15-319 / 15-619
Cloud Computing

Course Overview and Introduction

January 18 and 20, 2022

http://www.cs.cmu.edu/~msakr/15619-s22/

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

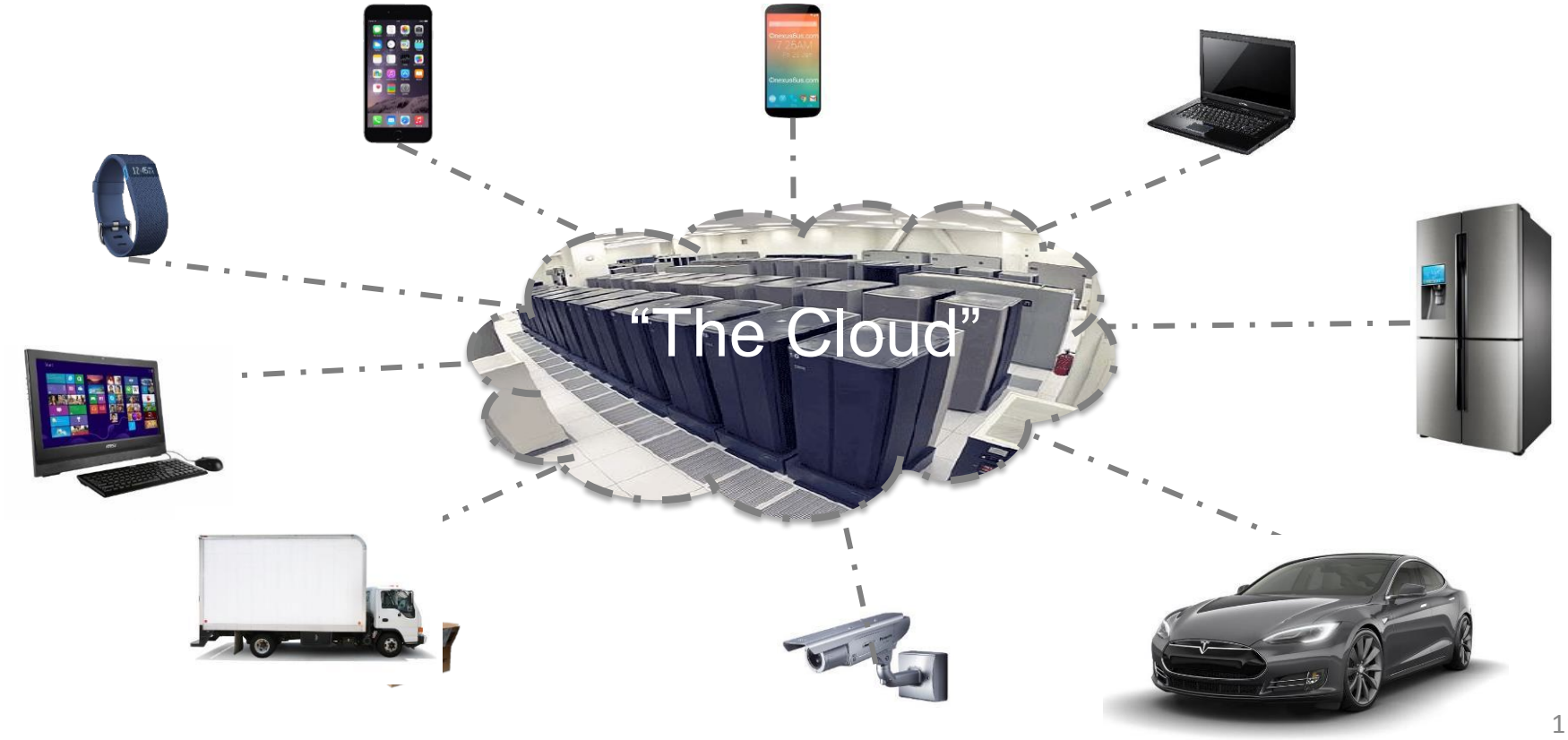
Microsoft Azure


US-East2 (Boydton, VA)

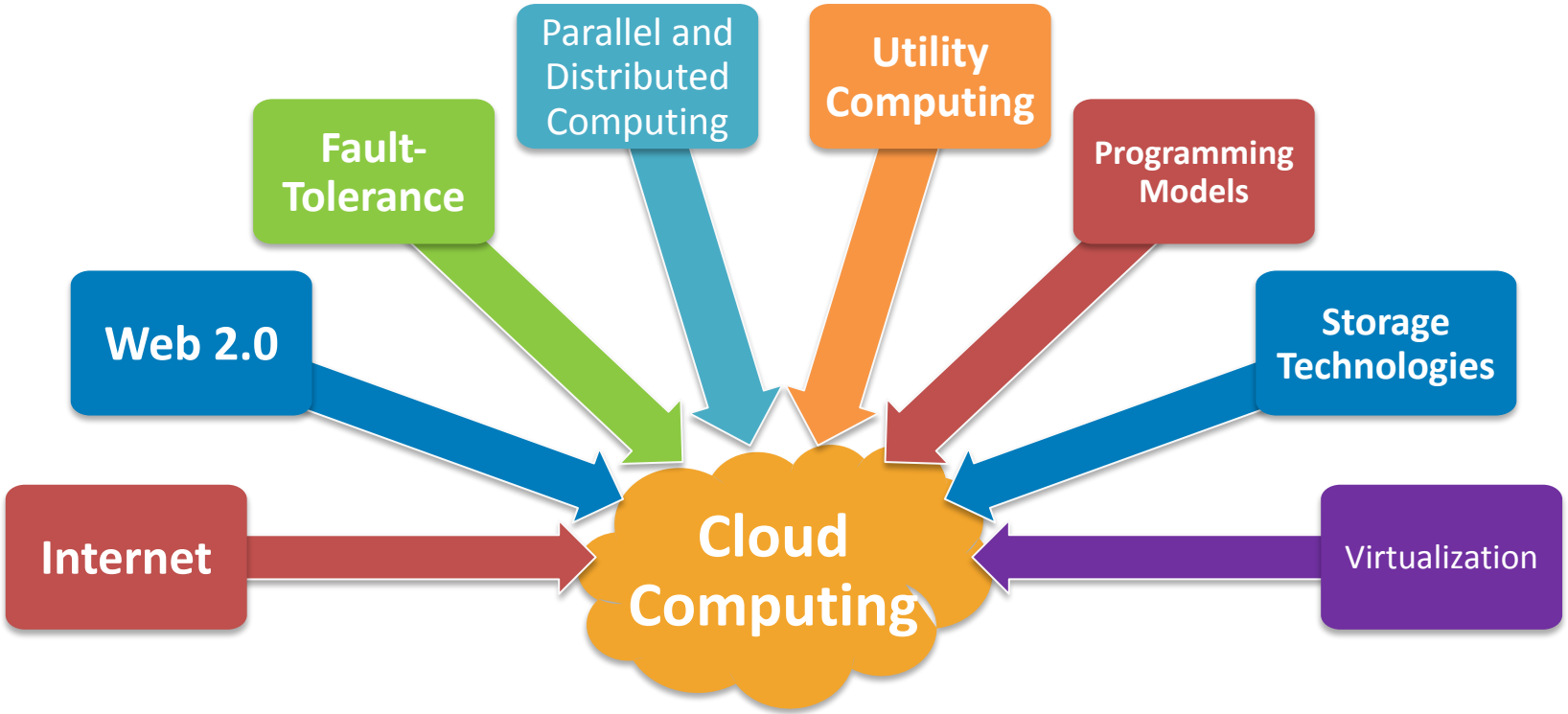

US-East2 (Boydton, VA)


