CS15-319 / 15-619
Cloud Computing

Recitation 1

Course Overview and Introduction

Aug 29 and 31, 2017

http://www.cs.cmu.edu/~msakr/15619-f17/

Outline

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

So What is Cloud Computing?

Data and Decision Making

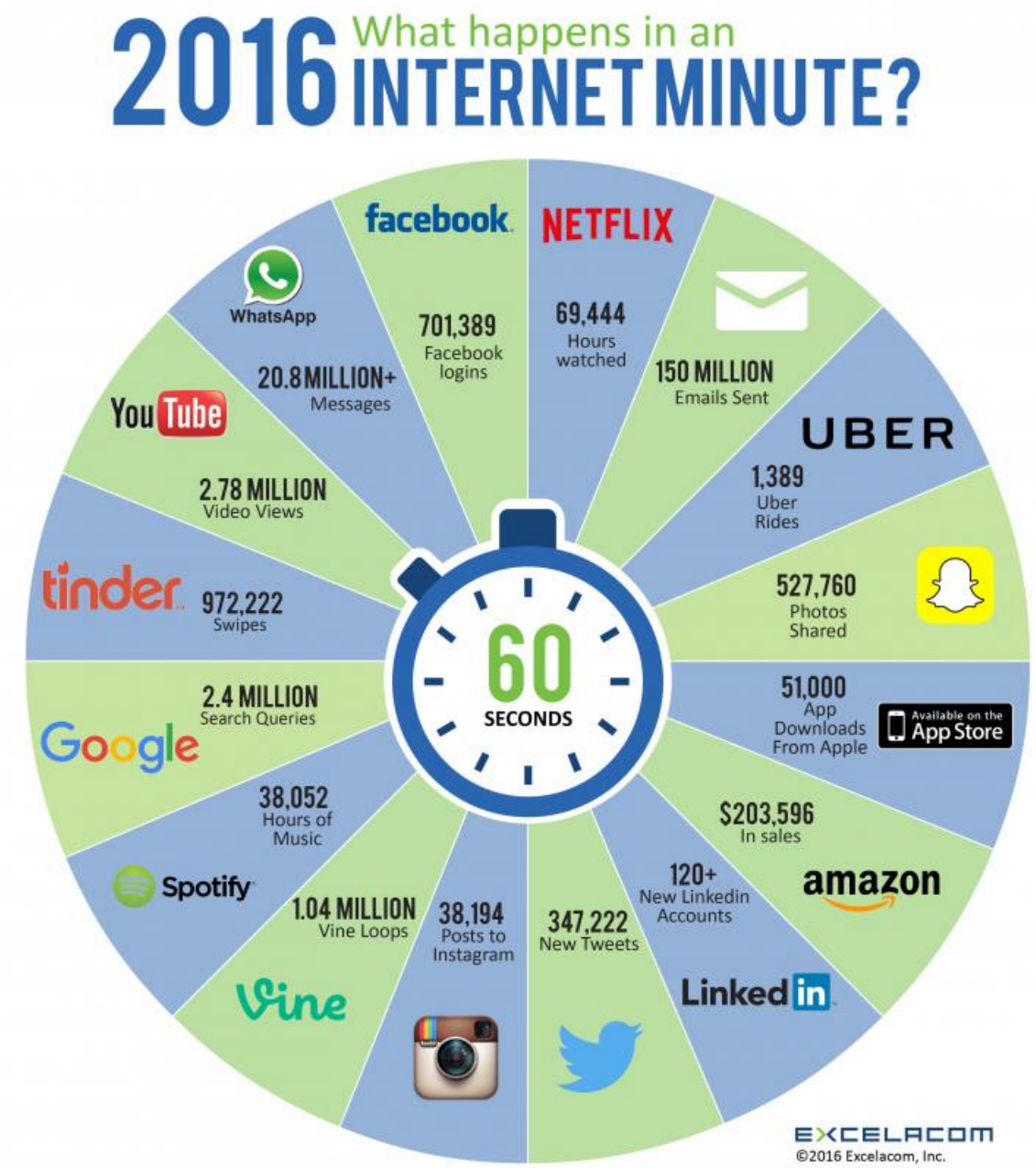
- Analyzing data reflects reality
- Walmart: hurricane warning
  - Stock beer and strawberry pop-tarts
  - 7x increase in sales during large storms
- Government: resource allocation decisions
  - Data mining in Maryland → crime hotspots
  - Shuffle resource allocation, more to hotspots
    - violent 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


2016 What happens in an INTERNET MINUTE?
facebook
701,389
Facebook logins
NETFLIX
69,444
Hours watched
150 MILLION
Emails Sent
UBER
1,389
Uber Rides
527,760
Photos Shared
51,000
App Downloads From Apple
Available on the App Store
$203,596
In sales
amazon
120+
New Linkedin Accounts
Linked in
347,222
New Tweets
38,194
Posts to Instagram
1.04 MILLION
Vine Loops
Vine
38,052
Hours of Music
Spotify
2.4 MILLION
Search Queries
Google
972,222
Swipes
tinder
2.78 MILLION
Video Views
YouTube
20.8 MILLION+
Messages
WhatsApp
60
SECONDS
EXCELACOM
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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…

