Five Commandments to Design Green SLA for Sustainable Development in the ICT Sector

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A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science and Engineering

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August, 2017

Declaration

Declare that the work presented in this thesis is the outcome of the research performed by me under the supervision of Khan Mohammad Habibullah, Lecturer, Department of Computer Science and engineering, East West University. We also declare that no part of this thesis has been or is being submitted elsewhere for the award of any degree or diploma.

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Letter of Acceptance

This Thesis entitled **"Five commandments to design Green SLA for sustainable development in the ICT sector"** submitted by Taslima Kabir Suchona (2012-3-60-021), to the Department of Computer Science and Engineering, East West University, Dhaka, Bangladesh is accepted by the department in partial fulfillment of requirements for the Award of the Degree of Bachelor of Science and Engineering on August, 2017.

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Acknowledgements

At first I want to thank Allah for giving me strength, patience and knowledge to complete this thesis work.

I would like to express my sincere gratitude to my supervisor Khan Mohammad Habibullah for his continuous support, patience, motivation and immense knowledge. All the time his guidance helped me in research and writing this thesis book.

I would like to express my deep gratitude to my all faculty members of the Department of Computer Science and Engineering, East West University, Bangladesh for supporting me to complete individual course studies.

Finally, I want to express my gratitude to my parents for giving me support, motivation and great contribution from the start to end.

Abstract

From the recent decade ICT industry is expanding rapidly and new technologies are uncovering in brief time. Therefore the usage of ICT industry is increasing. For producing the electricity to fulfill the demand, carbon emission is increasing accordingly which is alarming. The ICT industry itself also emits carbon as well. This carbon emission is caused for global warming. The services should provide such a way that will reduce carbon emission. For that the first step is to define SLA. SLA is an agreement between service providers and consumers. But basic SLAs don't cover eco-efficient green issue. That is why for sustainable development in ICT sector, GSLAs become very important. GSLA is an agreement in where all parameters of basic SLAs will exist as well as green issue like ecological, economical and ethical aspects will also exist. In near future the environment will be in risk if proper steps for reducing the carbon emission are not taken now by us. In this paper we propose five commandments for GSLA in ICT sector which will help to moving towards sustainable development in ICT sector by reducing carbon emission. These proposed five commandments can also help other service providers to make their GSLA as well as business strategies.

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List of Acronyms

SLA	Service Level Agreement
GSLA	Green Service Level Agreement
VM	Virtual Machine
NIST	National Institute of Standards and Technology
IT	Information Technology
ICT	Information and Communication Technology
QoS	Quality of Service
GHG	Greenhouse Gas

Chapter 1

Introduction

According to Moore's law the number of transistors in a dense integrated circuit doubles approximately every two years and also the chips performance is double in every 18 months. The growth of development in the ICT sector is increasing day by day and the expansion of the ICT industry itself is really impressive. The services of this sector are also getting popularity and to fulfill the demand of this sector, the rate of using electricity is also increasing. This electricity is produced by using fossil fuels which are accounted for carbon emission and this carbon emission causes global warming. In recent years, the increasing rate of energy consumption and carbon emission has become a serious concern because of the rapid expansion of the ICT industry. Recent reports [1] have revealed that the Information and Communication Technologies (ICT) account for 3 percent of the world's carbon emissions. Data centers by themselves accounts for about 10 percent of the ICT emissions worldwide. For instance, a recent study [2] showed that the firms' value would decrease significantly if it has a higher carbon footprint or even if it withholds information about its carbon emission rates. As a result, many IT companies are voluntarily disclosing their carbon emissions and regularly reporting their efforts towards deploying environmental-friendly solutions and services [3]. At the same time, governments are imposing taxes on carbon emissions in the hopes of pushing further this shift towards the adoption of green sources of energy and the reduction of carbon footprint [4]. That is why service providers and consumers are trying to reduce energy consumption and carbon emission.

The service should provide in a way so that it can reduce carbon emission and energy consumption. For doing that the first step is initiated SLA in where the details of the service which will provide are written in the SLA. SLA is basically an agreement between service providers and consumers. If the ways to reduce energy consumption and carbon emission are included in SLA then we can think for that service carbon emission will reduce in ICT industry. Basic SLAs are not green because its performance indicators are not enough to cover eco-efficient issue. In fact the main concern of SLA is service quality, availability, response time, etc. but not about environmental issue. In SLAs green performance indicators are also not present. In which these indicators present is Green SLA. Green SLA is also an agreement between service providers and consumers like SLA. GSLA holds green performance indicators and all the performance indicators of SLA which can help to cover environmental issues.

For green computing 3Es sustainability pillar is very important. Ecological, Economical, Ethical are the 3Es sustainability pillar. Ecological is also known as environment and economical is known as profit. In this paper, environmental issue will be our main concern. In this research we try to find five commandments which can apply to develop the services that will help to provide services which will be energy efficient and reduce carbon emission.

1.1 SLA

A Service level agreement is a document that includes a description about agreed service, service level parameters, guarantees, and actions and remedies for all cases of violations [5]. It's very important for both service providers and customers because it is an agreement where both of service provider and customer agree about few service terms like security, performance, availability, billing and penalties. Many elements can be included in SLAs but few elements must include in a SLA.