US-East2 Hub Expansion

The Cloud



Enabled by Maturing Technologies

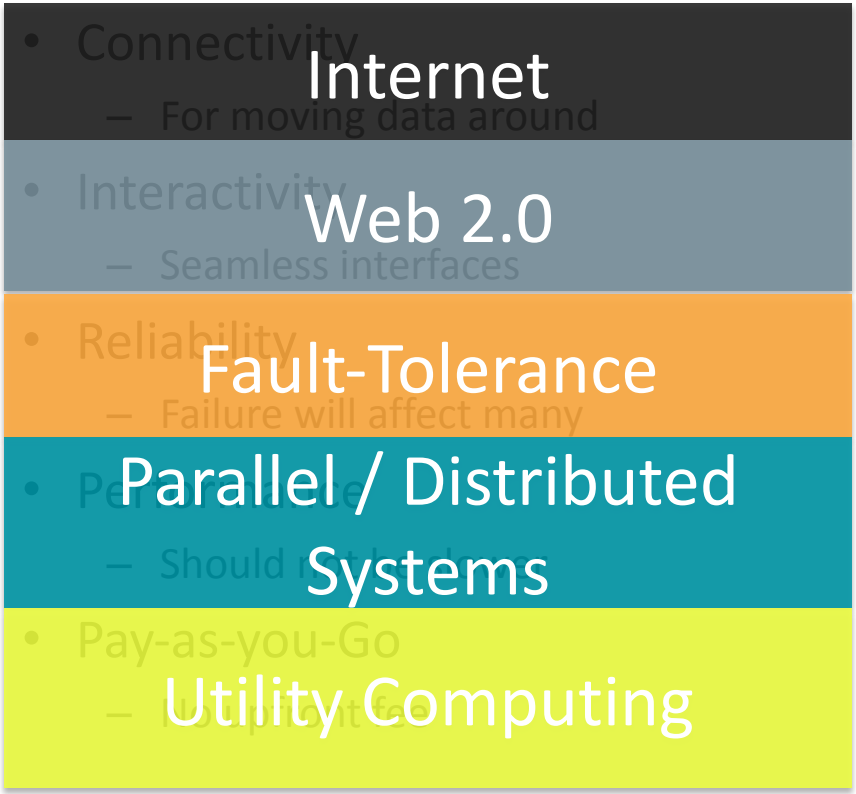


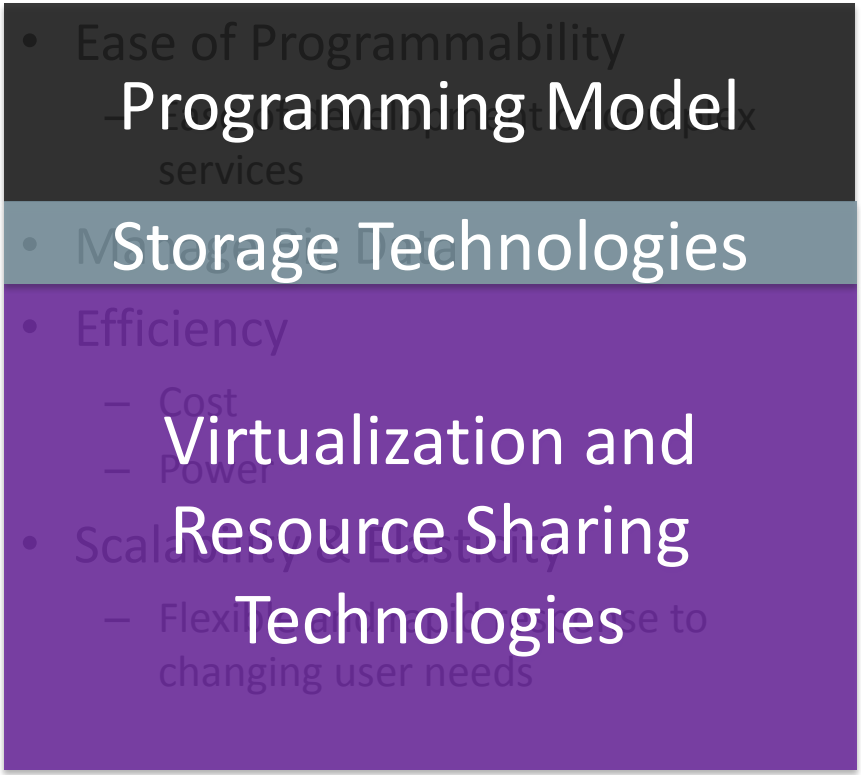
So… how would you transform information technology into a Service?

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?

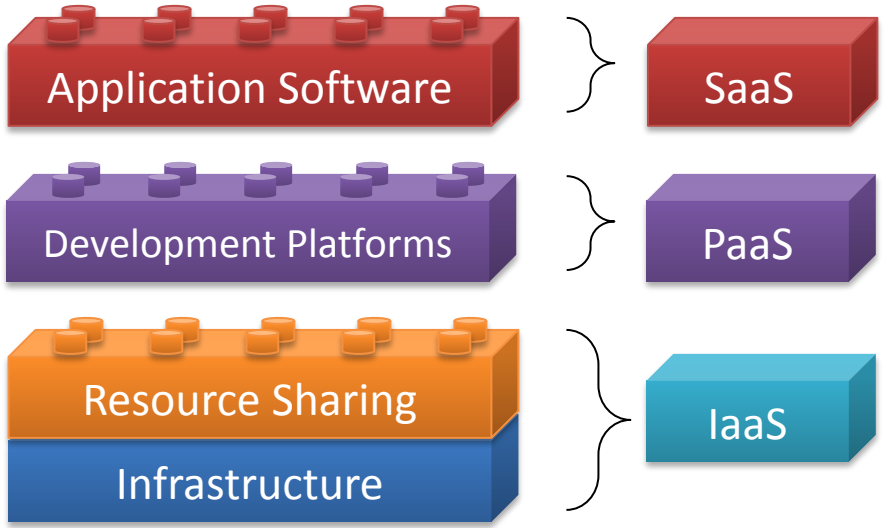




Cloud Building Blocks

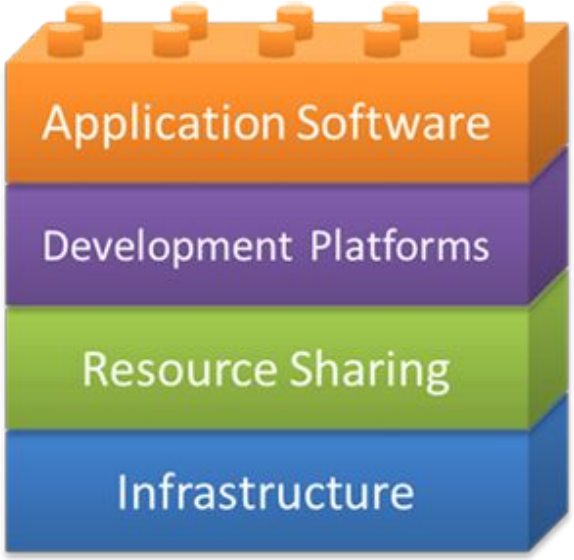
Cloud services are available in various forms, corresponding to the layer of abstraction desired by the user

- 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

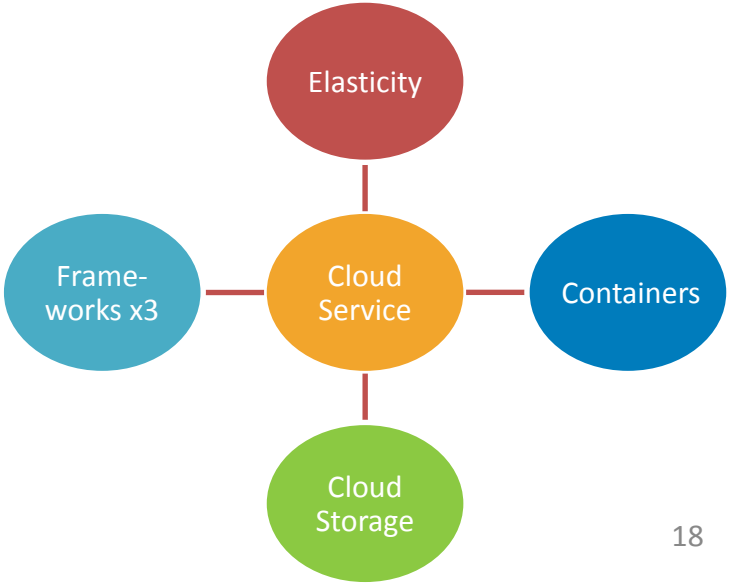
2.0 Cloud Infrastructure
Components, design considerations and power

