CPSC 438/538:
Big Data Systems
Trends & Challenges

Anurag Khandelwal

Yale

Today’s Agenda

- Introductions
- What is (this course on) big data systems all about?
- Class goals, logistics, policies, and roadmap

Introductions :)

Who am I?

- Anurag Khandelwal (He/him/his)
- Assistant Professor in CS, started Spring 2020 (Office: **AKW 205**)
- **Research:** Distributed Systems & Networks; Algorithm & Data structure design
- **Non-research:** Amateur mixologist (shh!), all things sci-fi (that's what got me into CS), voracious reader and aspiring writer (emphasis *aspiring*)
- Happy to talk about research and non-research interests!

Call me (in order of preference)

Anurag > Prof. Anurag > Prof. Khandelwal

(If you must)

Meet your TF

- Yupeng Tang (He/him/his)
- 2nd-year PhD student in CS, Advised by Anurag Khandelwal
- **Research:** Distributed Systems, Resource Disaggregation
- **Non-research:** Biker, photography lover, True basketball fan & player (Go LAL!)

Your turn now…

- What should we call you? What do you want to take this course? (At least one) non-academic interest?
- There are about 40 of you either registered or visiting
  - Even if we kept 1 min introductions, it would take 40 mins ;)
- Instead, let's use Ed Discussions to introduce ourselves
  - Look out for a post after the class today!
  - We will also get to know each other through project meetings (more on that later)

Let’s keep it interactive…

- This course will be a bit different from your traditional courses
- We’ll discuss details on how its different towards the end
- For now, just remember to keep this interactive
  - Think of it as a ***discussion,*** not a ***lecture***

What are Big Data Systems?

What is Big Data?

- Exactly what it sounds like…
- Why is “big data” important?
- What is “big”?
- Why is handling “big data” hard? Why do we need specialized systems for it?

Why is Big Data Important?

Helped create new businesses!

Helped disrupt existing businesses!

Retail: amazon

Rental: airbnb

Taxi: Uber lyft

Smart Home: nest ring

And is continuing to do so…

What is “Big” in Big Data: A Brief History[1]

Google, 1998

WELCOME TO THE GATHERING PLACE

Computer Networks and ISDN Systems 30 (1998) 107–117

COMPUTER NETWORKS and ISDN SYSTEMS

The anatomy of a large-scale hypertextual Web search engine [1]

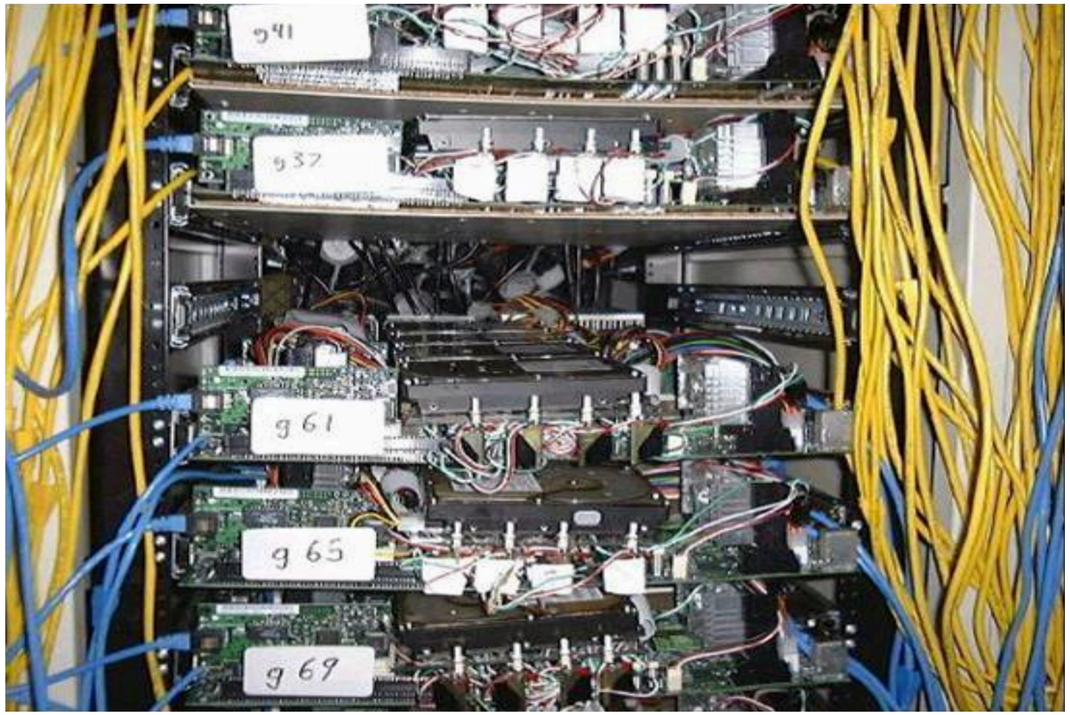
Sergey Brin [2], Lawrence Page [*,2]

