ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, Vol 9(44), DOI: 10.17485/ijst/2016/v9i44/105065, November 2016 ISSN (Online) : 0974-5645

A Survey on Green Power Efficient Resource Allocation Algorithm for Cloud Infrastructure

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Abstract

Cloud computing has become essential for users across the globe due to the computing power and resources which are provided in the form of service. With the increase in demand for cloud computing there is an increase in number of cloud service providers and data centers which consequentially leads to huge increase in resource consumption by these data centers. This requires use of green cloud computing techniques such as load balancing, VM migration and power metering. This paper aims to review various techniques proposed for efficient resource and energy consumption.

Keywords: Cloud Computing, Green Computing, Infrastructure as a Service, Load Balancing , Power Efficiency, Quality of Service (QoS), Reliability, Resource Utilization, Software as a Service

1. Introduction

Cloud computing also referred as the cloud (due to the internet's representation in flow diagrams) is an on-demand computing model which consists of independent, networked hardware and/or software resources. Cloud computing applies the concept of virtualization for optimal usage of hardware and/or software resources. In simple terms cloud computing is the virtualization of a pool of resources, under data centers for hosting cloud applications, which are made available to everyone on subscription basis. In cloud computing the hardware and software resources are made available by the providers for different users or clients. Service providers offer cloud services with predefined quality of service (QoS) terms through the Internet as a collection of easy-to use, scalable, and economically feasible services to the clients. The cloud services fall under three categories: Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS).

The characteristics of cloud computing have attracted many IT giants like Amazon, Google, Microsoft, SharePoint, VMware etc. Amazon is the leader amongst all cloud providers. The two most common services they provide are Amazon S3 a Simple Storage Service and Amazon EC2 Elastic Cloud Computing, both belong to IaaS service model.S3 and EC2 both work on a concept of pay-as-you-go model. Therefore, the number of people using these services are exponentially increasing with the increase in deployment of new applications on the cloud as well. Though cloud computing has the capability of handling many of users through virtualization concurrently, its power consumption and carbon emission has become a major environmental concern.

Green Cloud Computing: Green computing deals with processes of designing, maintaining and disposing of computer devices without doing any harm to the environment. Due to the growing concerns of increase in power consumption and carbon emissions by the IT industry the

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concept of green computing was realized. Most IT companies realized that taking a step towards green computing would not only reduce the carbon emissions but would also cut total costs of the system from a business perspective. Moreover, the probability of hardware failures increases due to higher power consumption as the heat dissipation also increases with it. The most commonly used green computing technologies are: Virtualization, Green Cloud Computing, Power Optimization, Green Data Centre and Grid Computing.

Green computing can efficiently use virtualization so as to improve the power efficiency of data centers by assigning the tasks of multiple Virtual Machines (VMs) to a single server. Server virtualization helps in workload consolidation by processing the tasks and turning off idle physical machines there by lowering the consumption of energy. By using virtualization technology, multiple applications can be hosted and executed on the same server in isolation which can process more tasks with the same power usage.

Another way for green computing to reduce power consumption is through Service Level Agreement (SLAs). SLA is an agreement between the service provider and the consumer which takes place before any allocation of resources. The SLA service can be related to storage space, bandwidth, and power consumption.

Several researchers have introduced various models and/or methods to conserve energy.

In[1] proposes a virtual infrastructure optimization solution using the Ant Colony Optimization (ACO) algorithm for finding better paths through graphs. The most common approach while performing workload consolidation is that the workload is allotted to a physical machine (e.g. CPU) and those resources which require excessive provisioning are converted into a lower power state.

In[2] proposes the use of a function that can ensure the most appropriate behaviour to the principles of Green IT but not the quality of service. For this he proposes the use of Green MACC (Meta Scheduling Green Architecture) and its module LRAM (Local Resource Allocation Manager) to automate the execution of all scheduling policies implemented in the Scheduling Policies Module so as to provide Quality of Service in Cloud Computing and determine its flexibility[2]. Algorithm for job scheduling has been devised that utilizes resources of grid environment efficiently.