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 & GraphLab

Quiz 1, Friday Jan 28, 2022

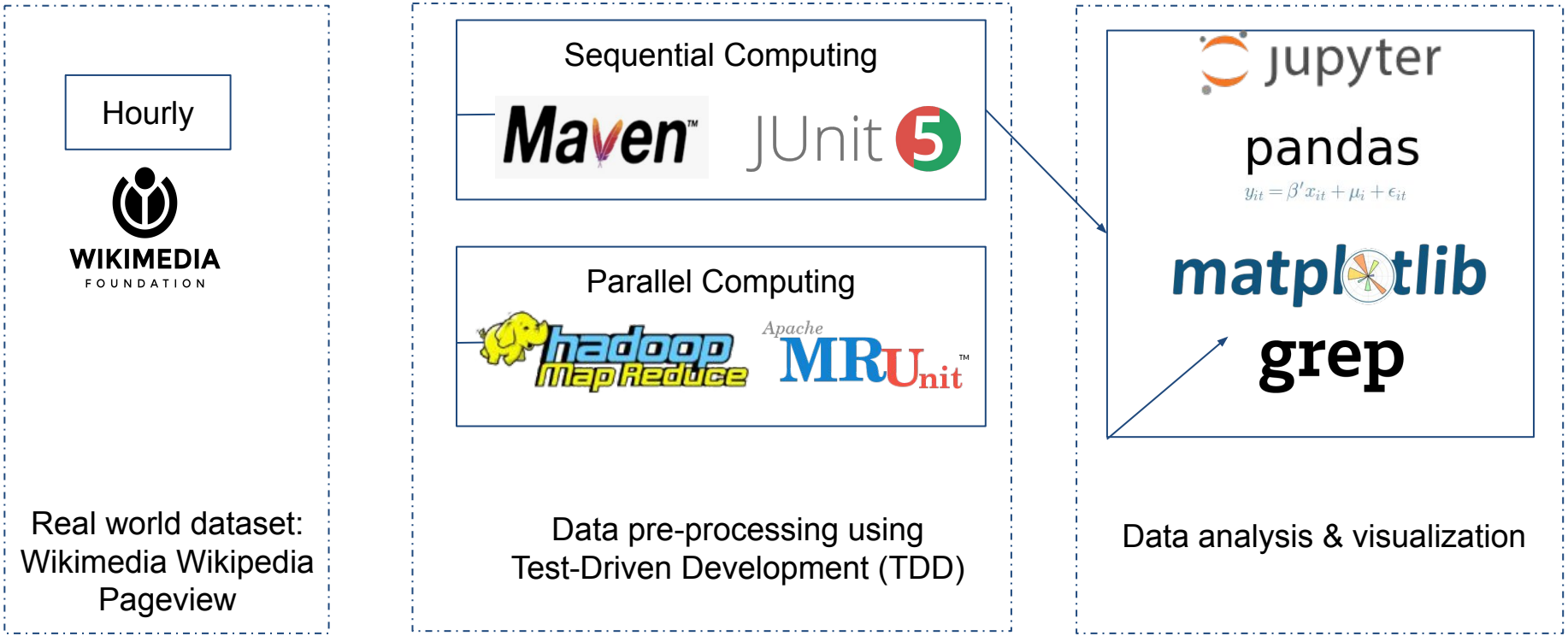
Projects on AWS/Azure/GCP Clouds

0. AWS/Azure/GCP Account Setup & Data Analytics	• Benchmarking VMs, SSH, Authentication, Billing, Security Groups, Vertical Scaling
1. Scaling, Elasticity and Failure with VMs	• Auto Scaling, Load Balancing, Monitoring
2. Cloud Elasticity with Containers & K8s	• Docker Containers, Kubernetes
3. Cloud Storage	• Standalone MySQL, HBase, Neo4J, MongoDB, Azure Managed SQL DB
4, 5, & 6. Analytics Engines for the Cloud	• Spark, DataBricks, Cloud ML Frameworks, Kafka/Samza
Team Project: A Cloud Native Web Service	• No restrictions on tools or AWS services • Evaluated based on cost and performance

Project Learning Objectives

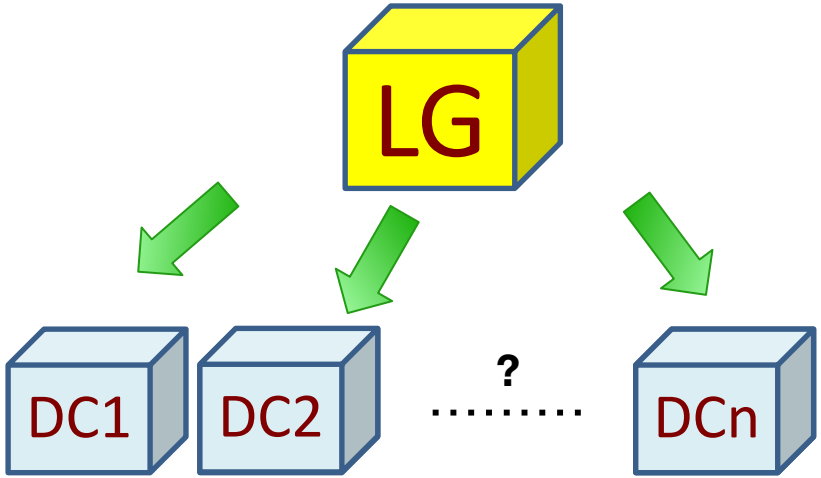
Compute & Elasticity	1) Design, implement, test, package, deploy and monitor cloud applications using Virtual Machines (VMs), and Containers cloud computing services.
Cloud Storage	2) Explore and experiment with different distributed cloud-storage abstractions and compare their features, capabilities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

P0: Big Data Analytics (ungraded)



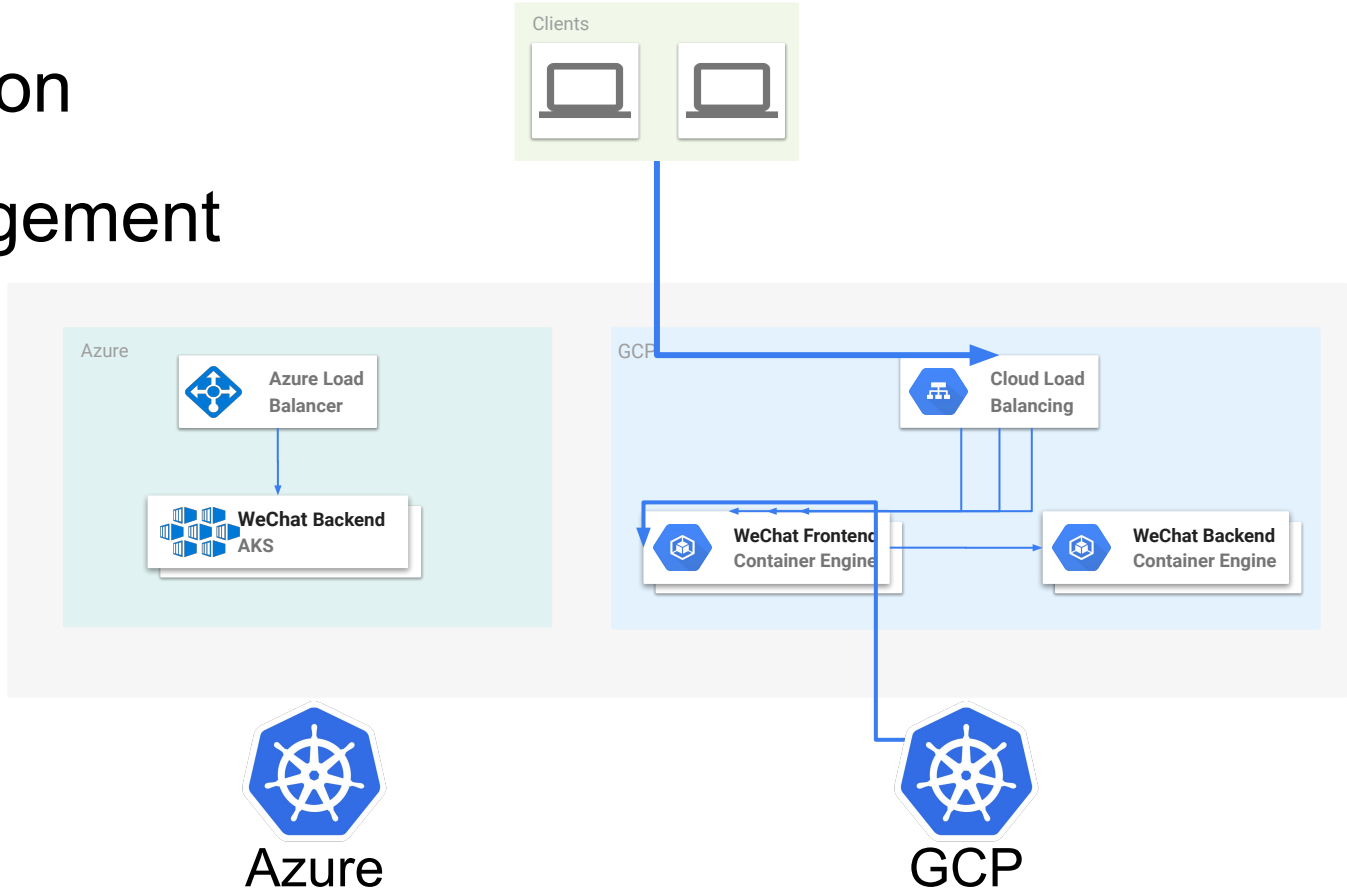
P1: VM Scaling, Elasticity & Failure

- 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.