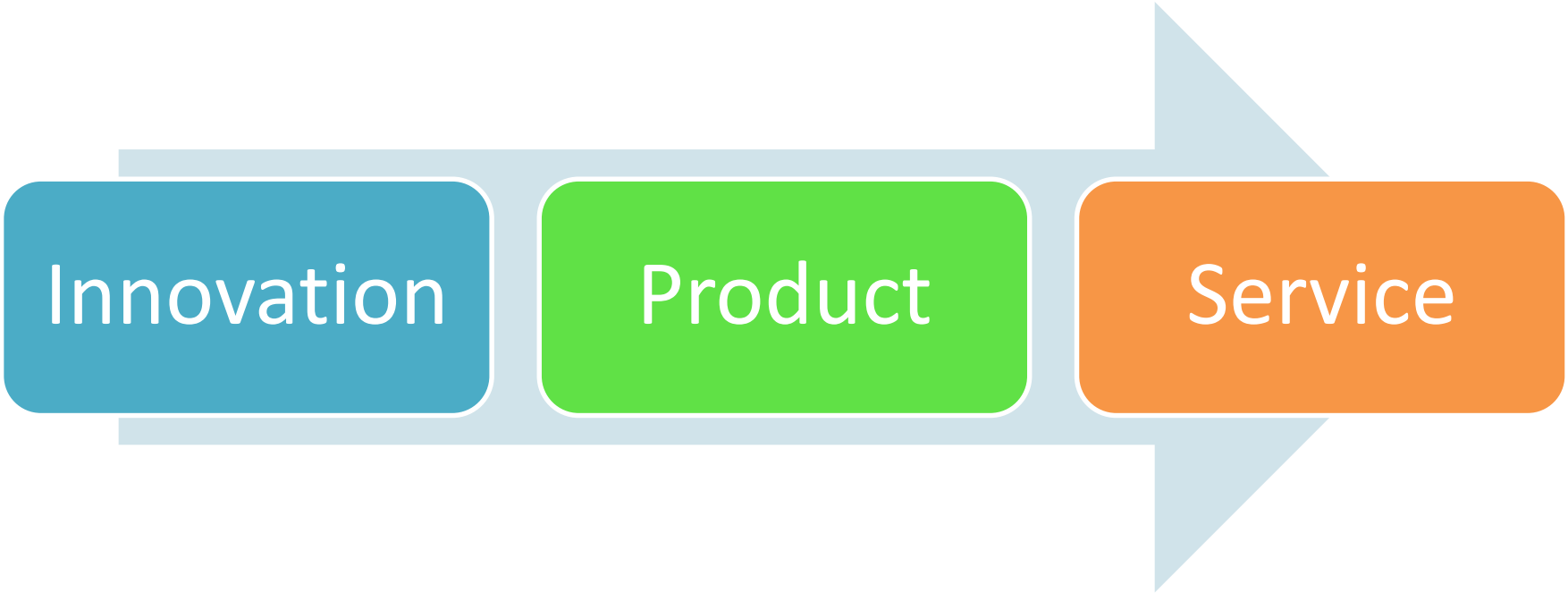
Large Scale Systems

Large Scale System Challenges

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

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

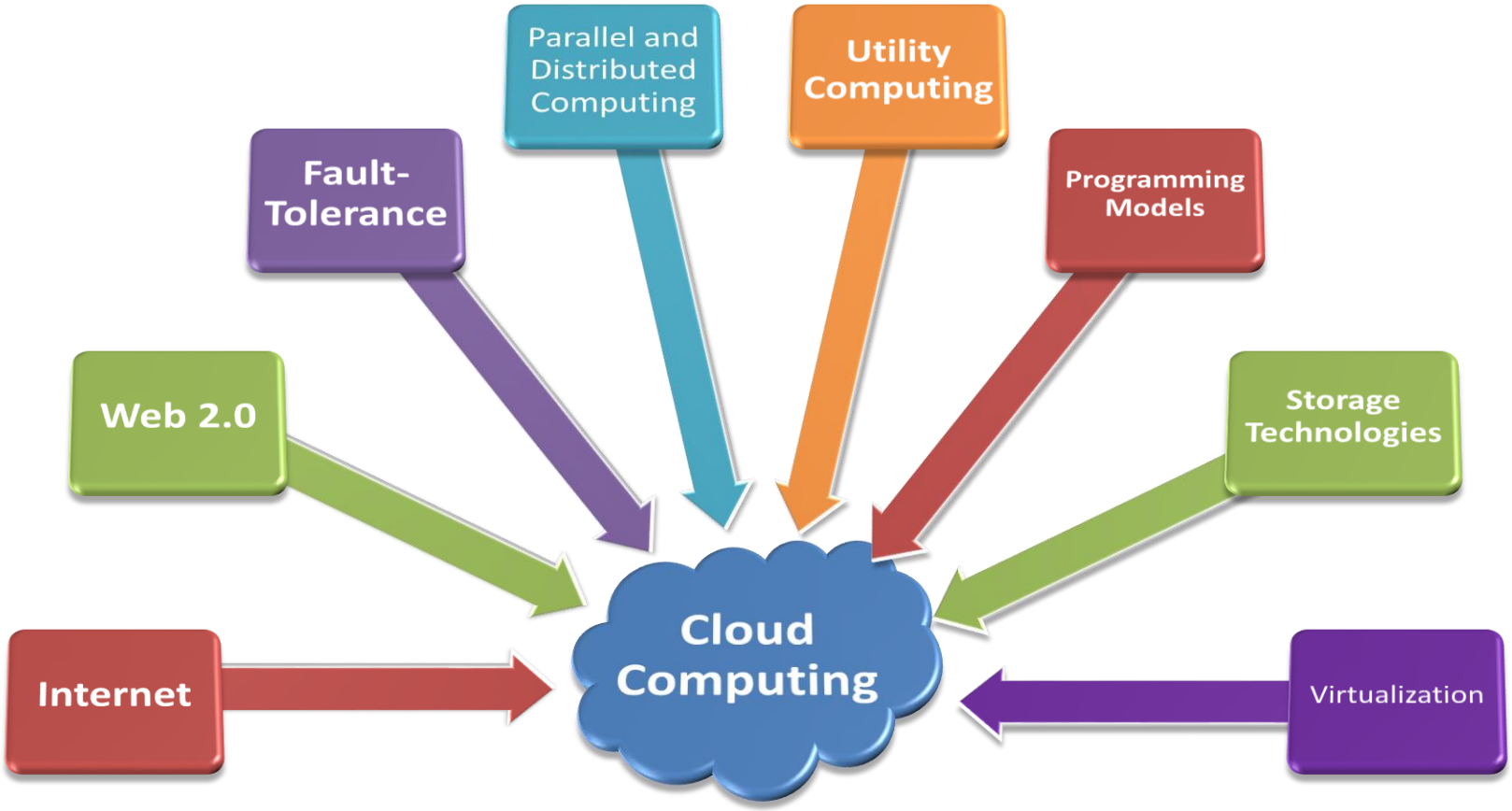
… for a more complete definition!

