CS144R/244R
Network Design Project
on
Software Defined Networking for Computing

(introduction and course overview)
9/2/2015

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Harvard Paulson School
of Engineering and Applied Sciences

Today’s Agenda

- Introduction to the course subject
- Course overview
- Goal and content of the course
- Administrative information

A History of CS144R/244R

One-semester project course, with a different focus on a hot and interesting topic each year

1997: “Mobile IP”
1999: “Quality of Service (QoS) Networking”
2000: “Service-oriented Computing”
2001: “Content Networks”
2002: “Future of Business Networks”
2004: “Digital Rights Management (DRM)”
2005: “Technology, Business and Policy in Cellphone Industry”
2006: “Unmanned Aerial Vehicle (UAV) networking”
2007: “Wireless Parallel Computing”
2008: “Parallel and Distributed Computing on the Wireless Backplane”
2009: “Cloud Computing”
2012: “Big Data”
2014: “Secure and Intelligent Internet of Things”
2015: “Software Defined Networking for Computing”

Transformative Power of Computer Networks

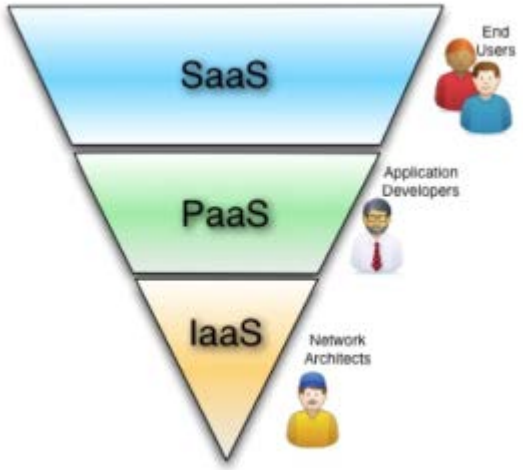
A brief recap of some highlights in the past 40 years:

- 1970s: File transfer and email (Donald Knuth urged us to use the word “email” instead of “e-mail”)
- 1980s: Online directories (yellow books no longer looked that important) and 10Mbps Ethernet
- 1990s: Wireless Ethernet, and ubiquitous desktop Internet support by Windows 98 (no more reboots after network configuration changes)
- 2000s: Buying books from Amazon for the first time, and massive network infrastructures for packet routing (by companies such as Cisco)
- 2010s: All content digitized, searchable, multimedia and streamed, social networking, and of course smart phones
- More recently, networking has enabled datacenters, cloud computing, mobile computing and big data (next slide)

Network-enabled Large-scale Services

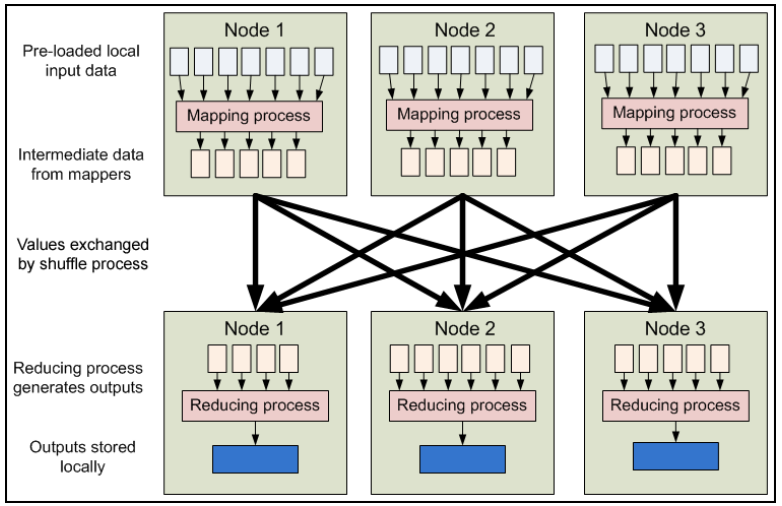
Datacenter

Cloud Computing



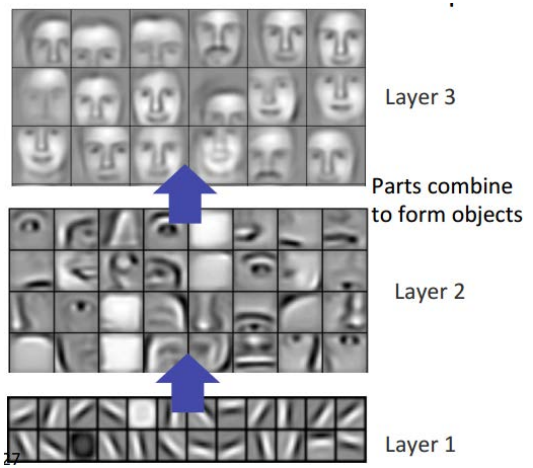
Mobile Computing

Big Data (e.g., MapReduce)

