Learning Cloud Computing and Security Through Cloudsim Simulation

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ABSTRACT: **:** *Cloud computing is fast evolving and growing and is rapidly transforming the IT service industry. Many universities are offering or planning to offer cloud computing courses to meet the growing demands for cloud computing professionals. However, most of the course offerings nowadays focus on theoretical aspects of cloud computing, and there is a lack of practical learning experiences for students. A hands-on labware will be a big plus for teaching and learning cloud computing. This paper proposes a cloud computing labware with the open source CloudSim (Cloud modeling and simulation toolkit) and its extension projects to promote authentic learning experiences for students. The proposed labware supports learning on important topics such as cloud principles, concepts, architecture, load balancing, and task scheduling. The proposed labware has been implemented in a cross-listed course (as both an undergraduate course and a graduate course) in two sections (hybrid section and fully-online section). At the end of the semester, an online survey has been conducted to evaluate the effectiveness of the CloudSim in the promotion of student learning experiences, and highly positive feedbacks were received from students. On average, over 80% of students gave non-negative feedback on all evaluation questions, and about 70% students agreed with the design objectives of the labware.*

Keywords: Cloud, Security, Labware, Cloudsim, Student Learning

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1.Introduction

Cloud computing is an emerging parallel and distributed service-oriented computing paradigm that provides platform service, software service, and infrastructure service through computing resource virtualization (Armbrust, Fox, Griffith, et al, 2009; Dean, 2008). Cloud computing is fast evolving and growing and is rapidly transforming the IT service industry (Kimball, Michels-Slettvet, and Bisciglia, 2008). Many universities are offering or planning to offer cloud computing courses to meet the growing demand for cloud computing professionals (Brown, 2009; Jararweh, Alshara, 2012). Some of them focus on big data processing programming using MapReduce with service charges from public cloud service (Rabkin, Reiss, Katz, & Patterson, 2012; Johnson, Liao, Rasmussen, Sridharan, Garcia, & Harvey, 2008; Calheiros, Ranjan, Beloglazov, De Rose, & Buyya, 2011; Beltrán, Guzmán, & Palomero, 2013), while many others teach cloud computing as a seminar type class without any hands-on labexercises. A hands-on labware will be a big plus for teaching and learning cloud computing. This paper proposes a cloud computing labware with the open source CloudSim (Cloud modeling and simulation toolkit) and its

extension projects to enhance computer science and information technology student learning. The proposed labware will support learning not only on MapReduce programming model but also on important topics including cloud principles, concepts, architecture, load balance, and task scheduling. To better understand the role of cloud computing in teaching and learning, we briefly describe cloud computing models and services in the following discourse.

1.1 Cloud Computing Models

The deployment models for cloud infrastructure are shown in the following:

• **Private Cloud.** This cloud infrastructure is owned by a single entity and is provisioned to provide services to multiple consumers within and outside the organization's premises.

• **Community Cloud.** This cloud infrastructure is designed with the purpose of providing services for a community of consumers.

• **Public Cloud.** This cloud infrastructure is designed for public consumption of services and is commonly located within the premises of the provider.

• **Hybrid Cloud.** This cloud infrastructure is configured with properties inherent to two or more of the distinct cloud infrastructures that are previously described.

1.2 Cloud Services

Cloud computing infrastructures are provisioned to provide essential business services to facilitate daily operations. These services are categorized by Voorsluys, Broberg, & Buyya [11] according to the following models:

• **Infrastructure as a Service (IaaS).** This model enables the provisioning of physical hardware and system to support operations. The system includes operating systems and software stacks that are customizable.

• **Platform as a Service (PaaS).** This higher level abstraction of cloud computing is provided so that users can create and deploy applications that are suitable to the business needs.

• **Software as a Service (SaaS).** This service model provides applications on a subscription basis and delivered over the Internet. The main advantage of this model is on the ease of software procurement and maintenance.

2. Labware Design

The objectives of the simulation based cloud computing labware are:

• To understand cloud computing principle and architecture;

• To understand cloud datacenter design and networking;

• To understand cloud virtualization and resource provisioning;

• To understand cloud security;

• To get hands-on experience on distributed and parallel data processing;

• To get hands-on experience on cloud performance analysis and task scheduling;

The proposed labware consists of a series of hands-on learning modules. Each module focuses on one cloud computing topic and has 3 components: Concept introduction, Hands-on lab activity, and post lab activity. The concept introduction introduces the concept, principle and technology for the related knowledge topic and provides related lecture notes/slides and reading references. The hands-on lab activity provides step by step cloud simulation environment setup configuration and demonstration guidelines so that students can easily follow and run the simulation themselves. The post lab activity is designed to enhance the students' critical thinking ability by requiring them to develop and implement a cloud simulation activity. The proposed labware is supported by the CloudSim simulation toolkit which is an open source platform developed in Java. The toolkit enables modeling and simulation for cloud computing. Many open source projects such as CloudSimEx, WorkflowSim, and DynamicCloudSim extend the CloudSim API for advanced cloud computing management and test purposes. The capability of modeling and simulating cloud environments overcomes many constraints for learning cloud computing

concepts with real cloud computing environment. A sample cloud structure by CloudSim is shown in Figure 1.