Computer Science Department, Stanford University, Stanford, CA 94305, USA

“…Storage space must be used efficiently to store indices and, optionally, the documents themselves. The indexing system must process hundreds of gigabytes of data efficiently…”

[1]History adapted from Shivaram Venkataraman’s Slides

What is “Big” in Big Data: A Brief History

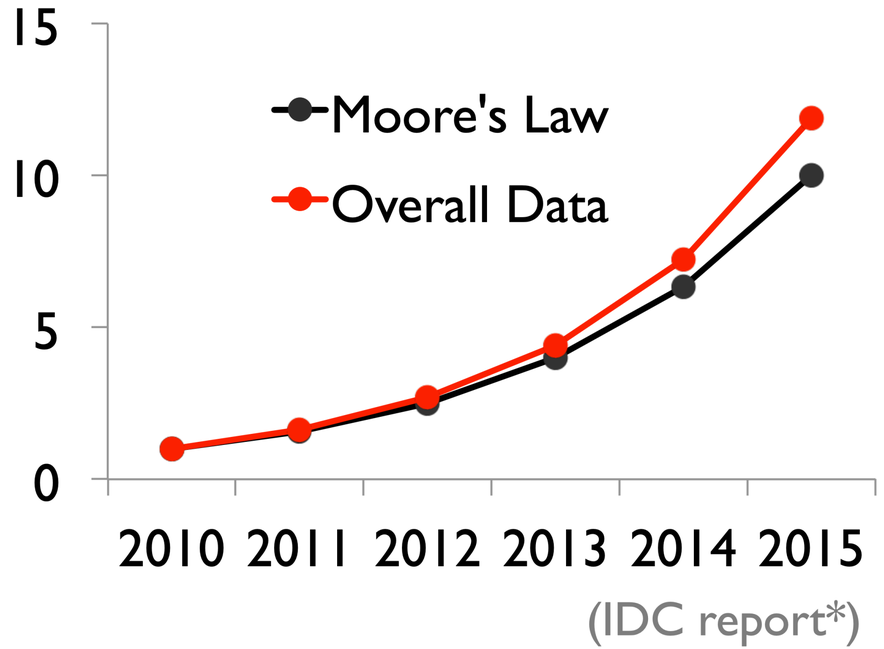


Google, 2001

- Commodity CPUs
- Lots of disks
- Low bandwidth network
- Cheap!

