# Using GENI, CloudLab and AWS together within a Cloud Computing course
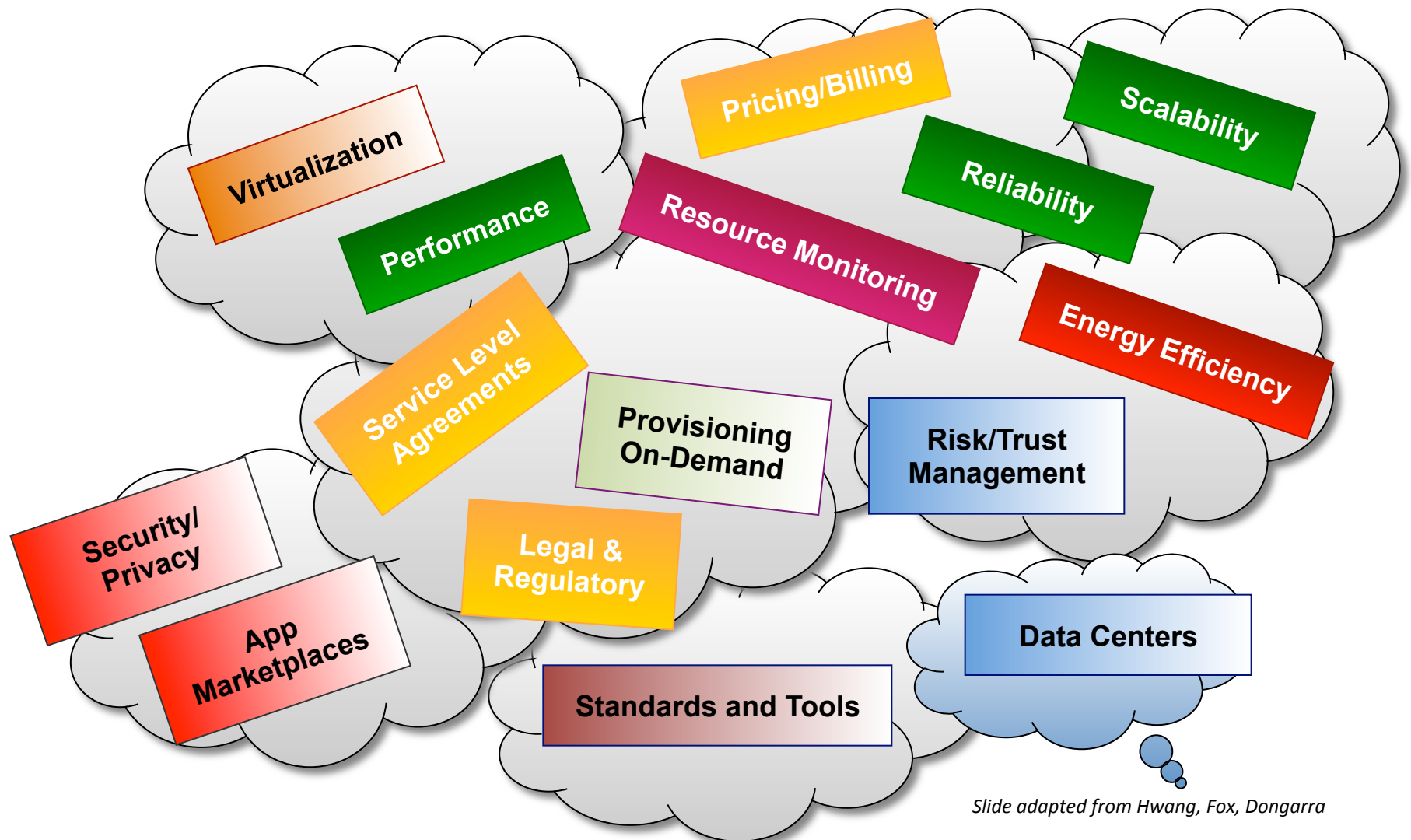
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# Topics covered on cloud computing and networking infrastructure