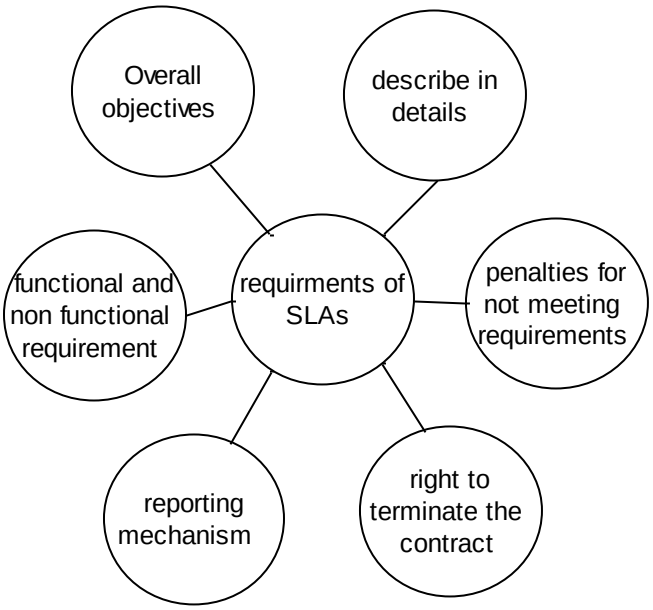

Figure 1.1: Requirements of SLAs

- Overall objectives for services should be written in SLA. For instance, if the motivation behind having an outer supplier is to enhance execution, spare expenses or give access to abilities and additionally innovations which can't be given internally, at that point the SLA should say as much.
- Description of the services should be written in details and in a clear way in SLA so that customer can easily understand about the services.
- The service providers must have to pay a penalty for not meeting service requirements. The penalty can be a fixed amount per interval.
- In the middle or any time of the contract if customers think that their requirements achieved or they don't want farther any update of their services then they have the right to terminate the contract.

- Service consumers can state whether the performance of the service fulfill their requirement or not. If service performance is not going to meet requirement then they report about that.
- Functional requirements are the statements of service which the system should provide. It will also include that in a particular situation hoe the system will react. As an example for online travel agency system functional requirements are :
  (i) User can search flight schedule .
  (ii) User can also book flight ticket, rent car.
  (iii) User can pay fee for ticket.
- Non- functional requirements are the constraints of the system like availability, scalability, storage requirements, response time etc.

1.2 Green SLA

Green computing is the act of utilizing processing assets proficiently and furthermore to decrease the use of hazardous materials, maximize energy efficiency during product's lifetime. For begin green computing 3Es sustainability pillars (Ecological, Economical and Ethical) are very important.

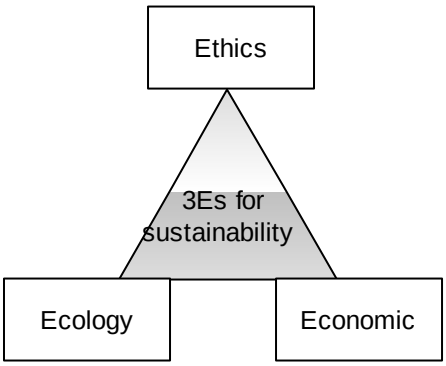

Figure 1.2: 3Es for sustainability

To fulfill the requirements of green computing the first step is to define green SLA. This is an agreement which focus on the energy consumption and carbon emission. In fact Green SLAs are defined as SLAs that induce more eco-efficient parameters compared to traditional performance-based SLAs (Thomas Schulze, 2011). GSLA can cover environmental issues since eco-efficient parameters are present in it where SLAs main concern is availability and quality of service not the reduction of energy consumption and carbon emission.
For any IT company making profit is main concern and for service consumer main concern is to meet the requirements of QoS. Along with these two things a new dimension will add where energy and carbon issue will be a main concern and also ethical issue will present. From 3Es

perspectives GSLA will be successful when it will satisfy all three main pillars of sustainability. From Ecological view GSLA focus on recycling, obsolescence indication, visual pollution these type of performance indicators. From Economical point GSLA focus on carbon taxation, cooling cost etc performance indicators.

1.3 Impact of high energy consumption for ICT technologies

ICT industry is expanding rapidly day by day as well as the demand of the technologies in this sector is also increasing and for high energy consumption the result is carbon emission which is caused global warming.

1.3.1 Energy consumption in cloud computing

In this ICT era the rapid development of cloud computing technology is really impressive. For this technology datacenters become popular platform day by day for delivering large-scale online services such as content delivery, social networking and e-commerce. Datacenters consume a large amount of electricity. This electricity is produced by using fossil fuels which is account for carbon emission and this carbon emission causes global warming.

1.3.2 Energy consumption in wired and wireless network

Nowadays the demand of network infrastructure is increasing as well as the number of new users is also increasing. For this reason traffic is increasing in communication system. To fulfill user requirements and provide a better service to them the number of network devices are increasing which consume high energy and the result is carbon emission. Moreover poor design in network considering worst situation is also consume high energy.

1.4 Organization of the Thesis Works

In this chapter we have already discussed cloud computing, SLA and GSLA. In next section, chapter 2 will be about related work. The contents of chapter 3 will be about five commandments and explanation of those commandments. In chapter 4 will be about conclusion and future work.

Chapter 2

Related Works

Now in IT sector high energy consumption and carbon footprint of cloud infrastructure are big concern which has a bad impact on environment. For controlling this environmental impact many researchers introduced and proposed some strategies and techniques.

Garg, S.K. and Buyya, R [6] have describe about the growing demand of cloud infrastructure, the increasing energy consumption of datacenter and also carbon emission which is not environmentally friendly as well as features of cloud enabling green cloud computing. They discussed cloud computing in details and also discuss about energy efficiency in network devices and datacenters.