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.**

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

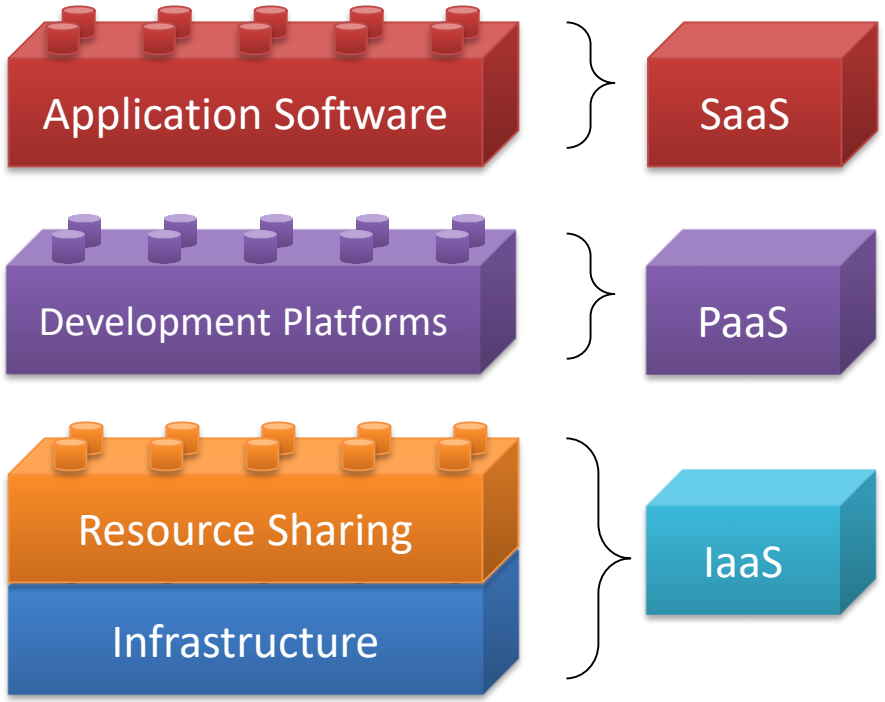
Storage Technologies

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**)



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

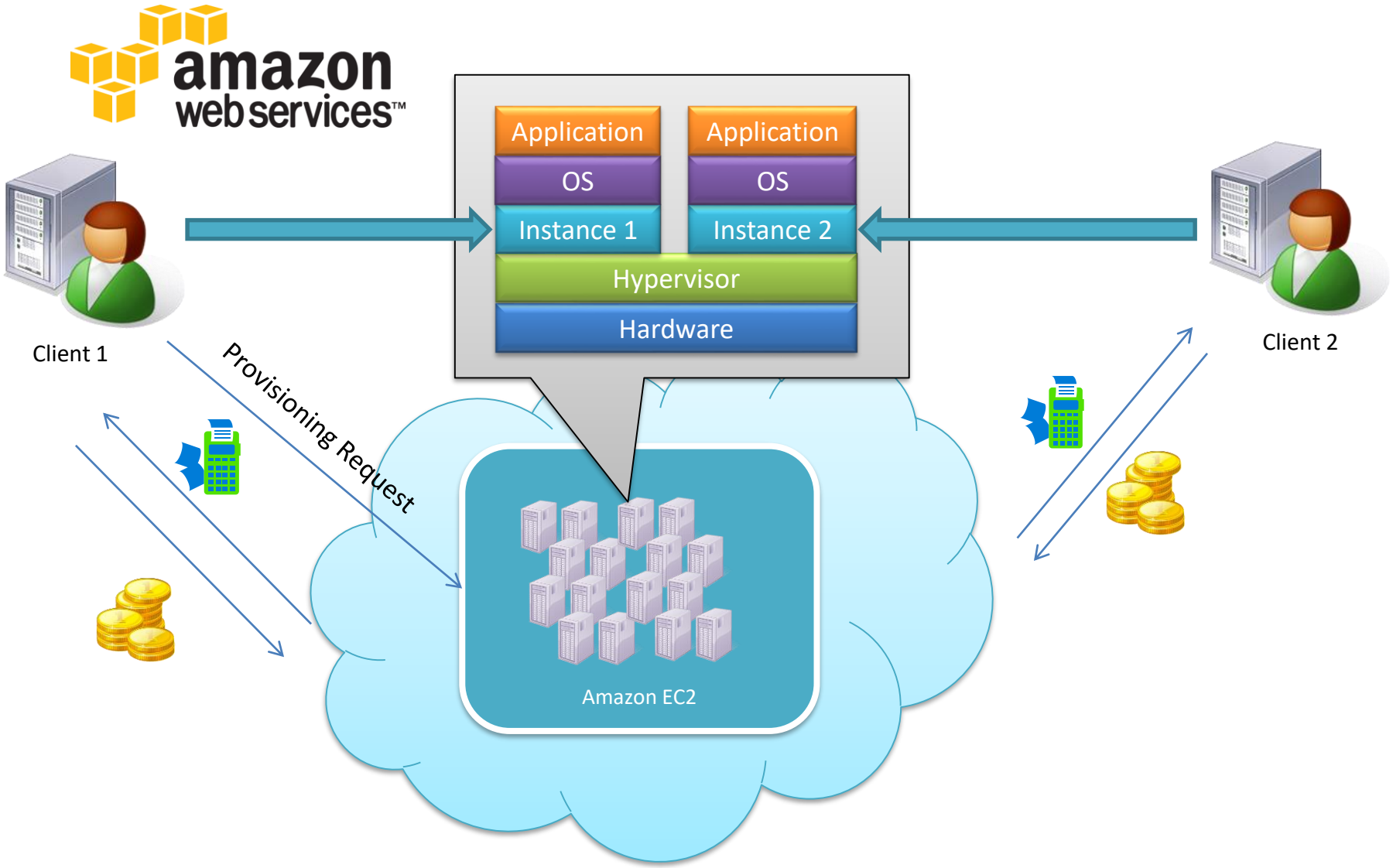
Platform as a Service (PaaS)

- 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** **o**ptions

Carbon **Footprint** decreased

Risks and Challenges

Migration

Security & Privacy

Vendor Lock-In

Legal

Internet Dependence

Service Level Agreements and Objectives (SLA/SLO)

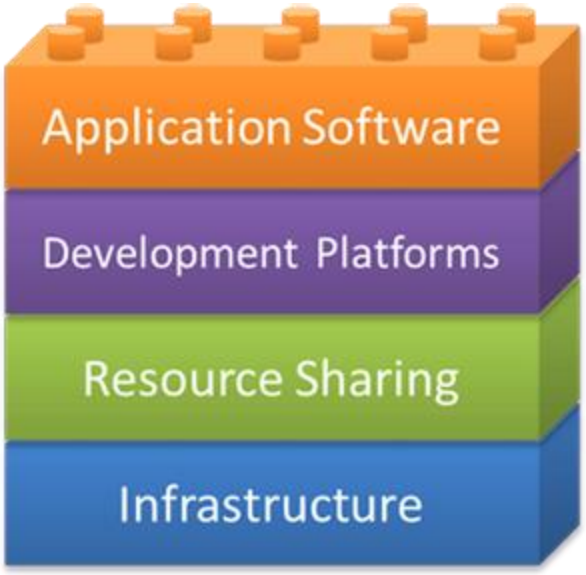
- SLA: Contract between cloud providers and users to define expected service
  - Service availability and delivery
  - Payment terms, bonuses and penalties for service
- SLO: Individual performance/service metrics regarding service delivery defined in the SLA
- Auditing: monitor resources to enforce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

