15-319 / 15-619
Cloud Computing

Recitation 1

Course Overview and Introduction

January 15 and 17, 2019

http://www.cs.cmu.edu/~msakr/15619-s19/

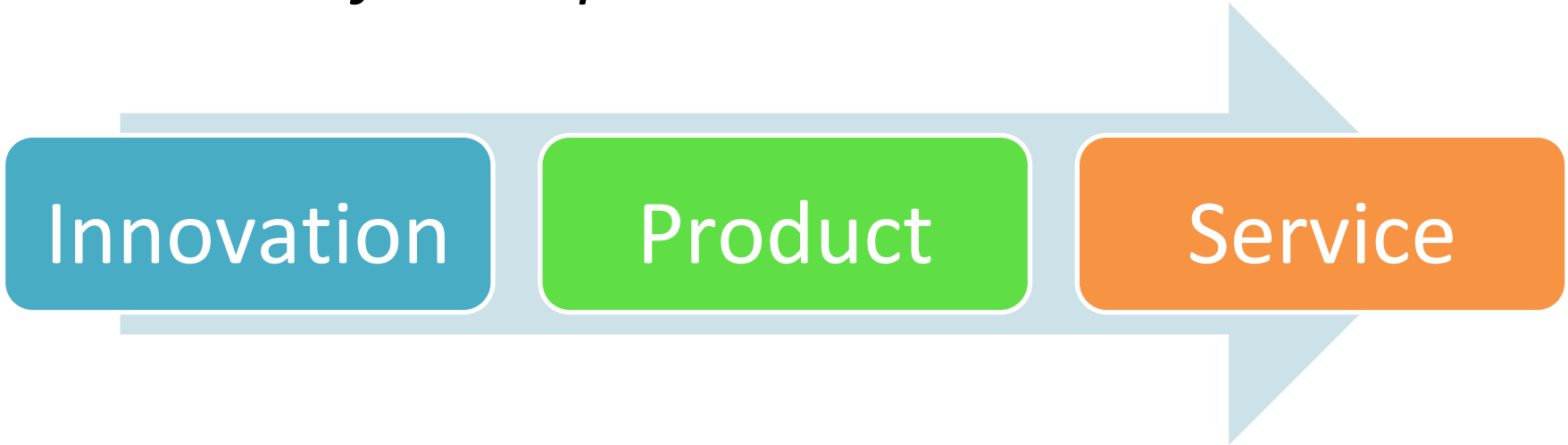
Outline

- **What is the course about?**
- What is an online course?
- Administrivia

So What is Cloud Computing?

Evolution of Computing

Cloud Computing is the transformation of“
”IT from a product to a service



Evolution of Electricity

Innovation

New Disruptive Technology

Product

Buy and Maintain the Technology

Service

Electric Grid, pay for what you use

A Cloud is …

- Datacenter hardware and software that the vendors use to offer the computing resources and services

Cloud-enabling Data Centers

- Large warehouse scale data centers
- Growing at a rapid rate
- Next is an example from Microsoft Azure
  - Azure US-East2 (Boydton, VA)
  - Azure Expansion 1
  - Azure Expansion 2

Microsoft Azure

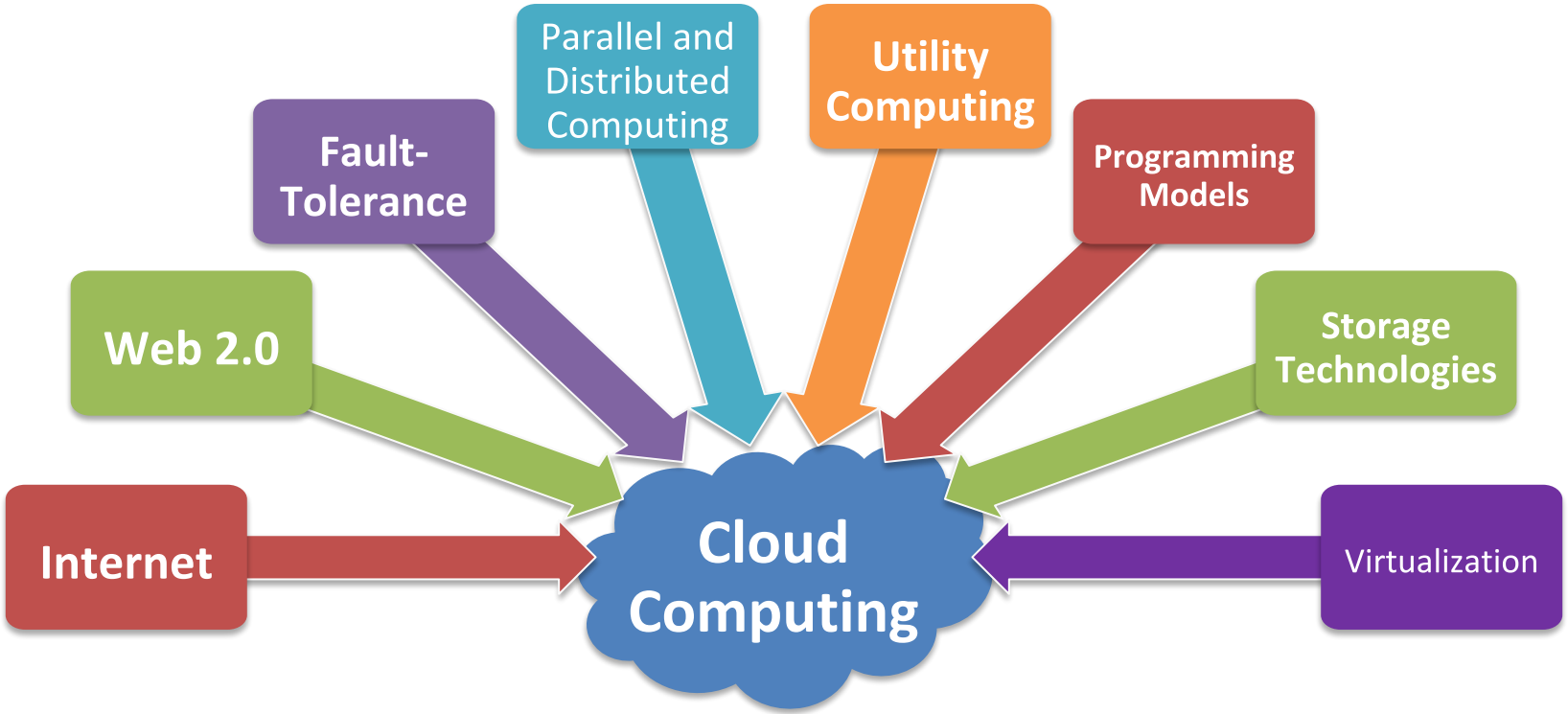

US-East2 (Boydton, VA)


US-East2 (Boydton, VA)


US-East2 Hub Expansion

The Cloud

Enabled by Maturing Technologies



So… how would you transform information technology into a Service?

How to Transform IT to a Service?

- Connectivity
  - For moving data around
- Interactivity
  - Seamless interfaces
- Reliability
  - Failure will affect many
- Performance
  - Should not be slower
- Pay-as-you-Go
  - No upfront fee
- Ease of Programmability
  - Ease of development of complex services
- Manage Big Data
- Efficiency
  - Cost
  - Power
- Scalability & Elasticity
  - Flexible and rapid response to changing user needs

How to Transform IT to a Service?

Internet

Web 2.0

Fault-Tolerance

Parallel / Distributed Systems

Utility Computing

Programming Model

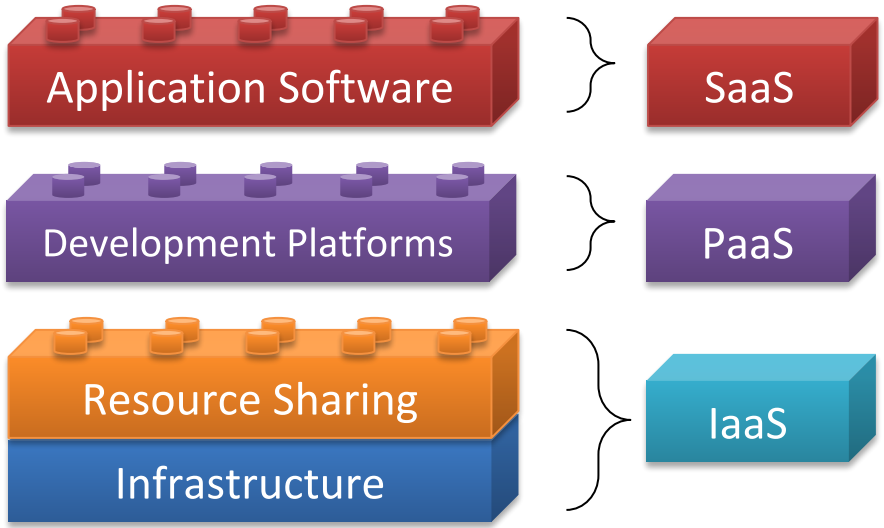
Storage Technologies

Virtualization and Resource Sharing Technologies

Cloud Building Blocks

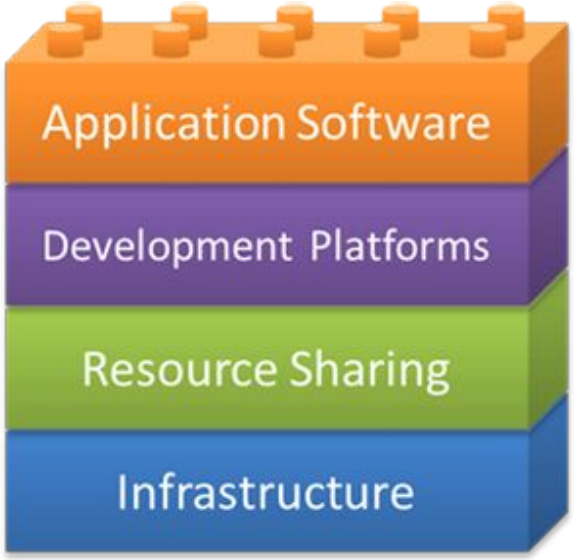
Cloud services are available in various forms, corresponding to the layer of abstraction desired by the user

