International Journal of GEOMATE, March, 2019 Vol.16, Issue 55, pp. 168 -175
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.55.71310
Special Issue on Science, Engineering & Environment

VIRTUAL MACHINE PLACEMENT OF CLOUD COMPUTING FOR ENERGY RESERVATION

*Yuthapong Somchit[1] and Pragan Wattanasomboon[2]

[1] Center of Excellence in Natural Disaster Management; [1,2]Faculty of Engineering, Chiang Mai University, Thailand.

*Corresponding Author, Received: 11 Sept. 2018, Revised: 24 Oct. 2018, Accepted: 10 Dec. 2018

ABSTRACT: Cloud computing has been widely deployed. The virtual machines (VMs) are created in servers upon the requests from users and they are deleted from the servers after the rental time expires. This is called dynamic workload condition. VMs should be consolidated into the servers to reduce the number of servers running VMs. Servers that do not have any VMs should be changed to sleep mode to reduce energy consumption. Therefore, VM scheduling which selects servers to run VMs has to find servers to place VMs and has to migrate servers under this dynamic workload condition. However, migration also consumes energy, so the number of migrations should be limited to save energy. In this paper, a VM scheduling method called Energy-Aware Scheduling Updating (ESU) which reduces total energy consumption in the data center is purposed. It chooses servers to create VMs. In addition, it updates the locations of VMs when changes occur while it limits the number of migrations to reduce energy consumption. The performance is of ESU is evaluated by computer simulation. The results show that ESU has a better performance considering energy consumption among the protocols used in comparison.

Keywords: Cloud Computing, Virtual Machine, Virtual Machine Placement Method, Energy Consumption

1. INTRODUCTION

Cloud computing has been widely used in information technology (IT) industry as it can reduce costs from infrastructures or physical machines. Various resources such as CPU and storages can be provided by virtual machines (VMs). One server can run multiple VMs depending on the available resources. The costs of using cloud computing of users are flexible and depend on the requirements of users and time of usages. The services from Amazon EC2, Google Cloud, Microsoft Azure, and Digital Ocean [1-4] are examples of cloud computing service providers.

The cloud service providers manage the placement of VMs in physical servers. The VMs are created once the VM requests from the users arrive at the cloud. The load balancing approach can be considered to distribute loads from VMs to the servers. Energy consumption of the servers significantly impacts the costs of the service providers. For example, according to [5], one data center has the number of servers from 50,000 to 80,000 servers. This large number of servers consumes much energy. In addition, carbon dioxide emission has been concerned. Therefore, the energy-aware approach of the VM placement has been widely studied. This approach tries to reduce the total energy consumed by servers in the data center.

The load balancing approach normally tries to distribute the number of VMs or loads of VMs among physical servers. Conversely, the energy-aware approach tries to reduce the number of servers running VMs by consolidating VMs into servers to decrease the total number of servers running VMs. The server that runs the VMs is in active mode and the server that does not run any VMs can be change sleep mode. It is considered that a server in the sleep mode consumes less energy than a server in active mode [6,7]. Therefore, reducing the number of active servers can reduce the total energy consumption of the service providers.

Many energy-aware approach researchers use scheduling method to find the placement of VMs in the servers. The work in [8] proposes a hierarchical scheduling algorithm with the best fit descending (BFD) for servers in a hierarchical model. However, the hierarchical model can cause a single point of failure problem. Therefore, the cluster model which is based on overlay network is preferable in the cloud computing. The VM Scheduling Algorithm (VSA) is proposed in [9] for scheduling VMs in servers of the cluster model. It shows that it can reduce energy consumption in the data center. The Energy-aware Virtual Machine Placement (EVP) method is proposed in [10]. EVP method selects the proper servers in the proper clusters to run the VMs once the requests arrive. EVP shows that it has lower energy consumption than VSA. However, EVP does not consider the case that VMs are removed as the users stop using VMs as in the real scenario. The time that each VM is used depends on

VM rental time requested by the user. VMs can be created and removed at any time depending on the incoming requests of the users. This condition is called dynamic workloads. The VM placement method should re-schedule VMs after some VMs are removed. The servers that the number of VMs decreases to some level should migrate the VMs to other servers in order that they can change to sleep mode to reduce energy consumption. EVP does not provide a method to update VM placement under this condition. Conversely, VSA provides an update method but it can increase energy consumption from excessive migration. Therefore, it is important to provide the method to update VM placement under dynamic workloads conditions, while the number of migrations has to be considered.