Cloud Computing Stack

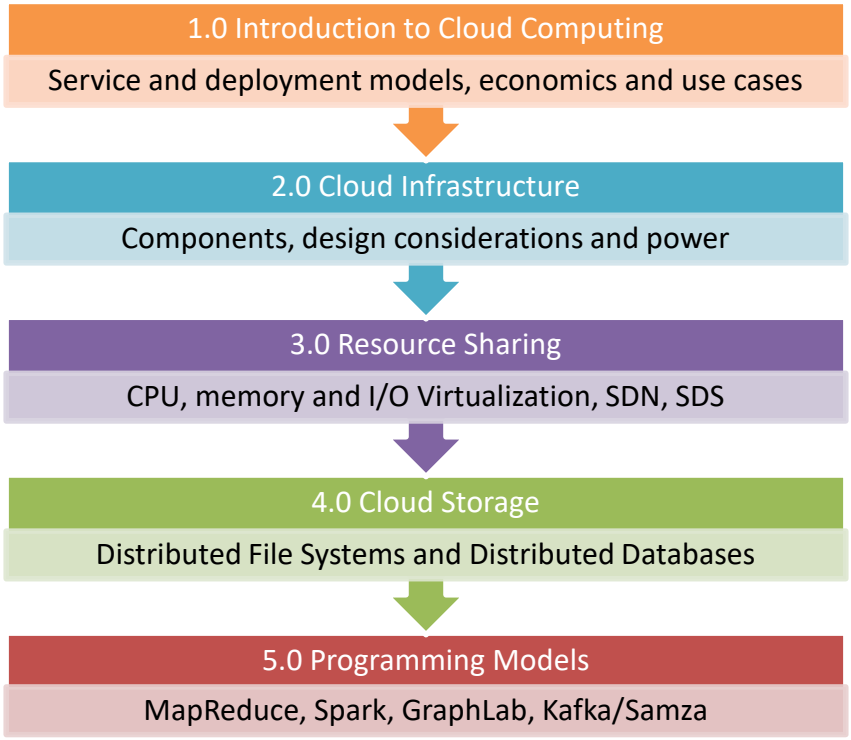
- Applications
- Development Platforms
- Elasticity
  - APIs to enable automation,
    Alarms, protocols, triggers, etc…
- Sharing mechanisms
  - Virtualization, SDX, …
- Distributed systems
  - Programming models
  - Storage
- Data centers



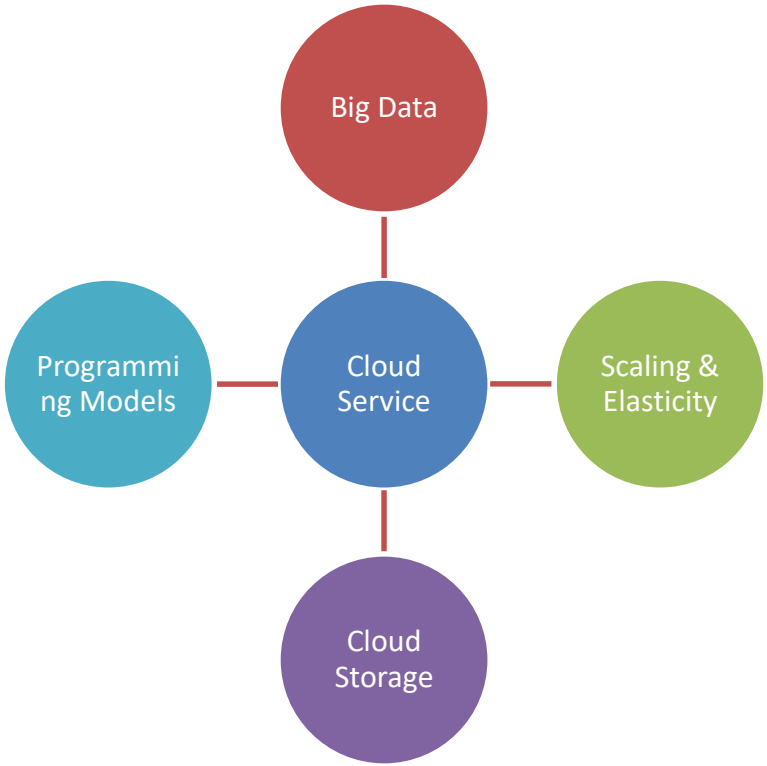
What is this course about?

- Applied aspects of cloud computing
  - Between systems and services

Conceptual content on OLI



Projects on AWS, Azure, & GCP



Course Objectives

Students will learn:

- the fundamental ideas behind **Cloud Computing**;
- the basic ideas and principles in **cloud infrastructure**, data center design and management; cloud software stack and software deployment on the cloud
- the resource sharing and **virtualization** techniques that serve in offering software, computation and storage services on the cloud; Software Defined Networks (SDN) and Software Defined Storage (SDS);
- about **cloud storage** technologies and relevant distributed file systems, NoSQL databases and object storage;
- the variety of **programming models** and develop working experience in three of them.

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 Quiz 1, Sep 8, 2017
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

Projects on AWS/Azure/GCP Clouds

Due 9/3/2017

0. AWS/Azure Account Setup & Tool Primer	• Benchmarking VMs, SSH, Authentication, Billing, Security Groups, Vertical Scaling
1. Big Data Analytics	• Amazon EC2, Amazon EMR, Azure HDInsight
2. Scaling, Elasticity and Failure	• Auto Scaling, Load Balancing, Monitoring, Containers, Kubernetes, Docker
3. Cloud Storage	• Amazon EBS, MySQL, HBase, Amazon RDS, MongoDB, Impala, Redshift
4. Analytics Engines for the Cloud	• Amazon EMR, MapReduce, Spark, GraphLab, 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

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

Projects

- Four Individual Projects (all students):
  0. Primers and P0 (Due Sunday, Sep 3, 2017)
  1. Big Data Analytics
  2. Scalability, Elasticity and Failure
  3. Cloud Storage
  4. Analytics Engines for the Cloud
- One Team Project, Twitter Analytics Web Service (15-619 students, extra 3-units)
  - One multi-week team project to build a complete web service