- Software as a Service (**SaaS**)
- Platform as a Service (**PaaS**)
- Infrastructure as a Service (**IaaS**)



Cloud Computing Stack

- Applications
- Development Platforms
- Elasticity
  - APIs to enable automation,
    Alarms, protocols, triggers, etc…
- Sharing mechanisms
  - Virtualization, Containers, …
- Distributed systems
  - Programming models
  - Storage
- Data centers



What is this course about?

- Applied aspects of cloud computing
  - Between systems and services

Conceptual content on OLI

1.0 Introduction to Cloud Computing
Service and deployment models, economics and use cases

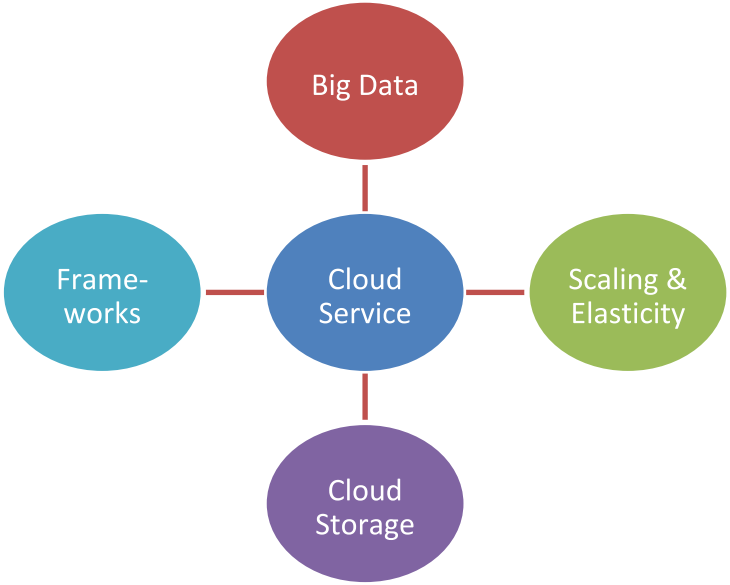
2.0 Cloud Infrastructure
Components, design considerations and power

3.0 Resource Sharing
CPU, memory and I/O Virtualization, SDN, SDS

4.0 Cloud Storage
Distributed File Systems and Distributed Databases

5.0 Programming Models
MapReduce, Spark, GraphLab, Kafka/Samza

Projects on AWS, Azure, & GCP



Course Goals

Students gain hands-on experience solving real world problems by completing projects in the areas of cloud **analytics**, **compute and elasticity**, **storage** and **frameworks**, which utilize existing public cloud tools and services. Students are exposed to real-world data, scenarios, infrastructure and budgets in order to learn how to:

1. Design, architect, implement, test, deploy, monitor and maintain cloud-based applications;
2. Identify the appropriate tools and architectures to implement a cloud-based design;
3. Analyze the tradeoffs between different tools and cloud offerings to meet real-world constraints;
4. Evaluate performance characteristics of cloud-based services to implement optimizations;
5. [15-619 only] Collaborate with a team on an open-ended project to incrementally realize an optimized end-to-end cloud-based solution.

Conceptual Content on OLI

Unit #	Title	Modules and Description
1	Introduction	Definition and evolution of Cloud Computing Enabling Technologies Service and Deployment Models Popular Cloud Stacks and Use Cases Benefits, Risks, and Challenges of Cloud Computing Economic Models and SLAs Topics in Cloud Security
2	Cloud Infrastructures	Historical Perspective of Data Centers Datacenter Components: IT Equipment and Facilities Design Considerations: Requirements, Power, Efficiency, & Redundancy Power Calculations and PUE Challenges in Cloud Data Centers Cloud Management and Software Deployment Considerations
3	Virtualization	Virtualization (CPU, Memory, I/O) Case Study: Amazon EC2 Software Defined Networks (SDN) Software Defined Storage (SDS)
4	Cloud Storage	Introduction to Storage Systems Cloud Storage Concepts Distributed File Systems (HDFS, Ceph FS) Cloud Databases (HBase, MongoDB, Cassandra, DynamoDB) Cloud Object Storage (Amazon S3, OpenStack Swift, Ceph)
6	Programming Models	Distributed Programming for the Cloud Data-Parallel Analytics with Hadoop MapReduce (YARN) Iterative Data-Parallel Analytics with Apache Spark & Graph-Parallel with GraphLab Stream Processing with Apache Kafka and Samza

Read the Syllabus

Quiz 1, Jan 25, 2019

Projects on AWS/Azure/GCP Clouds

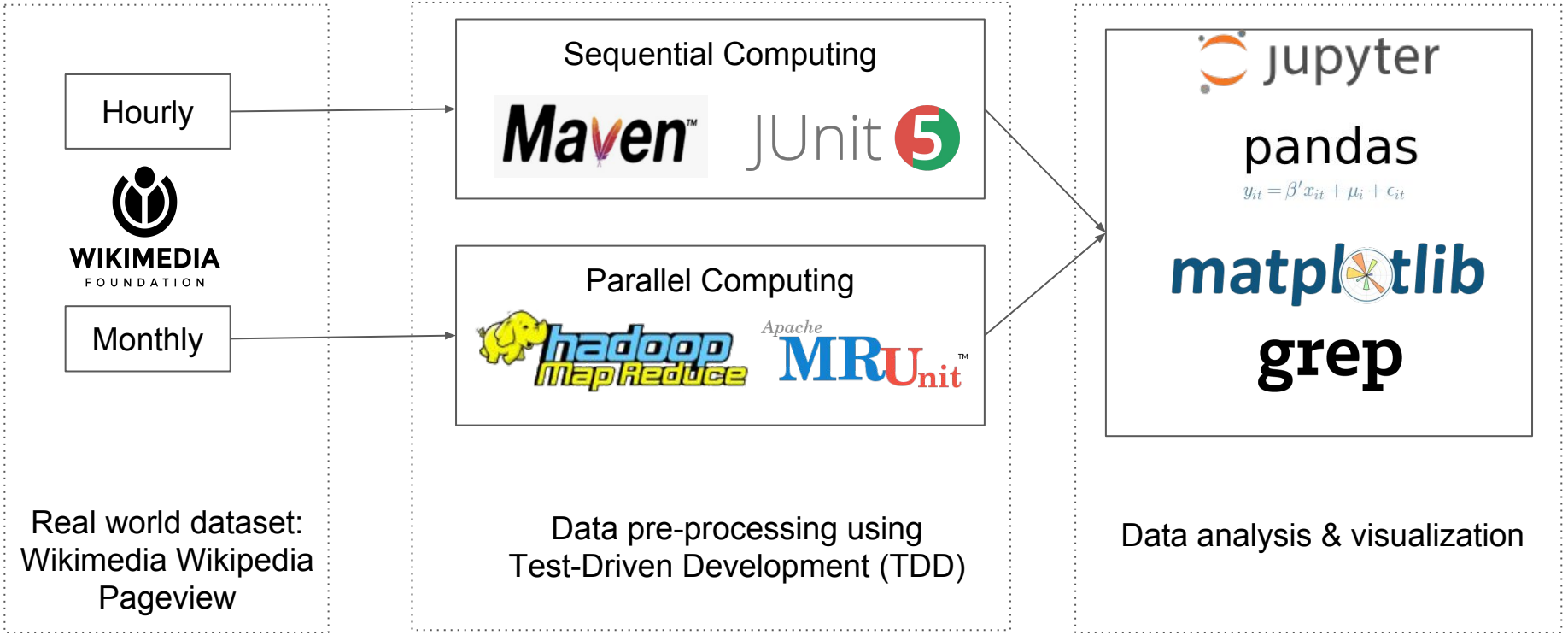
Due 01/20/2019

0. AWS/Azure/GCP Account Setup & Tool Primers	• Benchmarking VMs, SSH, Authentication, Billing, Security Groups, Vertical Scaling
1. Big Data Analytics	• Amazon EC2, Amazon EMR
2. Scaling, Elasticity and Failure	• Auto Scaling, Load Balancing, Monitoring, Docker Containers, Kubernetes, Functions
3. Cloud Storage	• MySQL, HBase, GCP Bigtable, GCP SQL DB, MongoDB
4. Analytics Engines for the Cloud	• Spark, DataBricks, Cloud ML Frameworks, Kafka/Samza
5. A Complete Web Service (**Team project, extra 3-units**)	• No restrictions on tools or AWS services • Evaluated based on cost and performance

