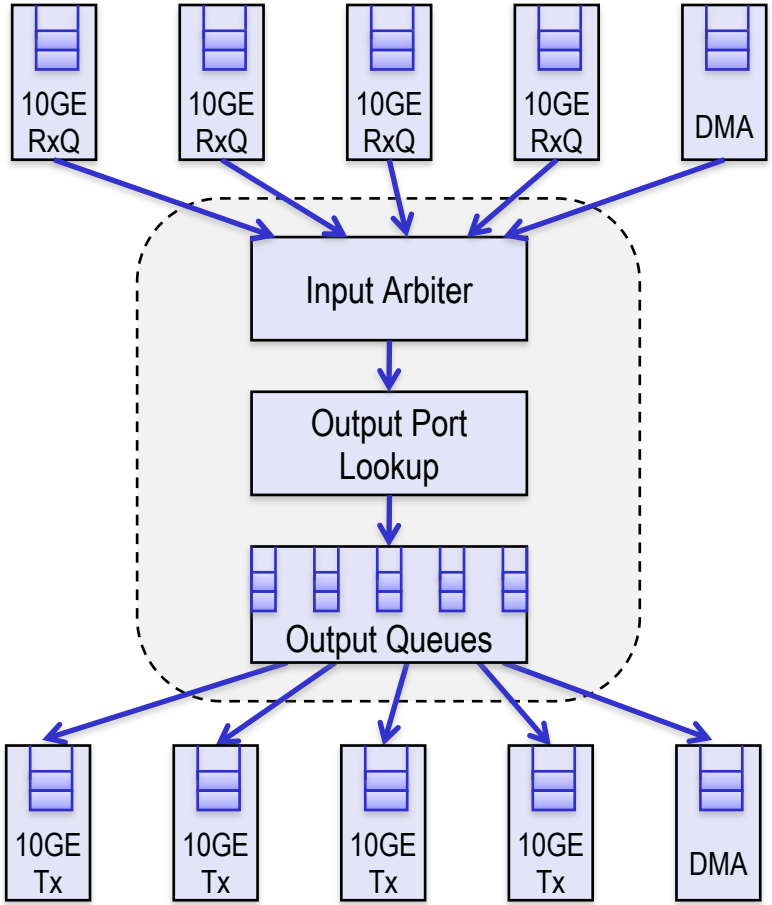
PC with NetFPGA

A hardware accelerator built with FPGA driving 1/10/ 100Gb/s network links



NetFPGA Reference Design

- Five stages
  - Input port
  - Input arbitration
  - Forwarding decision and packet modification
  - Output queuing
  - Output port
- 256-bit data bus
- 200 MHz



LOGISTICS

Course Website

- **https://cs344.stanford.edu**

CS344 Stanford

Build an Internet Router

About Documentation Policy Schedule Source Code Staff Teams Slack Lectures

Time and Location

Term: Spring 2019

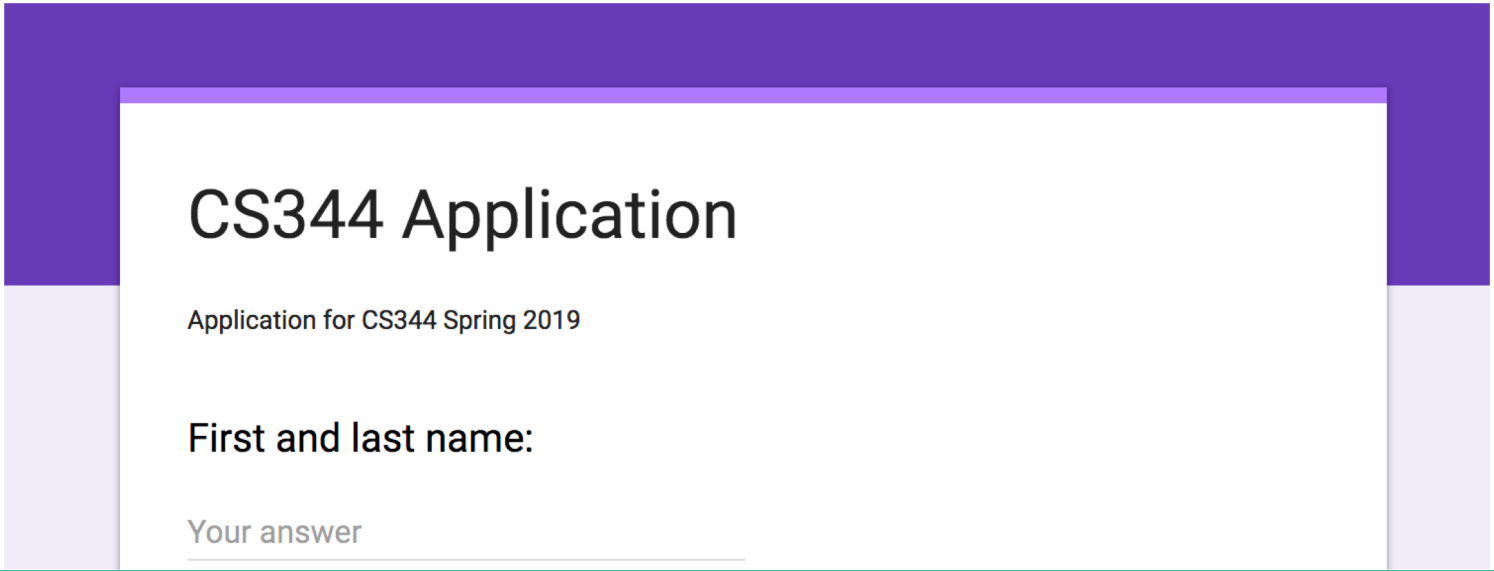
Lectures:

- Monday/Wednesday 4:30PM - 5:50PM
- Thornt207

Lab: Gates 325

Course Application due Today 11:59 PM

- https://tinyurl.com/cs344-19-app
- Team assignments: tomorrow by 5PM



Course Structure

- Four more lectures (possibly more)
- Two projects:
  - Internet Router - 5.5 weeks
  - Design challenge - 4.5 weeks
- Milestone deliverables
- Meetings with instructors
- Weekly progress documentation
- Final presentation / demonstration
- *No Midterm or Final*

Lecture Schedule

- *Wed, April 3rd:*
  - **P4 Language Overview (Milad Sharif – Barefoot Networks)**
- *Monday, April 8th:*
  - **Learn about P4→NetFPGA and how to use it**
- *Monday, April 15th:*
  - **P4 Applications - Guest lecture (TBD)**
- *Monday, April 22nd:*
  - **Intro to working with FPGAs**
- Others TBD

Teams

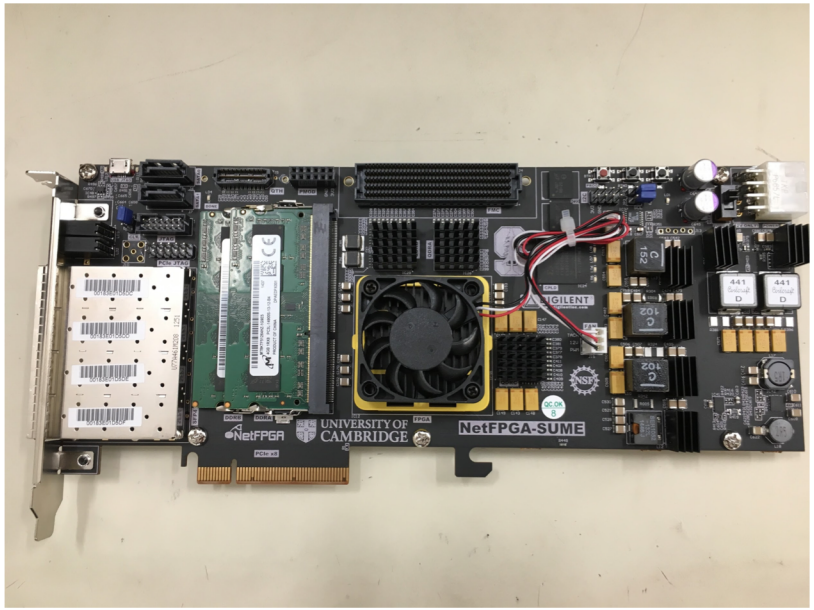
- Teams of 2, instructors will assign
- Indicate preferences on applications
- Each team decides how to divide work
- Each team assigned a development machine

Lab

- Gates 325
- One machine per team
  - One NetFPGA SUME board
  - One dual-port 10G NIC
- Key Access
  - Look for email from Andi Villanuueva
- Sharing hardware policy

Hardware

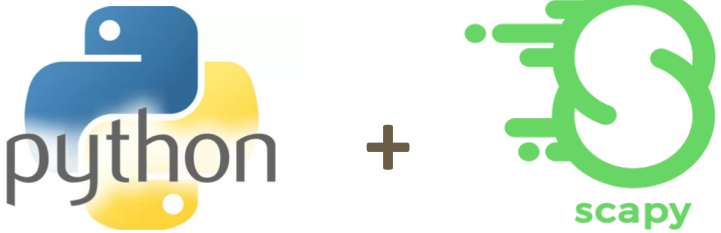
NetFPGA SUME



Dual Port 10G NIC

Development Tools

Control-Plane:



Hardware

Data-Plane:

Mininet

Data-Plane:

P4.org BMv2

Deliverables

- Getting Started - 1st deliverable, **due Friday April 5th, by 11:59 PM**
- Tutorial Assignments
  - **Assignment 1 – *Very* basic IPv4 forwarding in P4, test in Mininet**
  - **Assignment 2 – Switch calculator in P4, test in hardware and Mininet**
- Router
  - **Interoperability test proposal (entire class)**
  - **Static router interoperability test & baseline tests**
  - **PWOSPF router interoperability test & baseline tests**
- Design Challenge Project
  - **Proposal**
  - **Status report**
  - **Final presentation & demonstration**

Review & Submission Process

- Github used extensively
- Each team develops a fork of the starter code repo
- Submission:
  - Tag specific commits – explain who did what
- Instructor Feedback:
  - Github issues
  - Pull Requests (possibly)
- Final submission:
  - Pull Request to starter code repo