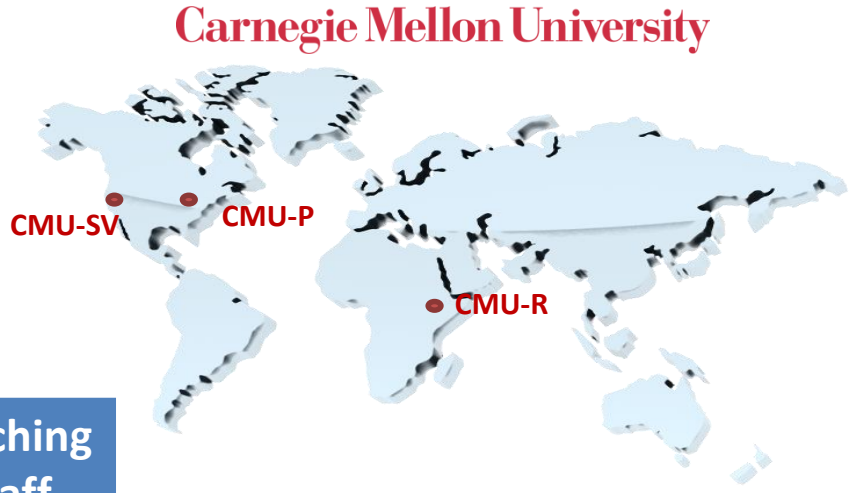
What this course is *not* about

- 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

Outline

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

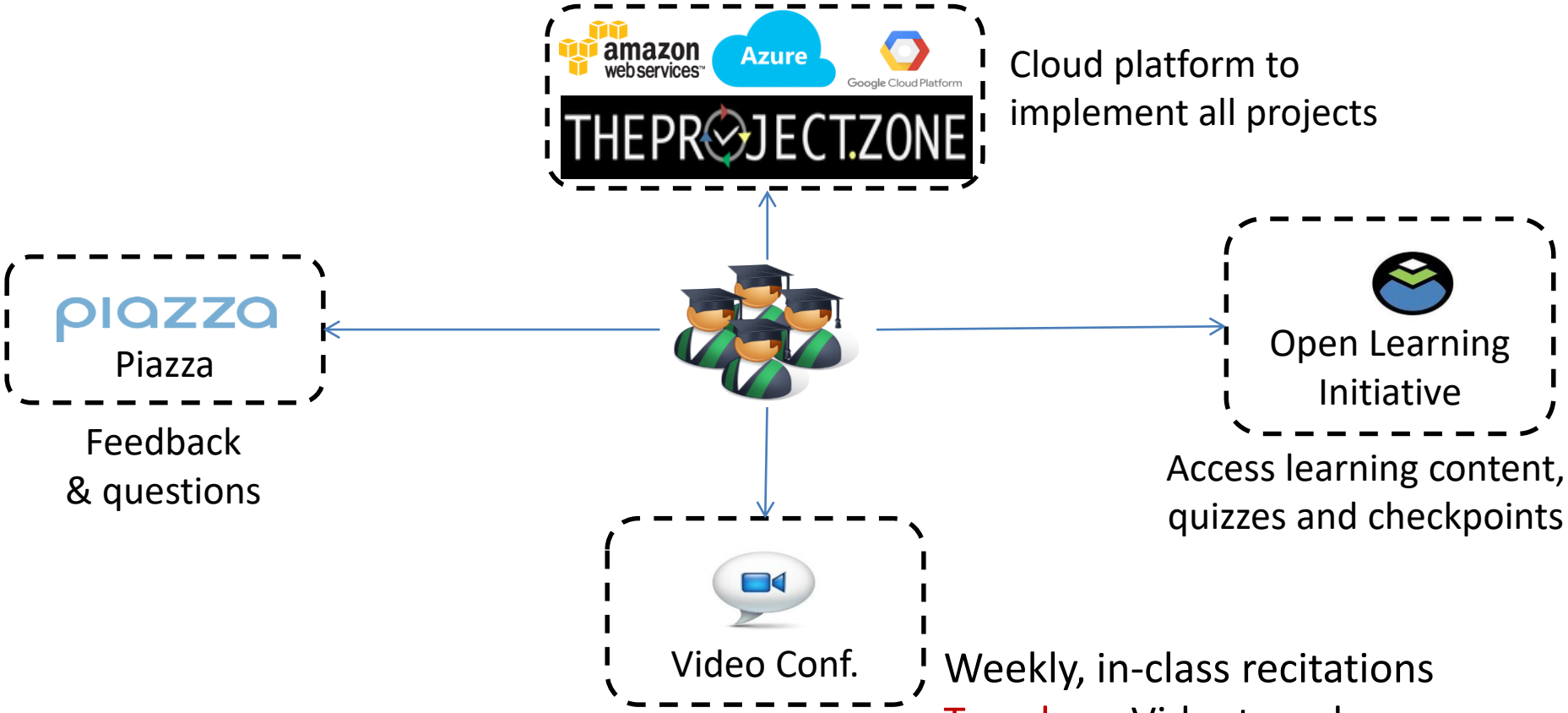
Carnegie Mellon Global Course



Location	Sections	Students	Teaching Staff
CMU Pittsburgh	A & B	139	14
CMU Silicon Valley	C	72	7
CMU Rwanda	D	2	0