Project Learning Objectives

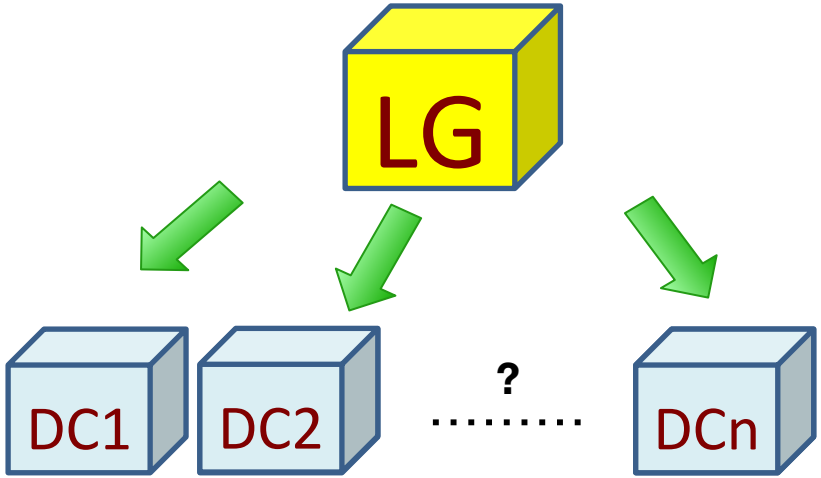
Data Analytics	1) Analyze and visualize small and large data sets on the cloud using interactive computing as well as data manipulation and analysis libraries.
Compute & Elasticity	2) Design, implement, test, package, deploy and monitor cloud applications using Virtual Machines (VMs), Containers and Serverless cloud computing services.
Cloud Storage	3) Explore and experiment with different distributed cloud-based storage abstractions and compare their features, capabilities and applicability. 4) Orchestrate, deploy and optimize a unified application that integrates heterogeneous SQL and NoSQL database systems. 5) Implement and compare consistency models to recognize the tradeoff between consistency and performance in replicated and distributed cloud storage systems.
Frameworks	6) Design, implement, test and debug applications using interactive, batch and stream processing frameworks and compare their suitability to different problem domains. 7) Illustrate and explain the execution workflow, overhead, fault-tolerance and logical flow of interactive, batch and stream processing frameworks. 8) Train and deploy a machine learning model using a cloud-based framework. 9) Analyze and identify potential sources of bottlenecks in programming frameworks to optimize their performance.
Team Project	10) [15-619 only] Design, build, and deploy a performant, reliable, scalable and fault-tolerant web service on the cloud within a specified budget. 11) [15-619 only] Perform extract, transform and load (ETL) on a large data set. 12) [15-619 only] Design schema as well as configure and optimize cloud-based databases to deal with scale and improve the throughput of a web service. 13) [15-619 only] Explore methods to identify the potential bottlenecks in a cloud-based web service and implement methods to improve system performance.
Overall	14) Practice gathering, cleaning and preparing data for analysis on the cloud. 15) Practice Test-driven Development (TDD) in the software development process. 16) Orchestrate and automate the process of managing and provisioning cloud resources through machine-readable definition files. 17) Make informed decisions about choosing an appropriate cloud tool that will satisfy a set of specified requirements.

P1.1 and P1.2: Big Data Analytics



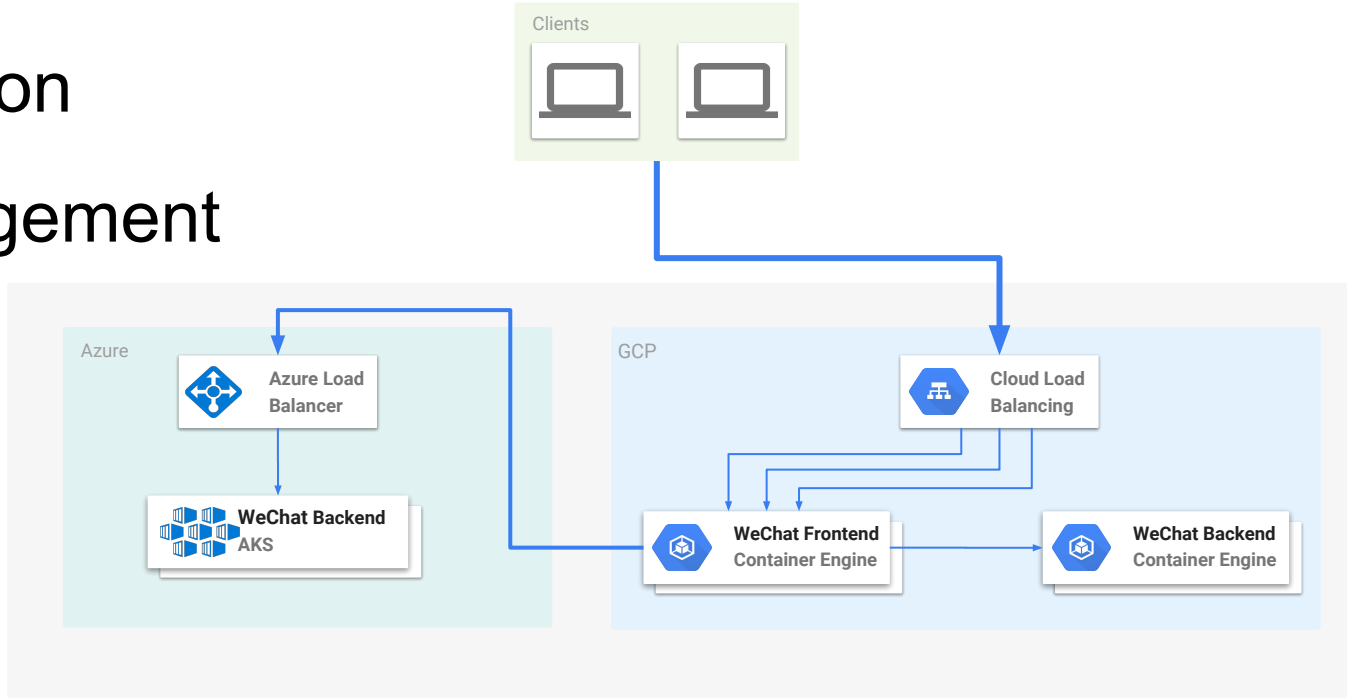
P2.1: VM Scaling, Elasticity & Failure

- Closed VMs
  - Load Generators
    - Dynamic load
  - Data Center Instances
    - Performance & failure
- Scale out & scale in DCIs to achieve desired RPS within budget
  - Auto-scale groups, elastic load balancers, monitoring, etc.