The proposed labware is organized and delineated by the following modules:

[1] Introduction to Cloud Computing; Architecture of cloud systems;

[2] Cloud Virtualization and its security;

[3] Resource provisioning(Cores, Memory, Storages) to VM;

[4] Federated clouds with datacenter network topologies and message passing;

[5] Energy-aware computational resources;

[6] MapReduce programming model with CloudSimEx(Extension of CloudSim);

[7] Task scheduling for load balancing with WorkflowSim(Extension of CloudSim);

[8] Data privacy and security on cloud;

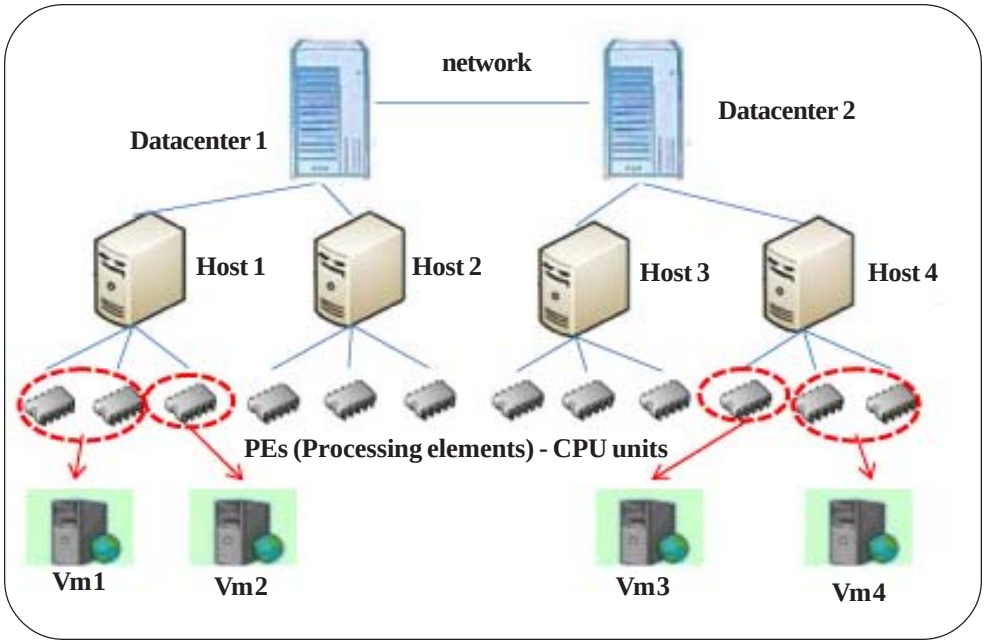

Figure 1 . A CloudSim Lab Architecture

3. Sample Labware

A developed cloud task scheduling lab with 2 VMs is illustrated in the following :

3.1 Lab Objectives

Upon completion of this lab students should be able to:

• Understand VM resource provisioning;

• Understand basics of VM load balance algorithms;

• Understand the importance of task scheduling in cloud computing;

3.2 Pre-lab Activity

• Introduction to the lab related concepts;

• Lab preparation;

3.3 Hands-on Lab Activity

A step by step lab guideline for cloud task scheduling lab with 2 VMs is shown below (Figures 2 and 3 depicts the load balancing algorithm and the simulation results, respectively):

Step 1: Initialize the Cloudsim package by calling CloudSim.init(int numUser, Calendar cal, boolean traceFlag);

Step 2: Create Datacenters and set the needed Datacenter Characteristics;

Step 3: Create Broker;

Step 4: Create virtual machine and set the configuration of each virtual machine, such as mips, size, ram and processing element number. Add virtual machine to the virtual machine list. Submit the virtual machine list to the broker;

Step 5: Create Cloudlet. Similarly, set the properties of each Cloudlet and add it into the cloudlet list. Submit the cloudlet list to the broker;

Step 6: Implement a tasks scheduling function (say named as: public void bindCloudletToVmsScheduling()) in the DatacenterBroker;

Step 7: Bind the cloudlets to VMs by calling the function defined in DatacenterBroker to apply your own task scheduling algorithm;

Step 8: Start the simulation by calling CloudSim.startSimulation ();

Step 9: Get the results by printing them out on the console or some other possible ways;

Step 10: Stop the simulation by calling CloudSim.stopSimulation ();

3.4 Post-lab Activity

Student add-on labs and assignments on cloud task scheduling;

Some basic practice labs are selected from the CloudSim open source project website [10] and other advanced labs such as task scheduling for load balance and cloud security are under our development. These lab modules can be used in cloud computing undergraduate courses. They can also be used for preparation work towards senior project and capstone courses because cloud computing builds on a broad range of body of knowledge in CS and IT such as computer architecture, computer networking, operating systems, distributed computing, and information security.

