Simulation Cloud Economics

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Problem Based Learning on Cloud Economics Analysis Using Open Source Simulation

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***Abstract*—The paper reports the use of an open source simulation software called GreenCloud to create a novel Problem Based Learning in a laboratory scale. The actual case of Indonesian government's plan to deploy cloud based data center infrastructure is taken as actual PBL case. GreenCloud enables the students to apply the case in simulation environment and then perform cloud economics analysis. There are three models of cloud architecture could be simulated namely Two-Tier, Three-Tier and Three-Tier High Speed. In addition, in terms of cloud economics analysis, there are three options available to be chosen, i) *non energy savings*, ii) *Dynamics Voltage and Frequency Scaling* (DVFS) and iii) *Dynamics Shutdown* (DNS). It has been shown that the novel PBL model could benefit learning processes.**

***Index Terms*—Cloud economics, problem based learning, economics analysis, GreenCloud.**

I. INTRODUCTION

Innovations in the field of information technology are evolving rapidly as we have witnessed both in terms of hardware and software. Various applications of information technology are available in different fields such as education, business, governent and many others.

E-government is a real example on the way digital technologies are used to improve efficiency and effectivity of government services to the citizens. In doing so, e-government systems strongly relies on development and improvement of information technology infrastructure to keep providing a user friendly e-public services [1].

However, updating hardware infrastructure has not always been an easy option for e-government particularly in developing countries due to budget limitation issues. Therefore, simple yet powerful solutions are needed to deal with the issue of extending information technology infrastructure with low cost in mind [2].

Cloud computing is regarded as appropriate technology to answer the problems arise in traditional client server approach though virtualization mechanisms that simplify hardware extensions without significant extra cost. In addition, cloud computing offers many other benefits to tradional approach such as low investment cost, simplicity in network management, on-demand scalable resources and many others. Unfortunately, the technology has serious side effect of potentially increasing power consumption at significant level. Therefore, IT managers must seriously take into account the issues at the beginning stage of any cloud based infrastructure development, particularly when green environment is strongly considered [3].

In Indonesia, renewing current e-government data center into cloud based one has been planned from couple of years ago. However, decision makers must carefully consider and quantify any costs associated with power consumption resulted from this plan. Having clear understanding of energy consumption when applying cloud computing is vital for successful implementation while reducing failure factor of future e-government projects [1].

The question to be addressed in this study is how to approach the real case of cloud e-government initiatives from economics perspectives and then adopt the case into a laboratory practice. Taking real world problems into laboratory practices is known as Problem Based Learning [7]. PBL has been proven as powerful way of learning which is favored by lecturers and students to enrich learning outcomes at higher education level.

To support the analysis, GreenCloud, an open source cloud computing simulation software was applied. Unlike other simulation software with mostly designed with technical in mind, GreenCloud is specifically devoted to analyze and measure economics aspect of cloud energy consumption from different point of views [4].

The use of this software offers many advantages. First of all, since GreenCloud is open source software so there is no additional cost for its implementation in laboratory environment. Secondly, it is relatively easy and straightforward to deploy GreenCloud whether running it as a virtual machine or directly install it into a server. Finally, cloud economics simulation on energy consumption is a novel topic to be covered within the course of Advanced Networks Management which previously only addresses technical aspects of the network engineering such as DNS, TCP/IP, Routers, Internet security, Grid and Cloud computing as well as IPv6.

The rest of this paper is organized into the following sections. The second part describes fundamental concept behind cloud computing. It is followed by cloud computing scenarios that will be applied by next generation of e-government infrastructure in section 3. In section 4, description of the simulation software is given. Section 5 represents the cloud simulation procedures followed by in depth analysis from economics viewpoints. Finally, conclusion is given in last section as well as future research direction.

II. CLOUD COMPUTING

Cloud computing is an advanced computing model thatenables ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interactions [5]. Cloud computing basically has five fundamental characteristics, three service models, and four deployment models [5,6].