Amokrane, A [7] discussed about definition of Green SLA and investigated how a CP can meet an SLA with green requirements. Their aim was to reduce operational cost and green SLA violation penalties. They also propose a resource management framework allowing cloud providers to provision resources in the form of Virtual Data Centers (VDCs) across a geo-distributed infrastructure.

Ahmed, I., Okumura, H. and Arai, K [8] discussed about 3Es of (Ecology, Economy and Ethics) sustainability pillars, basic SLA parameter, green performance indicators for existing green SLA. Basically their survey was on different basic SLA parameters for various in ICT sector. Their main focus was on finding the gap and incorporating basic SLA parameters with existing green computing issues. They also discussed about ethical issues for different services in computing domain.

Bezemer, C.P. and Zaidman, A [9] research about Multi-tenancy which is a software architecture principle. In this paper they also discussed tenant, Characteristics of multi-tenancy and the benefits of multi-tenancy. Multi-tenancy has challenges which may be faced in software application.

Schroeter, J., Cech, S., Götz, S., Wilke, C. and Aßmann, U [10] identified requirements for such a runtime architecture addressing the individual interests of all involved stakeholders. They also described Multi-Tenant SaaS Application with an example and the example is Video Portal Multi-Tenant Application. They identified requirements for variable multitenant aware architectures.

Kaur, A., Kaur, R. and Jain, P. [11] described task consolidation problem, maximize resource utilization and also three existing energy conscious heuristics such as ECTC (Energy-Conscious Task Consolidation) Task Consolidation Algorithm and MaxUtil (Maximum rate Utilization) Task

Consolidation Algorithm and Bi-objective Task Consolidation algorithm offering different energy saving possibilities were analyzed. Bi-objective Task Consolidation algorithm is combination of ECTC and MaxUtil task consolidation algorithm.

Habibullah, K.M [12] discussed about green networking, the way to reduce energy consumption in network infrastructure like switch off mode, sleeping mode and hibernation. They also discussed that the network topology was reorganized using clustering method based on the spectral approach for putting network switches to hibernate or switched off mode considering the time and communication among them. They also showed case study in their paper based on spectral approach. They consider in their study bandwidth, link load and traffic matrices as input parameters which have the highest contribution to energy footprints of network switches during usage phase and energy consumption as output.

Chapter 3

Five Commandments

Five Commandments for GSLA

Nowadays the rate of carbon emission is rapidly increasing. Gartner estimated that the Information and Communication Technologies (ICT) industry generates about 2% of the total global CO2 emissions, which is equal to the aviation industry [13]. Five commandments are the strategies to decrease the carbon emission and energy consumption.

(i) Multi-tenancy
(ii) Server utilization
(iii) Green networking
(iv) Optimize rather maximize
(v) Shop locally

3.1 Multi-tenancy

A multi-tenant application lets customers (tenants) share the same hardware resources, by offering them one shared application and database instance, while allowing them to configure the application to fit their needs as if it runs on a dedicated environment where tenant means a group of users who take the service of SaaS application.

If the service is not multi-tenant then single instance will need for user. When the number of users will increased then the number of required resources will be increased. If the number of resources will then the energy consumption will also increase. Moreover users will have their own database then instead of deploying single database update it will be needed to deploy N database update. So a single tenant application is not efficient for using resource optimization.

Multi-tenancy should be included in Green SLA because of few reasons. As tenants can share same resources so multi-tenancy increases optimize resource utilization as well as reduces operational complexity and cost to manage the software for delivering service. Multi-tenancy is also transparent for SaaS user.

3.1.1 Key Characteristics of Multi-Tenancy

3.1.1.1 Hardware Resource Sharing

In multi-tenant mode users don't have their own server. They share same resources. By placing several tenants on the same server, the server utilization can be improved [14, 15]. While this can also be achieved through virtualization, virtualization imposes a much lower limit on the number of tenants per server due to the high memory requirements for very virtual server [16]. The following variants of (semi-)multi-tenancy can be distinguished [17, 18]:

a. Shared application, separate database.
b. Shared application, shared database, separate table.
c. Shared application, shared table (pure multi-tenancy).

Throughout this paper we will only focus on pure multi-tenancy.

3.1.1.2 High Degree of Configurability

Every tenant has their own server and share same application instance in single tenant environment. On the other hand tenants share same application instance and same database. Because of this, a key requirement of multi-tenant applications is the possibility to configure and/or customize the application to a tenant's need, just like in single-tenancy [19]. In multi-tenancy this is no longer possible and configuration options must be integrated in the product design instead [20], similar to software product line engineering [19].

3.1.2 Challenges

3.1.2.1 Performance

Resource utilization is high because of sharing same resources by multiple tenants. But it is also necessary to maintain the service quality so that all the tenants can utilize the resource according to their requirements.

3.1.2.2 Scalability

In multi tenancy application scalability is an important issue. At any time new tenant, new hardware can be added for this type of reason quality of the software should not be changed. In multi-tenant application tenant can require more than one application and database server.

3.1.2.3 Capacity Optimization and reduce cost

For maximizing capacity and reduce cost database administrator need to understand in which network which tenant should be deployed. This is method is any sophisticated by the necessity to ceaselessly align capability with business demand and needs suppliers to manage the particular and forecasted resource utilization for all their servers.

3.1.2.4 Avoiding race condition

As in multi tenancy tenants share the same application and hardware resources, so there is a possibility that tenants can require same service at the same time like in online travel agency there is a possibility that at the same time many user may book flight for same slot and date in this case it is difficult to handle. So it is important to avoid this type of situation.