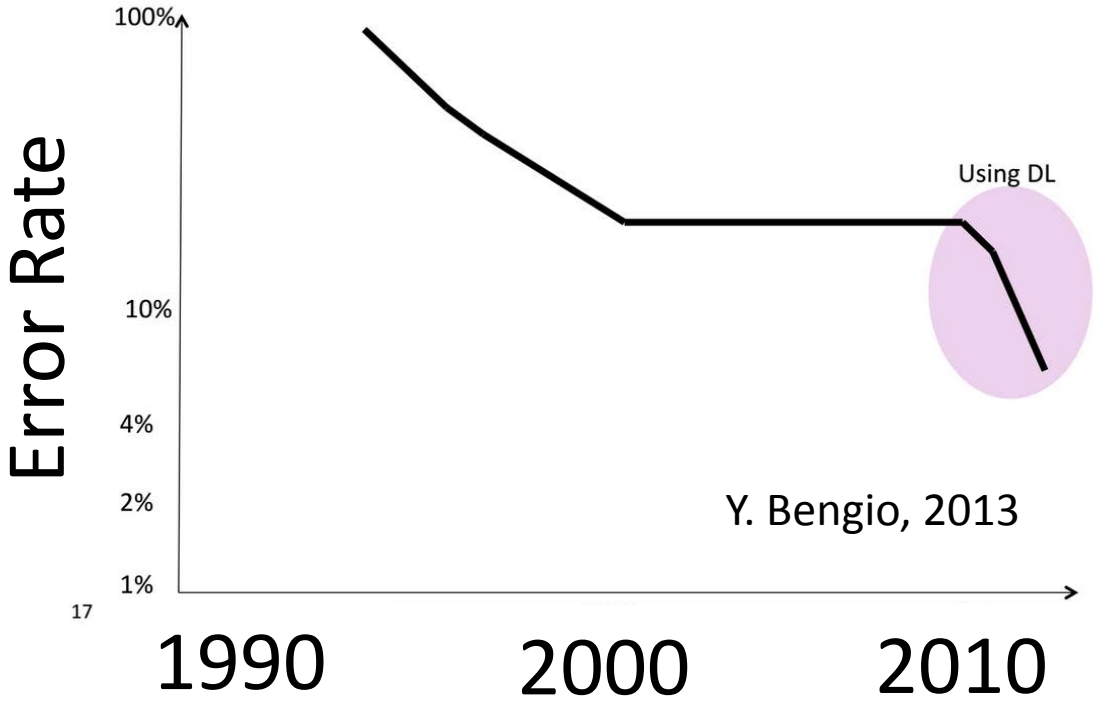


Data-driven Machine Learning

Deep learning has been hugely successful for some important tasks in speech recognition, compute vision, and text understanding. For example