Please move to the section for your campus ASAP

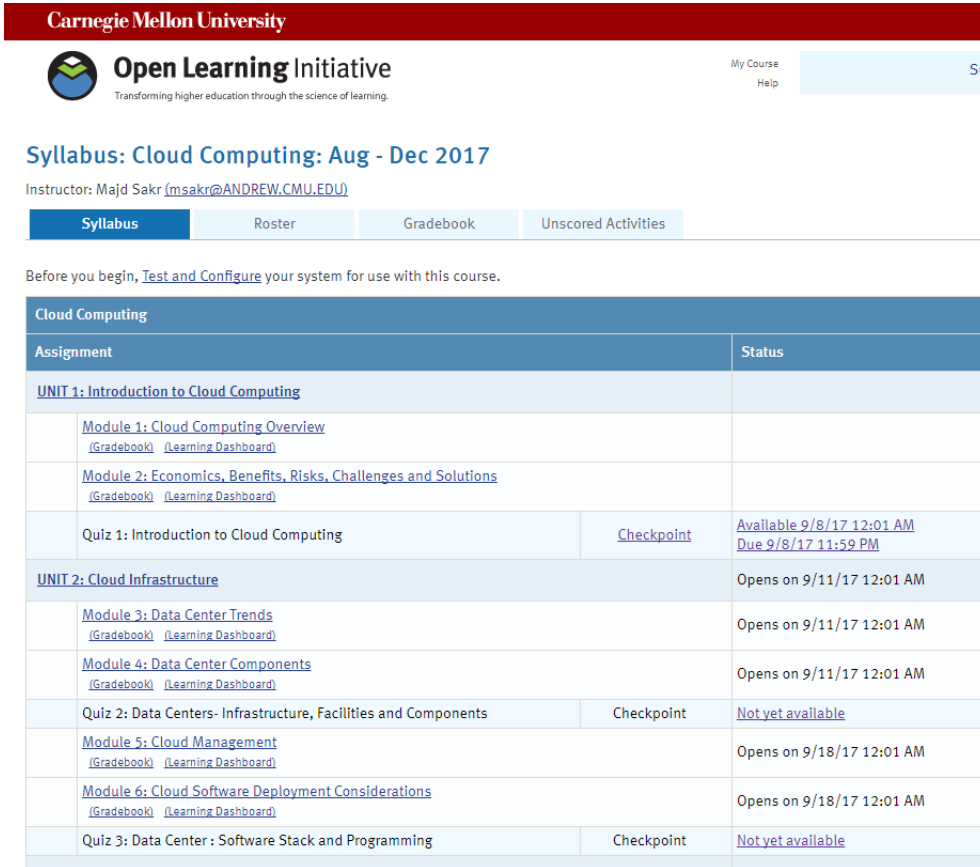
Online Course Engagement Model



Online Course Content - OLI

Course content is on the Open Learning Initiative:

- Students are automatically registered
- Access to OLI is through Canvas
  - canvas.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



Carnegie Mellon University

Open Learning Initiative

Transforming higher education through the science of learning.

My Course
Help

Syllabus: Cloud Computing: Aug - Dec 2017

Instructor: Majd Sakr (msakr@ANDREW.CMU.EDU)

Syllabus | Roster | Gradebook | Unscored Activities

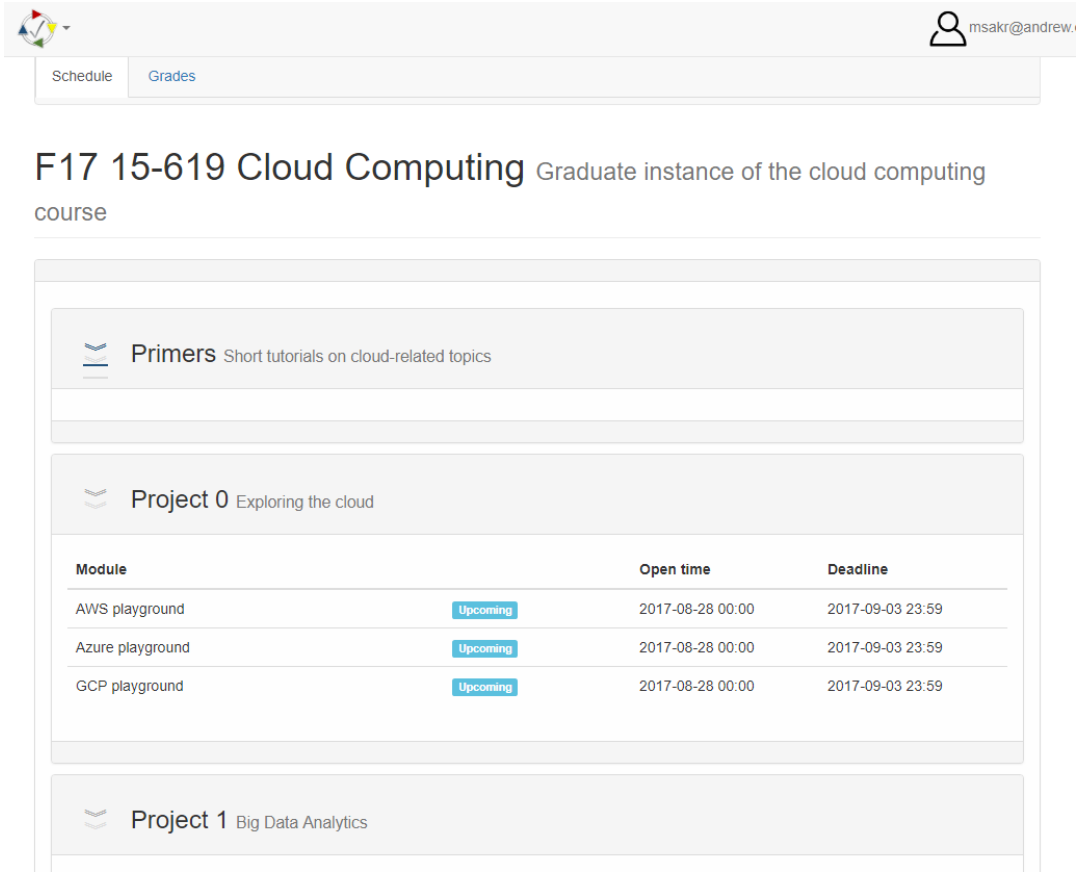
Before you begin, Test and Configure your system for use with this course.

Cloud Computing		
Assignment		**Status**
UNIT 1: Introduction to Cloud Computing		
Module 1: Cloud Computing Overview (Gradebook) (Learning Dashboard)		
Module 2: Economics, Benefits, Risks, Challenges and Solutions (Gradebook) (Learning Dashboard)		
Quiz 1: Introduction to Cloud Computing	Checkpoint	Available 9/8/17 12:01 AM Due 9/8/17 11:59 PM
UNIT 2: Cloud Infrastructure		Opens on 9/11/17 12:01 AM
Module 3: Data Center Trends (Gradebook) (Learning Dashboard)		Opens on 9/11/17 12:01 AM
Module 4: Data Center Components (Gradebook) (Learning Dashboard)		Opens on 9/11/17 12:01 AM
Quiz 2: Data Centers- Infrastructure, Facilities and Components	Checkpoint	Not yet available
Module 5: Cloud Management (Gradebook) (Learning Dashboard)		Opens on 9/18/17 12:01 AM
Module 6: Cloud Software Deployment Considerations (Gradebook) (Learning Dashboard)		Opens on 9/18/17 12:01 AM
Quiz 3: Data Center : Software Stack and Programming	Checkpoint	Not yet available

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
FALL 2017

1. OVERVIEW

Title: Cloud Computing
Units: 15-319 is 9 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
Piazza: http://piazza.com/cmu/fall2017/1531915619/home

Recitation:

1. **Tuesday, 8:00 AM – 8:50 AM, GHC 4307 (Videotaped)**
2. **Thursday, 4:30 PM – 5:20 PM, GHC 4307 (VC to SV) (First three 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)

Prof. Seth Copen Goldstein
seth@cs.cmu.edu
GHC 7111, +1-412-268-3828
Office hours: TBA