This paper proposes the VM placement method under the dynamic workload condition. The users define how long they want to use the VMs when they send requests. Under this condition, placing the VMs at the right place at the first time as in EVP is not sufficient. It is required the method for updating the placement of current VMs when there are enough changes. A method to update VM placement called Energy-Aware Scheduling Updating (ESU) method is proposed in this work. The proposed method consists of two algorithms. The first algorithm updates the VMs within the intra-cluster. The other algorithm updates the VMs in the inter-cluster. ESU uses a Lower Workload of Cluster (*LWC*) threshold and a Lower Workload of Server (*LWS*) threshold to as the triggers for updating the VM placement. In addition, the energy consumption models in servers and network devices from migration are provided in this work.

The rest of this paper is organized as follows. Section 2 explains the related work and section 3 explains VMs and energy consumption in the cloud. Section 4 explains the proposed method and section 5 evaluates the proposed methods. Finally, section 6 concludes this work.

2. RELATED WORK

The VSA is proposed in [9]. The VSA schedules the VMs in both intra-clusters and inter-clusters. When VM requests arrive at the data center, it forwards the requests to the nearest clusters considering geological distances and selects the servers to create VMs using the round-robin method. Then, it checks the workloads of all servers. The servers with workloads lower than defined threshold migrate their VMs to the servers in the same cluster with maximum workloads by using the intra-cluster algorithm. It also checks the overall workloads of all clusters. Any clusters with workloads lower than the threshold are called Power Saver (PS) Clusters. All VMs in PS clusters are migrated to the clusters with the lowest workloads called Neighbor Server (NS) clusters. However, when the workloads of NS clusters exceed the threshold later, VMs have to be migrated again. This causes the extra energy consumption from migration.

The EVP is proposed in [10]. It proposes that the VMs should be placed to the proper servers in the proper clusters once the requests arrive to reduce the energy consumption from migration. This work also proposes methods to calculate the energy consumed by VMs migration. The EVP method uses two algorithms. The first algorithm is a Cluster Selection (CS) algorithm. It chooses the clusters that the VMs should be created. The other algorithm is a Server Selection (SS) algorithm. After the clusters are selected, the proper servers are selected using this algorithm. This reduces the total energy consumption because VMs do not need to be migrated. This work also proposes the equations based on the work in [10-12] for calculating the energy consumption from VM migration. However, it does not consider the condition that VMs are removed. Consequently, a method to update VM placement is not provided.

In this work, the method to update VM placement considering the dynamic condition in the cloud computing is proposed. The energy consumption from servers running VMs and migration is considered.

3. VIRTUAL MACHINES IN CLOUD COMPUTING

This section explains the structure of cloud computing forming data center and the energy consumption models of VM migration. The equations for calculating energy consumption in the data center are explained. The energy consumption is calculated from servers running VM. In addition, the energy consumption from VM migration is also calculated from both servers and network devices.

3.1 Cluster Model

The cluster model is widely implemented in the cloud computing. The physical servers are grouped into clusters depending on their locations. One cluster physically connects to one or more clusters. An example of this model is shown in Fig.1. This creates a full-mesh overlay network where all clusters connect to all other clusters logically. The full-mesh overlay network provides high reliability for large-scale network and avoids a single point of failure problem. Multiple VMs can be created in a single physical server. VMs can be migrated to other physical servers. Migrating VMs consumes energy from data transfer. The energy is consumed by servers and network devices. Migrating VMs within the cluster, which is called intra-cluster migration, consumes energy less than moving VMs between clusters, which is called inter-cluster migration.

It should be considered that the cluster connection is still based on the physical connection. Two clusters can send data directly to each other in the overlay point of view, but data might be transferred among multiple clusters according to their physical connection. Since the energy consumption from data transfer depends on the distance between source and destination, migrating VMs to one specific cluster might consume more energy than migrating to other clusters. For example, from Fig.1, migrating VMs from cluster 1 to cluster 3 consumes more energy than migrating VMs from cluster 1 to cluster 2.