The first one of its fundamental characteristics is *On-Demand Self-service* which allows user to unilaterally provision computing capabilities as needed automatically without human intervention on the provider side. Secondly, *Broad Network Access* is a unique characteristic of cloud computing to enable any devices such as mobile phones, tablets, laptops, and workstations to get access to various services available through the cloud. Then, *Resource Pooling* means the provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. *Rapid Elasticity* is the next characteristic of cloud computing that enables cloud services to be elastically provisioned and released, to scale rapidly outward and inward commensurate with demand in any quantity at any time. Finally, the last one is known as *Measured Service*. It means that cloud computing has ability to automatically control and optimize resource use by leveraging a metering capability [5].

Furthermore, there are three service models offered by cloud computing. *Software as a Service (SaaS)* is the capability provided to the consumer to use any applications running on cloud infrastructures. *Platform as a Service (PaaS)* is the capability provided to the consumer to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, and tools provided by the provider. *Infrastructure as a Service (IaaS)* is the capability given to user to use any computing infrastructure such as, storage, networks, and other fundamental computing resources by which they can deploy and run arbitrary software [5].

In terms of deployment model, there are four types cloud computing provides. *Private cloud* is provisioned for internal usage by an organization where cloud infrastructure developed, managed and operated by internal staff of the organization. *Public cloud* is associated to the business application of cloud technology. Users rent and run the many required services whenever they need over the cloud. *Community cloud* is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns. Finally *Hybrid cloud* enables a combination of two or more distinct cloud infrastructures (private, community, or public) [5].

III. PROBLEM BASED LEARNING ON CLOUD ECONOMICS

Problem Based Learning is a method of learning that stimulates students' knowledge and skills through particular real case [7]. Applying PBL in class will attract students' attention and participation [8,9]. In terms of computer and information technology related courses, several cases have been reported that PBL implementations have been significantly increased student participation and understanding [10].

It is argued that the novelty of PBL in this study lies on the use of actual case study of Indonesia e-government to adopt cloud computing which requires economics analysis. In addition, it also offers new insight of cloud economics aspects in simulation environment since most of the practical laboratory topics covered in the course of Advanced Network Management were technical based on textbooks provided by the lecturer.

A. Cloud Architectures Scenario

Based on the case study there are three scenarios of cloud architecture that possibly deployed to create cloud data center for e-government as described below.

First of all, *Three-tier architecture* is structured into three levels of network, *Access Network*, *Aggregation Network*, and *Core Network* as can be seen in the figure 1.

Secondly, *Three-tier High Speed architecture* is an extended version of the *Three-tier* one. It is designed particularly to optimize the number of *nodes*, to streamline the capacity of both *core* and *aggregation networks* in order to reduce bottleneck accidents in the network which mostly caused by these layers. Therefore, it is sometimes regarded as *simplified Three-tier architecture* as depicted in figure 2.

Finally, *Two-tier* as the name suggests only has two layers of network, *core* and *access networks.* It simplifies the common architecture by omitting *aggregation network as* illustrated as depicted in figure 3.

B. Cloud Economics Schemes

Cloud economics in this case refers to managing power consumption of cloud computing infrastructure as lower as possible. For such analysis, GreenCloud is equipped with two cloud economics schemes commonly applied in real data center.

The first scheme is called *Dynamics Voltage and Frequency Scaling* (DVFS). Basically, DVFS is power management on computer architecture by which voltage used by computer can be increased or decreased according to the requirements. Its dynamic auto scaling is not only applied to voltage but also to the frequency being used. DVFS's ability to turn the frequency up and down is very powerful to enhance productivity and reduce energy consumption.

The second method for reducing energy consumption on cloud computing infrastructure is called *Dynamics Shutdown* (DNS). The idea behind DNS scheme is that machines or servers in *idle* condition still operating and consume up to 66% of the full energy which is not economically efficient [11]. Therefore, *Dynamics Shutdown* scheme works by shutting down any servers and switches in *idle* condition after some period of time. Therefore, this scenario is effective to reduce energy consumption of cloud computing operation at significant level.

IV. SIMULATION

At the beginning of PBL, students were required to learn the real case of cloud e-government using three cloud architectures as mentioned previously. Also, they need to understand why cloud economics analysis is important in terms of green environment perspective.

Then in small groups, they started to develop a virtual machine whether in Linux or Windows operating systems by using Virtual Box. Then, the open source software for analysis tool called GreenCloud simulation software was then installed and tested. Figure 4 depicts working GreenCloud software over Linux server.

Once GreenCloud installed, the next step is to define the parameters to be used in performing simulation which are actually the derived from the actual case study in order to meet Problem Based Learning requirements.

