CS 268
Graduate Computer Networks

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Spring 2021

About me: Sylvia Ratnasamy

- Background
  - PhD from UC Berkeley
  - Worked in industry ~10 years
  - Returned to UCB to join the faculty in 2011
  - Co-founded a startup (in the NFV space) in 2016
  - Networking has been my focus throughout

- My teaching style
  - I'm a much better teacher when you engage with my questions!
  - I talk too fast -- the more bored you look, the faster I talk!

CS268 via Zoom

- Not ideal but let's try our best to make it work – will need your help for this!

- Here's the current plan but we can iterate as we go:
  - Please turn on your video!
  - I will not "mute all"; do mute yourself if you're in a noisy environment
  - If you have a question/comment:
    - Raise your (zoom) hand or post your question in the chat window
    - If the presenter doesn't spot it, feel free to just interrupt
    - Presenters: periodically stop and poll for questions
  - We'll use breakout rooms for discussions (more on this later)

Today's lecture

- What is this course about?
- Course logistics

Goals of this course

- To become familiar with Internet research
- To learn how to analyze a proposal
  - Critique problem selection *and* solution
- To get some practice in the art of expressing your point of view
- To apply what you've learnt by doing an original piece of work

What's involved? Quick glance.

- Read ~50 papers
- You submit a review for each paper
- We'll discuss them together in class
- Each student will lead the in-class discussion for one paper
- You define, execute, and present a research-oriented class project
- No exams or problem sets!
- 7 fantastic guest speakers!

Why is any of this interesting?

(1) The Internet is important

The Internet has transformed everything

- The way we do business (retail, advertising, cloud computing)
- The way we have relationships (facebook, twitter)
- The way we learn (wikipedia, search engines, MooCs)
- The way we govern (e-voting, censorship, cyber-warfare)
- The way we cure disease (digital health, remote medicine)

(2) Designing for the Internet is uniquely challenging

What's your formal model for the Internet? -- theorists

Isn't this just about writing code for a new type of system? – OS community

You don't have performance benchmarks??? – hardware folks

What are the top 10 problems in networking?– new grad students

(2) Designing for the Internet is uniquely challenging

- Tremendous scale
- Enormous diversity
- Prone to failure
- Distributed and asynchronous
- A federated system
  - Competing network providers cooperate to provide a universal service!
  - This complicates innovation: how do you differentiate when interoperability means supporting common protocols?

(2) Designing for the Internet is uniquely challenging

- Tremendous scale
- Enormous diversity
- Prone to failure
- Distributed and asynchronous
- A federated system
- Shared by stakeholders with varying incentives
  - Leads to a constant tussle between business and technical factors

Architectural questions tend to dominate Internet design

- Definition, decomposition, and placement of function
  - What to do, where to do it, who does it
- The “division of labor”
  - Between hosts and the network; between vendors, operators, users; between HW and SW

(2) Designing for the Internet is uniquely challenging

What's your formal model for the Internet? -- theorists

Too complex for theoretical models

Isn't this just about writing code for a new type of system? – OS community

"Working code" doesn't mean much

You don't have performance benchmarks??? – hardware folks

Performance benchmarks too narrow

What are the top 10 problems in networking?– new grad students

Depends who you ask!

The creation of the Internet required a new design paradigm
(One that changed computer science!)

The Internet design paradigm

- Decentralized control
- Layering
- Best-effort
- IP as “narrow waist” interface
- Dumb network / smart endpoints
- The end-to-end design principle
- Fate-sharing

A radical departure from systems at the time

Example: a best-effort service model

- Fundamental question: what's the right service model that a network should support?
  - "contract" between network and its users/end-hosts