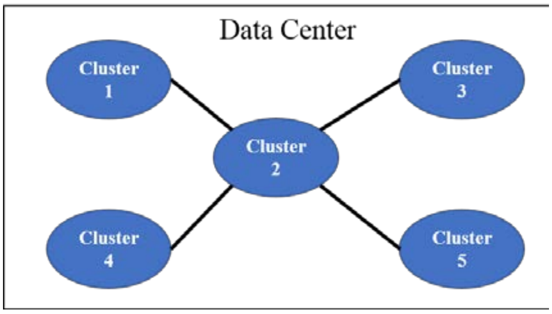

Fig.1 An example of a cluster model

3.2 Energy Consumption

The energy consumption in the data center is from servers. Servers in sleep mode consume less energy than servers in active mode. Furthermore, this work also considers energy consumption from network devices during VM migration, which the work in [10] considers only energy consumption from servers during the migration. The energy consumption is calculated from power consumption and the time that the VMs are running on servers or the time of migration processes.

3.2.1 Power and Energy Consumption in Servers

The same equations in [10] are used for calculating the power consumption from servers. The energy consumed from the active servers is proportional to the number of resources used by VMs of the server. Resources required by each VM depends on the request from users. In this work, the amount of the resources is represented as workloads and is in the unit of resources. Any servers can create VMs within their capacities. The active server that does not have any VMs is called the idle server. The active server that is idle still consumes energy more than the server in sleep mode. To calculate the energy, the power consumption in each server is first calculated. The power consumption of the active server is calculated by Eq. (1). Then, the total energy consumption from all servers in the data center (E_D) is calculated by Eq. (2).

$$P_{a_{i,t}} = P_d + (\frac{\omega_{i,t}}{C_s}) \times D_a \quad (1)$$

$$E_D = \sum_{t=1}^{Sn} \left(\sum_{i=1}^{k_a} P_{a_{i,t}}\right) + \sum_{t=1}^{Sn} (N_t \times P_s) \quad (2)$$

$P_{a_{i,t}}$	Power consumption in the active server *i* at time *t*
P_d	Power consumption when the server is idle
$\omega_{i,t}$	Workload in the server *i* at the time *t*
C_s	Capacity of the server
D_a	Power consumption difference between the idle server and the server with full workloads
E_D	Total Energy consumption in data center
S_n	The time that the last VM is destroyed
N_t	The number of servers in sleep mode at time *t*
P_s	Power consumption of the server in sleep mode

3.2.2 Power and Energy Consumption from VM Migration

Work in [10] does not consider migration energy from the network devices. Network devices have to transfer the VMs between servers and this also consumes energy. Therefore, this work also considers energy consumption caused by the network devices as the VMs have to be migrated between servers that could be in the different clusters. It is called network energy consumption.

The migration energy consumption includes the energy consumed from VM migration processes on the servers and the energy consumed by network devices during VM transfer process. The equation for calculating the energy consumption of the server from VMs migration process is shown in Eq. (3).

$$E_M = t_m \times \sum_{i=1}^{k}(c_s + 0.17x_i) \quad (3)$$

E_M	Energy consumption of the servers from migration
t_m	A time constant of VM migration
k	The total number of migrated servers
c_s	A constant of energy consumption from the migration process
x_i	The number of resources of the migrated VM

The energy consumed by network devices in migration is considered. From the studies in [11-12], the energy consumption is based on the distance of the source and the destination. In this work, it is assumed that the distance depends on the number of the clusters between the source and the destination that the VMs are migrated considering their geological locations. For example, the energy consumed by transferring the VM between two directly connected clusters is less than the energy consumed by transferring the VM between two clusters that are not directly connected to each other. In this work, the equation for calculating the energy consumption of the network from VMs migration process (E_N) is calculated by Eq. (4).

$$E_N = t_m \times \sum_{i=1}^{k}(c_m + N_i) \quad (4)$$

c_m A constant value of power consumption from migration caused by the network devices

N_i The power consumption from the migration of server i based on the network distance

3.2.3 Total Energy Consumption

The total energy consumption (E_T) in the data center is calculated by the Eq. (5).