3.1.2.5 Maintenance

Maintenance is very important for multitenant application. If any failure occurs in system then service delivery can interrupt. As multiple users get the service through same application so it will quite difficult to change or upgrade the software system according to the all the users requirements.

3.1.3 Example

In this paper we introduce online travel agency as a multi-tenant application where the above challenges are not present.

Here we consider two tenants A and B share this application and this application can provide multiple services like flight booking, hotels booking, vacation package. Tenants can choose any of those services as well as more than one service. Other component system manager is user interface where tenants can choose their flight according to time and date. Tenant can also book hotels or rent car according to their desired cost. If they have any requirement or suggestion or they face any problem related to the application then they can report through feedback. Here tenant A select one way trip for flight_booking, hotel_booking and vacation_package services whereas tenant B select round trip, vacation_package and car_rental services.

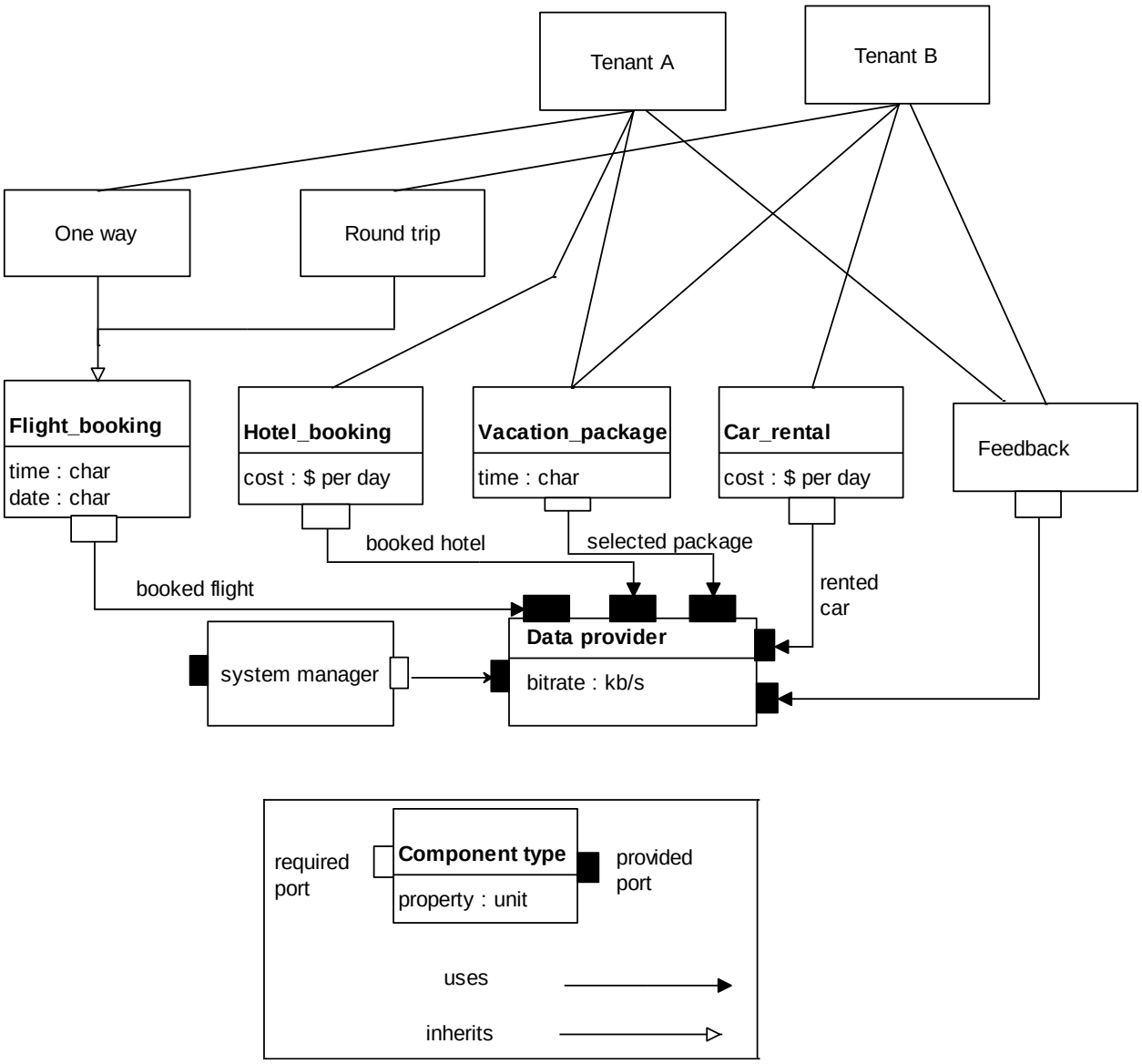

Figure 3.1: Online Travel Agency Multi-Tenant Application including two Tenant configurations.

In the above example if flight & hotel booking service were not separated then all tenant could not utilize this service as per their requirement. Because some tenant can want just flight booking service not hotels booking service. In this case they had to take both services which may not their requirement. But here flight and hotels booking services are separate so that tenants can choose services as per requirement like if any tenant will just want to get flight booking service then they can take that service. So here the challenge “performance” is not present.

In case of challenge “scalability” application database should be store in every server so that if any server goes down then data can be access from the other servers. In the above application many new tenant can be added to the application in vacation time means there is a chance for traffic overloading, in that time the provider must have to provide the services without changing services quality. For handling this overloading new server will have to be added in the network.