4. Course Exprience

The modules in the labware are designed to be self-contained so that they can both be used in a dedicated Cloud computing/ security course and also be integrated into existing courses. The development of the modules is in progress, so in this paper we present our experience in using pilot modules in IT-4903/6903 (Cloud Computing and Security course) in Spring 2014 (2 sections and 38 students; none of them has prior CloudSim development experience). At the end of the semester, students were asked to complete a survey that consists of the following five questions to evaluate the idea and the effectiveness of the labware:

Q1. I like being able to work with this hands-on labware.

Q2. The CloudSim labs helped me understand better on cloud computing.

Q3. The hands-on labs help me gain authentic learning and working experience on cloud computing.

Q4. The online lab tutorials help me work on student add-on labs/assignments.

Q5. The project helps me apply learned knowledge in cloud computing and cloud programming.

In total, thirty-eight students participated in the lab activities and completed the survey. Figures 4 and 5 show the students' feedback in the two sections of IT-4903/6903. On average, over 80% of students gave non-negative feedback on all evaluation questions, and about 70% students agreed with the design objectives of the labware.

In addition to the above survey results, students also provided their comments on the CloudSim labware. We list representative

positive feedback in the following. Students found the labs fun, educational, and promoting their interests in Cloud Computing and Security. They enjoyed the real hands-on experience with the labs and gained self-efficacy from the practices:

• What I liked about the CloudSim is that it helps reminds me of what I learned in my java programming class. There should be more CloudSim assignment to enhance students knowledge of the cloud and to helped them gain better understanding on cloud computing.

• The labs are very useful and give that experiential knowledge that can translate into future work. It is an excellent addition to the course. We need more hands-on work in the MSIT program!

• I found the course to be very useful because it made me understand Cloud Computing much better. The hands-on lab was particularly useful.

• I really liked the CloudSim labs. I think that they should be more complex as the semester progresses.

• CloudSim gave me a better understanding of how the cloud operates.