Task consolidation is an efficient method which is used to reduce power consumption by increasing the resource utilization but due to task consolidation resources may still draw power while being in the idle state. In[3] has introduced two algorithm to maximize the utilization of resources of the cloud. The two algorithms are ECTC and MaxUtil. ECTC works on the premise of calculating the energy which is being used by a particular task when there are simultaneous tasks running parallel with it, and then it is compared with the optimal energy which is required. MaxUtil focuses more on the mean usage of a particular task when it is being processed[3]. In[4] presents a simulation environment for data centers to improve their utilization of resources. Apart from working on the distribution of the tasks, it also focuses on the energy used by the data center components. The simulation outcomes are obtained for various architectures of data centers[4].

In[5] proposes the use of proper optimization policies reducing the power usage and increasing the resource utilization without sacrificing the SLAs. He developed a model which worked on incrementing the capability of the processor to process tasks[5].

In[6] proposes a Three Threshold Energy Saving Algorithm [TESA] which has three thresholds to divide hosts between heavy load, light load and middling load. Then based on TESA 5, VM migration policies are suggested which significantly improves energy efficiency[6].

In[7] proposes Green Monster protocol which improves renewable energy consumption while maintaining performance by dynamically moving services across Information Distribution Companies (IDCs). Green Monster uses Evolutionary Multi-objective Optimization Protocol [EMOA] to make service placement and migration decisions[7].

In[8] proposes a new VM architecture which has capabilities of Live Virtual Machine Migration, VM placement optimization and online VM Monitoring. This architecture gives us considerable energy saving[8].

In[9] proposes a power metering solution for virtual machines. The proposed solution has a very small runtime overhead and provides accurate and practical information for power capping to improve the energy efficiency of the data centers[9].

An Improved Hybrid Scheduling Algorithm for Grid (IHSAG)[10] proposed by Seema at al. for job scheduling technique worked effectively for grid as well as cloud scenarios.

2. Analysis

First we take the readings for finding out and comparing the Ant Colony Optimization with other policies. The results clearly define that the ant colony optimization algorithm works better than the greedy algorithm[1]. Table 1 describes the energy consumed when we use different policies and Figure 1 shows that ACO is better as it saves more energy.

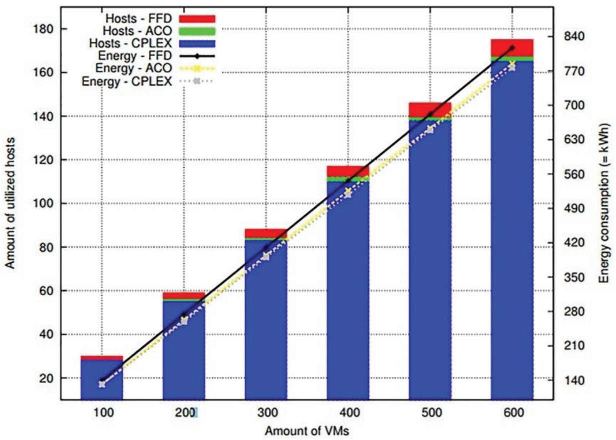

Figure 1. Energy-aware ant colony based workload.

ACO provides better energy gains when evaluated with the greedy algorithm and the results are almost optimal (i.e., 1.1% deviation). Energy efficient utilization of resources in cloud is shown in Figure 2 and 3[3].

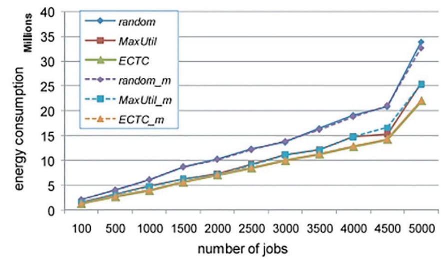

Figure 2. Energy efficient utilization of resources in cloud without migration.

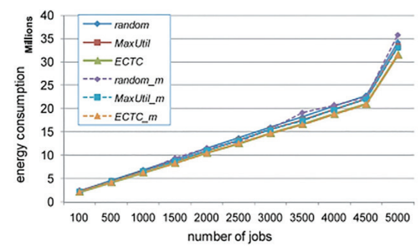

Figure 3. Energy efficient utilization of resources in cloud with migration.