$$E_T = E_D + E_M + E_N \quad (5)$$

4. ENERGY-AWARE SCHEDULING UPDATING METHOD

In this paper, more conditions in cloud computing as in the real-world implementation are considered. First, there is not only energy consumption of migration from servers but also network devices. Second, the number of VMs varies during the time because there are new VM requests from users and VMs have to be removed as their leased times expire. This creates the dynamic workload condition in cloud computing. Therefore, the algorithm in this work has to consider workload changes and tries to migrate VMs to reduce energy. Additionally, it has to consider energy consumption from migration as well. The proposed method is called the Energy-Aware Scheduling Updating (ESU) method. It is different from the work in [10] that the work in [10] does not consider the dynamic workload condition because of VM removal, so it does not provide the VM placement updating method to migrate VMs. In this work, two algorithms to update the locations of VMs according to the dynamic changes are purposed. The first algorithm is the algorithm for updating VMs in intra-cluster. The other is the algorithm for updating VMs between inter-clusters. Both algorithms have to reschedule the VM locations while the energy consumed from migrations has to be considered. Therefore, the threshold is used as the trigger to make a migration decision. When there are requests sent to the data center, the VMs are created in the clusters and servers by using the same algorithms as in EVP. Then, when there are VMs removed from the servers, the algorithms check whether the rest VMs have to be migrated within the cluster or to other clusters.

Both algorithms use the threshold called Lower Threshold of Cluster (*LTC*) to make the migration decision. When there are VMs removed from the cluster CR_i, the workload of that cluster has to be recalculated. If the workload is higher than or equal to the *LTC*, VMs should be migrated to servers within the same clusters. This is the Intra-Cluster update algorithm. However, if the total workload is lower than *LTC*, all VMs are migrated to other clusters in order that all servers in this cluster can be changed to sleep mode. This is the Inter-Cluster update algorithm.

The Intra-cluster update algorithm is shown in Table 1.

Table 1 Intra-Cluster Update Algorithm

Algorithm I Intra-Cluster Update

INPUT: Cluster having VM removal (CR_i) and its workload (WCR_i) is higher than or equal to *LTC*.

Output: Servers changing mode to sleep mode

Sort servers by workloads in ascending order to set of S_i
For each S_i in the CR_i **Do**
  If $WS_i < LWS$ **Then**
    Sort all *VM* by remaining time in descending order
    For j = 1 to N_i **Do**
      Create S_{list} = set of other S except S_i
      Do
        Find S_k in S_{list} with maximum workload
        If there are more than 1 S_k **Then**
          Select S_k with highest remaining time
        End If
        Migrate VM_j to S_k
        If migration fails **Then**
          Remove S_k from S_{list}
        End If
      While (migration is not successful)
    End for
End for
Change all idle servers to sleep mode

When any VMs are removed, the algorithm checks the workloads. If the total workloads are higher than or equal to *LTC*, VMs are migrated to servers within the same cluster. The algorithm first sorts servers by their workloads in ascending order.

The server S_i compares its workloads WS_i to a threshold called Lower Workload of Server (*LWS*). If WS_i is lower than *LWS*, all VMs in S_i are migrated other servers in the same cluster.

The VMs in that S_i are sorted by their workloads in descending order. The *VM* with maximum workloads is migrated first. It is migrated to the server with the highest workloads. If there is more than one server with the highest workloads, the server with the longest remaining time is chosen. The remaining time is the time interval between current time to the time that the last VM in the server is removed. The server with longer remaining time should be used because if the VMs are moved to servers with shorter remaining time, it is possible that some VMs are removed after their lease times expire. If the workloads become lower than *LWS*, the rest VMs have to be migrated again. However, if the selected server does not have enough resource for the migrated VM, the server is removed from the list and the procedure to find the server to migrate VMs is repeated. Finally, when all VMs are migrated from servers with workloads lower than *LWS*, those servers are changed to sleep mode to save energy. The Inter-Cluster Update shown in Table 2.

The Algorithm 2 migrates all VMs from the cluster to other clusters when total workloads of the cluster are lower than *LTC*. When the workloads of the cluster are low, all VMs in the cluster should be migrated to other clusters in order that all servers in that cluster can be changed to sleep mode. The algorithm first sorts the servers in the current cluster by their workloads in descending order. The server with the highest workload migrates the VMs first. Within the server, VM with highest workloads is also migrated first. If there is more than one VM with the highest workloads, the VM with the longest remaining time is chosen. It then finds a new cluster to migrate VMs to. Only the clusters with total workloads higher than the cluster that VMs are migrated are listed. The VM is migrated to the new cluster with the highest workloads. If the workloads of the cluster are the same, the remaining time is used as a tiebreaker.

After selecting the cluster, it then finds the server in the new cluster to migrate VM. VM is migrated to the server with the highest workloads in the new cluster. If there is more than one server with the highest workloads, the one with the longest remaining time is chosen. However, if there are no servers in that cluster available, the cluster is removed from the list. The next cluster with highest workloads in the list is considered instead. The process is repeated until there are no VMs in left in that cluster. Then, the all servers in that cluster are changed to the sleep mode.