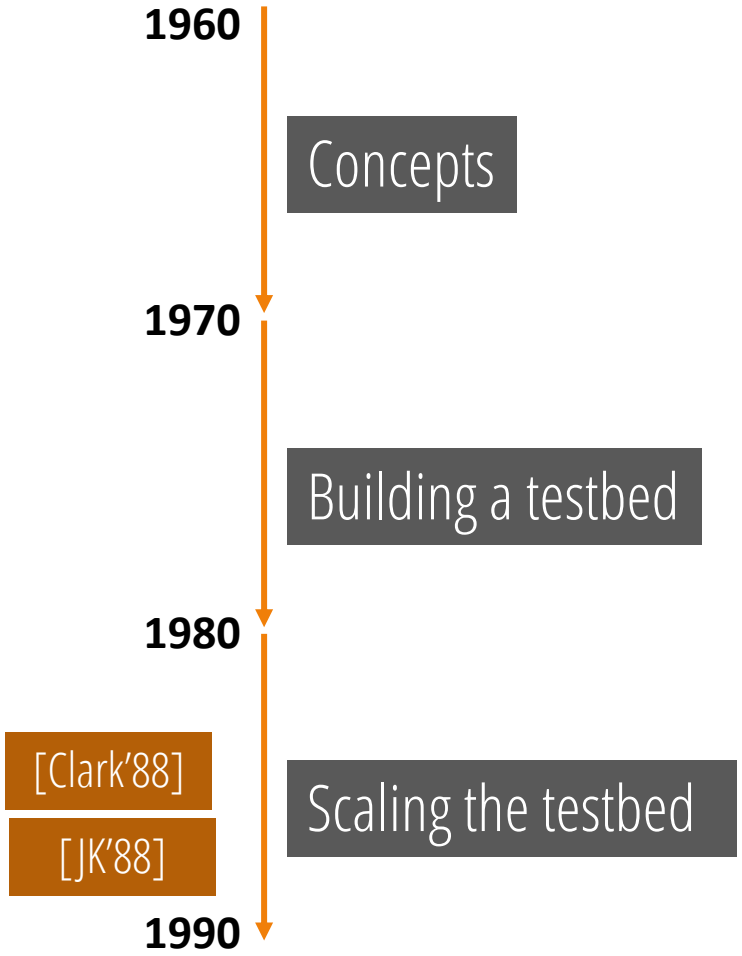
- Some possibilities:
  - "guarantee that data will be delivered"
  - "guarantee that data will be delivered within X time"
  - "return a confirmation of successful delivery or an error"

- Instead, what the Internet supports: "best effort" delivery of data
  - No guarantee on whether or when data will be delivered
  - No notification of outcome!

So, is networking about studying a beautiful design from the past?

"But the Internet seems to be working now …" – *my parents*

(3) The Internet architecture is constantly evolving



packet switching

statistical multiplexing

Military interest in a communication infrastructure to withstand a nuclear attack

NCP

email

TCP/IP

Scientists want to share data

DNS

CIDR

Congestion Control

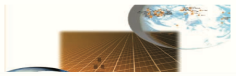
The rise of Ethernet and the PC

Email as killer app

Leading to commercialization and the beginnings of a new field in computer science

Leading to a new economy but also the rise of vendors and a trajectory of complexity and rigidity