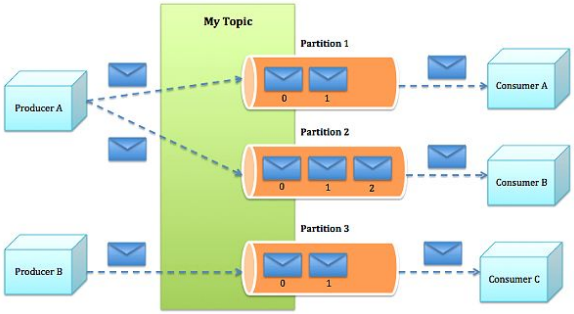
P2: Containers and Kubernetes

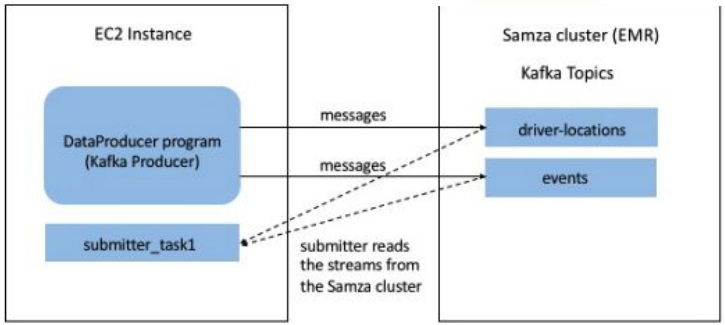
- Containerization
- Cluster Management
- Multi-Cloud Deployment



P5: Uber-like Application for NYC

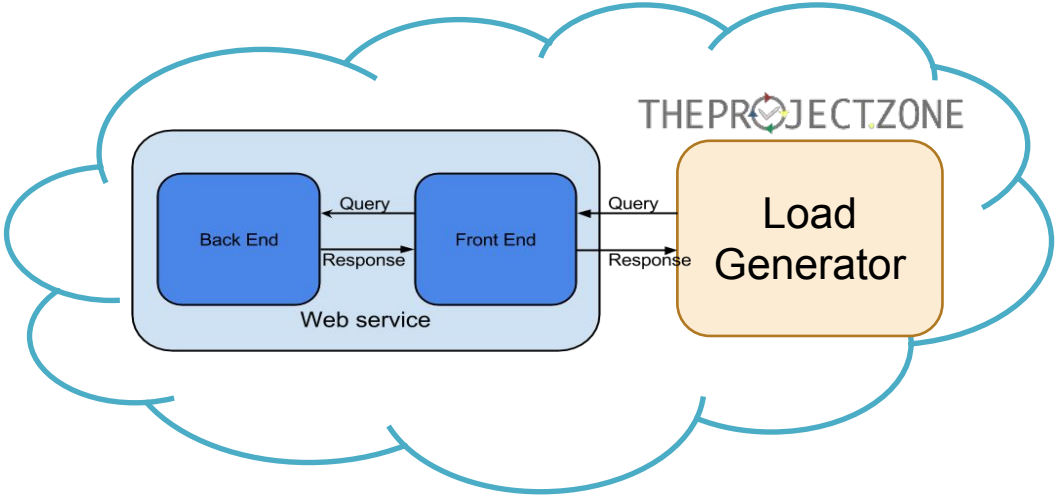
- Stream Processing with Kafka/Samza
  - Stream 1: Car GPS coordinates
  - Stream 2: Customers
- Task:
  - Match customers with cars to minimize travel time & other constraints





Team Project: Web Service

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



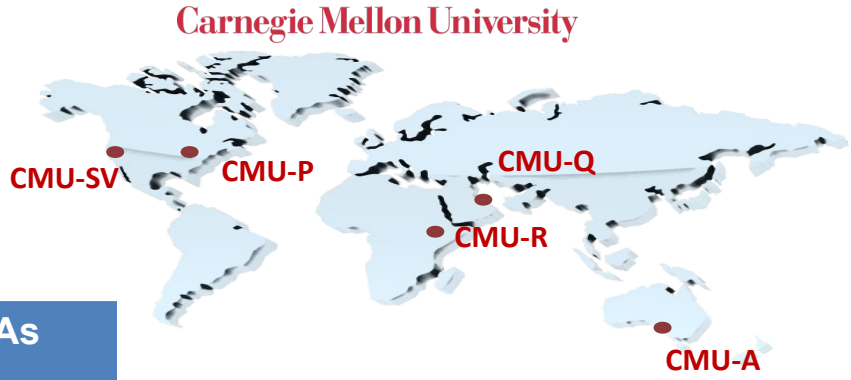
Phases	Microservices
Phase 1	M1 & M2
Phase 2	M1, M2, & M3
Phase 2 Live Test	M1, M2, & M3
Phase 3	M1, M2, & M3 (Managed services)
Phase 3 Live Test	M1, M2, & M3 (Managed services)