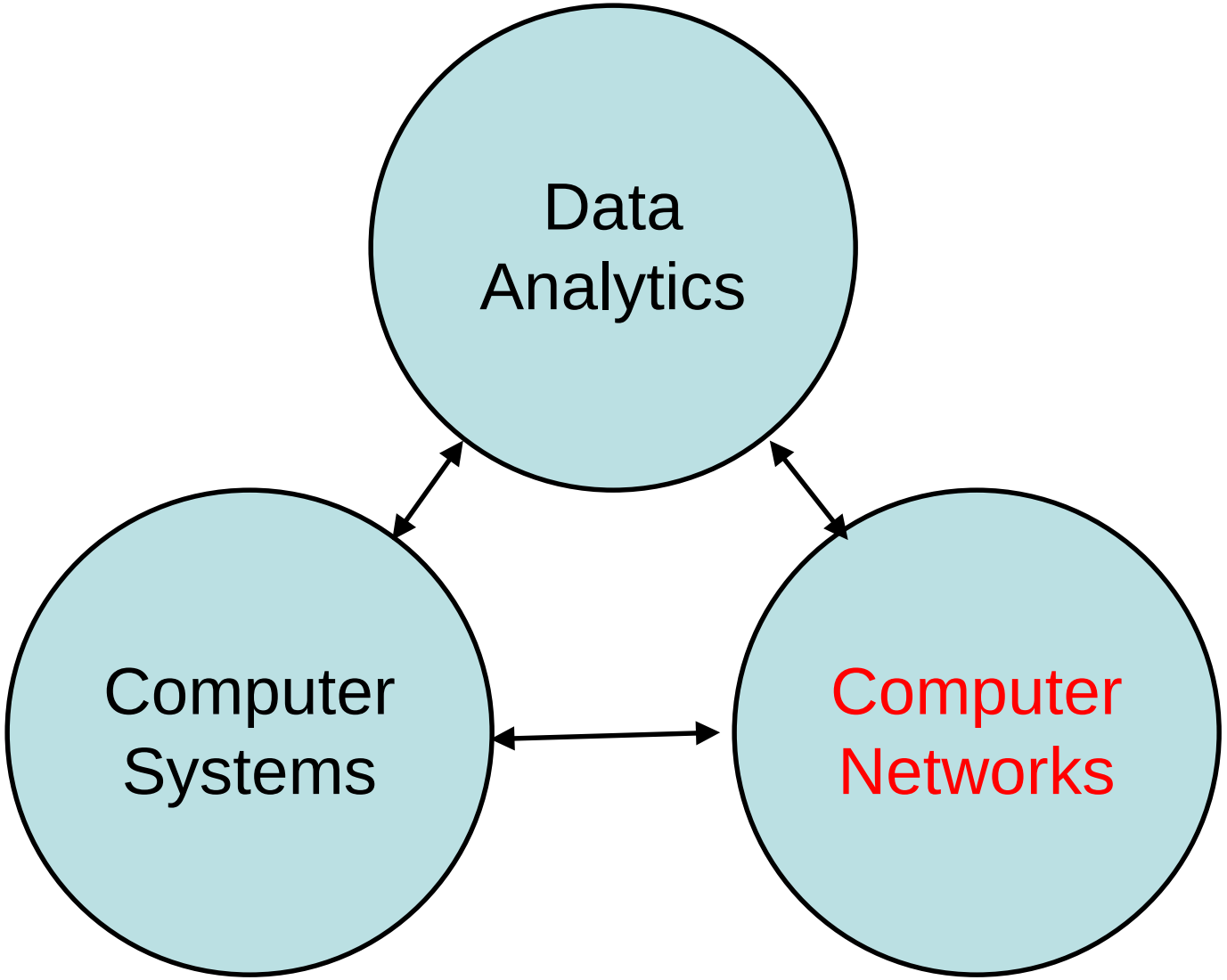
The dramatic impact of Deep Learning on Speech Recognition



These days it seems that **"only machines can learn!"**

However, these learning algorithms take a long time to run. We need to **scale computation** to very large clusters over networks

Three Major Areas of Computing

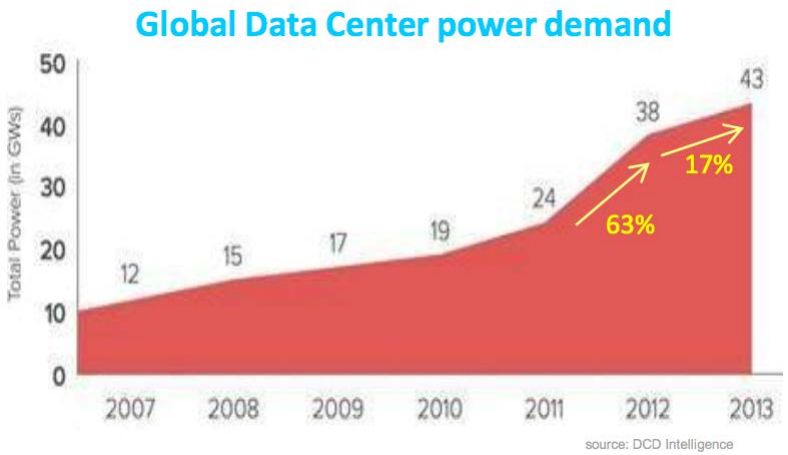


Networking for Computing: Motivations

1. Meeting Moore's law is getting to be (really) hard. (This "law" stipulating # transistors on a chip doubles every two years has held for the past 40 years!)
   - Most of future speed up will come from parallel and distributed computing. This requires **programmable networks** to meet different computation needs (e.g., configuring networks for MapReduce)
2. Mobile computing is the norm (computing anywhere, anytime, any device, ….)
   - This demands high-bandwidth, low-latency, massive **wireless** networks (4G is to be evolved into ambitious 5G in the next 5-10 years)
3. Smart living and workplace (smart everything!)
   - **Internet of Things**
4. Energy-efficient computing is essential for sustainability
   - **Networks for virtualization** to allow efficient use of computing resources in datacenters (next slide)