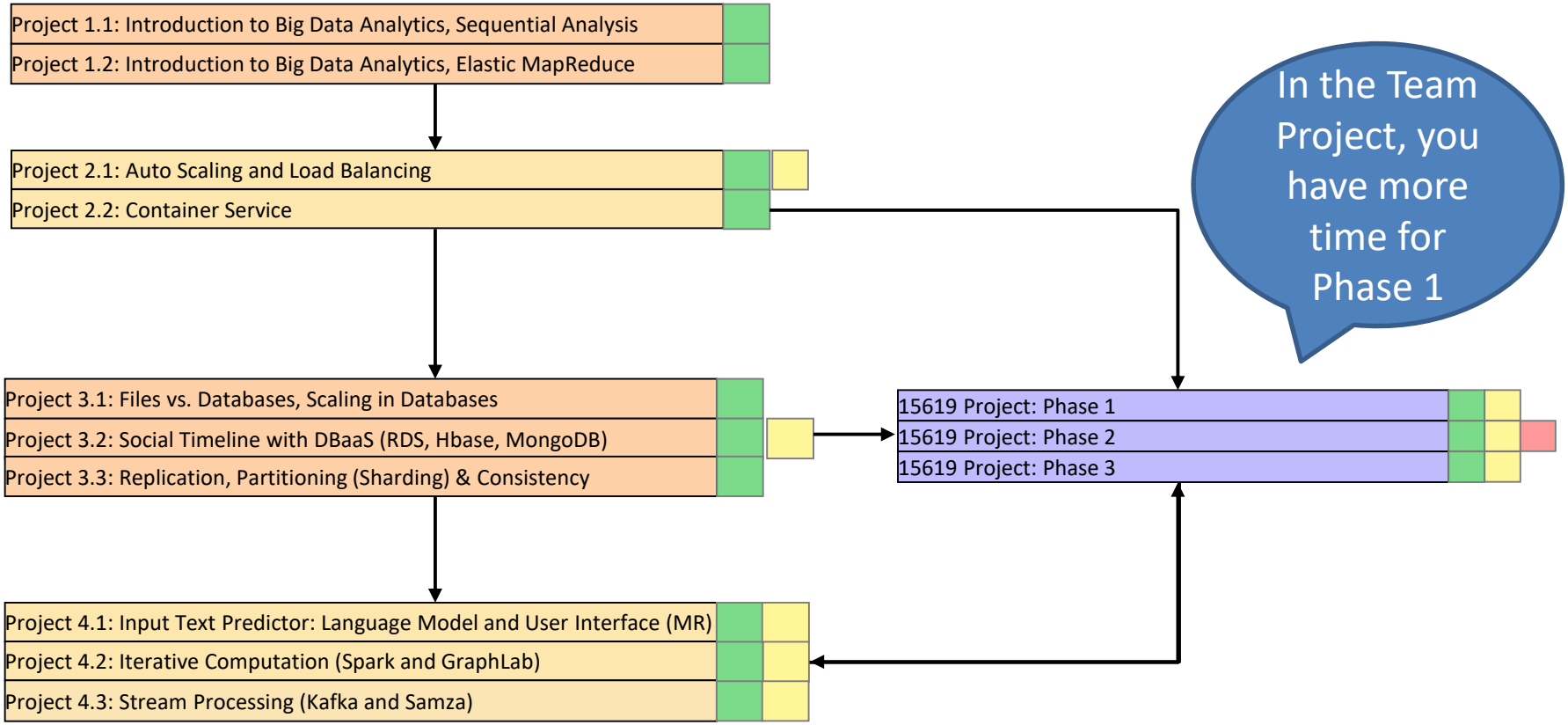
TAs in Pittsburgh typically hold office hours in GHC 5th Floor Teaching Commons. The TA office hours are posted on Piazza:

Tentative Schedule

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

Week	Monday	OLI Content	Individual Projects	Team Project	Quizzes
1	8/28/2017	Unit 1, Module 1, 2	Primers/P0 (Sep 3)		Q0 (Ac. Integ.)
2	9/4/2017	Unit 1, Module 1, 2	P1.1 (Sep 10)		Q1 (Sep 8)
3	9/11/2017	Unit 2, Module 3, 4	P1.2 (Sep 17)		Q2 (Sep 15)
4	9/18/2017	Unit 2, Module 5, 6	P2.1 (Sep 24)		Q3 (Sep 22)
5	9/25/2017	Unit 3, Module 7, 8, 9	P2.2 (Oct 1)		Q4 (Sep 29)
6	10/2/2017	Unit 3, Module 10, 11, 12	P3.1 (Oct 8)		Q5 (Oct 6)
7	10/9/2017	Unit 3, Module 13	P3.2 (Oct 15)	Project Out (Oct 9)	Q6 (Oct 13)
8	10/16/2017	Unit 4, Module 14	P3.3 (Oct 22)		Q7 (Oct 19)
9	10/23/2017	Unit 4, Module 15		Phase 1 Due (Oct 29)	Q8 (Oct 27)
10	10/30/2017	Unit 4, Module 16, 17	P4.1 (Nov 5)		Q9 (Nov 3)
11	11/6/2017	Unit 5, Module 18		Phase 2 Due (Nov 12)	Q10 (Nov 9)
12	11/13/2017	Unit 5, Module 19, 20	P4.2 (Nov 19)		Q11 (Nov 17)
13	11/20/2017	Thanksgiving			
14	11/27/2017	Unit 5, Module 21, 22		Phase 3 Due (Dec 3)	Q12 (Dec 1)
15	12/4/2017		P4.3 (Dec 8)		

Projects: Timeline and Dependencies



Grading

Course Elements	#	Weight
Projects	4 or 5	80%
OLI Unit Checkpoint Quizzes	12	20%

- Projects weights
  - 15-319
    - 80 %, 10 individual project modules, each 8%
  - 15-619
    - 60%, 10 individual project modules, each 6%
    - 20%, 1 team project, three phases
- Weekly quizzes (12 in total)
  - equal weight

Pass/Fail option is no longer available for this course

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

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

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
  - $100 for this course
  - Students will provide an MSA on theproject.zone
  - We will create a subscription on Azure
- If you are careless in spending
  - Spending penalty
  - You will run out of money ($100) for a given project
    - You will have to pay-as-you-go

GCP Coupon

- Google Cloud Platform provides the cloud computing course with one coupon per student
  - $100 for this course
  - Students will access a $50 coupon through theproject.zone
- 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

This Week

- Academic Integrity Module on OLI
  - **Sunday, Sep 3, 2017**
- Become familiar with conceptual content on OLI
  - Start reading Unit 1, Module 1 & Module 2
  - Quiz 1: Unit 1, Module 1 & 2, **Friday, Sep 8, 2017**
- 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, Sep 3, 2017**
- Check that you were enrolled on Piazza

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!