Table 2 Inter-Cluster Update Algorithm

Algorithm II Inter-Cluster Update

INPUT: Cluster having VM removal (CR_i) and its workload (WCR_i) is lower than *LTC.*

Output: Cluster changing mode to sleep mode

1. Sort servers by workloads in ascending order to S_i
2. **For** each S_i in the CR_i **Do**
3. Sort all *VMs* by workload in descending order. If workloads are equal, use remaining time as a tiebreaker.
4. **For** j = 1 to N_i **Do**
5. Create C_{list} set of clusters with workloads higher than WCR_i
6. **Do**
7. Find C_k in C_{list} with maximum workload
8. **If** there are more than 1 cluster **Then**
9. Select *Ck* with highest remaining time
10. **End If**
11. Migrate VM_j to C_k
12. Create S_{list} set of servers in C_k
13. Find S_k in C_k with maximum workload
14. **If** there are more than 1 S_k **Then**
15. Select S_k with highest remaining time
16. **End If**
17. Migrate VM_j to S_k
18. **If** migration fails **and** S_{list} is not empty **Then**
19. Remove S_k from S_{list}
20. **Else If** migration fails **and** S_{list} is empty **Then**
21. Remove C_k from C_{list}
22. **End If**
23. **While** (migration is not successful)
24. **End For**
25. **End For**
26. Change all servers in the cluster to sleep mode

5. PERFORMANCE EVALUATION

5.1 Experiments

In this work, ESU is evaluated by computer simulation. The performances of ESU are compared to EVP and VSA. The energy consumption is evaluated by energy consumed in all servers and energy consumed from migration.

In the experiment, there is one data center with five clusters and there are 160 servers inside each cluster. All servers have equal resources and the amount of resources is defined in the term of the resource unit. Each server has available resources for 100 units. For the power consumption, a server model of Intel Core2 Duo CPE E8400 with 3GB memory as in [10,13] is used. This provides the power consumption of idle mode (P_d) for 52 watts and sleep mode (P_s) for 6 watts. In addition, the power consumption of active mode (D_a) is 77 watts. The VM migration consumes power (c) 20 watts on the server. For the power consumption of the network, the model in [11] is applied. The power consumption depends on the number of clusters that VMs have to be migrated and it is represented by the parameter (N_i) that has the value from 0 to 2. This provides network power consumption varying from 85 to 87 watts. The *LTC* is 0.2 and the *LWS* is 0.15 as in VSA and EVP for performance comparison. The VM requests require resources for 1, 2, 4, or 8 units randomly. The rate of the requests is randomly generated from 1000 to 10000 requests per minute. The rental time of each VM is also randomly selected from 5 minutes to 50 minutes. The VM migration time is 7 seconds. The experimental time is counted until the last VM is removed.

5.2 Experimental Results

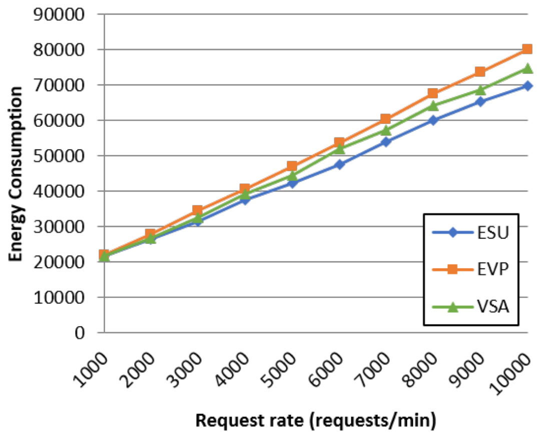

Fig. 2 Energy consumption of servers running VMs in the data center against the request rate

Fig. 2 shows the total energy consumption of server in three methods when the request rate varies. The energy consumption is calculated from the servers running VMs. The number of servers in sleep mode has an impact on energy consumption of servers. The EVP consumes the most energy among other protocols. This is because EVP does not migrate any VMs when there are VMs removed. Therefore, after VMs are removed, some servers become under-utilized and cannot be changed to sleep mode. Conversely, ESU and VSA update the VM placement when the VMs are removed. ESU consumes the least energy among other protocols. ESU uses the VM placement as in EVP to place VMs at the proper server cluster when the requests arrive. EVP has shown that it consumes less energy than VSA when VMs are not removed because it can reduce the number of the total active server [10]. However, the lack of the update degrades the performance of EVP in this dynamic condition. To improve the performance, the ESU updates the VM placement while it considers that the number of the active servers should be reduced. The energy consumption by servers running VMs of ESU is the least among the three protocols.