In case of challenge **“**Capacity Optimization and reduce cost” cost can reduce by applying different shortest path algorithm like Dijkstra's, Bellman-Ford, prim’s and so on.

In the vacation time many tenants can want to get vacation package. So in this time they can hit this service. For avoiding this problem when a tenant will choose the package in that time another tenant will have to wait until the first one will not select the package. This waiting time can be minimize by follow some scheduling algorithm like round Robin Scheduling algorithm, Priority Scheduling algorithm, First-Come, First-Served (FCFS) Scheduling algorithm. Thus the challenge “avoiding race condition” can be solved.

In the above example tenants can give their suggestion or requirement through feedback. They can also report through feedback if they face any problem in the application like any tenant fail to access any service. Provider can solve the problem by monitoring those feedbacks and base on the tenant requirements the provider must be upgrade carefully so that it does not affect rest of the features of the application for other tenant. Best way to overcome the challenge of frequent upgrade is use of some automation testing tools like Selenium and QTP.

3.2 Server utilization optimization

Energy consumption and resource utilization in clouds are highly coupled. Specifically, resources with a low utilization rate still consume an unacceptable amount of energy compared with their energy consumption when they are fully utilized or sufficiently loaded. According to recent studies in [21–24], average resource utilization in most data centers can be as low as 20%; and the energy consumption of idle resources can be as much as 60% or peak power. In response to this poor resource utilization, task consolidation is an effective technique to increase resource utilization and in turn reduces energy consumption.
In this paper, we present two energy-conscious task consolidation heuristics (ECTC and MaxUtil) through online travel agency application, which aim to maximize resource utilization and explicitly take into account both active and idle energy consumption.

3.2.1 ECTC Task Consolidation Algorithm

The cost function, termed ECTC [11], computes the actual energy consumption of the current task by subtracting the minimum energy consumption required to run a task, if other tasks would be running in parallel with that task. That is, the energy consumption of the overlapping time period among the running tasks and the current task is explicitly taken into account. The cost function tends to discriminate the task being executed in a standalone mode.

Algorithm:

Step 1: Let r*=Ø
Step 2: Repeat Step 3 to Step 5 for all ri € R
Step 3: calculate cost function fi,j where fi,j=[(pΔ×uj+pmin)×τ0]−[pΔ×uj+pmin ×τ1+ pΔ×uj×τ2]
Step 4: if fi,j>f*,j
Then go to step 5
Else go to step 2
Step 5: Set r*=ri and f*,j=fi,j
Step 6: Set r*=tj
Step 7: Exit

where fi,j cost function, pΔ is the difference between pmax and pmin, uj is the utilization rate of tj , and τ0, τ1 and τ2 are the total processing time of tj , the time period tj is running alone and that tj is running in parallel with one or more tasks, respectively.

3.2.2 MaxUtil Task Consolidation Algorithm

The MaxUtil [11] cost function is derived with the average utilization during the processing time of the current task, as core component. The cost function aims to increase consolidation density and its advantage is two-fold. The first and obvious advantage is energy consumption is reduced. And, the second benefit is that MaxUtil's cost function implicitly decreases the number of active resources since it tends to intensify the utilization of a small number of resources compared with ECTC's cost function. In other words, MaxUtil makes task consolidation decisions based on resource utilization, which is a key indicator for energy efficiency in our scenario.

Algorithm

Step 1: Let r*=Ø
Step 2: Repeat Step 3 to Step 5 for all ri € R
Step 3: calculate cost function fi,j where fi,j = ($\sum_{\tau=1}^{\tau 0}$ Ui) / τ0

Step 4: if fi,j>f*,j
Then go to step 5
Else go to step 2
Step 5: Set r*=ri and f*, j=fi, j

Step 6: Set r*=tj
Step 7: Exit
where fi,j cost function, pΔ is the difference between pmax and pmin, uj is the utilization rate of tj , and τ0, τ1 are the total processing time of tj , the time period tj is running alone.

Energy model
For a resource ri at any given time, the utilization Ui is defined as

$$\mathrm{Ui} = \sum_{k=0}^{n} \mathrm{Uij}$$

where n is the number of tasks running at that time and ui,j is the resource usage of a task tj .
The energy consumption Ei of a resource ri at any given time is defined as
Ei = (pmax − pmin)×Ui + pmin
where pmax is the power consumption at the peak load and pmin is the minimum power consumption in the active mode.

3.2.3 Example

Assume that Service requests in our study arrive in a Poisson process and the requested processing time follows exponential distribution. We assume that the processor/CPU usage (utilization) of each service request can be identifiable. Also assume that number of task t, number of resource r.
Here through online travel agency application we will try to understand how a set of resource will allocate for a set of task by following two task consolidation algorithm and whether maximize resource utilization will achieve or not. We consider number of task, arrival time, processing time and the rate of utilization are given below:
Table 1:

Task	Arrival time	Processing time	Utilization
0	0	20	40%
1	3	8	50%
2	7	23	20%
3	14	10	40%
4	20	15	70%

When tenant give task info through online travel agency application then these info will submit in scheduler section. In there it will decide that which resource or server will allocate for which task number. Here task t0 & t1 are assigned in resource r0 and task t2 is assigned in resource r1. As ECTC makes its decisions based rather on the (sole) energy consumption of that task so when task 3 (t3) arrives at time 14 after tasks 0, 1 and 2, and it is assigned onto resource 1 (r1) based on energy consumption (40 with pmax and pmin of 30), even though the utilization of

resource 0 (r0) is higher if t3 is assigned on r0. Because Task t0 do not fully overlap task t3 on resource r0 but t3 can be fully consolidated with the task t2. On the other hand MaxUtil assigns t3 onto r0 and this leads to a better match for t4 compared with ECTC.