Virtualization

Pricing/Billing

Scalability

Performance

Reliability

Resource Monitoring

Energy Efficiency

Service Level Agreements

Provisioning On-Demand

Risk/Trust Management

Security/ Privacy

Legal & Regulatory

App Marketplaces

Data Centers

Standards and Tools

*Slide adapted from Hwang, Fox, Dongarra*

# Cloud Computing Course Information
## *Two classes taught: Fall 2013 and Spring 2015*

- **Pre-requisites:**
  - Object Oriented Programming
  - (Operating Systems-I), (Computer Networks-I), (Cyber Security-I)
- **Students:**
  - **Fall 2013: 23 Graduate, 7 Undergraduate, 5 visitors (Total: ~30+)**
  - **Spring 2015: 24 Graduate, 36 Undergraduate, 5 visitors (Total: ~60+)**
- **Textbook:**
  - Distributed and Cloud Computing - by K. Hwang, J. Dongarra, and G. Fox; First Edition [ISBN: 9780123858801] (required)
- **Teaching Assistants:**
  - Sripriya Seetharam, Ronny Antequera & Amit Akula – attended GENI Summer Camp, GECs, Thesis Research that uses GENI infrastructure
  - Work closely with GPO (Thanks! Niky, Sarah and Vic)
  - Monitors and answers student issues in Blackboard Discussion Forum
- **Uni. of Missouri GENI Rack Tour**

*Follow-up Cloud Computing II course will be offered in Fall 2015*

# Cloud Computing Course Objectives

- Be <u>competent</u> with principles and architectures that integrate computing theories and information technologies

- Be <u>competent</u> with distributed system models, computer virtualization concepts, network virtualization concepts

- Be <u>competent</u> with the design, programming and application of *distributed* and *cloud computing* systems
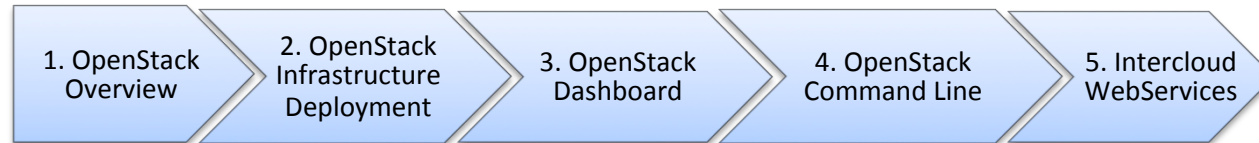
and…

- Be <u>familiar</u> with cyber-security and service-oriented concepts relating to use/design of cloud computing systems

- Be <u>familiar</u> with App customization of cloud computing infrastructures, and standards through hands-on experience

# Course Lab Assignments

- 6 labs to develop technical background and skills for working with distributed system and related software environments

- 3 Amazon Web Services (AWS) labs - http://aws.amazon.com
  - Received $100 usage credit per student through their academic program
  - Focus areas:
    - Instance setup with Cloud Watch alarm for billing alerts
    - Web App setup with EC2, S3 and Cloud Watch
    - Autoscaling to handle user load bursts in a Web App
  - Additional AWS Elastic MapReduce "WordCount" homework/lab

- **3 GENI labs** - http://groups.geni.net/geni/wiki **+ 1 CloudLab homework/lab**
  - "Calyam_UMissouri_Fall2013" Project in GENI portal (http://portal.geni.net)
  - **Focus areas:**
    - **Slice setup for "Hello GENI" experiment** (available on GENI Wiki)
    - **Instrumentation & Measurement Web App setup with GENI Rack VMs and OnTimeMeasure software** (New but available on GENI Wiki)
    - **OpenFlow controller programming for 2 traffic engineering applications: QoS Control based on enterprise policy, and Load Balancing** (New)
  - **Additional CloudLab InterCloud Webservices homework/lab**