Overcoming the Internet Impasse through Virtualization



A Blueprint for Introducing Disruptive Technology into the Internet*

1990

Tussle in Cyberspace: Defining Tomorrow's Internet

David D. Clark
MIT Lab for Computer Science
ddc@lcs.mit.edu

John Wroclawski

is king" – *Bill Gates (1996)*

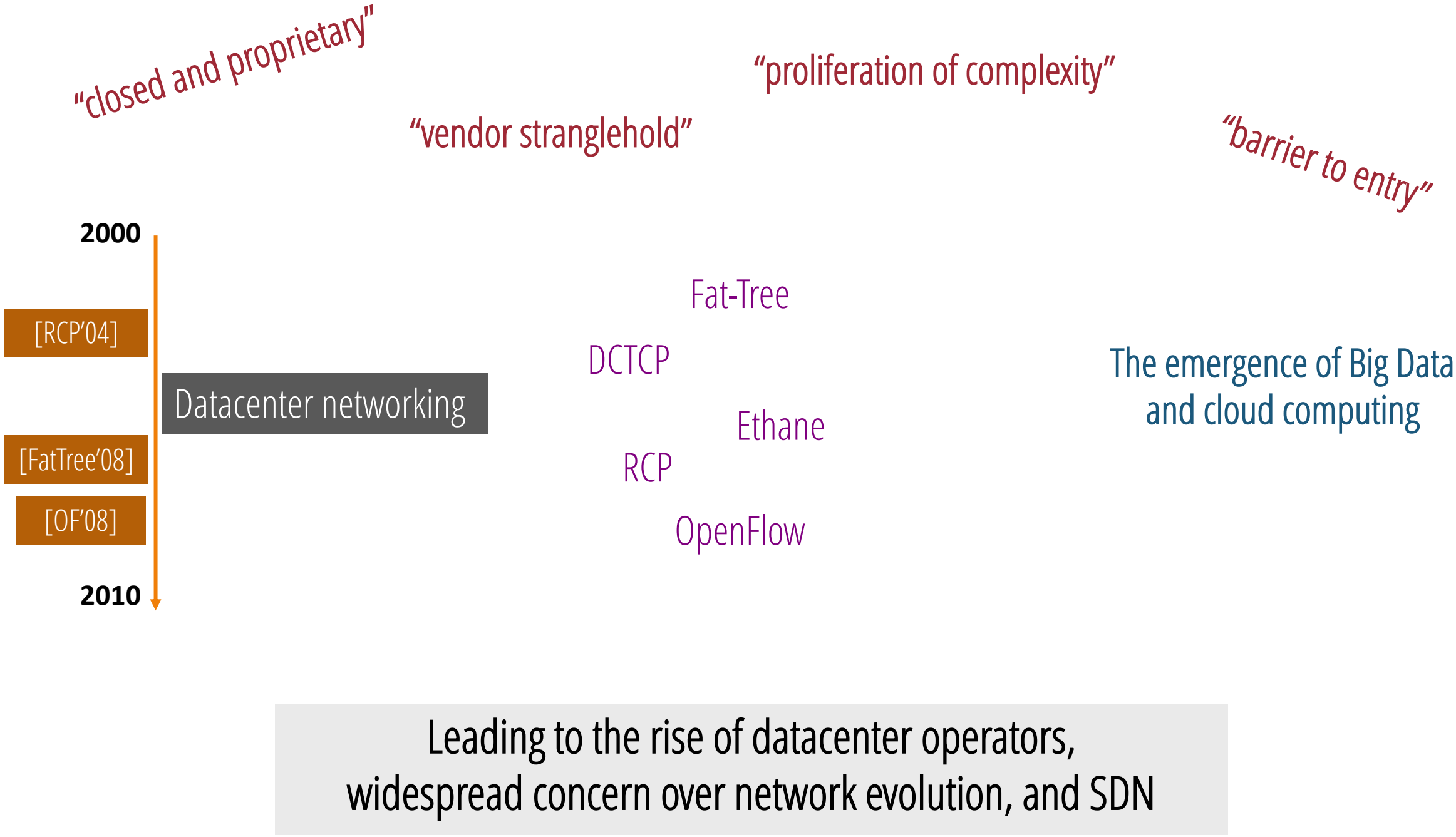
2000

A Clean Slate 4D Approach to Network Control and Management *

Albert Greenberg, Gisli Hjalmtysson, David A. Maltz, Andy Myers,
Jennifer Rexford, Geoffrey Xie, Hong Yan, Jibin Zhan, Hui Zhang

Leading to a new economy but also the rise of vendors and a trajectory of complexity and rigidity

And (research) concern over network evolution



Leading to the rise of datacenter operators,
widespread concern over network evolution, and SDN

Network programmability
(by network operators)

SDN

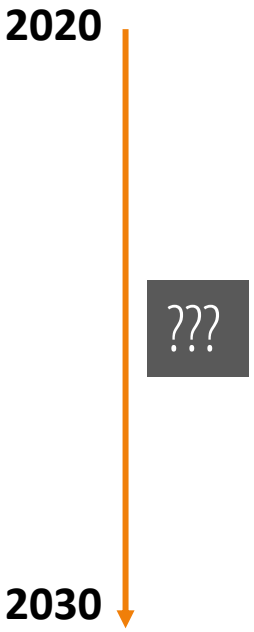
NFV

RMT (prog. hardware)
& SmartNICs

Disaggregation

Cloud, Big Data, and AI

Leading to ???



Blurring boundary between cloud providers and Telcos (edge)

IoT

The end of Moore's law and Dennard's scaling

Societal issues: equal access, privacy, censorship

Simplification

Your thoughts?

Leading to ???

Architectural questions tend to dominate Internet design

- Constant evolution means we're always revisiting the big questions!

- Example: data delivery decomposed into computing routes and forwarding packets
  - Computing routes: implemented in routers (in control plane software)
  - Forwarding packets: implemented in routers (in data plane hardware)

- SDN: implement route computation *outside routers*, in a *centralized manner*
- NFV: implement (some) packet forwarding *outside routers,* in *software*
- Programmable switches: packet forwarding in routers, but *defined by operators*

Network architecture*

- More about thinking rigorously than doing rigorous math
- More about understanding tradeoffs than running benchmarks
- More about practicality than optimality

Done right, can be a powerful thing

Network architecture*

- More about thinking rigorously than doing rigorous math
- More about understanding tradeoffs than running benchmarks
- More about practicality than optimality

Done right, can be a powerful thing

The Internet design paradigm

- Decentralized control → SDN: centralize?
- Layering
- Best-effort → Cloud networking?
- IP as “narrow waist” interface
- Dumb network / smart endpoints → NFV and prog. HW: richer in-network compute?
- The end-to-end design principle → middleboxes?
- Fate-sharing → edge computing?