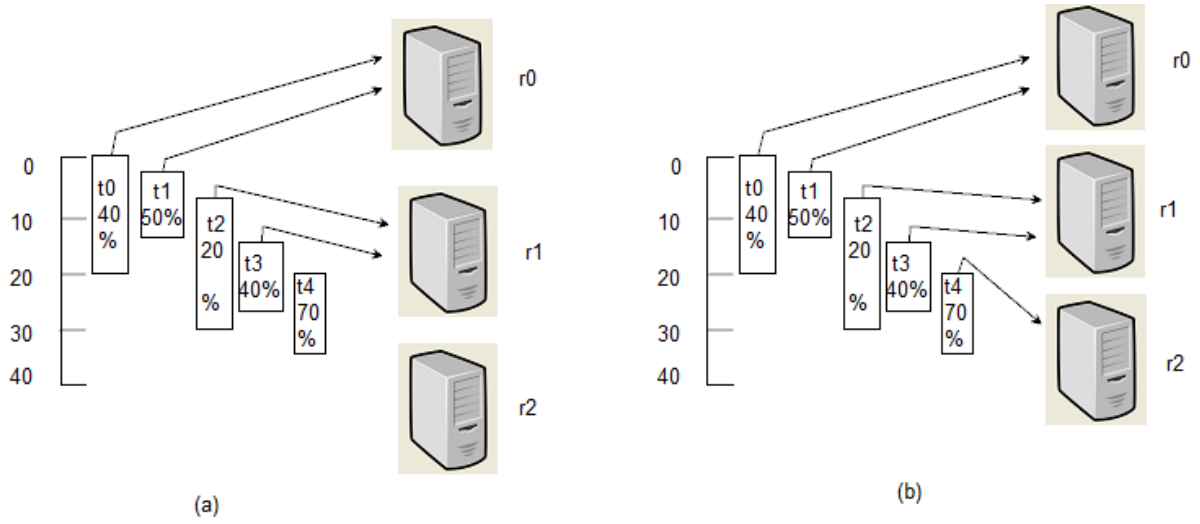

Figure 3.2: Consolidation example for tasks in Table 1 using ECTC

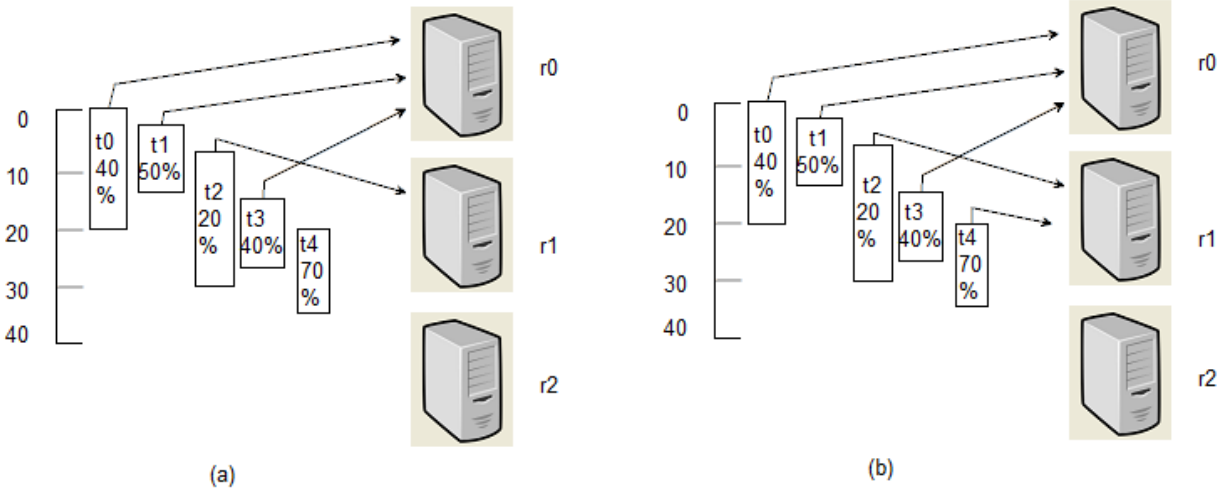

Figure 3.3: Consolidation example for tasks in Table 1 using MaxUtil

3.3 Green networking

Cloud providers provide the services and get the charge according to customer usages. For providing and getting these services both cloud provider and customer make an agreement which is known as SLA. This agreement makes sure that the customer will get the service of maximum QoS level. The carbon emission and energy consumption parameter are not present in the SLA which produced by the cloud resources. But those parameters are present in GSLA as well as the basic SLA parameters are also present. GSLA is also an agreement between cloud provider and service consumer.

In the network infrastructure, especially in wired network energy consumption is much. The purpose of green networking is to minimize the energy consumption by maintaining same quality of performance. Resource consolidation, hibernate or switch off, sleep mode are the way and cluster approach is the method to reduce energy consumption. Resource consolidation helps in regrouping the under-utilized devices to reduce the global consumption. When workload is low that time server can be in sleep mode so that energy can be saved at that time. Hibernate means any network devices like router, switch, server are turned off or lose network connection.