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 enough 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"!

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

The Penalties are Severe

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

LET IT NOT BE YOU!

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 P1	Cheating on P1
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

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 September 3, 2017

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 118)
    - First 3 weeks only, afterwards only when needed
- Office Hours
  - Check Piazza for Office Hour schedule

Teaching Staff

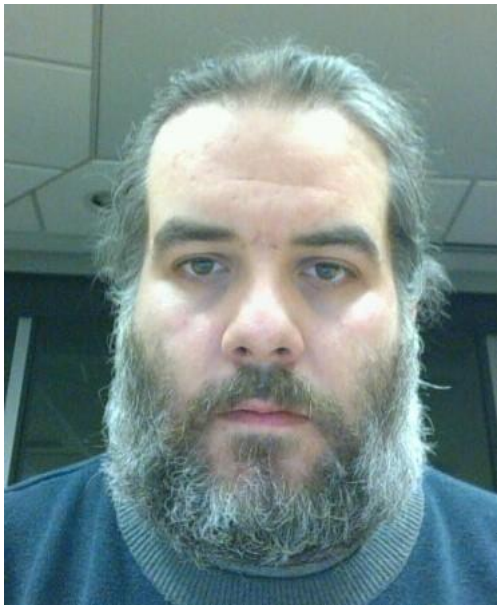
- Majd Sakr
  - GHC 7006
  - msakr@cs.cmu.edu
  - Office Hours
    - Tuesdays, 3-4pm (Pittsburgh)

- Seth Goldstein
  - GHC 7111
  - seth@cs.cmu.edu
  - Office Hours
    - TBD

Teaching Staff

- Cameron Dashti

- Marshall An



- Chaskiel Grundman

Pittsburgh: Teaching Assistants

- Mao Cai

Pittsburgh: Teaching Assistants

- Jimesh Chokshi

Pittsburgh: Teaching Assistants

- David Dai

Pittsburgh: Teaching Assistants

- Amanda Eng

Pittsburgh: Teaching Assistants

- Nick Guan

Pittsburgh: Teaching Assistants

- Yihan He

Pittsburgh: Teaching Assistants

- Ankit Jain

Pittsburgh: Teaching Assistants

- Harsha Konda

Pittsburgh: Teaching Assistants

- Zebing Lin

Pittsburgh: Teaching Assistants

- Yifang Liu

Pittsburgh: Teaching Assistants

- Sachin Menezes

Pittsburgh: Teaching Assistants

- Yiqun Ouyang

Pittsburgh: Teaching Assistants

- Peng Wang

Silicon Valley: Teaching Assistant

- Edam Li

Silicon Valley: Teaching Assistant

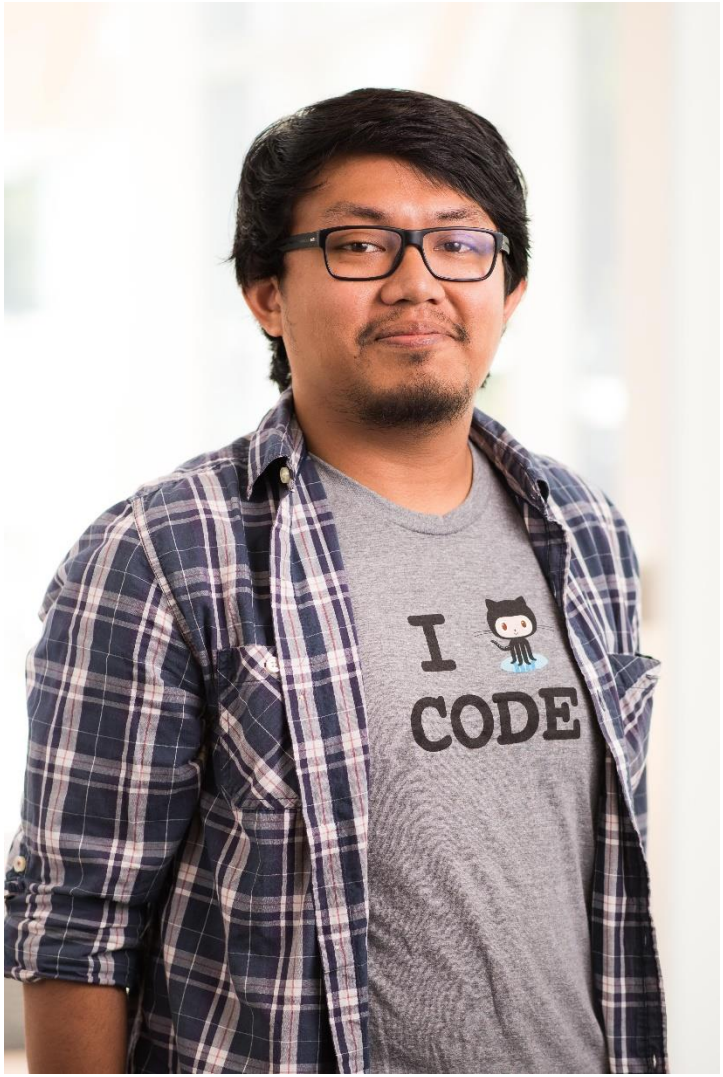
- Shiyue Liu

Silicon Valley: Teaching Assistants

- Shardul Mahadik

Silicon Valley: Teaching Assistant

- Imre Nagi



Silicon Valley: Teaching Assistant

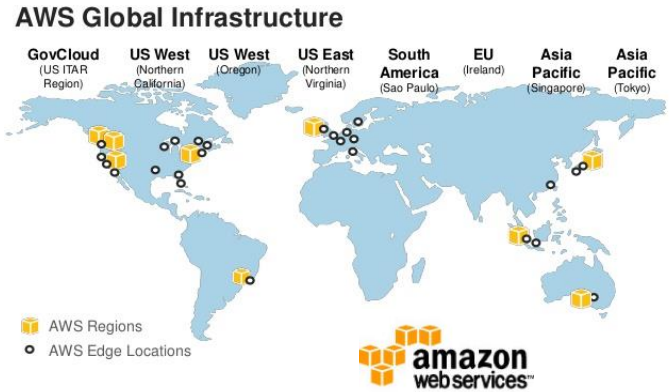
- Jiupeng Sun

Silicon Valley: Teaching Assistant

- Henry Yang

Era of Globalization

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



Questions?