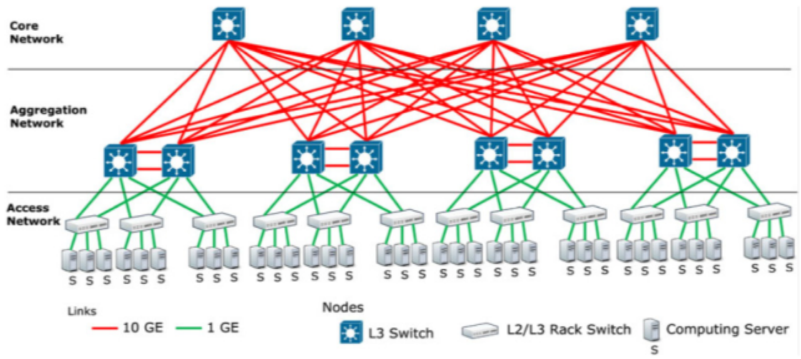

Figure 1. Three-tier architecture

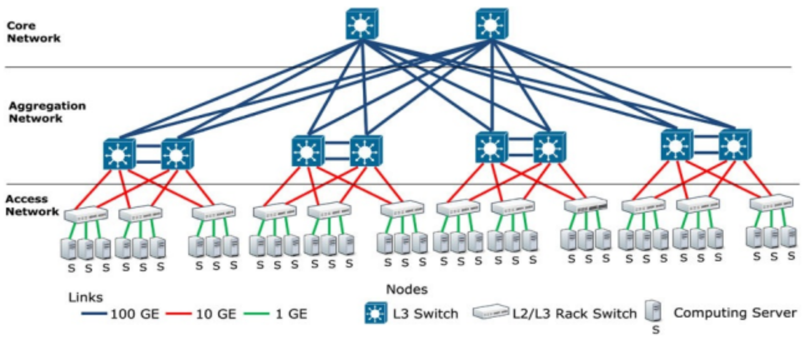

Figure 2. Three-tier High Speed architecture

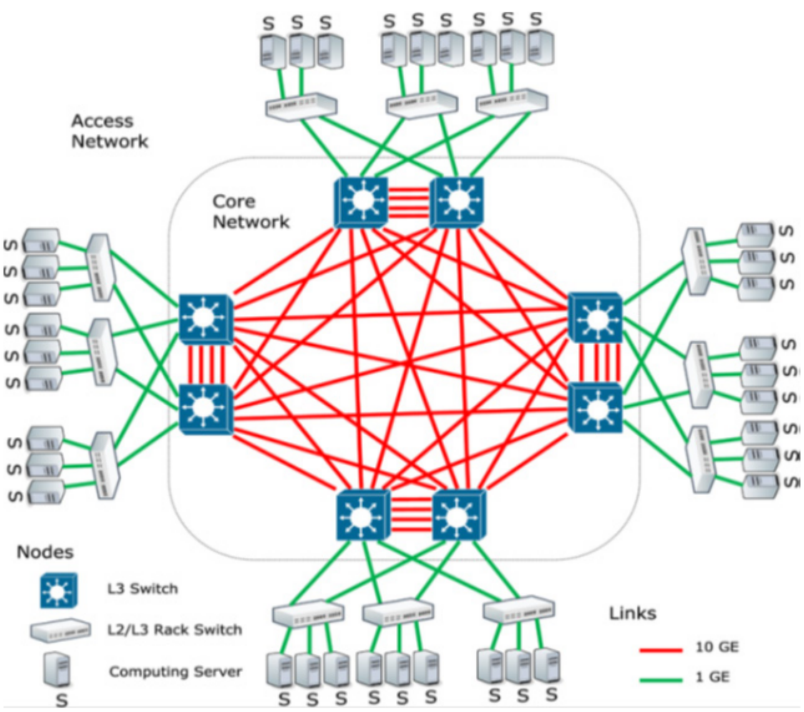

Figure 3. Two-tier architecture

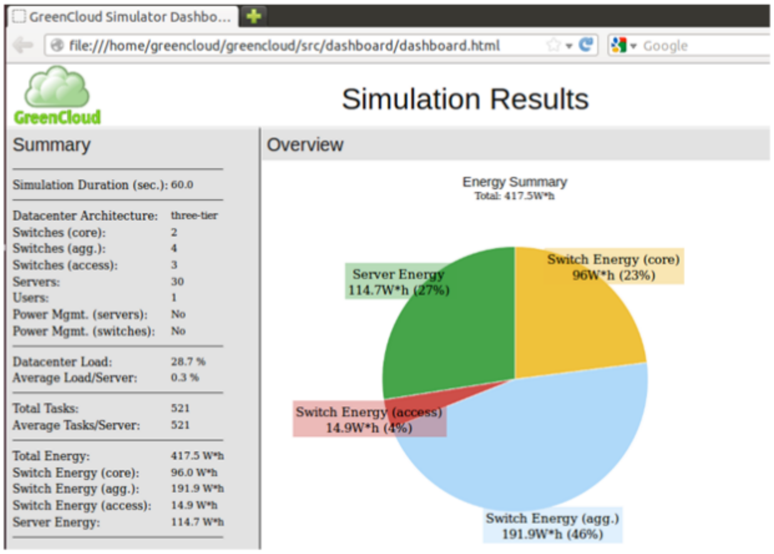

Figure 4. GreenCloud simulation

The parameters to be defined in this case are number of core, number of aggregation, switches and others. They must be defined in advance in order to closely replicate the original case of cloud computing for e-government (i.e. storage or data center) which is represented in details in Table 1.

After completing the parameters to three cloud scenarios, students were asked to activate energy saving option, a specific feature within GreenCloud software to perform cloud economics analysis.

In terms of energy saving simulation, there are three optional conditions to be set up by students. The first option called *non energy saving scheme* in which there is no single energy management applied to all cloud architectures. In this scenario, students run the simulation of each cloud architecture according to the predefined parameters (see Table 1) and the amount of energy consumption calculated and presented by GreenCloud.

The second option is by applying *Dynamics Voltage and Frequency Scaling* (DVFS) energy saving scheme on GreenCloud. In this step, students must enable DVFS option in GreenCloud before running the simulation similar to the first one. After some time, the amount of energy consumed by three cloud architectures could be obtained as shown in GreenCloud reports.