3.3.1 Clustering Approach

Consideration of information flows is very important to design network architecture. The objective of network designer is to confine the strong co-operation and communication with sub-network to avoid flooding and overloading the whole network. In order to minimize overloading, intra-group communication should be maximum and inter-group communication should be minimum. To achieve this network scalability objective, clustering method has been widely pursued by the research community. In this research work, clustering algorithm has been used to reduce communication; isolate groups for hibernating or switched off part of the network [25].

3.3.2 Example with clustering approach

End users can get their desired service at any time through online travel agency application. The followings are few assumption:

- Total number of server is 6
- Maximum capacity of each server is 100000 hits
- Server A1 and A2 are for both flight booking service
- Server B1 and B2 are for both hotel booking service
- Server C1 and C2 are for car rental service

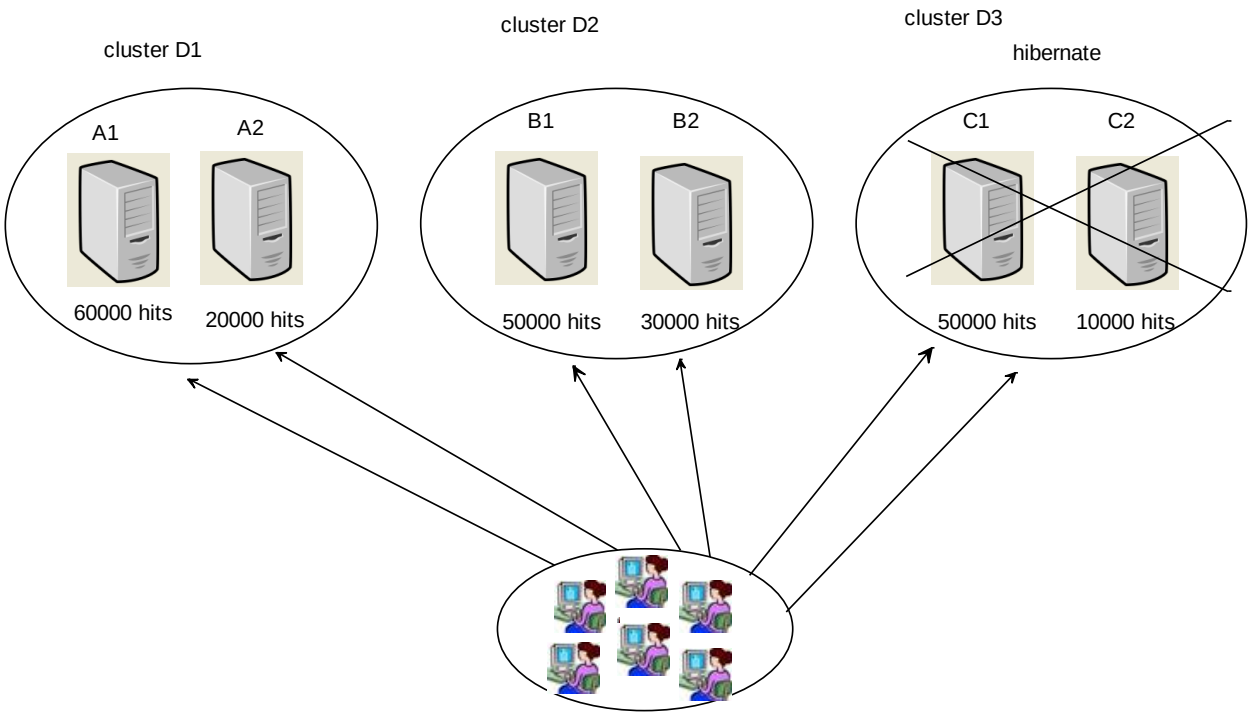

Figure 3.4: Number of request (hits) for each service for each server

Now considering that 60000 hits comes for server A1, 20000 hits for server A2, 50000 hits for server B1 and server C1, 30000 hits for B2, 10000 hits for C2. Server A1 and A2 is in cluster D1, B1 and B2 servers are in cluster D2, C1 and C2 servers are in D3 cluster. Here the hits rate of each server is less than maximum capacity so server is under-utilized. We can consider that at midnight the hit rate of car rental service will low. So cluster D3 can be gone in hibernate or sleep mode. But we can't tell that no one will not request or hit for the car rental service, if one hit is come for cluster D3 then the servers of this cluster will have to be active and by doing that the energy of cluster D3 will not be saved for much time. So here re-grouping will be needed among those servers.

After applying spectral algorithm among those servers, server A1, B1, C1 are in cluster D1, server A2, B2 and C2 are in cluster D2. Now in case of server under-utilize all the hits of A2 server will be placed in server A1 and similarly all the hits of B2 and C2 servers will be placed in according to server B1 and C1 in cluster D1. After doing that cluster D2 can be gone in sleep mode or hibernate and if 500 hits come for car rental service then cluster D2 will not have to be in active mode because those hits will placed in server C1 in cluster D1 as the maximum capacity is not exceed. Thus more energy will save. In day time or peak time cluster will automatically come in active mood and that can be possible by setting timer.