# Homework #3 Problem:
## InterCloud Lab with OpenStack



| 1. OpenStack Overview | 2. OpenStack Infrastructure Deployment | 3. OpenStack Dashboard | 4. OpenStack Command Line | 5. Intercloud WebServices |

- **Purpose of the Lab**
  - Deploy your own "personal cloud" on NSF CloudLab (https://www.cloudlab.us) to understand how to program web services across multi-cloud platforms that are orchestrated using OpenStack cloud operating system
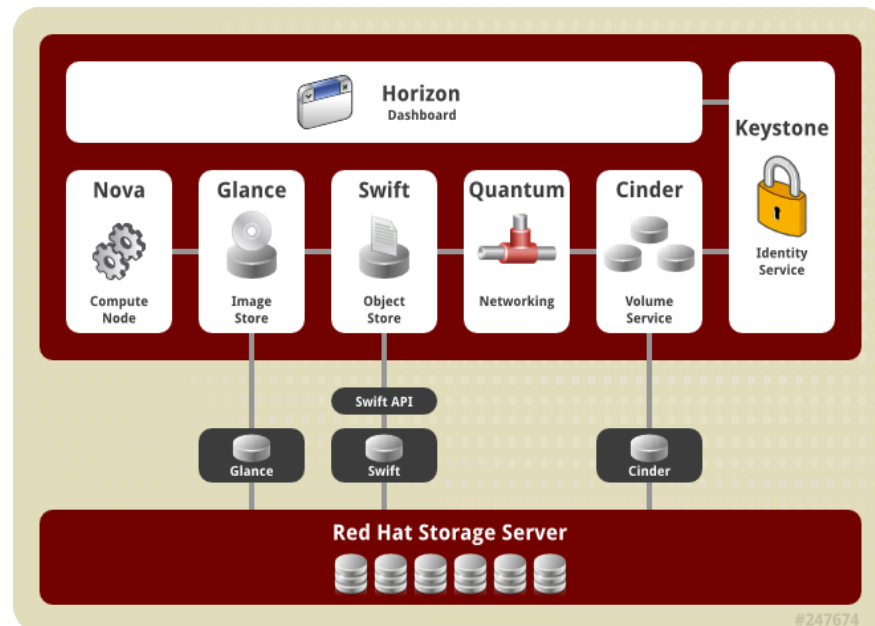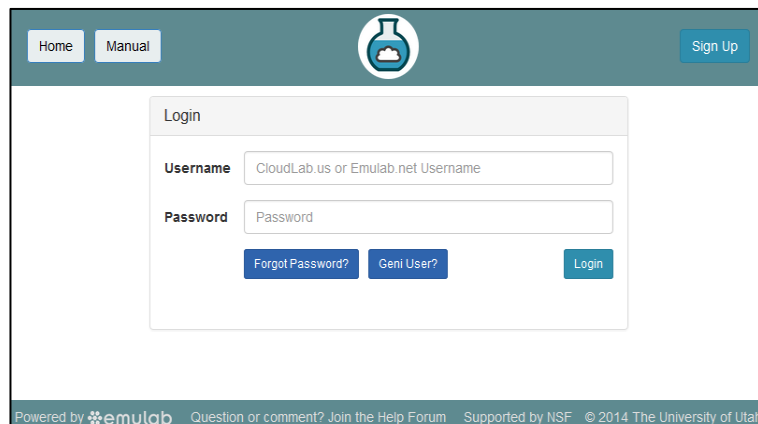
# InterCloud Web Services
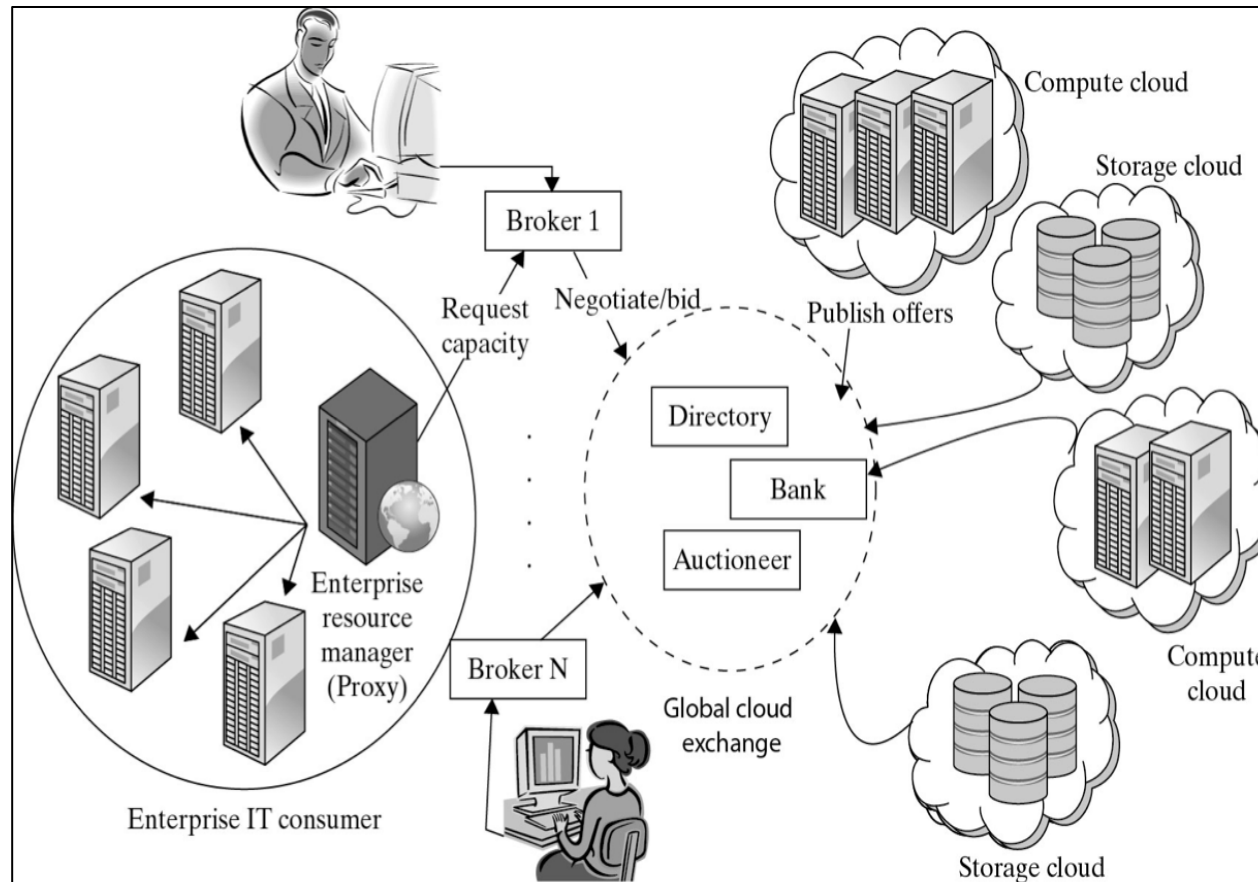