Outline

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

Carnegie Mellon Global Course

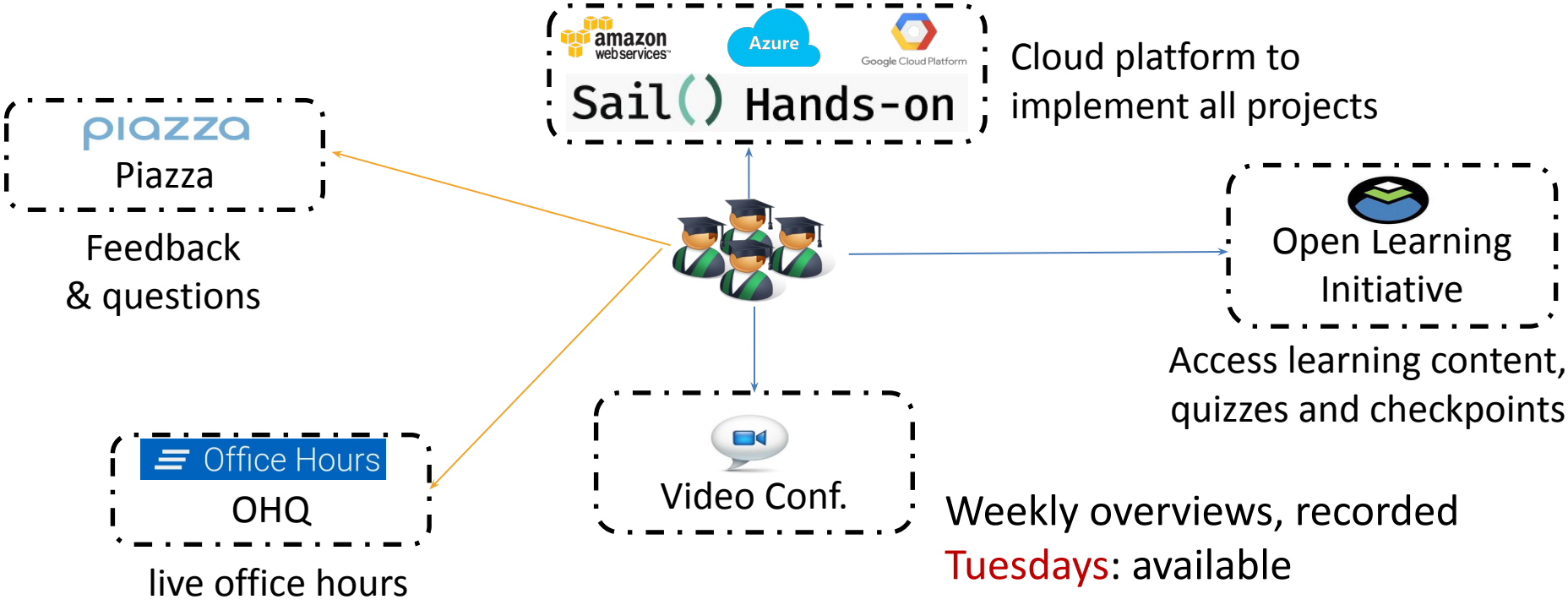
15-319 - 12 units
15-619 - 15 units



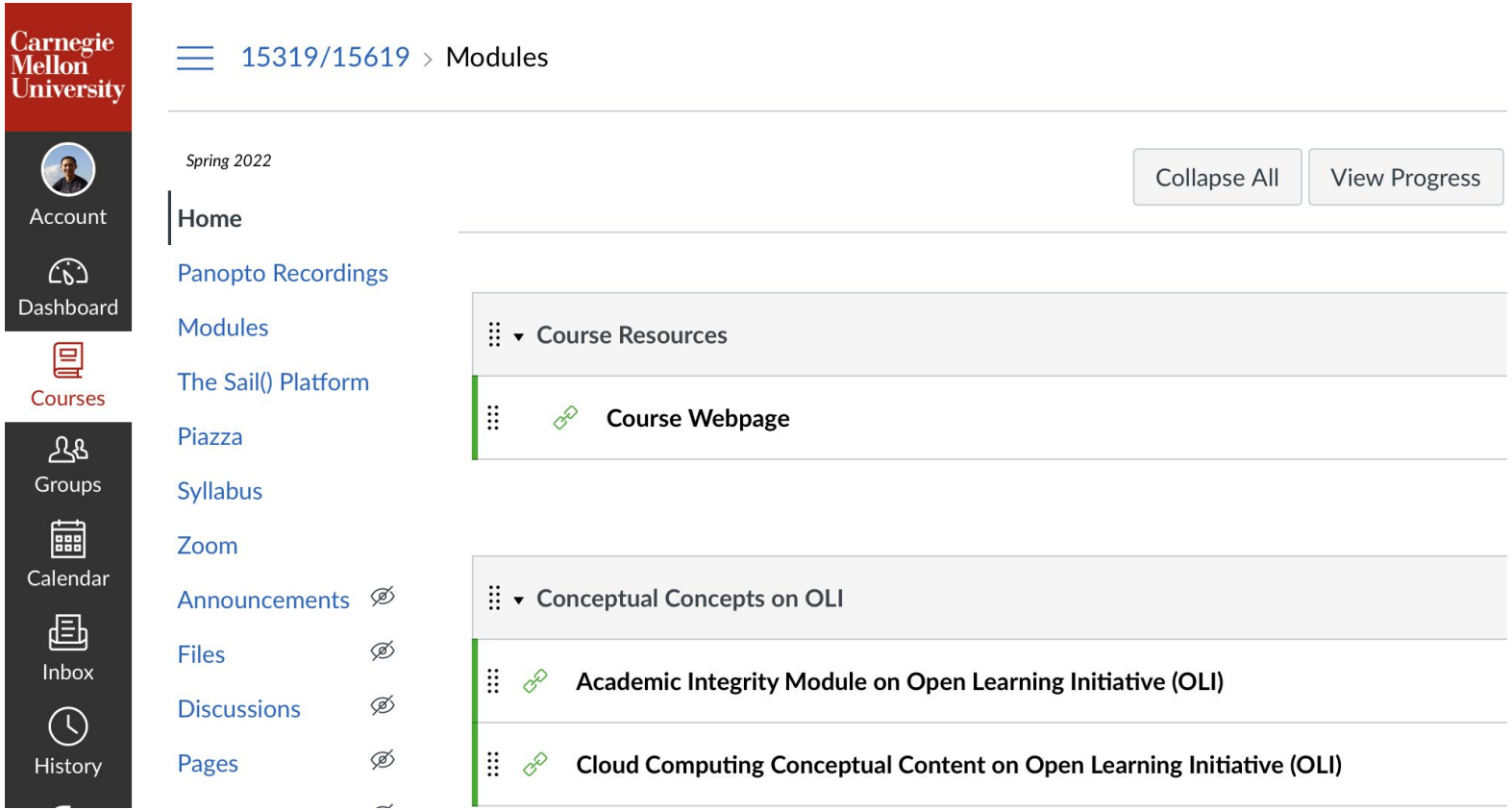
Location	Sections	Students	TAs
CMU Pittsburgh	A & B	271	12
CMU Rwanda	C	20	1
CMU Adelaide	D	9	2
CMU Silicon Valley	E	42	1

Please move to the section for your campus ASAP

Online Course Engagement Model



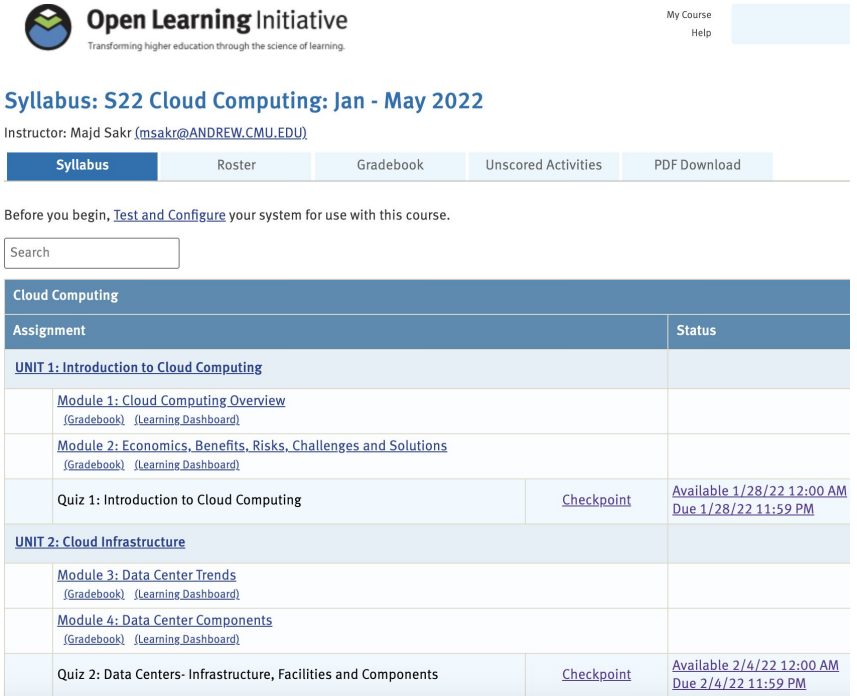
Canvas


Carnegie Mellon University
Account
Dashboard
Courses
Groups
Calendar
Inbox
History
15319/15619 › Modules
Spring 2022
Home
Panopto Recordings
Modules
The Sail() Platform
Piazza
Syllabus
Zoom
Announcements
Files
Discussions
Pages
Collapse All
View Progress
Course Resources
Course Webpage
Conceptual Concepts on OLI
Academic Integrity Module on Open Learning Initiative (OLI)
Cloud Computing Conceptual Content on Open Learning Initiative (OLI)

Online Course Content - OLI

Conceptual content is on the Open Learning Initiative:

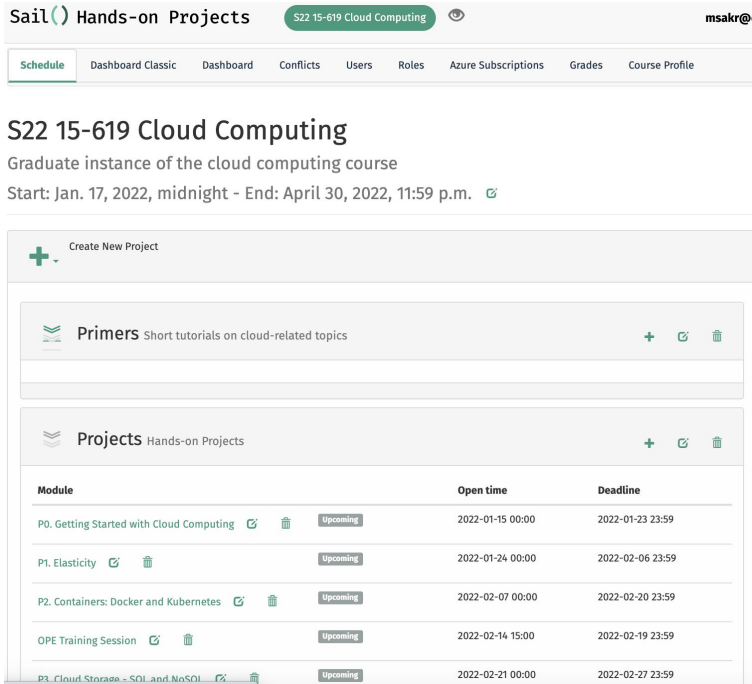
- Students are automatically registered
- Access to OLI is through Canvas
  - canvas.andrew.cmu.edu
- Provide feedback on OLI
  - Bottom of each page
  - End of each module
- Do not copy or share content