We Need New Networking Technologies for Green Computing

- Data centers consume 2% of the United States' total power, costing approximately $2 billion per month
- Energy demands grow rapidly
- Two of the most effective ways to reduce computing's energy consumption are:
  - **Workload consolidation**, so we can shut down idle servers
  - **Location optimization,** so we can limit computing to a relatively small area of the datacenter and shut down the rest



- Virtualization is the key for these. We virtualize servers, storage, network appliances, etc. **Software-defined networking (SDN)** and **Network Function Virtualization (NFV)** are enabling technologies

Conversely, Networking Can Be Enhanced by Data Analytics

- We can use data-driven prediction to anticipate traffic loads and quality of services requirements. These predictions can help configure the network for optimal performance
- Data-driven prediction will be especially important for controlling next-generation networks such as ultra-dense 5G networks, in resource schedule and interference mitigation

Moreover, We Anticipate Massive Internet of Things (IoT)

- Population of the world: 7 billion
- Population of Internet users: 3 billion
- Population of mobile phone users: 1 billion

- A game of asserting multiples
  - Suppose there will have 10 IoT devices per mobile user
  - Then we have a multiple of 10
  - This means **10 billion** IoT devices in year like 2020. (Indeed, 26 billion predicted by Gartner, 30 billion by ABI Research and 50 billion by Cisco)