The third option is by activating *Dynamics Shutdown* (DNS) energy saving scheme on GreenCloud. Similar to the second option, before running the simulation students were required to activate DNS option in GreenCloud. Later, the amount of energy consumed by three cloud architectures could be obtained in a reportthat automatically geberated by GreenCloud software.

Finally, after collecting all data from three cloud economics options, the last step is to perform comparative analysis in order to determine the best cloud architecture and the best cloud economics option.

V. RESULTS AND DISCUSSION

This section presents simulation results of all cloud architecture scenarios under three options of cloud economics schemes by GreenCloud, namely non energy savings scheme, DVFS savings scheme and DNS savings scheme.

Table II presents GreenCloudsimulation results of Two-Tier, Three-Tier, and Three-Tier High Speed architectures without applying any energy savings schemes.

In general, Three-Tier has the lowest energy consumption of 62,565.6 kWh, followed by Two-Tier of 103,581.6 kWh and Three-Tier High Speed of 133,933.6 kWh. The-

TABLE I.
PARAMETERS FOR ALL CLOUD SCENARIOS

Parameter	2-Tier	3-Tier	3-Tier High Speed
Core (C1)	8	4	2
Aggregation node (C2)	-	8	8
Access Switch (C3)	4	8	16
Server (S)	96	96	96
Core (C1)	8	4	2
Aggregation Node (C2)	-	8	4
Access Switch (C3)	64	128	256
Link (C1-C2)	10 GE	10 GE	100 GE
Link (C2-C3)	1 GE	1 GE	10 GE
Link (C3-S)	1 GE	1 GE	1 GE
Simulation period	3600 sec	3600 sec	3600 sec

TABLE II.
RESULTS FOR NON ENERGY SAVINGS SCHEME

Parameter	2-Tier	3-Tier	3-Tier High Speed
Server	22007.8 (21%)	22007.8 (35%)	22007.8 (16%)
Switch	81573.8 (79%)	40557.8 (65%)	111925.8 (84%)
Core (C1)	76848.0	11944.0	56800.0
Aggregation node (C2)	0	23888.0	50400.0
Access Switch (C3)	4725.8	4725.8	4725.8
DC Load	28.5%	28.5%	28.5%

se results are obtained by the total of energy consumed by servers and switches.