The Sail() Platform

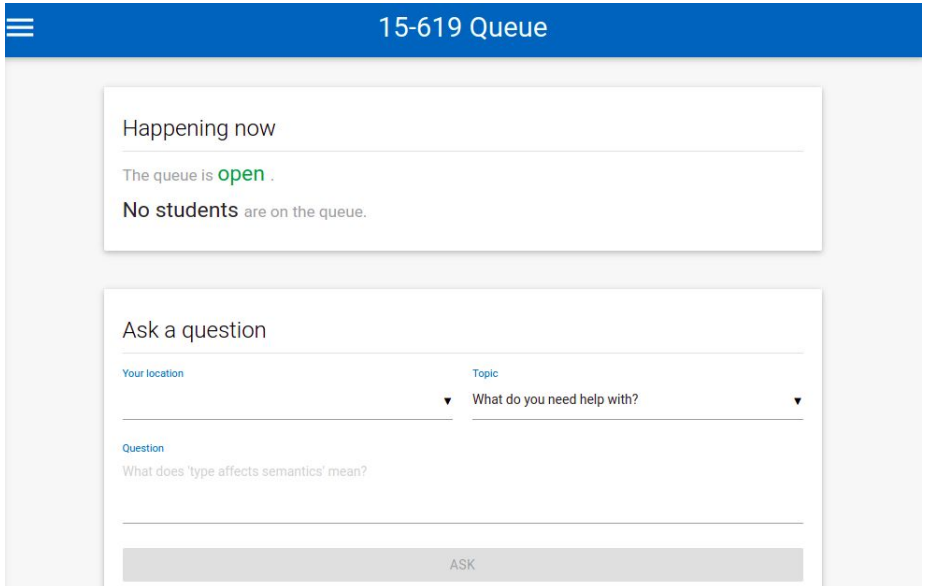
Course projects are on https://projects.sailplatform.org:

- 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



Office Hours

- Majd's office hours on Zoom (Tue 3pm ET)
- TA Office hours on OHQ+Zoom
  - See Piazza
  - Use OHQ 15-619



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 2022

1. Overview

Title: Cloud Computing
Units: 15-319 is 12 units and 15-619 is 15 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.

Canvas Course: https://canvas.cmu.edu/
OLI Course: Accessed through Canvas
The Sail() Platform: Accessed through Canvas
Piazza: https://piazza.com/cmu/spring2022/1531915619/home
Webpage: http://www.cs.cmu.edu/~msakr/15619-s22/
Weekly Overview: Tuesdays (Videotaped)

Teaching Staff:

Prof. Majd Sakr

Tentative Schedule

- Schedules:
  - Quizzes on OLI
  - Projects on The Sail() Platform
- No extensions

Week	Monday	OLI Content	Individual Projects	Team Project	Quizzes
1	1/17/2022	Unit 1, Module 1, 2	Primers/P0 (Jan 23)		Q0 (Ac. Integ.)
2	1/24/2022	Unit 1, Module 1, 2	P1 Elasticity		Q1 (Jan 28)
3	1/31/2022	Unit 2, Module 3, 4			Q2 (Feb 04)
4	2/7/2022	Unit 2, Module 5, 6	P2 Containers & K8s		Q3 (Feb 11)
5	2/14/2022	Unit 3, Module 7, 8, 9		Project Out (Feb 14)	Q4 (Feb 18)
6	2/21/2022	Unit 3, Module 10, 11, 12	P3 Storage		Q5 (Feb 25)
7	2/28/2022	Unit 3, Module 13			Q6 (Mar 03)
8	3/7/2022	Spring Break			
9	3/14/2022	Unit 4, Module 14	P4 Spark	Phase 1 Due (Mar 20) Phase 2 Out (Mar 21)	Q7 (Mar 18)
10	3/21/2022	Unit 4, Module 15, 16, 17			Q8 (Mar 25)
11	3/28/2022	Unit 4, Module 18	P5 Streaming	Phase 2 Due (Apr 03) Phase 3 Out (Apr 04)	Q9 (Apr 01)
12	4/4/2022	Unit 5, Module 19, 20			Q10 (Apr 08)
13	4/11/2022	Unit 5, Module 21, 22	P6 AI/ML	Phase 3 Due (April 17)	Q11 (Apr 15)
14	4/18/2022				
15	4/25/2022				

Grading

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

Course Elements - 15-319	#	Each	Weight
Individual Projects	5/6	16%	80%
OLI Unit Checkpoint Quizzes	10/11	2%	20%

Course Elements - 15-619	#	Each	Weight
Individual Projects	5/6	12%	60%
Team Project - Phase 1	1/1	4%	4%
Team Project - Phase 2	1/1	6%	6%
Team Project - Phase 3	1/1	10%	10%
OLI Unit Checkpoint Quizzes	10/11	2%	20%

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 The Sail() Platform
  - 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 have been enrolled on Canvas and Piazza
- Academic Integrity Module on OLI
  - **Monday, January 24, 2022**
- Become familiar with conceptual content on OLI
  - Start reading Unit 1, Module 1 & Module 2
  - Quiz 1: Unit 1, Module 1 & 2, **Friday, January 28, 2022**
- Create an account on AWS, Azure and GCP (ASAP)
  - Submit your AWS account info using the link provided in the primers on The Sail() Platform
- Projects on The Sail() Platform
  - Primer and P0, due **Sunday, January 23, 2022**

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

Time Management is Key

- 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 24, 2022

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
- Piazza
  - Email does not scale
  - Discussion forum to support each other
- Course Overview
  - Tuesdays (recorded)
    - Will be posted before Tuesday at Noon
- Office Hours
  - Check Piazza for Office Hour schedule
  - Will use OHQ and Zoom [links on piazza]

Teaching Staff

- Majd Sakr
  - msakr@cs.cmu.edu
  - Office Hours
    - Tuesday 3pm ET
    - Zoom link on piazza

Marshall An

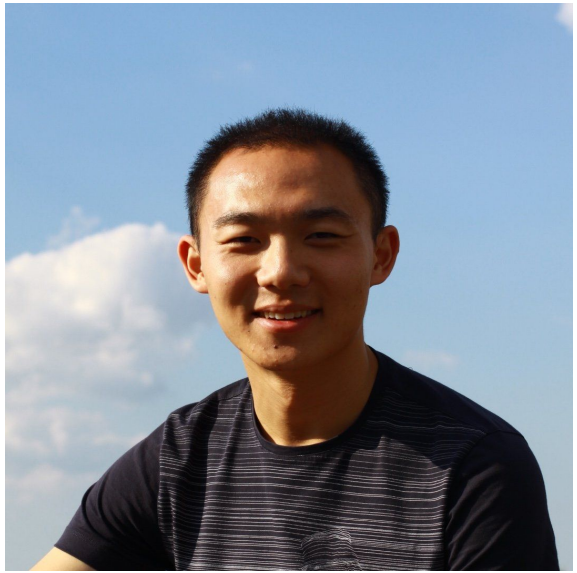
Project Scientist @ SCS

Siddharth (Sid) Kandimalla

- Senior Project Scientist @ SCS

Adam Zhang

Data Scientist @ SCS



Baljit Singh

Full Stack Engineer @ SCS

Bhakti Chaudhari

M.S. Information Networking (INI), December 2022

Wenxing Deng

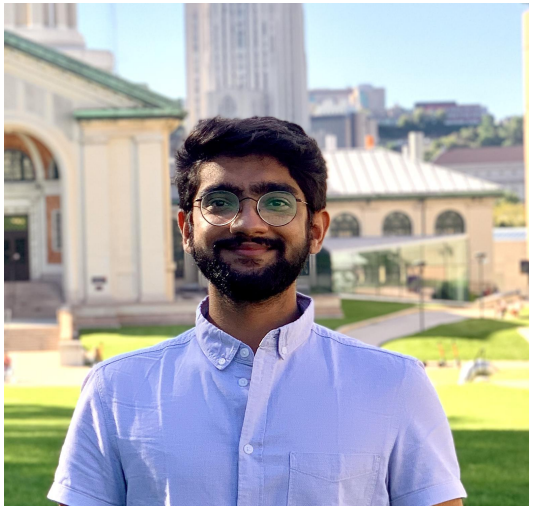
Master of Computational

Data Science(MCDS)