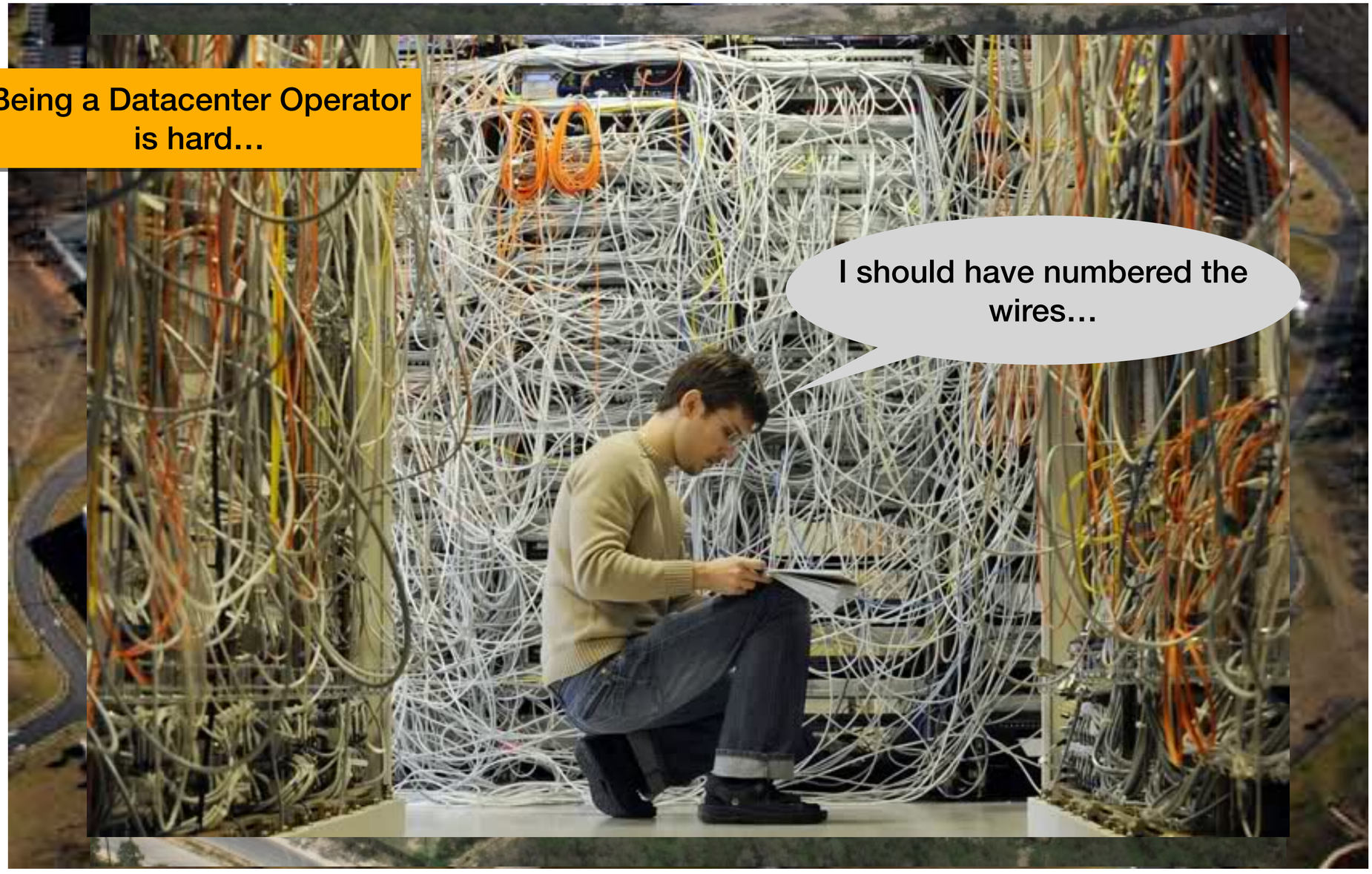
Datacenter Evolution

- **Early 2010s:** Data growth at unprecedented rates
  - Facebook's daily logs: **60 TB**
  - Google's web index: **10+ PB**
  - Scientific data: **2PB** for solar-flare prediction
- **Lead to the Datacenter Evolution!**
  - Large, inexpensive network of servers comprising commodity hardware



(IDC report*)

Datacenters Today



How Big are Datacenters Anyway?

- **> 1million servers/site [Microsoft/Amazon/Google]**
- **> $1billion to build a site [Facebook]**
- **> $20million/month/site operational costs [Microsoft]**

To handle massive volumes (petabytes) of data!

But users expect same performance, regardless of data size

What’s so hard about big data?