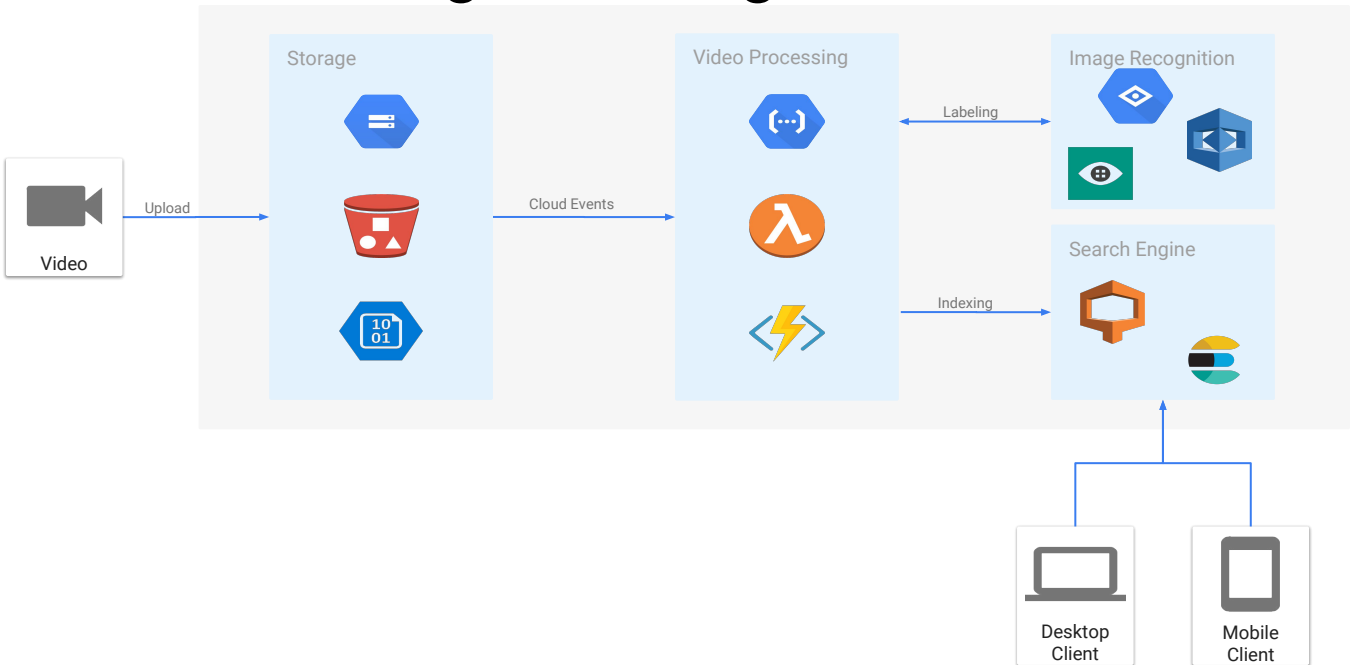
P2.2: Containers and Kubernetes

- Containerization
- Cluster Management
- Multi-Cloud Deployment

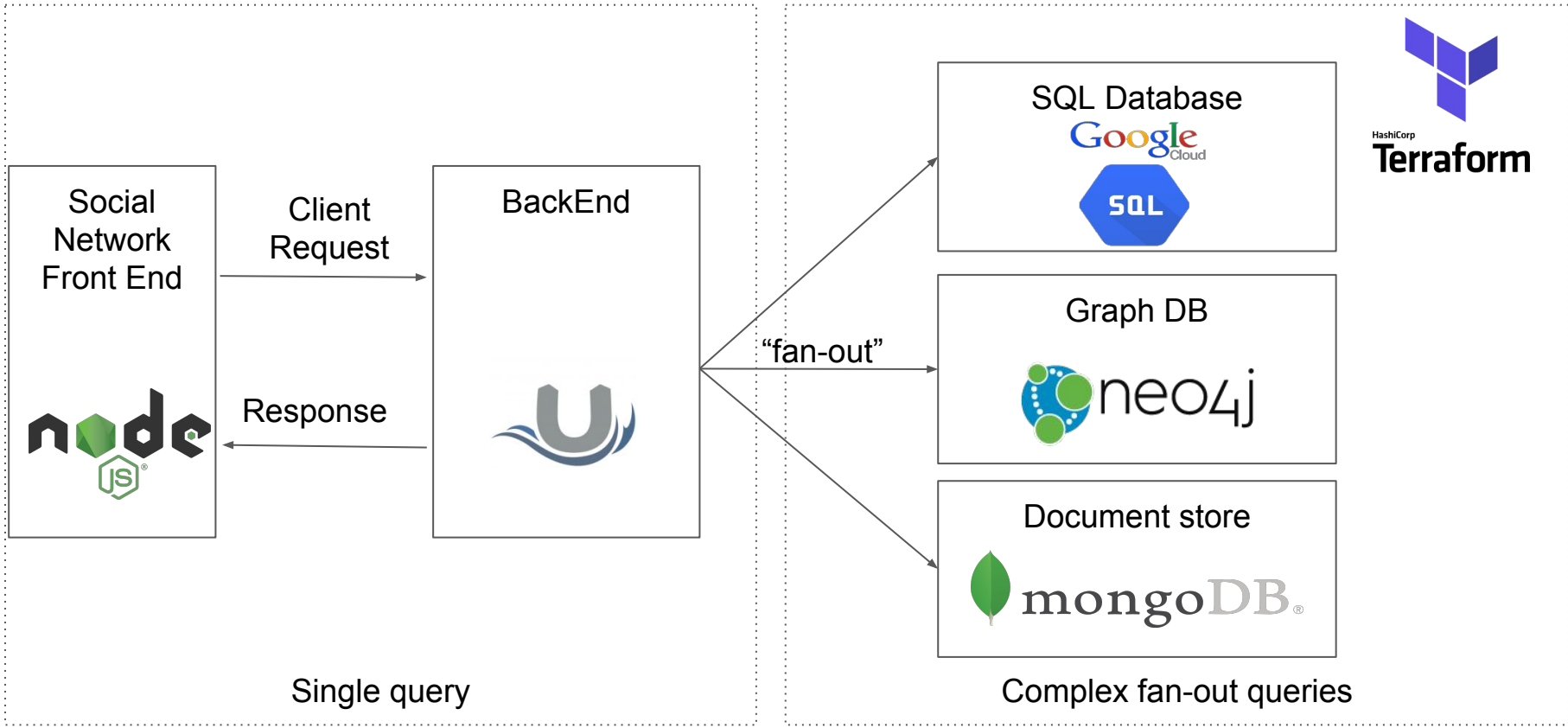


P2.3: Video Processing Pipeline - Serverless

- Functions and FFmpeg to process videos
- Use a cloud ML API for image labeling
- CloudSearch to index videos

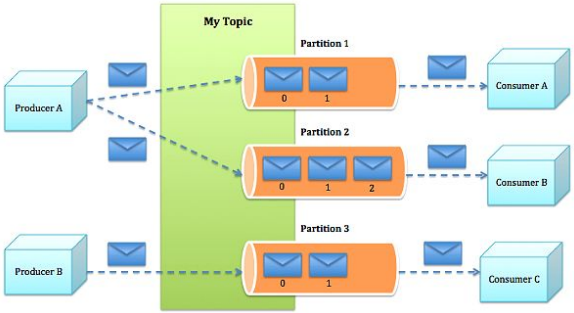


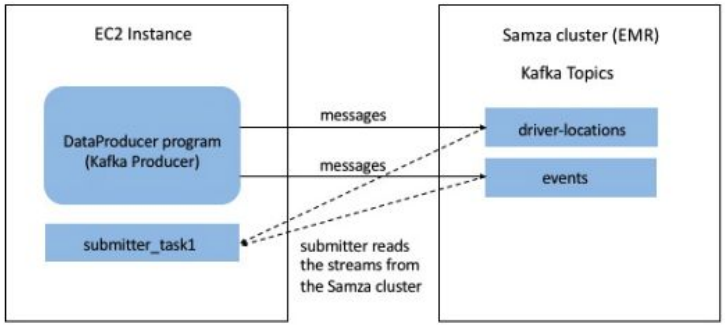
P3.2: Social Networking with Heterogeneous Backends



P4.3: Uber-like Application for NYC

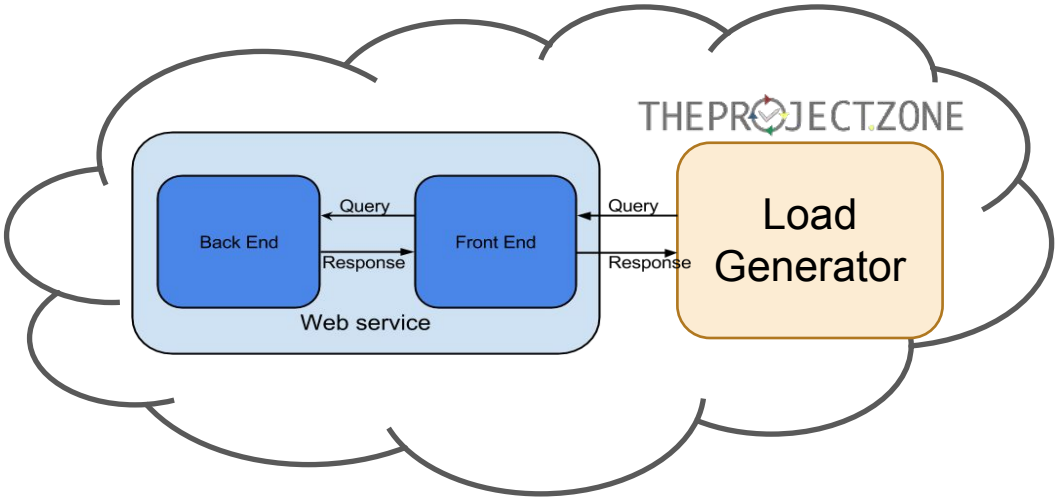
- Stream Processing with Kafka/Samza
  - Stream 1: Car GPS coordinates
  - Stream 2: Customers
- Task:
  - Match customers with cars to minimize travel time & other constraints