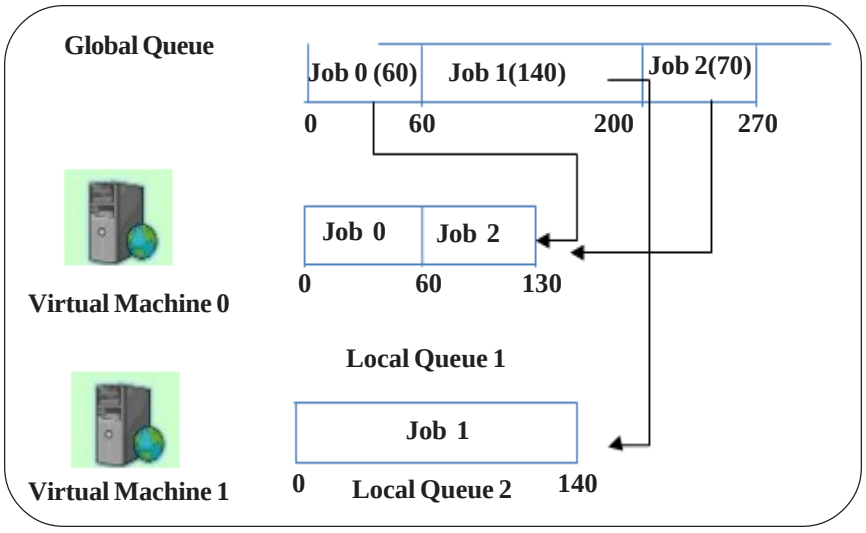

Figure 2. Lab for Load Balanced Shortest Task First Scheduling

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========== OUTPUT ==========
Cloudlet ID    STATUS    Data center ID    VM ID    Time    Start Time    Finish Time
    0        SUCCESS        2             0        60        0        60
    2        SUCCESS        2             0        70        60        130
    1        SUCCESS        2             1        140        0        140
*****PowerDatacenter: Datacenter_0*****
User id         Debt
3               224.8
**********************************
ExtendedExample finished!
```

Figure 3. Lab Results

The representative negative comments provided by students are listed in the following. Their concerns were concentrated around the installation of the lab environment and the precision of lab instructions. In the future, we will work on reducing the complexity of the lab environment setup and improve the lab instructions.

• As was addressed in the class, the instructions to loading and using the software need to be clarified and worked on.

• Overall, I think the labs were good, but the instructions could be a little more detailed in some cases.

• I think it would be helpful to have the software installed in the CSE labs on the computers and a step-by-step instruction

video for installation on personal computers. Additionally, having designated lab hours in the lab with a GA to help with any issues would be great.

• CloudSim labware might have not had enough examples to help with the various techniques used especially on VM scheduling. The various assignments did not elaborate fully on the specific out comes.

To sum up, our CloudSim labware and learning approach to Cloud Computing and Security received positive highly feedback from students. Through the programming of CoudSim projects, students are able to obtain more hands-on experience on how Cloud is operating. The proposed labware has provided students with authentic learning experience. Progresses are made towards the objectives of promoting students' interests and improving their experience in Cloud Computing and Security.

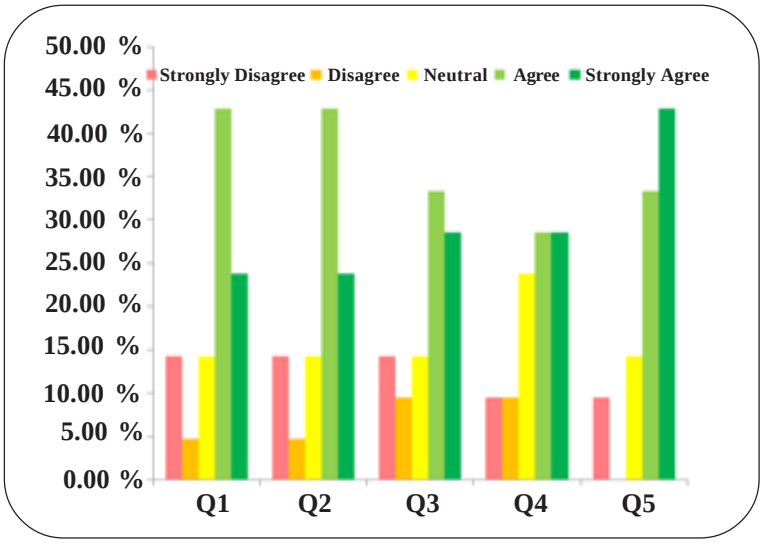

Figure 4. Survey Results of CloudSim Labware (IT-4903/6903 online section)

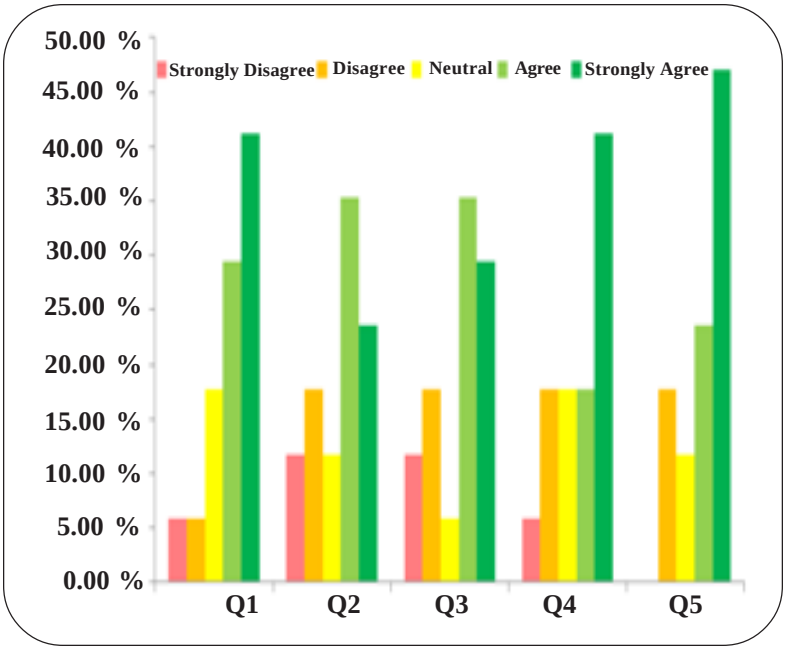

Figure 5. Survey Results of CloudSim Labware (IT-4903/6903 in-classroom section)

5. Conclusion

The proposed open course CloudSim base cloud computing labware can be easily integrated into any existing cloud computing related courses without additional costs to schools and students. Preliminary work on the labware shows that the proposed hands-on exercises by cloud simulation based labware will not only provide students with better understanding on the concepts and principles of cloud computing such as data centers and their federation, load balance and task scheduling, but also enable the test and development environment for potential research opportunity on cloud computing. This proposed labware will promote and enhance the cloud computing environment in computer science and information technology disciplines. Lastly, we envision this contribution as a catalyst for the development of more advanced cloud computing pedagogical tools.

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