Challenge#1: Need performance at scale

- *“How do I answer your google search query in < 100ms over PBs of data, using ~tens of thousands of servers?”*

The joys of commodity hardware: Jeff Dean @ Google

Typical first year for a new cluster:

- ~0.5 overheating (power down most machines in <5 mins, ~1-2 days to recover)
- ~1 PDU failure (~500-1000 machines suddenly disappear, ~6hours to come back)
- ~1 rack move (plenty of warning, ~500-1000 machines powered down, ~6 hours)
- ~1 network rewiring (rolling ~5% of machines down over 2-day span)
- ~20 rack failures (40-80 machines instantly disappear, 1-6 hours to get back)
- ~5 racks go wonky (40-80 machines see 50% network traffic lost)
- ~8 network maintenances (4 might cause ~30 min random connectivity issues)
- ~12 router reloads (takes out DNS and external vIPs for a couple of mins)
- ~3 router failures (have to immediately pull traffic for an hour)
- ~dozens of minor 30-second blips for DNS
- ~1000 individual machine failures
- ~thousands of hard drive failures
- Slow disks, bad memory, misconfigured machines, flaky machines, etc.
- Long distance links: wild dogs, sharks, dead horses, drunken hunters, etc.

Failure is a part and parcel of datacenter life

What's so hard about big data?

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Challenge#2: Failures happen all the time

- *"How do I provide reliable google maps service when my servers are failing all the time?"*

The Rise of Public Cloud

- **Pre-2006 world**
  - Amazon had huge datacenters that only ran @ 10% capacity for most of the year
  - Why?

Christmas shopping

amazon

aws

Today: 12.5% of total Amazon revenue

Yes, Andy?

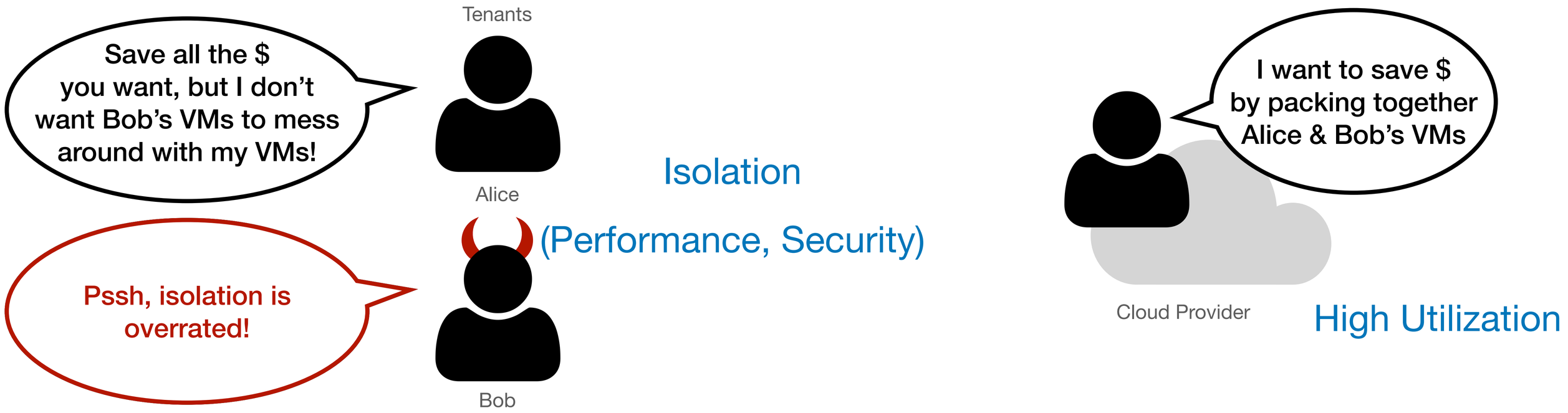
Jeff Bezos

Andy Jassy

Why don't we rent out our unused capacity?

Public Cloud & Infrastructure as a Service

- Users (***tenants***) ***rent*** out slices of a server (virtual machines, ***VMs***) from ***cloud provider***
- Gives rise to ***multi-tenancy***: multiple tenants must now share the infrastructure
- How does this affect tenants? Cloud providers?