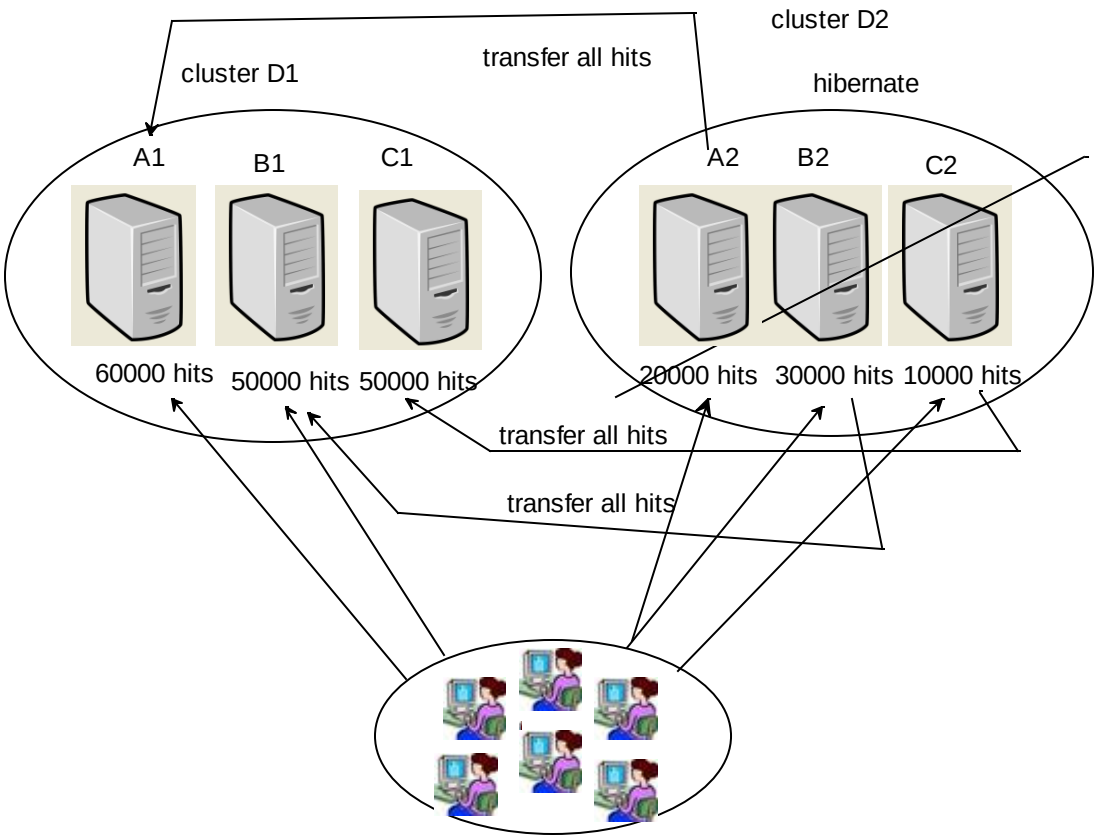

Figure 3.5: After applying Spectral Approach

In case of server over-utilize means if 70000 hits come for both flight and hotel booking service then the maximum limit of server will be exceed, cluster D2 will have to be in active mode and the extra hits will placed in server A2 in cluster D2.

For clustering Spectral algorithm, novel CRO based energy efficient clustering algorithms (nCRO-ECA), Single-Level clustering Algorithm etc can be used.

3.4 Optimize rather than maximize

Day by day technology is upgrading at the same time carbon emission is also increasing in IT sectors which has a bad impact on environment. For reducing carbon emission optimization is a better option than maximization. It can be said in other way that increasing product quality is better than increasing quantity. As an example in computer network to give service to the many customers in case of wired connection there may need more wire means quantity of wire can be increased. But too many wires can be the reason of bad impact on environment. If in network increase bandwidth instead of increasing quantity of wire then at the same time many customer can get the service and this will not have bad impact on environment.

In the same way server capacity can be increased instead of increasing number of servers. If capacity of server will increase then it can handle more jobs efficiently.

3.5 Shop locally

Nowadays cloud computing technology is increasing as well as datacenter is also increasing for delivering online service. In this sector energy consumption becomes a big concern for environmental impact. Datacenters consume a large amount of electricity and for producing more electricity more energy will be needed which can be the reason of bad impact on environment. That is why reducing energy consumption is needed for sustainable environment. In this case location of datacenter can help to reduce energy consumption in two ways. One way is reducing supplying energy and cost and the other way is reducing energy for cooling system.

As datacenter consume electricity and for producing electricity more water is needed so location of datacenter should be chosen such a place where water resource is available or chosen such a place which is not so far from water resource so that supply cost will be less.

Datacenters also need cooling system for decreasing the heat which is generated in there and that contributes a lot of energy consumption. For reducing energy consumption location of datacenter should be chosen by such a place where outside temperature is not more than the datacenter temperature so that outside temperature will enough to reduce the datacenter temperature. Thus the required energy for cooling system will be reduced.

Chapter 4

Conclusion and Future Work

4.1 Conclusion

The increasing rate of carbon emission is caused global warming. A portion of global carbon emission is generated by IT and ICT industry. This carbon emission should be reduced for moving towards a sustainable society. That is why governments are imposing tax on carbon emission and for this reason service providers and consumers are trying to adopt energy efficient service as well as reduce carbon emission. Initiate SLA is the first step to reduce carbon emission in IT and ICT industry. In this book, we have proposed five commandments which can be apply on SLA for any technology in ICT industry like cloud computing, mobile networking which will help to move towards sustainable development. This can also work as a guideline for others service provider to make their SLA for service.

4.2 Future work

In future we will extend our research for the following issues:

- Find new green performance indicators with appropriate units which can be associated with existing performance indicators
- Make a tool in where all green performance indicators will be set as a benchmark and compare other SLAs with that benchmark whether the SLAs are green or not. And also suggest missing green performance indicators.

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