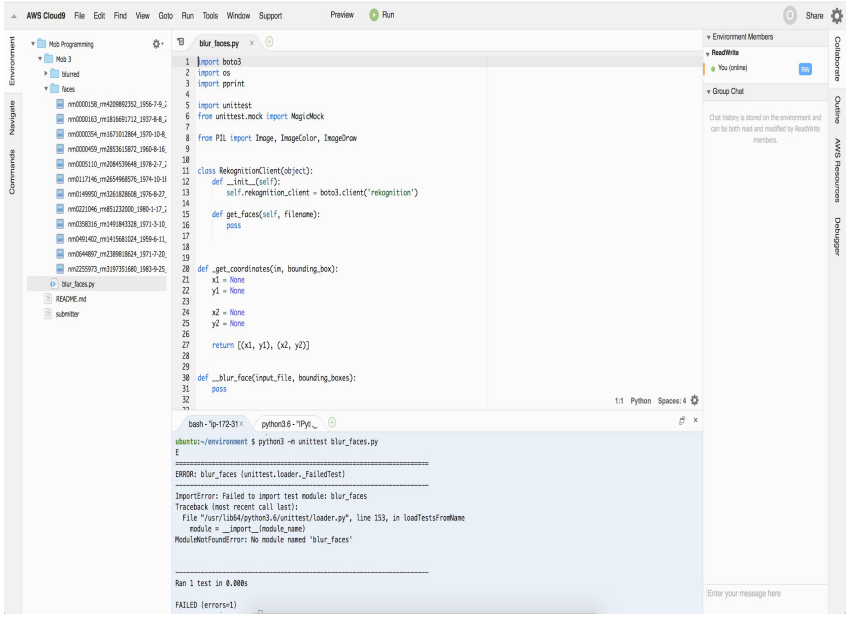
Team Project: Web Service

- Team-based
- 1.2 TB of raw data
- Specified queries
- Constraints
  - Correctness
  - Throughput
  - Budget
  - Time

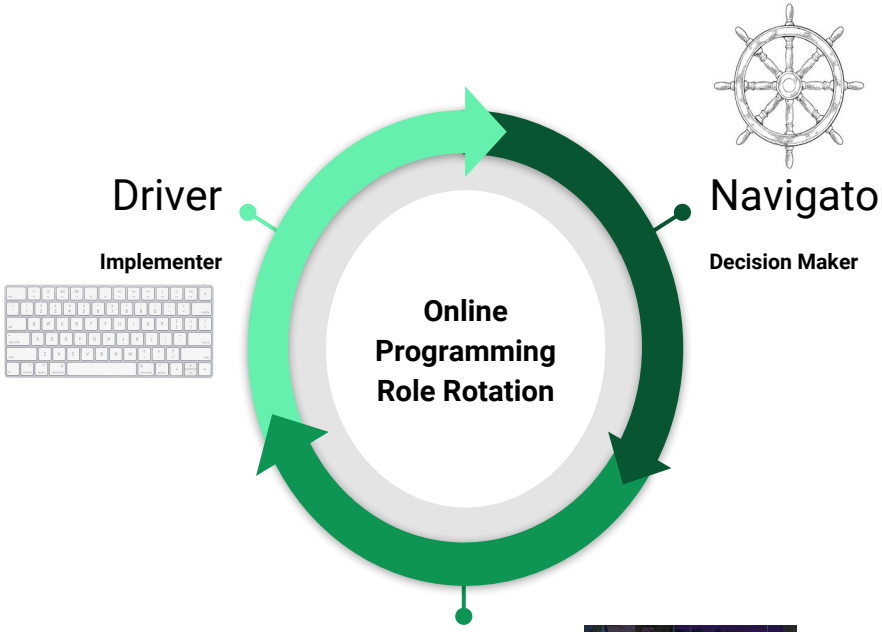


Phases	Duration	Query Type
Phase 1	2 weeks	Q1, Q2
Phase 2	2 weeks	Q1, Q2, Q3
Phase 2 Live Test	6 hours	Q1, Q2, Q3, mix-Q1Q2Q3
Phase 3	2 weeks	Q1, Q2, Q3
Phase 3 Live Test	6 hours	Q1, Q2, Q3, MIX-Q1Q2Q3

Participate in Online Programming Exercise Sessions



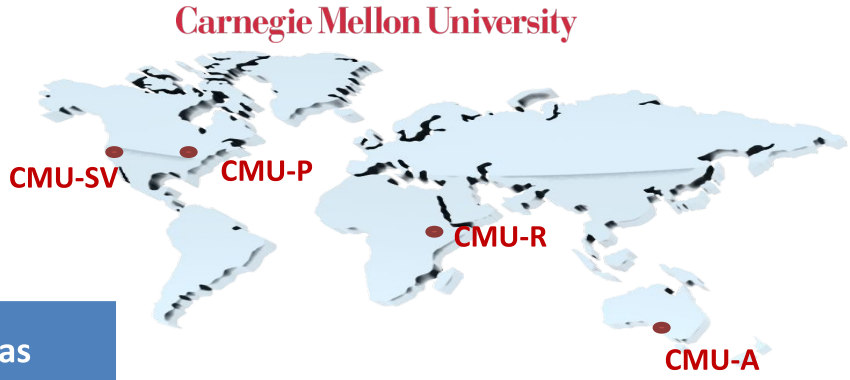
Cloud IDE: AWS Cloud9



Outline

- What is the course about?
- **What is an online course?**
- Administrivia

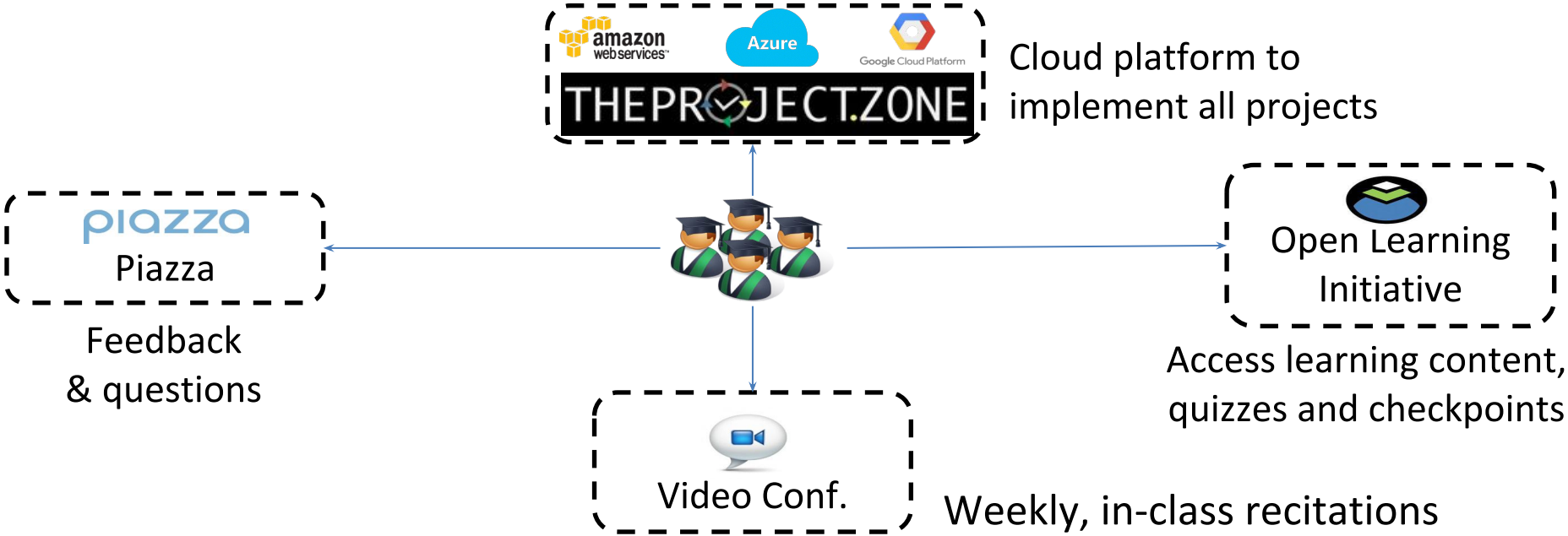
Carnegie Mellon Global Course



Location	Sections	Students	Tas
CMU Pittsburgh	A & B	160	16
CMU Rwanda	C	8	0
CMU Adelaide	D	4	0
CMU Silicon Valley	E	48	3

Please move to the section for your campus ASAP

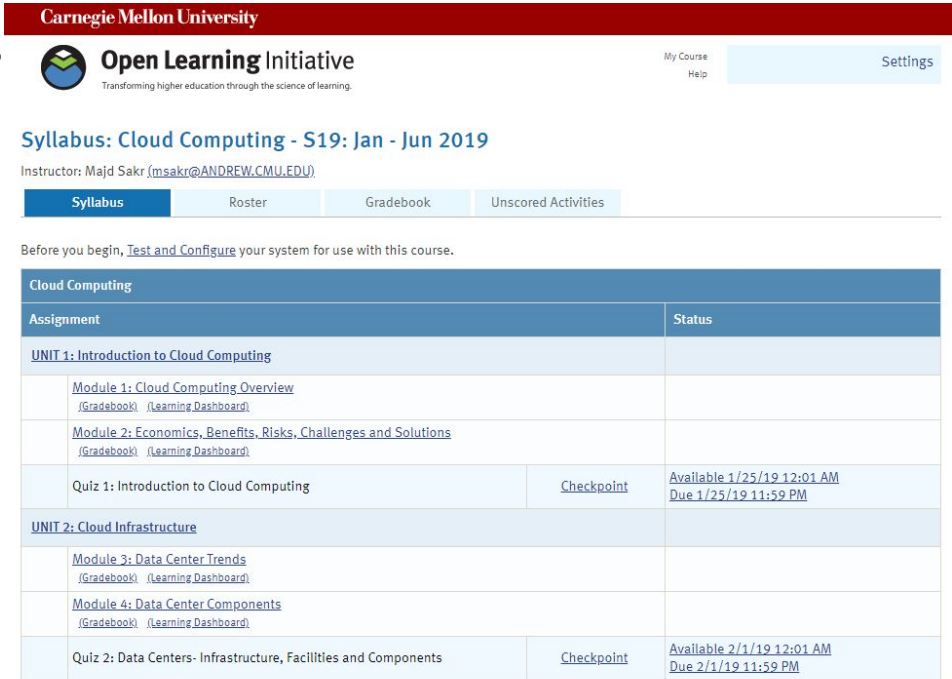
Online Course Engagement Model



Online Course Content - OLI

Conceptual content is on the Open Learning Initiative:

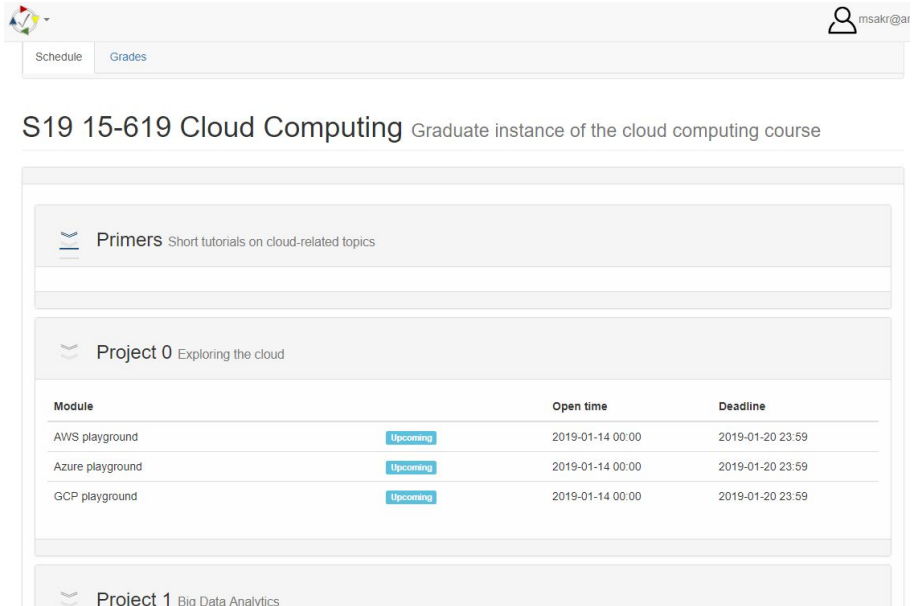
- Students are automatically registered
- Access to OLI is through Canvas
  - canvas.andrew.cmu.edu
- Check if Flash is installed
- Provide feedback on OLI
  - Bottom of each page
  - End of each module
- Do not copy or share content



TheProject.Zone

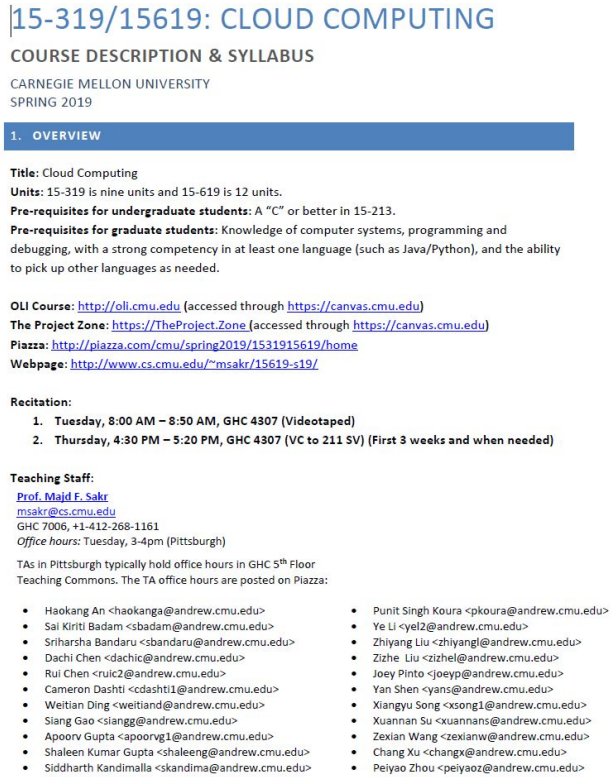
Course projects are on https://TheProject.Zone:

- Learn through repetitive attempts and feedback
- Students are automatically registered
- Access through browser
  - Not mobile friendly yet
- Work in progress
  - We will encounter bugs
  - Provide feedback on Piazza
  - Please be patient



Syllabus

- Updated on webpage
- Provides details on:
  - Course Objectives
  - Learning Outcomes
  - Policies
  - Grading
  - Tentative Schedule



15-319/15619: CLOUD COMPUTING

COURSE DESCRIPTION & SYLLABUS

CARNEGIE MELLON UNIVERSITY
SPRING 2019

1. OVERVIEW

Title: Cloud Computing
Units: 15-319 is nine units and 15-619 is 12 units.
Pre-requisites for undergraduate students: A "C" or better in 15-213.
Pre-requisites for graduate students: Knowledge of computer systems, programming and debugging, with a strong competency in at least one language (such as Java/Python), and the ability to pick up other languages as needed.

OLI Course: http://oli.cmu.edu (accessed through https://canvas.cmu.edu)
The Project Zone: https://TheProject.Zone (accessed through https://canvas.cmu.edu)
Piazza: http://piazza.com/cmu/spring2019/1531915619/home
Webpage: http://www.cs.cmu.edu/~msakr/15619-s19/

Recitation:

1. **Tuesday, 8:00 AM – 8:50 AM, GHC 4307 (Videotaped)**
2. **Thursday, 4:30 PM – 5:20 PM, GHC 4307 (VC to 211 SV) (First 3 weeks and when needed)**

Teaching Staff:

Prof. Majd F. Sakr
msakr@cs.cmu.edu
GHC 7006, +1-412-268-1161
Office hours: Tuesday, 3-4pm (Pittsburgh)

TAs in Pittsburgh typically hold office hours in GHC 5th Floor Teaching Commons. The TA office hours are posted on Piazza:

- Haokang An <haokanga@andrew.cmu.edu>
- Sai Kiriti Badam <sbadam@andrew.cmu.edu>
- Sriharsha Bandaru <sbandaru@andrew.cmu.edu>
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- Chang Xu <changx@andrew.cmu.edu>
- Peiyao Zhou <peiyaoz@andrew.cmu.edu>

Tentative Schedule

- Schedules:
  - Quizzes on OLI
  - Projects on TheProject.Zone

Week	Monday	OLI Content	Individual Projects	Team Project	Quizzes
1	1/14/2019	Unit 1, Module 1, 2	Primers/P0 (Jan 20)		Q0 (Ac. Integ.)
2	1/21/2019	Unit 1, Module 1, 2	P1.1 (Jan 27)		Q1 (Jan 25)
3	1/28/2019	Unit 2, Module 3, 4	P1.2 (Feb 3)		Q2 (Feb 1)
4	2/4/2019	Unit 2, Module 5, 6	P2.1 (Feb 10)		Q3 (Feb 8)
5	2/11/2019	Unit 3, Module 7, 8, 9	P2.2 (Feb 17)		Q4 (Feb 15)
6	2/18/2019	Unit 3, Module 10, 11, 12	P2.3 (Feb 24)		Q5 (Feb 22)
7	2/25/2019	Unit 3, Module 13	P3.1 (Mar 3)	Project Out (Feb 25)	Q6 (Mar 1)
8	3/4/2019	Unit 4, Module 14	P3.2 (Mar 10)		Q7 (Mar 7)
9	3/11/2019	Spring Break			
10	3/18/2019	Unit 4, Module 15, 16, 17	P3.3 (Mar 24)		Q8 (Mar 22)
11	3/25/2019	Unit 5, Module 18		Phase 1 Due (Mar 31)	Q9 (Mar 29)
12	4/1/2019	Unit 5, Module 19, 20	P4.1 (Apr 7)		Q10 (Apr 5)
13	4/8/2019	Unit 5, Module 21, 22		Phase 2 Due (Apr 14)	Q11 (Apr 12)
14	4/15/2019		P4.2 (Apr 21)		
15	4/22/2019			Phase 3 Due (Apr 28)	
16	4/29/2019		P4.3 (May 3)		

Grading

Course Elements	#	Weight
Projects	4 or 5	80%
OLI Unit Checkpoint Quizzes	11	20%

- Projects weights
  - 15-319
    - 80 %, 10 out of 11 individual project modules, each 8%
  - 15-619
    - 60%, 10 out of 11 individual project modules, each 6%
    - 20%, 1 team project, three phases
- Weekly quizzes (11 in total)
  - 10 out of 11, 2% equal weight