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Challenge#3: Sharing with high utilization & isolation

- *"How do I run Netflix and Twitch on together on AWS cost-efficiently, without letting either service compromise on security or performance?"*

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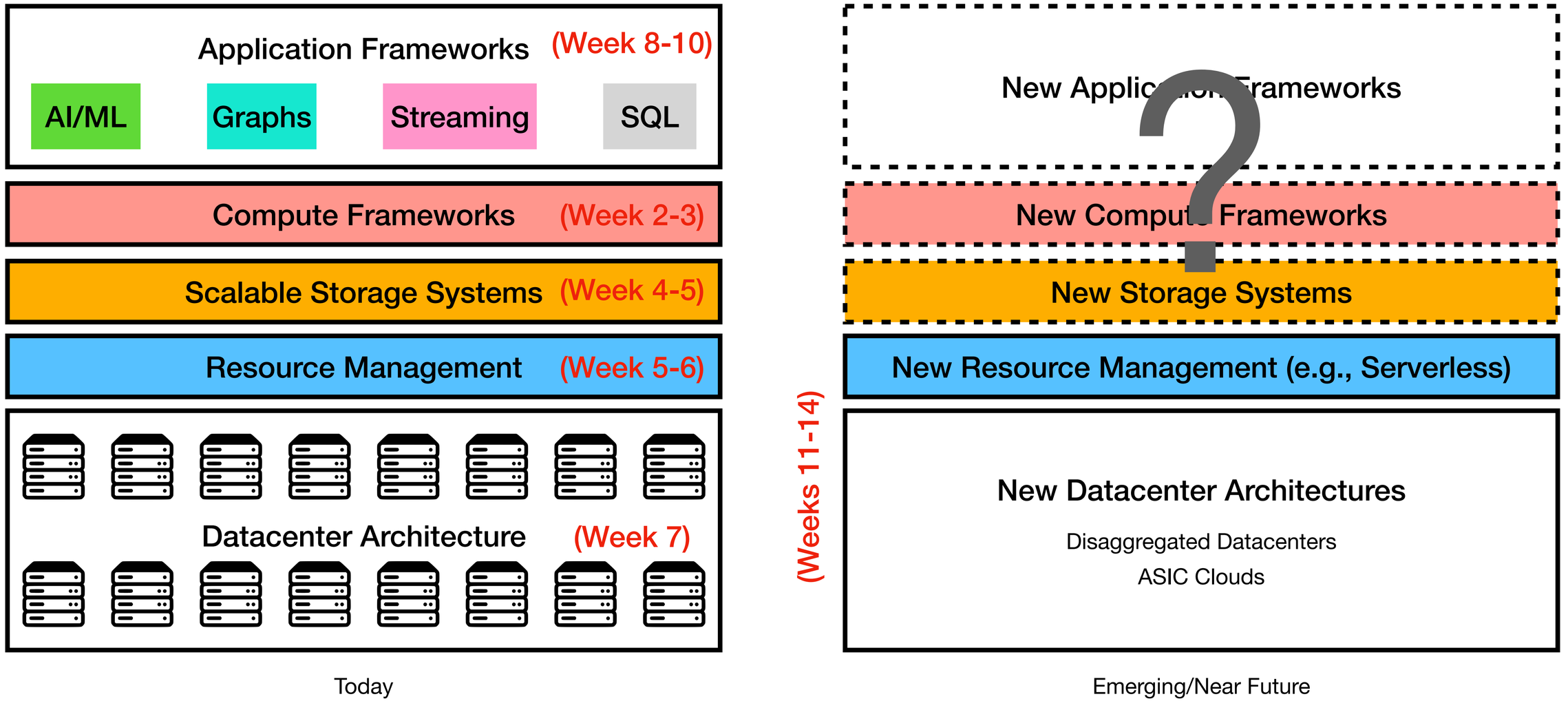
And many more challenges… (later in the course)

Big-data systems:
Managing the Complexity

Big Data System Stack



Administrivia

Course Goals

At the end of the course, you will be able to:

- Explain the design and architecture of big data systems
- Compare, contrast and evaluate research papers
- Design, articulate and report new research ideas

Paper Reviews

Discussion

Research Project

Paper Reviews

- Every class has 2 required paper readings (along with some optional ones)
- You are required to fill out paper review for **at least one of the two papers** using the google form linked on Canvas
- Must be submitted latest by the **noon before the class,** i.e., Monday and Wednesday noon.

How many of your have never read research papers before?

How to read a paper?