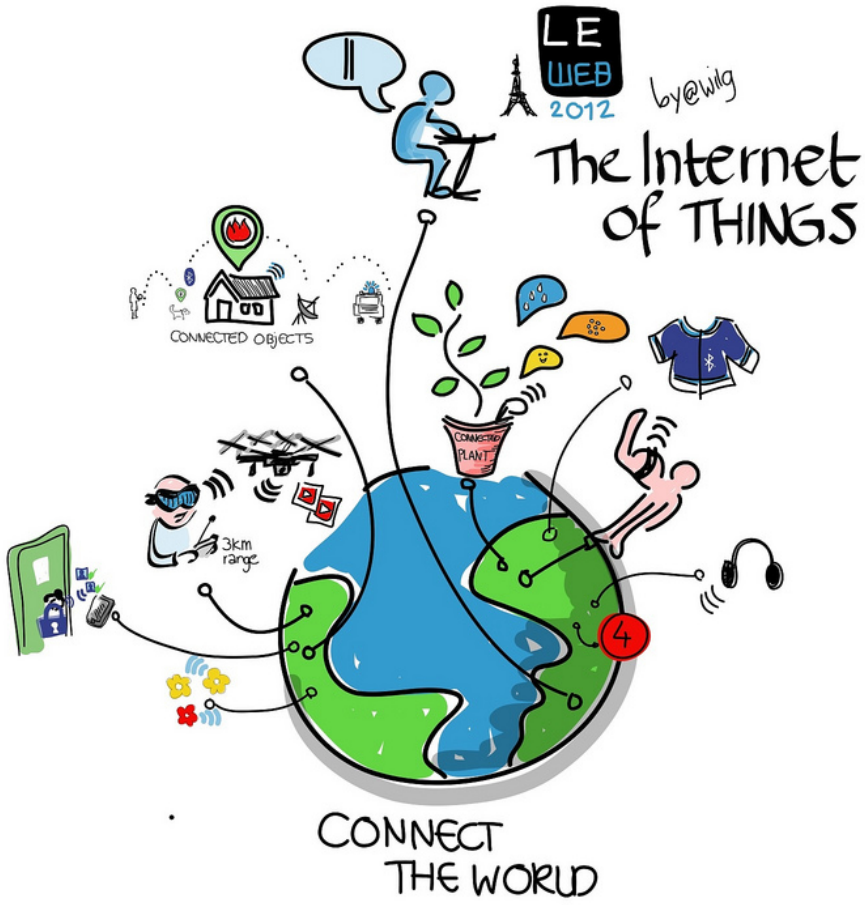


Image courtesy: Wilgengebroed

IoT: Far-reaching Implications

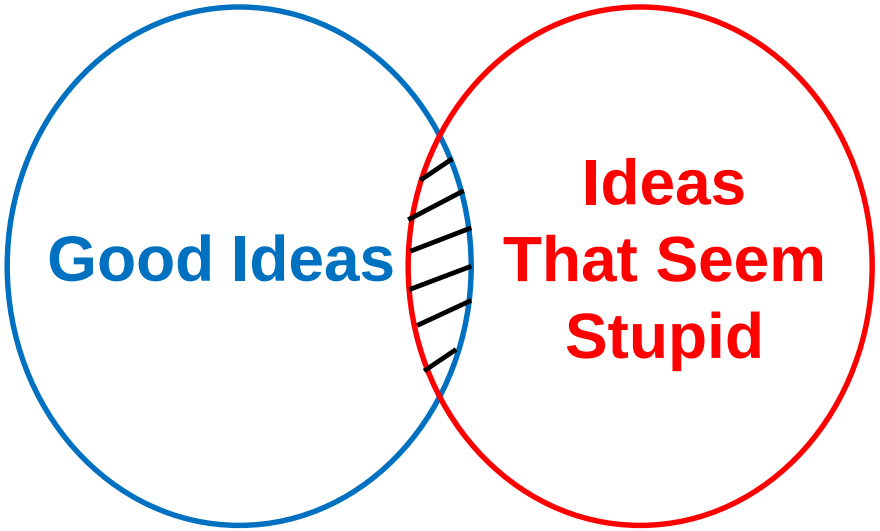
1. It connects **things** beyond people
   – Can track and control many devices
2. It is **physical** beyond information
   – Can directly impact physical aspects of our life (comfort, health, safety, green, …)
3. It empowers **sensing** and **reasoning** about the environment
   – Can be an assistant or agent for human beings, robots, or autonomous vehicles

All these mean new interdisciplinary opportunities and challenges, in areas such as devices, networking, systems, machine learning, security and privacy

IoT in Two Markets

1. IoT for enterprises
   - Smart meters (utility companies), smart vehicles (car companies), intelligent healthcare (insurance companies), …
2. IoT for consumers
   - Wearables such as smart watches, smart bands, and intelligent headsets
   - Smart homes which are open to various consumer IoT appliances
   - Many new IoT devices being introduced every week

It’s An Interesting Time for IoT



By Peter Thiel

Big opportunities
are in the intersection

- It is unclear yet where some big IoT opportunities (so-called “killer apps”) are
- We need to think deeply and be educated, in order to make better bets

Why Take This Course?

1. In this course, you will learn in some depth new networking topics (SDN, NFV, IoT, 5G, etc.) and gain hands-on knowledge through project work
2. It is **good for your career**. You should prepare yourself for something which will likely grow substantially in the next 10 years, like personal computers in the 1980s and the Internet in 1990s
3. You can do a serious network-related course project which you always wanted to do. The teaching staff will eagerly listen to you and help you when necessary

Prerequisites

- Programming experience (CS 50 should be fine) and interest in the subject matter
- Importantly, CS 143 is NOT a prerequisite
  - Labs and extra support will provide preparation in the first weeks of the semester to help students quickly obtain the networking background necessary to excel in the course

A Student's Work: Deliverables

1. Readings and Quizzes: Students will be responsible for completing reading assignments before each lecture, and answering a few short questions by midnight before the next lecture
2. Midterm: There will be an open book midterm on October 19 in class
3. Course project: Students will complete a project of their own design in 2-person or 3-person groups. The work for the project will include a project proposal presentation, project discussion with teaching staff, five interim checkpoint reviews, a final project presentation, and a final project report. The projects will need to be original, and involve network protocol design, implementations and applications
   - Students will be provided with hardware and software resources for their projects
   - Teaching staff will facilitate collaborations with industrial partners
4. Give a research presentation on a couple of research papers to prepare your course projects
5. Attend classes, labs, and participate in discussion

Eight Course Modules

1. A View of the Future
2. Basic Network Design and Protocols
3. Software Defined Networking (SDN)
4. Datacenter and Networking
5. Cross-Disciplinary Applications of Next Generation Networking
6. Wireless Networking
7. Connecting the Internet of Things
8. Next Generation Networking Enabled Infrastructure