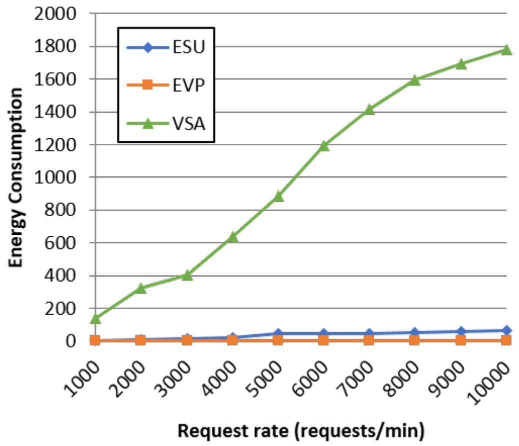

Fig. 3 Energy consumption of servers caused by migration against the request rate

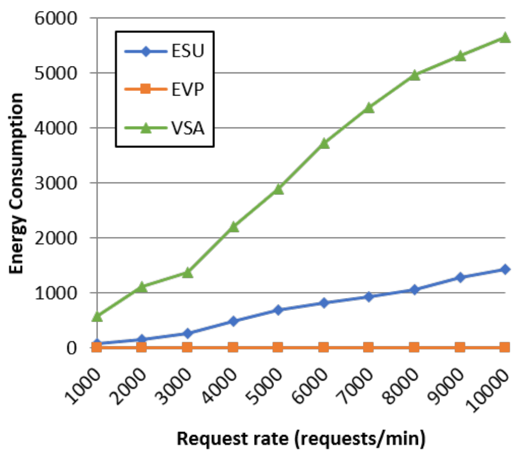

Fig. 4 Energy consumption of the network caused by migration against the request rate

Fig. 3 shows the energy consumption of servers caused by the migration when the request rate varies. When VMs are migrated, it consumes the energy on the servers as it is previously explained in section 4. Fig. 4 also shows the energy consumption of the network caused by the migration. EVP does not migrate any VMs, so it does not consume any energy from migration. VSA consumes energy much higher than ESU because the VMs are migrated many times. When the requests arrive, VSA creates VMs in servers that are close to locations that requests arrive. Then, it migrates VMs to the proper servers later. Conversely, ESU and EVP place VMs at the proper servers in the proper clusters just when the requests arrive. Therefore, they do not have to migrate VMs by the arrival of requests. In addition, when the workloads change, ESU migrates VMs to other servers under the consideration that VMs should not be migrated many times as it is previously explained in section 4. Therefore, ESU consumes energy from migration less than VSA. It should be considered that the energy from migration consumed by the network is more than the energy consumed by the servers. In addition, the energy consumption from network noticeably increases when the request rate increases. This is because when the number of VMs increases, it is possible that inter-cluster migration occurs more often. This increase the energy consumption of the network.

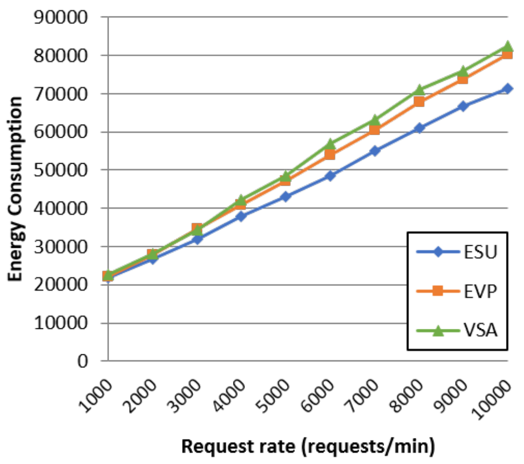

Fig. 5 Total energy consumption against the request rate

Finally, the total energy consumption when the request rate varies is shown in Fig. 5. When only energy consumption from servers running VMs is considered, VSA consumes less energy than EVP. However, when the total energy consumption is considered, VSA consumes the most energy. This shows that migration has a significant impact on the total energy consumption. Conversely, EVP does not migrate any VMs at all, but total energy consumption is quite close to VSA. This shows that VMs should be migrated under the dynamic workload condition to change servers into sleep mode. However, the number of migrations should be limited so that the energy is not consumed too much from migration. ESU shows that it has the best performance considering energy consumption. It places the VMs at the proper servers in the proper clusters once the requests arrive. In addition, it migrates VMs according to the dynamic workload condition. It uses several parameters to make a decision of migration. Therefore, the number of migrations is limited, and the energy consumption is the least among other protocols in the experiment. This shows that ESU has the best performance among protocols in the evaluation.