- **Some really good resources for this:**
  - *How to Read a Paper*, S. Keshav (linked on Canvas)
  - *Efficient Reading*, Michael J. Hanson (linked on Canvas)
- **2 Pass approach:**
  - *Pass#1:* Read abstract, introduction, section headings, conclusion
  - *Pass#2:* Read all sections, make notes
    - What is the problem? Key contributions? How do they improve over prior work? What is their technical contribution? What was the evaluation setup? Does it back up their claims in earlier parts of the paper?…

What will your paper review contain?

- **Problem Statement (1-2 sentences) (1 point)**
- **Why are existing solutions insufficient? (1 point)**
- **Solution summary (1-2 sentences) (2 points)**
- **3 Strengths, 3 Weaknesses (3 points)**
- **Validity of evaluation (i.e., does evaluation back up claims?) (2 points)**
- **One idea for future work (1 point)**

Paper Discussion

- For classes marked as discussions, **students will lead discussion**
  - **Goal:** Learn how to present research, learn how to evaluate and discuss research
- Each student will have to lead **~1-2 discussions (depending on number of students registered), ~30 mins per paper**
- If you are presenting a paper, you will read the paper, prepare a presentation, and send me the slides **2 days before** the designated class for review
- How to prepare the presentation?

How to Lead a Discussion?[1]

- Assume everyone (including you) has read all the papers.
- 2 papers per 75 min class: 30 min per paper, 5 min break, 10 min synthesis.
- **Discussion Lead first summarizes the paper [20 mins]:**
  - What is the problem the authors are trying to solve?
  - How did prior work address the problem, and where did they fall short?
  - New “technical nugget” in this paper: **this is where you spend most time**
  - How did they evaluate their claims?
  - **Note:** with questions, this may already take up 30 mins, and that’s ok!

[1]Adapted from notes by Randy H. Katz; original notes linked in Canvas

How to Lead a Discussion? [Contd.]

- **Discussion Lead then moderates the discussion [10 mins]:**
  - Be ***fair but critical*** of the paper
  - Is the problem real, or fabricated for “publishing a paper”?
  - Are the assumptions reasonable, or simply chosen to make analysis easy?
  - Is the approach feasible, or in impractical to implement?
  - Is their evaluation methodology appropriate, or are key elements left out?
  - What have the authors ***not*** solved, and left to future research?
    - We stand on the shoulder of giants!

Research Project

- Main graded component of the course (60-70%)!
- In groups of ***2-3*** people (working alone only through my permission)
  - Expectation for a group of 3 will be > a group of 2 :)
- Inter-disciplinary teams encouraged!
- Pick a new problem of your choice to solve, either:
  - From a suggested list of projects I provide (around 4th class)
  - Or, on your own, from your own sub-area (must be related to big-data systems!)
- I will set up regular meetings for each group, for guidance and help

Research Project: Deliverables

- **Initial project proposal (~2 pages)**
  - Problem statement, survey of related work, high-level idea/approach
- **Mid-term report (~5 pages)**
  - + Details of techniques & system design, + Progress on implementation
- **End-term report (~10 pages)** **(Target: 70-85% of a conference paper)**
  - + Finalized, detailed description of system, + comprehensive evaluation
- **Final project presentation (poster presentation, date TBD)**
  - Will be open to all of CPSC, so show off your hard work!!

Grades

- Last thing you should worry about :-)

Component	438	538
Paper critiques	20%	15%
Paper discussions (lead)	15%	10%
Paper discussions (non-lead)	5%	5%
Project: Initial Project Proposal	10%	10%
Project: Mid-term Report	15%	20%
Project: End-term Report	20%	25%
Project: Presentation	15%	15%

30-40%

60-70%

Class Communications

- **Canvas for lecture slides (from me), discussion slides (from you)**
- **Canvas for submitting project reports**
- **Ed Discussions for all discussions**
- **Will setup 30 min project meetings after groups are finalized**
  - In person at AKW 205, can be on Zoom if necessary
- **No regular OH (me or TA)**
  - Already have project meetings!
  - Happy to schedule meeting by appointment!

Summary

- Learn about and evaluate state-of-the-art research
- Work on exciting project — **start next generation of impactful research :-)**

Next tasks:

- Introduce yourself on Ed Discussions!
- Start forming groups for research project (use Ed Discussions)

Next class:

- Datacenter as a computer + hardware trends over the years
  (see reading — summary not needed!)