May 2023

Femin Dharamshi

Master of Information Systems Management (MISM), December 2022



Yanfei Liu

M.S. in SE (Silicon Valley campus)

May 2022

Daria Mashanova

Senior in math and CS

May 2022

Dinah Onyino

M.S in Information Technology, May 2022

Jacob Li PengCheng

Master in Entertainment Technology @ETC

May 2022

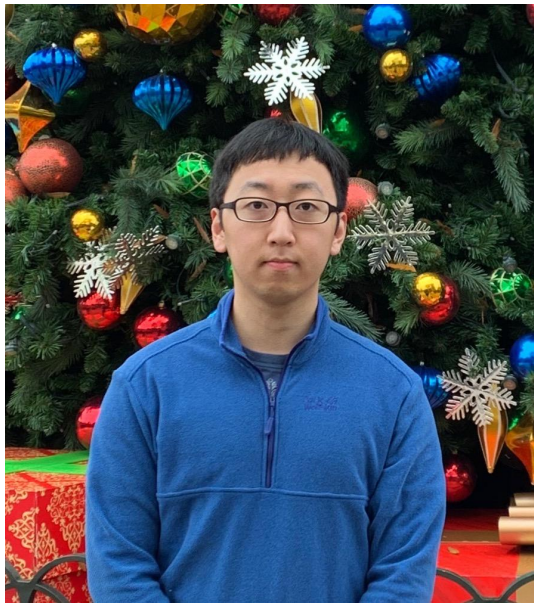
Ziteng(Paul) Shu

M.S. in ECE,

Dec 2022

Yifan Song

M.S in Computational Data Science, May 2022



Adarsh Sreedhar

M.S. Information Networking (INI), December 2022

Shubham Virmani

Master of Computational Data Science, Dec 2022

Yuanxin (Michael) Wang

M.S in Computational Data Science, May 2022

Yucen Xu

M.S. in Information System Management, Dec 2022

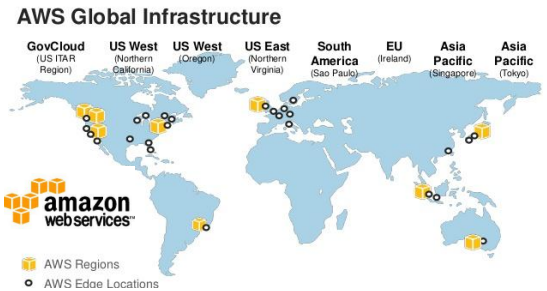
Qing (Connie) Zhao

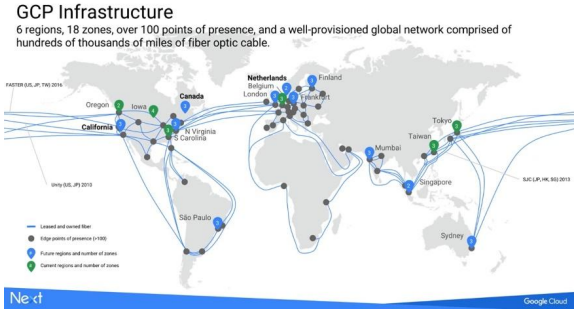
Master of Mobile and IoT Engineering (MSMITE)

May 2022

Era of Globalization

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





Questions?

Data and Decision Making

- Analyzing data reflects reality
- Walmart: hurricane warning
  - Stock beer and strawberry pop-tarts
  - 7x increase in sales during large storms
- Government: resource allocation decisions
  - Data mining in Maryland ➔ crime hotspots
  - Shuffle resource allocation, more to hotspots
    - violent crime down by 25%
    - $20 million saved in the city of Baltimore

Data Science

- Data Science is the science of learning from data
- Employs statistical, machine learning and data mining techniques
  - Look for trends, patterns or anomalies in the data
- Affects research in many domains
  - Business, Economics and Finance
  - Biological Sciences and Bioinformatics
  - Social Sciences and Humanities
  - …

An Increase in Data Capture

- Physical Sensors and Sensor Networks
  - Environmental, safety, transportation
- Social Media Interactions
  - Facebook, Twitter, Instagram
- Public Video and Image Capture
  - Surveillance, mobile phones, …
- Customer Spending Habits
  - Loyalty programs and purchase data

What is Big Data?

- Big Data
  - Volume, Velocity, Variety, Veracity
  - Data of next year >> data of this year
- Many Challenges
  - Store, share, analyze, search, transfer, visualize, and secure

we need…

Large Scale Systems

Large Scale System Challenges

- Lengthy procurement cycles
- Lengthy deployment effort
- Costly power and cooling
- Costly systems administration
- Low utilization
- Costly disaster recovery

Software as a Service (SaaS)

- Software is delivered through the internet over a browser or mobile application
- Replace desktop software with cloud-based versions
- Webmail, Productivity Software, ERP, CRM etc.
- Centrally managed, globally available, automatically updated

Adobe Creative Cloud

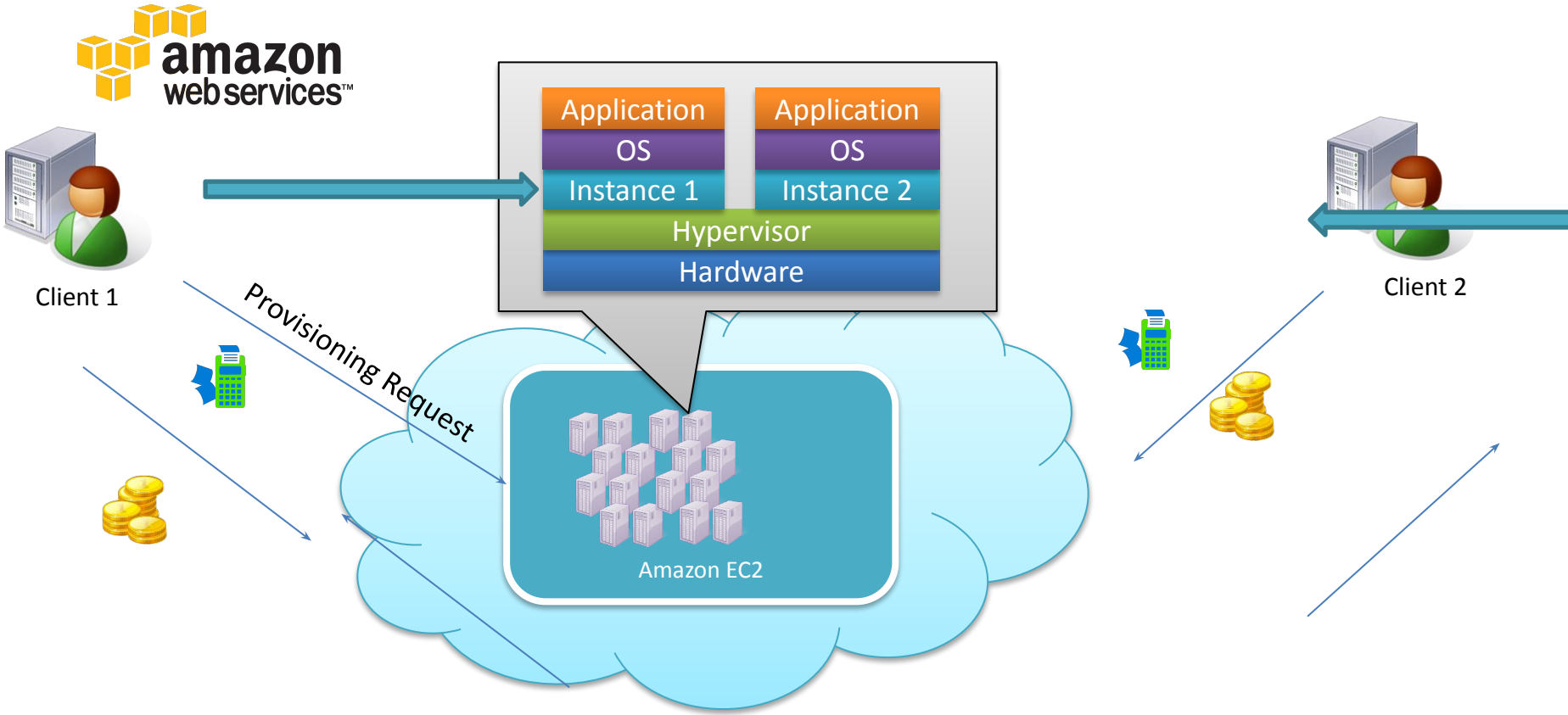
Platform as a Service (PaaS)