6. CONCLUSIONS

This paper proposes the new method for VMs scheduling called Energy-Aware Scheduling Updating (ESU) for cloud computing in the cluster environment with the dynamic workload condition. In the dynamic workload condition, VMs are added according to the requests and they are removed from the servers after their rental times expire. This causes the existing VMs should be migrated to consolidate them into the fewer of servers. The servers without any VMs are changed to sleep mode to save energy. ESU places the new added VMs using the same method as in Energy-aware Virtual Machine Placement (EVP). In addition, the algorithms to update the placement of VMs both intra-cluster and inter-cluster are proposed. The migration also consumes energy; therefore, the number of migrations should be limited. The thresholds are used to make a decision that VMs should be migrated to servers in the same cluster or other clusters. The proper values of the thresholds are left as an open issue in this work. In addition, it also provides a method to choose servers in order that the number of migrations is not too many. The experimental results show that ESU consumes less energy consumption in the data center than other protocols in the experiments.

For future research, the time complexity of the algorithm should be considered. In addition, the services delay time from VMs to users should be considered.

7. REFERENCES

[1] Amazon EC2, https://aws.amazon.com/ec2.
[2] Google Cloud, https://cloud.google.com.
[3] Microsoft Azure, https://azure.microsoft.com.
[4] DigitalOcean, https://www.digitalocean.com.
[5] Johnson P., With the Public Clouds of Amazon, Microsoft and Google, Big Data Is the Proverbial Big Deal, https://www.forbes.com/sites/johnsonpierr/2017/06/15/with-the-public-clouds-of-amazon-microsoft-and-google-big-data-is-the-proverbial-big-deal/#5e63b15e2ac3.
[6] Orgerie A.C., Lefevre L., and Gelas J.P., Demystifying Energy Consumption in Grids and Clouds, in Proc. Green Computing Conference, 2010 International. IEEE, 2010, pp. 335-342.
[7] Chase J.S., Anderson D.C., Thakar P.N., Vahdat A. M., and Doyle R.P., Managing Energy and Server Resources in Hosting

Centers, in Proc. the 18th ACM Symposium on Operating Systems Principles, 2001, pp. 103-116.

[8] Wen G., Hong J., Xu C., Balaji P., Feng S., and Jiang P., Energy-Aware Hierarchical Scheduling of Applications in Large Scale Data Centers, in Proc. Cloud and Service Computing (CSC), 2011 International Conference on IEEE, 2011, pp. 158-165.

[9] Adhikary T.,Das A.K., Razzaque M.A., and Sakrka A.M.J., Energy-Efficient Scheduling Algorithms for Data Center Resources in Cloud Computing, in Proc. High Performance Computing and Communications & 2013 IEEE Embedded and Ubiquitous Computing (HPCC EUC), 2013 IEEE 10th International Conference on. IEEE, 2013, pp. 1715-1720.

[10] Wattanasomboon P. and Somchit Y., Virtual Machine Placement Method for Energy Saving in Cloud Computing, in Proc. the 7th international on Information Technology and Electrical Engineering (ICITEE), 2015 IEEE, October 2015, pp. 275-280.

[11] Shirayanagi H., Yamada H., and Kenji K., Honeyguide: A VM Migration Aware Network Topology for Saving Energy Consumption in Data Center Networks, Transaction on Information and Systems (IEIC), vol. 96, no. 9,2013, pp. 2055-2064.

[12] Baliga J., Ayre R.W., Hinton K., and Tucker R.S., Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport, Proceeding of the IEEE, vol. 99, no. 1, pp. 149-167, 2010.

[13] Huang Q., Gao F., Wang R., and Qi Zi, Power Consumption of Virtual Machine Live Migration in Clouds, in Proc. Communications and Mobile Computing (CMC), 2011 Third International Conference on. IEEE, 2011, pp. 122-125.