Audit & Pass/Fail option is not available for this course

Outline

- What is the course about?
- What is an online course?
- **Administrivia**

Target Audience

- Technical Majors
- Undergraduate Juniors / Seniors
  - Pre-requisites:
    - 15213 – Introduction to Computer Systems
- Graduate Students
  - Experience:
    - Unix, scripting, python, & java

Course Administration

- Students are automatically registered on OLI through canvas.cmu.edu
- A *single* Piazza course page is created
  - We manually register students to Piazza
- Schedule of units and quizzes is on OLI
  - Content weekly quizzes are due on Fridays
- Schedule of weekly projects is on TheProject.Zone
  - Weekly project modules are due on Sundays

Public Cloud Infrastructure

- Paid Cloud Service
  - billed by the hour/minute
- Start a resource only when you need it
- To explore, use inexpensive instances
- Terminate all other resources as soon as you are done with them
- Students will be penalized for over usage
  - We have a fixed budget, do not abuse the resources!
  - Intentional or unintentional abuse ➔ grade penalties
  - Resources need to be tagged, otherwise ➔ penalties

This Week

- Check that you were enrolled on Canvas and Piazza
- Academic Integrity Module on OLI
  - **Sunday, January 20, 2019**
- Become familiar with conceptual content on OLI
  - Start reading Unit 1, Module 1 & Module 2
  - Quiz 1: Unit 1, Module 1 & 2, **Friday, Jan 25, 2019**
- Create an account on AWS, Azure and GCP (ASAP)
  - Submit your AWS account info using the link provided in the primers on TheProject.Zone
- Projects on TheProject.Zone
  - Primer and P0, due **Sunday, January 20, 2010**

Diverse Technical Preparation

- Students come from diverse backgrounds and technical preparation
  - We offer primers to get you started.
  - If your programming skills are rusty, take the first two weeks to improve.
  - If you don’t think you have the skills required, allocate more time each week for the projects.
  - The first couple of weeks are less demanding, take advantage of them.

Perfect Conditions Do Not Exist

- Don’t ask to be trained under perfect conditions
  - We will not provide a sanitized sandbox for you to learn
- You will encounter
  - Badly formed data, inaccurate documentation, intermittent services, insufficient information, etc.
  - Learn how to deal with all these issues
  - Very valuable experience for your career

We are NOT special!

- We are as good as what skills, and hard work we bring to the table.
- Don’t ask for special circumstance due to drama.
  - Find out the source of the drama and make adjustments.
- …

Academic Integrity

It is the responsibility of each student to produce her/his own original academic work.

- Individual work:
  - Weekly Project Modules
  - Unit Checkpoint Quizzes
- Team work:
  - 15-619 Project

Read the university policy on Academic Integrity.

Disciplinary Policies

- First offense:
  - Minimum: worse than not doing the work.
  - Maximum: immediate expulsion.

- Second offense results in expulsion. Always.
  - Previously undiscovered offenses can count as “first offense”!

The Penalties are Severe

- Cheating leads to several students being dismissed from the university every semester

LET IT NOT BE YOU!

Academic Integrity Module on OLI

- Required for all students
- Process
  - Pretest Quiz
    - Please take this without looking at the modules
  - Page 1, Overview
  - Page 2, Policies
  - Page 3, Methods of Prevention
  - Quiz
    - Complete this quiz this week
      - By January 20, 2019

Working within Budgets

- Design is a critical element to success
- Develop a budget for
  - Development
  - Testing
  - Drama
- If funds are left over in the budget, feel free to explore and learn!

Tagging is painful, why the penalty?

- Your boss has a budget and a boss
- The budget is allocated among the team
- Your boss has to keep track of how the resources are being spent in order to
  - Re-allocate budget or ask for more resources
- On the cloud, the only way to keep track is through tagging
  - Learn how to tag correctly, don’t complain about penalties!

Getting Help

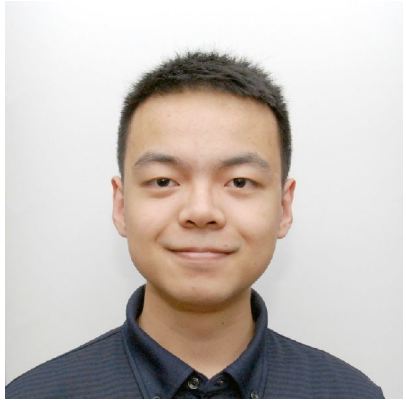
- TAs in Pittsburgh, Rwanda, Silicon Valley and Adelaide
- Piazza
  - Email does not scale
  - Discussion forum to support each other
- Recitations
  - Tuesdays (recorded)
    - At 8AM in **GHC 4307** (GHC 4401 for the first recitation **only**)
  - Thursdays (video conferenced to SV)
    - At 4:30PM in **GHC 4307** (1:30PM in SV 211)
    - First 3 weeks only, afterwards only when needed
- Office Hours
  - Check Piazza for Office Hour schedule

Teaching Staff

- Majd Sakr
  - GHC 7006
  - msakr@cs.cmu.edu
  - Office Hours
    - Tuesdays, 3-4pm (Pittsburgh)