- Tools and APIs to develop and deploy cloud-based applications
- Create customized SaaS in the form of Web or mobile applications

Infrastructure as a Service (IaaS)

- Compute, storage and network resources bundled in the form of virtual machines
- Fully flexible in terms of software and environment

Infrastructure as a Service



Benefits of Cloud Computing

Pay-as-You-Go economic model

Simplified IT management

Elasticity
Scale quickly & effortlessly

Customization
Flexible options

Carbon Footprint decreased

Risks and Challenges

Migration

Security & Privacy

Vendor Lock-In

Legal

Internet Dependence

Service Level Agreements and Objectives (SLA/SLO)

- SLA: Contract between cloud providers and users to define expected service
  - Service availability and delivery
  - Payment terms, bonuses and penalties for service
- SLO: Individual performance/service metrics regarding service delivery defined in the SLA
- Auditing: monitor resources to enforce SLOs and SLAs

Cloud Use Cases: Start-ups

- Infrastructure on demand
- Save money on data center real estate, servers, power and cooling
- Saving in capital expenditure which could be used to drive other areas of business growth
- Scale infrastructure as the business grows
- Levels the infrastructure playing field with established companies

Expectations

- Real world practical experience
  - Learn on your own
    - Languages, API, debugging
  - Overcome challenges
  - Deal with uncertainty
- Self paced learning
- Using experimental tools
  - Bleeding edge comes with risks

Amazon Web Services

- Paid Cloud Service – billed by the hour
- Start a resource only when you need it
- To explore, use a micro instance
  - You can keep one micro instance running 24x7
- 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

Microsoft Azure

Azure Subscription

- Microsoft Azure provides the cloud computing course with one coupon per student
  - Students will provide an MSA on The Sail() Platform
  - We will create a subscription on Azure
- If you are careless in spending
  - Spending penalty
  - You will run out of money for a given project
    - Make a private Piazza post

GCP Coupon

- Google Cloud Platform provides the cloud computing course with one coupon per student
  - Students will access to a GCP coupon through The Sail() Platform
- If you are careless in spending
  - Spending penalty
  - You will run out of money for a given project
    - You will have to pay-as-you-go

Typical Reasons

- I didn’t know that this would be considered an AIV at Carnegie Mellon.
- I started late, ran out of time, looked online to see if there are any solutions that will help me regain some time.
- I took too many demanding courses at the same time. I had no choice.

Outcomes of Committing an AIV

- Positives
  - It's a terrible way to learn an important lesson
- Negatives
  - Grade Penalty
    - Ranges from significant penalty to failure
    - Lose time and change plans since you have to retake course
  - Dismissal from program/university
    - Time, money and emotion
    - Job offers indicate
      - "Upon successful completion of your program"
    - Having to go home and tell everyone

What is Cheating

- Sharing code or other electronic files either by copying, retyping, looking at, or supplying a copy of any file.
  - Other students, github, stackoverflow, anywhere on the internet,…
- Copying answers to any checkpoint quiz from another individual, published or unpublished written sources, and electronic sources.
- Collaborating with another student or another individual on Unit Checkpoint Quizzes or Project Modules.
- Sharing written work, looking at, copying, or supplying work from another individual, published or unpublished written sources, and electronic sources.
- Collaboration in team projects is strictly limited to the members of the team.
- …(read the syllabus and the university policy)

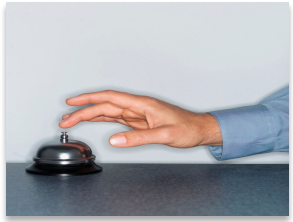
Minimum Cheating Penalty

- Must be worse than not submitting anything
  - Example impact of a -100% penalty on a project

	Perfect Score	Not submitting	Cheating
Assessment #1	20%	20%	20%
Assessment #2	20%	20%	20%
Assessment #3	20%	20%	20%
Assessment #4	20%	20%	20%
Assessment #5	20%	0%	-20%
Total	100%	80%	60%

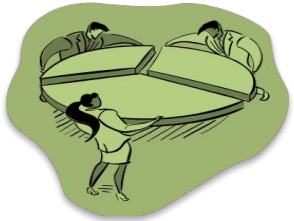
  - Typical penalty, “R” in the course

… for a more complete definition!



Cloud Computing is the delivery of computing as a **service** rather than a **product,**

whereby **shared resources, software**, and **information** are provided to computers and other devices,



as a **metered service** over a **network.**

Hands-on Skill Building Course

- Experience with
  - Elasticity, scalability, monitoring, load balancing
  - Cloud storage (HDFS, SQL, NoSQL, etc.)
  - Frameworks (MapReduce, Spark, Kafka/Samza)
  - Latest cloud services (AWS, Azure and GCP)
- Real world
  - data, projects, infrastructure within a budget

What this course is *not* about

- Building Cloud Stack Modules
  - OpenStack
- Cloud Software Development
  - SaaS software engineering
- Distributed Systems
  - Synchronization, Consistency, …
- Operating Systems
  - Developing a hypervisor
- Networks
  - Routing and switching protocols

Skill training to help with your goals

- Student has goals
  - Internship, job, graduate school, research project
- Student hires Carnegie Mellon to help achieve goals
- Student and Carnegie Mellon are partners in Learning effectively
- But, how do we learn?

Deeper Processing Leads to Deeper Learning

- Studying a lot
  - You will forget it soon
- Infrequent testing
  - You will still forget most of it soon
- Frequent testing
  - Helps improve retention a great deal
- Project work using/exploring/attempting to solve a problem
  - Helps even more

The deeper you think, the more you practice, the more you will learn and retain.

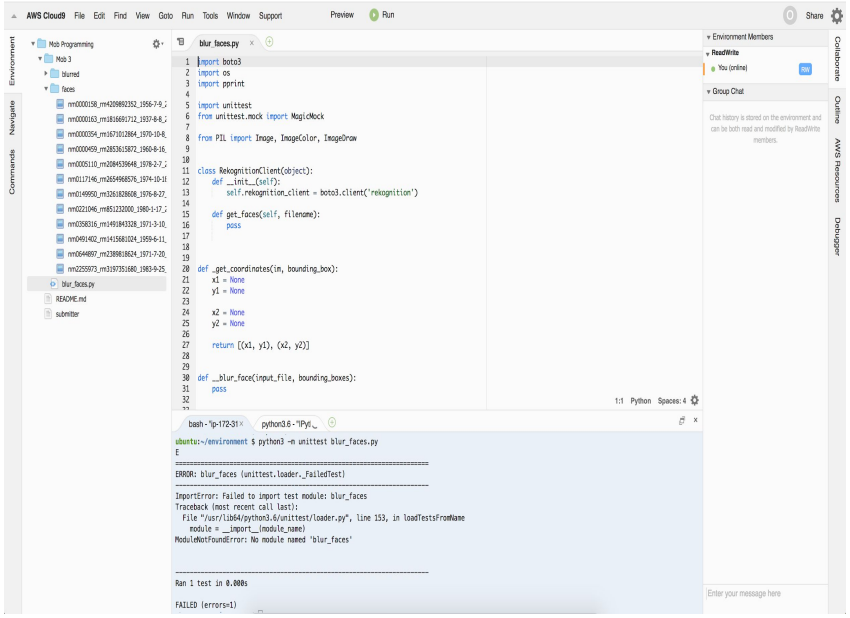
Working on Projects

- Understand the context and tasks/problem
- Choose a path towards a solution
- Attempt the path
- Face obstacles
  - Ask for help?
  - Look for another path on Stackoverflow and try?
  - Choose another path?
  - Find the reason behind the obstacle?
- Which is the hardest?

Performance versus Mastery

- If you have high performance but low mastery
  - ➔Means high grades but low skills & confidence
    - ➔Get an interview but will not pass
- The grades will not get you the job
  - Companies care about what you know and what you can do
- When you have high mastery, you will be in very high demand
  - Seek mastery!

Participate in Online Programming Exercise Sessions



Cloud IDE: AWS Cloud9