Why is any of this interesting?

1. The Internet is important

2. Designing for the Internet is uniquely challenging

3. The Internet is constantly evolving
   - Means new (challenging and important) problems to tackle
   - Means new opportunities for impact!

Today's lecture

- What is this course about?
- Course logistics

Course information

- Syllabus and announcements:
  - https://piazza.com/berkeley/spring2021/cs268/home
- Lecture will start on “Berkeley time” (9:40am)
- Reach me on piazza or email (sylvia@eecs.berkeley.edu)
- Prereq: CS168 or equivalent (http://cs168.io)

Grading

Paper reviews and class participation	30%
Paper presentation	30%
Term project	40%

- Can miss up to 3 paper reviews with no penalty (don't need to inform me when you do)
- Frequent absenteeism will affect your grade

Papers we will read

- A bit of architecture (principles, service models)
- A bit of how things work (algorithms, infrastructure)
- A bit of the classics (QoS, Active Networks)
- A bit of recent directions (SDN, NFV, satellites, censorship)

- Topics that are given short shrift
  - Wireless, security (see Vern's class)

Why these papers?

- Papers that changed **practice**; e.g., [J88, OF]
- Papers that changed **how** we think; e.g., [XCP, Jellyfish, Consensus]
- Papers that changed **what** we think about; e.g., [verification, space-nets]
- Papers that brought **awareness**; [pktDynamics, Aplomb]
- Papers that brought **clarity**; e.g., [Design, E2E]

Reading papers

- Plenty of advice out there
- My take: don't overthink it. Just read it. Start to end. In depth.
- Then set the paper aside and think
    - What problem are they solving? -- in 1-2 sentences
    - Replay their motivating arguments – do they make sense?
    - Replay how their solution works for a simple example -- can you? If not, go back to step 1.
- Once you're sure you understand, start critiquing
    - Is the problem important? ambitious? hard? have a long shelf-life?
    - Is the solution effective? Under what conditions does it break?
    - What other approaches are possible? Etc.

Reviewing papers

- Write a short review for each paper
  - Review ≠ summary !!
  - Length: less than one page
  - Be honest
- Submissions via google forms - I will post the link on piazza
- Reviews are due 5pm the night before class

Typical format of the review

1. What is the problem being addressed?
2. Do you believe the problem is/was important?
   - Explain your thinking
   - Consider context
3. What is the solution's main insight (nugget)?
4. Do you think the solution is a good one? (strengths and weaknesses)
   - Explain
5. Did you enjoy the paper?

Lecture format

- 40 minutes per paper
  - ~15 minutes presentation and initial discussion
  - ~10 minutes discussion in breakout rooms
  - ~15 minutes deep-dive discussion all together

- Class discussion
  - Come prepared to discuss the main ideas, gaps, etc
  - We will all learn from each other
  - ~~Let's have no open laptops in class~~

Presenting Papers

- Each of you will be responsible for presenting and leading the discussion on one paper

- Go through the syllabus and and fill out a form with your preferred papers by 5pm on Saturday, January 23th
  - I will post the form on piazza today after lecture
  - I will follow a first-come-first-serve policy for assignments

- Student presentations will start on 02/02

Presenting papers (cont'd)

- Organize presentation to suit your style
  - Summarize-then-discuss, discuss-as-you-go, ...

- Some tips/expectations
  - Assume the class has read the papers →recap, don't explain
  - Go beyond the assigned paper: your job is to give the class a more complete picture
  - Prepare a set of questions to initiate discussions

- Send me your slides at least THREE days before your presentation

- Recall: this is 30% of your grade

Research Project

- Ideally, work with a partner

- Investigate new ideas and solutions
  - Start early and consider scope

- Deadlines:
  - Due 02/28 (midnight): Submit a 1-2 page project proposal
  - 04/27 and 04/29: In-class project presentations
  - Due 05/13 (midnight): final project writeup

Recap: this course

- We will read and review ~50 papers

- Three components to your grade
  - Project (40%)
  - Paper presentation (30%)
  - Paper reading and class participation (30%)

Next Lecture

- Classics in Internet design
  - Required reading: design principles [Clark'88]
  - Optional reading (but highly encouraged): end-to-end principle [Clark'81]

- You must turn in a review for [Clark'88]

- Given the short deadline you can submit reviews up to 10pm on Wednesday

Recap: Your Immediate Action Items

- Read and review Clark'88 by tomorrow 10pm
- By this Saturday (January 23) submit your preferences for papers you'd like to present
- If you plan to drop this course, please let me know promptly (and unregister on piazza)

Thanks!