- Create an Intercloud API to display deployed instances in your experiment that can be accessible externally through RESTful web services
- Start by creating a web application, then convert it into a RESTful service to allow client requests to display various available instances information

# Your "Personal Cloud" Access



**Curl Client**

**Browser RESTClient**

**Instance Types**

# CloudLab Homework Q&A
## *What to turn in for Grading?*

1. Provide a screenshot of the "Network Topology" after a new instance is created; Explain the graph.

2. Provide screenshot of the 'controller' node with the MAC Address clearly displayed.

3. List in detail the resources available for the deployed cloud infrastructure (vCPUs, RAM, Floating IPs, Security Groups, and Volumes)

4. List the necessary changes in the profile file to add an extra compute node, and submit a revised RSpec.

5. Extend the Intercloud API to display user list (KEYSTONE) as:

   curl -u clouduser:EasyPassword15 -i http://[IP]:8090/**list_user**

   Provide screenshot of the output.

6. By using your AWS instance setup in AWS Lab-2, write a web service client (use any language of your preference) to request and display the cloud information available in the JSON file in a simple web site. Include the Amazon DNS link and the code in your submission report.

# Final Course Project

- **Objective**:
  - To develop programming and performance evaluation skills
  - To reinforce the understanding of major concepts in the course
    - *Graduate Student team projects* require use of either C/C++ or Java, as well as cloud-platform specific tools and applications
    - *Undergraduate student participation is optional (extra credit)*

- **Approach:**
  - Solve a "real" problem in a GENI/AWS testbed
    - **Teams**: *Core Logic Team*, *Testbed Team*, *User Interface Team*
    - Must use web services, show design tradeoffs *(e.g., how VM obfuscation for 'security' complicates 'manageability' of infrastructure)*
    - Build upon Cloud Computing material covered in class
    - Student domain expert for each project
  - In-Class "Circle Time" to provide on-going guidance
  - Final Project Presentations/Demos
  - 25% Grade based on overall team performance, peer-reviews

# Spring 2015 Final Course Projects

1. **Custom Image Templates enabled Platform-as-a-Service**
   - Based on requirements from SoyKB testbed in GENI and AWS
   - Concepts of Custom Image Templates, Service Optimization, Workflow Monitoring
   - Domain Experts: *Ronny Bazan Antequera, Yuanxun Zhang*

2. **Software-defined Networking for Visual Computing in the Cloud**
   - Based on requirements from LOFT (Likelihood of Features Tracking of Vehicles)
   - Concepts of Network Virtualization, Overlay Path Computation, Fog Computing
   - Domain Expert: *Dmitrii Chemodanov*

3. **Moving Target Defense for Resilient Cloud Management**
   - Based on requirements from cyber attack defense testbed in DeterLab
   - Concepts of Cyber Attack Generation, Proactive and Reactive Migration Triggers
   - Domain Experts: *Saptarshi Debroy and Ravi Akella*

4. **Hosting and Pricing of an Advanced Manufacturing App Marketplace**
   - Based on requirements from "Factory of the Future" testbed in GENI and AWS
   - Concepts of App Workflow Chaining, Resource Brokering, App Pricing Models
   - Domain Expert: *Amit Kumar Akula*

# Conclusion: How GENI helped!

- GENI provided an excellent platform to develop and administer hands-on laboratory exercises for students in the Course on cloud computing topics such as:
  - distributed system resource discovery and management
  - federated identity and access management
  - application/system/network performance measurement and adaptation
  - software-defined networking with OpenFlow
  - experimental testbed setup, related web services, and programming practices
- Student Learning enabled through GENI
  - Perception change of App and their high scalability in Cloud
  - Understanding Architecture diagrams!
  - Hands-on Experience with advanced computing technologies
  - Supplement class discussions of concepts through Lab exercises

# Conclusion: How GENI helped! (2)
## Some Student Quotes

"I am able to visualize the architecture diagrams"

"Labs in GENI were exciting!"

"There are a lot of technologies and terminology…"

"It takes time to understand detailed instructions in labs"

"I no longer view Apps as simply code executing on a single machine"

"I appreciate the fact that there is a 'user view' and 'provider view'…"

"When to use what virtualization is challenging"

# Other thoughts…

- Detailed instructions were needed to complete the labs
  - Using distributed system/network resources and working with tools such as those in GENI/AWS was a new experience

- AWS and GENI/CloudLab combination benefits
  - Many similarities in tools, best practices – reinforced learning!

- GENI Project Office/CloudLab co-ordination was important
  - To determine timing of labs, ensuring resource availability

- Offering a two parts (Cloud Computing I & II) course in consecutive semesters could be effective
  - Allows to have more in-depth GENI, CloudLab and AWS experiments, hands-on education, graduate research initiation

# Thank you for your attention!