Documentation Requirement

- README file in project directory
- Every Friday instructors will check for:
  - Progress update
  - Next steps
  - Open questions
- Opportunity for instructors to offer feedback

Meetings with Instructors

- Total of four 15-min meetings
- Two before PWOSPF interoperability test - router project
- Two after PWOSPF interoperability test - advanced features project
- Purpose: discuss progress, ask questions
- Sign up on starter code wiki page:
    - https://github.com/cs344-stanford-19/P4-NetFPGA-CS344-19/wiki/Team-Meeting-Slots

Interoperability

- You prove to us that your routers are interoperable
- Develop a plan early! Submit plan for approval
- April 17th – Interoperability planning
- April 18th – Interoperability test proposal (entire class)
- April 24th – Static router interoperability pre-testing
- ***April 29th – Static router interoperability test & baseline tests***
- May 1st & 6th – PWOSPF interoperability pre-testing
- ***May 8th – PWOSPF interoperability test & baseline tests***

Collaboration Policy

- Each team must do their own work
- No code sharing!
- No reusing code from online sources.
- We will use tools to compare against previous years and online sources.
- Do not misuse sudo privileges

Final Presentation / Demonstration

- A presentation on your design challenge project
- 15 min + 5 min questions
- Wednesday June 12th @ 3:30PM

Grading Breakdown

Marks are awarded to an individual (I) or the team (T).

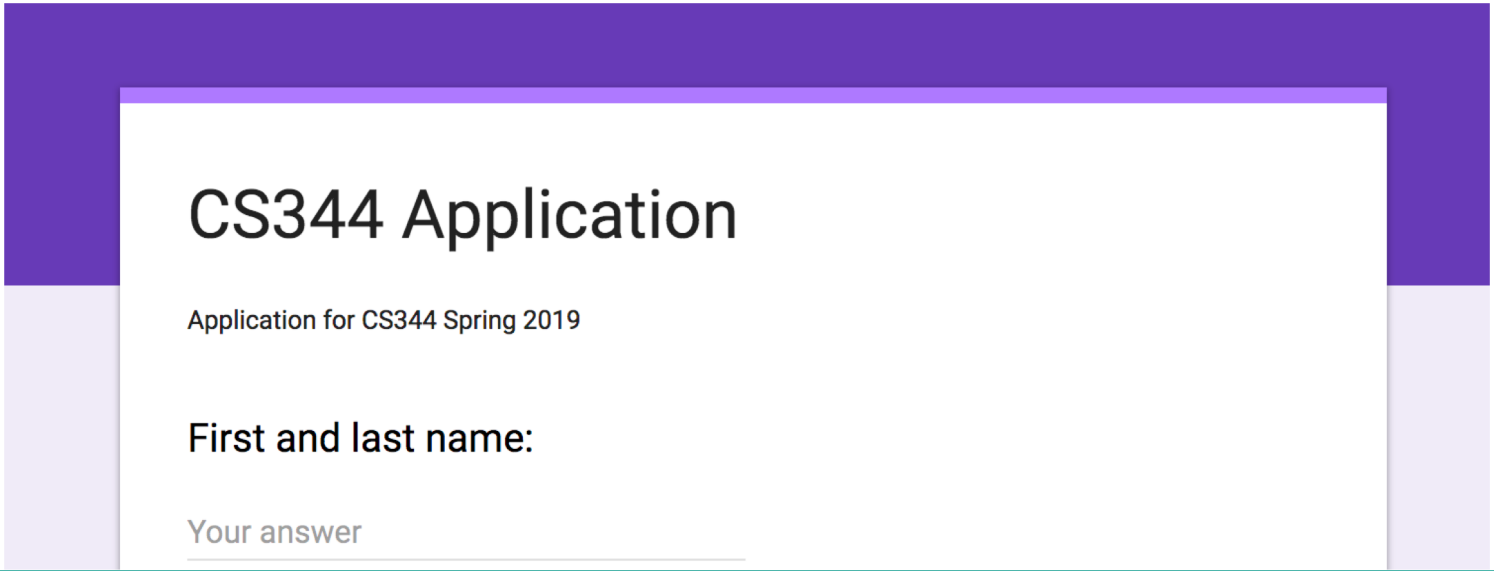
Points	Item	Description
10 (I)	Participation	This will be a subjective judgement by us based on aspects such as our interaction with you in regular meetings, your team's documentation on who did what, and by watching the online discussions.
5 (T)	Interoperability	Your router should interoperate correctly with the routers from all other teams. We will conduct an interoperability test session to verify interoperability.
50 (T)	Functionality	The code deliverables
25 (T)	Documentation	The weekly documentation checks + advanced features status report
10 (T)	Presentation	Final presentation

Ask for help!

- Slack
- Office hours
- Meetings with instructors
- Classmates

TF: Steve Ibanez

CA: Sarah Tollman

Course Application due Today 11:59 PM

- https://tinyurl.com/cs344-19-app
- Team assignments: tomorrow by 5PM