Course Schedule

			Lecture	Lab	Project	Midnight Quizzes Due Midnight Before Class Day
Sep	2	Wed	Introduction and Course Overvew			
Sep	7	Mon	University Holiday: Labor Day			
Module 1: A View of the Future						
Sep	9	Wed	A View of the Future I: Network Programability			
Sep	14	Mon	A View of the Future II: 5G Wireless	Basic Networking I		Quiz 1
Sep	16	Wed	A View of the Future III: Applications and IoT			Quiz 2
Module 2: Basic Network Design and Protocols						
Sep	21	Mon	Basic Networking I			Quiz 3
Sep	23	Wed	Basic Networking II	Basic Networking II		Quiz 4
Module 3: Software Defined Networking (SDN)						
Sep	28	Mon	SDN I	Setting Up Your		Quiz 5
Sep	30	Wed	Course Project Brainstorming and SDN II	SDN Experimentation		Quiz 6
Oct	5	Mon	SDN III	Environment		Quiz 7
Module 4: Datacenter and Networking						
Oct	7	Wed	Project Proposal Presentations	Tools and Libraries		
Oct	12	Mon	University Holiday: Columbus Day			
Oct	14	Wed	Datacenter Networking	Midterm Review	Checkpoint 1	Quiz 8
Oct	19	Mon	Midterm			
Module 5: Cross-Disciplinary Applications of Next Generation Networking						
Oct	21	Wed	Cross Disciplinary Applications I: Machine Learining		Checkpoint 2	Quiz 9
Oct	26	Mon	Cross Disciplinary Applications II: Distributed Computing			Quiz 10
Module 6: Wireless Networking						
Oct	28	Wed	Project f2f Checkpoint 3			
Nov	2	Mon	Wireless: Basic Concepts			Quiz 11
Nov	4	Wed	5G Networks		Checkpoint 4	Quiz 12
Module 7: Connecting the Internet of Things						
Nov	9	Mon	IoT			Quiz 13
Module 8: Next Generation Networking Enabled Infrastructure						
Nov	11	Wed	Network-function virtualization (NFV) I		Checkpoint 5	Quiz 14
Nov	16	Mon	NFV II			Quiz 15
Nov	18	Wed	Network Security			Quiz 16
Project Presentations and Discussion						
Nov	23	Mon	Research Paper Presentations			
Nov	25	Wed	University Holiday: Thanksgiving			
Nov	30	Mon	Presentations I			
Dec	2	Wed	Presentations II			
Dec	8	Tue	Project Report Due			

Labs

- Labs will be provided to give extra instruction on topics covered in the course. In general, they will be held in the evenings
- Below are tentative schedule and topics
  - Sep 14: Basic networking I
  - Sep 23: Basic networking II
  - Sep 28: SDN experimental environment
  - Oct 7: Tools and libraries
  - Oct 14: Midterm review

Collaboration Policy

1. Students may talk generally about the subject matter of the class and lectures with one another, as this is an excellent way to better learn and understand the material
2. However, they cannot talk about or collaborate on the midnight quizzes. If clarifications are needed on questions, students should contact the teaching staff directly via Piazza or come to office hours. When students ask for clarifications on midnight quizzes, responses will be posted on Piazza
3. Students form 2-person or 3-person teams to collaborate on course projects and related research presentations. For this work, students may only work within their own groups. Projects can be small, but must be original work by students for this course. Copying work used in another course or projects by others is not allowed

Late Day Policy

- No late days are allowed for midnight quiz submissions
  - Note, however, that bottom 2 quiz scores received on submitted questions will be ignored for each student
- A total of five late days are allowed for project checkpoints 1, 2, 4 and 5 (checkpoint 3 is f2f)

Administrative Information

1. Instructor:
   – HT Kung <kung@Harvard.edu>
   (see http://www.eecs.harvard.edu/htk/)
2. TF:
   – Marcus Comiter <mcomiter@g.harvard.edu>
3. Lecture notes and lab materials will be available. No textbooks are required
4. Lab sessions will be announced online
5. Course Website:
   – https://canvas.harvard.edu/courses/6673
6. Course message board on Piazza:
   – To enroll, visit https://piazza.com/harvard/fall2015/cs144r244r

Course Grading Formula

1. Answers to midnight quizzes: 20%
2. Helpful comments on Piazza: 5%
3. Classroom participation and discussion: 5%
4. Project proposal: 10%
5. Project checkpoints: 25%
6. Midterm: 10%
7. Research presentation on related work: 10%
8. Project presentation and report: 15%

CS244R vs. CS 144R

Students may choose to take the class as either CS144R or CS244R

Note the following:

1. In assigning grades, CS244R will assume a higher standard than CS144R
2. That is, B-, B, B+ and A- for CS244R will become B, B+, A- and A for CS144R, respectively

Course Sign Up

1. If you are interested in taking the class (I hope you are), please email:
   kung@harvard.edu
   with **YES** on the subject line
2. This will help the teaching staff determine resources required for the course
3. This will also let you receive course announcements immediately