Teaching Staff

- Cameron Dashti



- Haokang (Marshall) An

Pittsburgh: Teaching Assistants

- Sai Kiriti Badam

Pittsburgh: Teaching Assistants

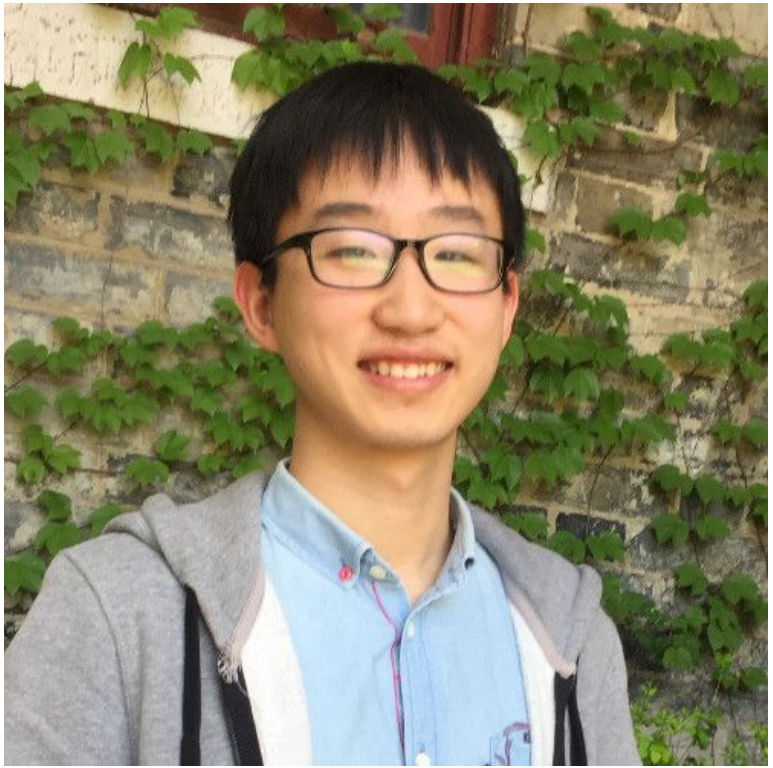
- Sriharsha (Harsha) Bandaru

Pittsburgh: Teaching Assistants

- Dachi (Albert) Chen

Pittsburgh: Teaching Assistants

- Rui Chen



Pittsburgh: Teaching Assistants

- Weitian Ding

Pittsburgh: Teaching Assistants

- Siang Gao

Pittsburgh: Teaching Assistants

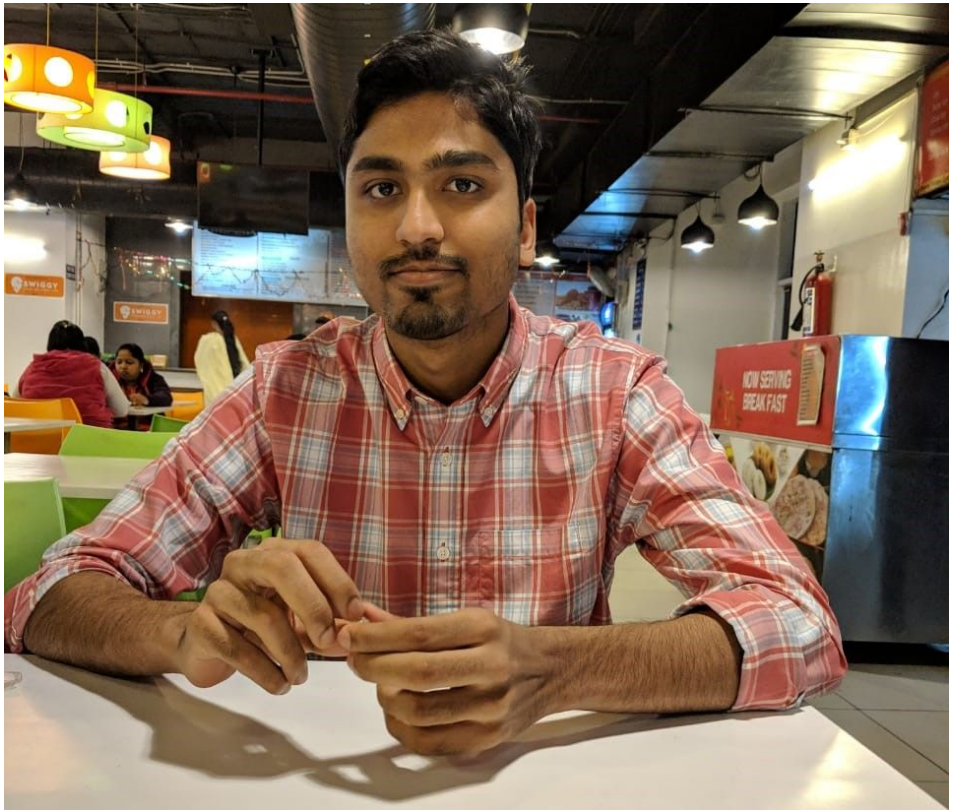
- Apoorv Gupta

Pittsburgh: Teaching Assistants

- Shaleen Kumar Gupta

Pittsburgh: Teaching Assistants

- Siddharth (Sid) Kandimalla

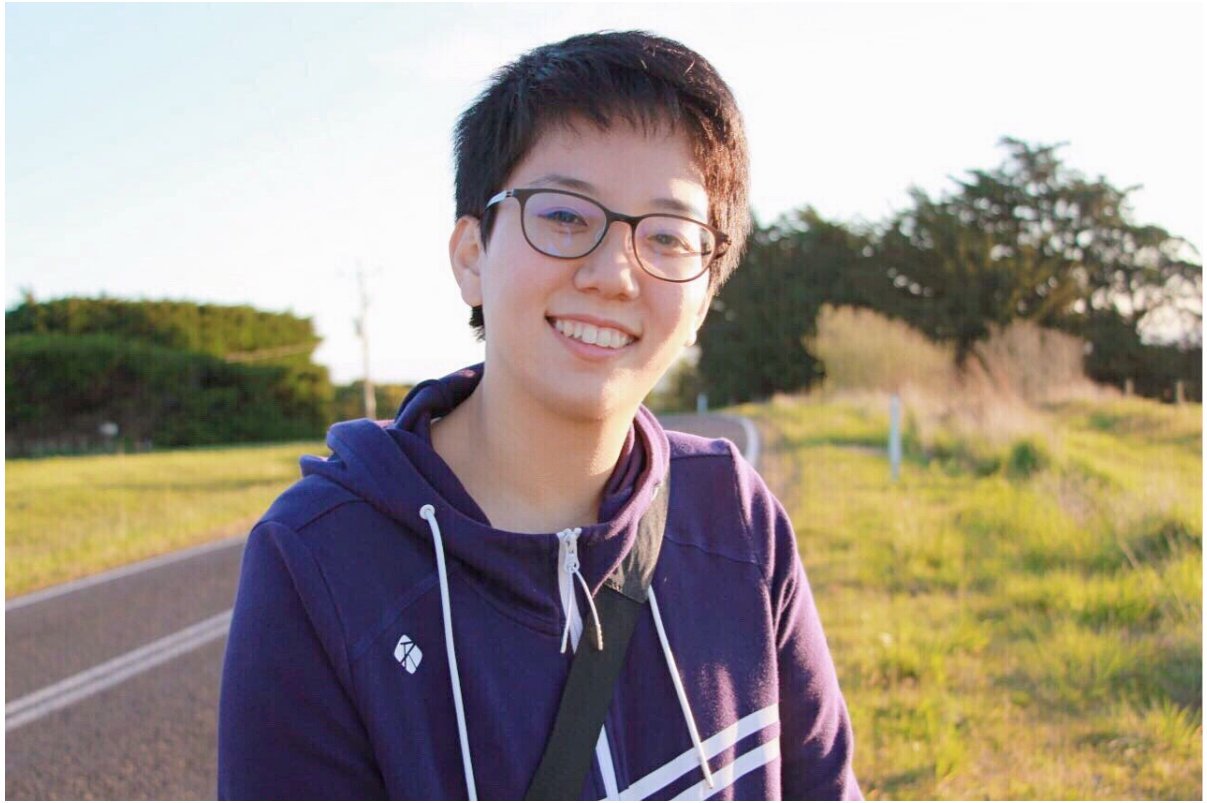


Pittsburgh: Teaching Assistants

- Punit Singh Koura

Pittsburgh: Teaching Assistants

- Zhiyang (Zoe) Liu



Pittsburgh: Teaching Assistants

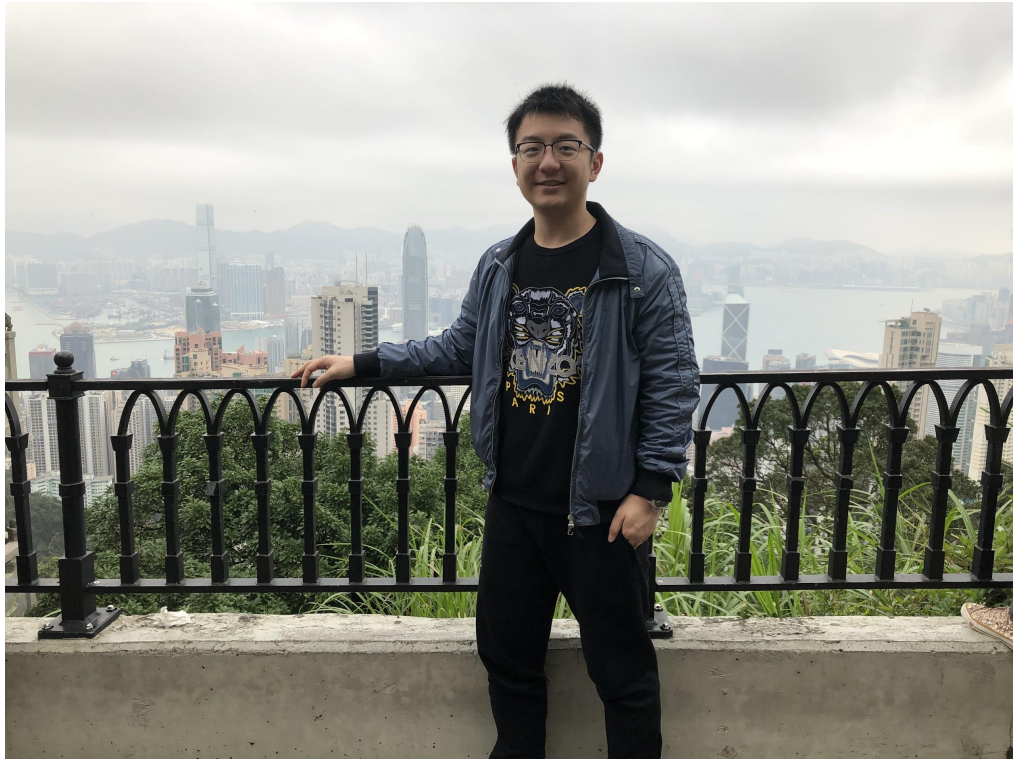
- Zizhe (Lucas) Liu

Pittsburgh: Teaching Assistants

- Yan Shen

Pittsburgh: Teaching Assistants

- Xiangyu (Eric) Song



Pittsburgh: Teaching Assistants

- Xuannan Su

Pittsburgh: Teaching Assistants

- Zexian Wang

Pittsburgh: Teaching Assistants

- Chang Xu

Silicon Valley: Teaching Assistant

- Ye (Leo) Li

Silicon Valley: Teaching Assistant

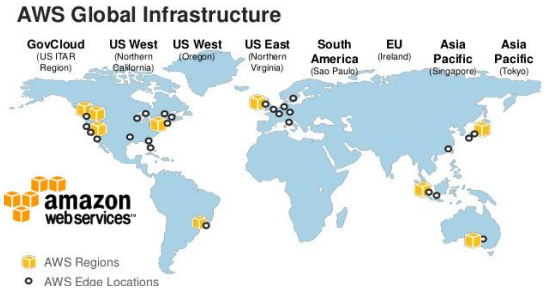
- Joey Pinto

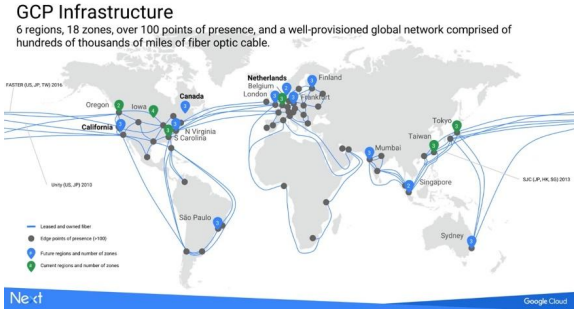
Silicon Valley: Teaching Assistant

- Peiyao (Julia) Zhou

Era of Globalization

- Economics
- Communication
- Entertainment
- Sports
- Education
- Compute Services ☺
  - You're programming the global computer.





Questions?