In this scenario where there is no energy savings mechanism applied, the server and access (C3) will continue to consume energy although they are in the idle state. The amount of energy consumed by server and Access (C3) in all three architectures are the same of 22007.8 kWh and 4725.8 kWh respectively. Thus, the total amount of energy consumption will be strongly determined by Switch, which means Three-Tier architecture with fewer switches will require lowest energy to operate in comparison to other cloud architecture.

The next simulation is measure how much energy consumed by all cloud architectures by applying DVFS energy savings scheme. Table III represents the results.

As the name suggests, DNS scheme works by shutting down any servers and switches whenever they are in idle state. As seen in the above table, in comparison to previous simulations, DNS scheme successfully shows significant drop in total energy consumption for Two-Tier, Three-Tier and Three-Tier of 8557.8 kWh, 8557.7 kWh, and 8557.9 kWh respectively.

As can be seen in in Table III, the results are similar to Table II. These are in line with previous research [12,13] claimed that DVFS scheme would not give significant impact on network of less than 100 servers and switches since the scheme mainly manages voltage and frequency being used by servers and switches up and down and let them use the power although in idle state. In other study, it was reported that DVFS works fine to considerably reduce cloud energy consumption up to 1000 servers [14].

The last simulation is to analyze the impact of applying DNS energy savings over the three cloud architectures and the results are presented in Table IV.

In addition, it is indicated that Three-Tier architecture always outperforms two other architectures in terms of lowest total energy consumption in all simulation scenarios, non-energy savings, DVFS energy savings and DNS energy savings. Finally, all results obtained in three simulations as represented previously in Table III, Table IV and Table V are finally summarized in figure 5. It is clearly shows that DNS scheme consumes minimum energy compare to non-energy scheme and DVFS scheme.

VI. SUMMARY

A novel Problem Based Learning has been presented in this paper in order to enrich students' knowledge and experiences about cloud computing from economics perspectives. GreenCloud, an open source simulation software has been successfully utilized to assist the creation of novel PBL based on real case of e-government cloud computing planand finally enables students to conduct cloud simulation and economics analysis through virtual networks.

In the future, current research will be extended by adopting different real cases, such as cloud computing in business to obtain deeper understanding of cloud energy consumption. Another possible future research from this study might be from user interface development by creating a responsive user interface for laboratory practices to enable better distance learning experiences by lecturers and students.

TABLE III.
RESULTS FOR DVFS NON ENERGY SAVINGS SCHEME

Parameter	2-Tier	3-Tier	3-Tier High Speed
Server	22007.8 (21%)	22007.8 (35%)	22007.8 (16%)
Switch	81573.8 (79%)	40557.8 (65%)	111925.8 (84%)
Core (C1)	76848.0	11944.0	56800.0
Aggregation node (C2)	0	23888.0	50400.0
Access Switch (C3)	4725.8	4725.8	4725.8
DC Load	28.5%	28.5%	28.5%

TABLE IV.
RESULTS FOR DNS ENERGY SAVINGS SCHEME

Parameter	2-Tier	3-Tier	3-Tier High Speed
Server	8557.6 (100%)	8557.6 (100%)	8557.6 (100%)
Switch	0,2 (0%)	0,1 (0%)	0,3 (0%)
Core (C1)	0.2	0.0	0.2
Aggregation node (C2)	0.0	0.1	0.1
Access Switch (C3)	0.0	0.0	0.0
DC Load	28.5%	28.5%	28.5%

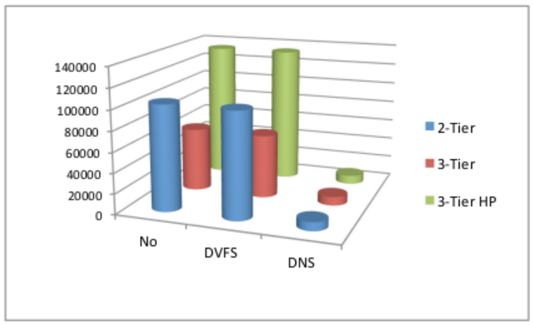

Figure 5. Final comparative result

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