Table 1. Energy consumed by different policies

VIRTUAL MACHINES	POLICY	HOSTS	EXECUTION TIME(sec)	ENERGY(kwh)	ENERGY GAIN(%)
100	First Fit decreasing	30	0.39	139.62	
	ACO	28	37.47	131.41	5.88
	CPLEX	28	0.45	131.41	5.88
200	First Fit decreasing	59	0.58	275.13	
	ACO	56	4.51min	262.83	4.47
	CPLEX	55	1.27	258.71	5.96
300	First Fit decreasing	88	0.77	410.65	
	ACO	84	15.04 min	394.28	3.98
	CPLEX	83	2.86	390.12	4.99
400	First Fit decreasing	117	1.03	546.16	
	ACO	112	34.23 min	525.75	3.73
	CPLEX	110	5.07	517.43	5.26
500	First Fit decreasing	146	1.39	681.67	
	ACO	139	1.17 h	653.17	4.18
	CPLEX	138	9.41	648.84	4.81
600	First Fit decreasing	175	1.75	817.19	
	ACO	167	2.01h	784.75	3.96
	CPLEX	165	12.95	776.14	5.02

Using the Figures 2 and 3 we can see that energy-conscious task consolidation heuristics have better resource provisioning. The results therefore prove that the use of the two algorithms will definitely reduce the energy consumption. Next we compare work on a packet level simulator of energy aware cloud computing data centers[4]. Now we discuss the how to reduce the power usage and increasing the resource utilization without sacrificing the SLAs[5]. It describes the processor types with δ where δi is the factor for reduction in the power consumption Pi of core I, $Pri = \delta i Pi$. Table 2 represents the power consumption of data center components. Table 3 shows the power consumption of data center components. Table 4 discourses the parameters used during simulation. Table 5 shows the distribution of power consumption over the data centers.

Table 2. Energy savings when we use a particular policy

Migration	Policy	Energy Savings
no	MaxUtil	25%
	ECTC	33%
yes	MaxUtil	23%
	ECTC	32%

Table 3. Power consumption of data center components

Parameter	Power consumption (W) Servers
Server peak	301
Server CPU peak	130
Server other (memory, peripheral , mother board, fan, PSU losses)	171
Server idle	198

Table 4. Parameters used during simulation

Parameter	Data center architectures		
	Two-tier	Three-Tier	Three-Tier high speed
TOPOLOGY			
Core nodes (C1)	16	8	2
Aggregation nodes (C2)		16	4
Access switches (C3)	512	512	512
Servers (S)	1536	1536	1536
Link (C1–C2)	10 GE	10 GE	100 GE
Link (C2–C3)	1 GE	1 GE	10 GE
Link (C3–S)	1 GE	2 GE	3 GE
Link propagation delay	10 ns		

Table 5. Distribution of data center power consumption

Parameter	Power consumption (kW h)		
	Two-tier (2T)	Three-Tier 3T	Three-tier high speed 3THS
Data center	477.8	503.4	508.6
Servers	351	351	351
Switches	126.8	152.4	157.6
Core (C1)	51.2	25.6	56.8
Aggregation (C2)		51.2	25.2
Access (C3)	75.6	75.6	75.6

Table 6 compares the value of the reduction factor for different cores at different frequencies. The values of the reduction factor δ for different frequencies of a processor as shown in Table 7. When the processors are fully used the reduction factor also varies. The Table 8 indicates the idle power consumption of the components. The figures compare the energy consumption by each of the model which is done without violating the SLAs. Table 9 shows Idle power consumption of components, Now we will study a new energy saving algorithm based on three thresholds and minimizing migration[6].Three Threshold, Energy Saving Algorithm is proposed which has three thresholds $0<a<b<c<1$. If utilization is lower than 'a' the host is considered to have light load, if utilization is between 'a' and 'b' the host is considered to have proper load, if utilization is between 'b' and 'c' the host is considered to have middle load, if utilization is greater than 'c' the host is considered to have light load. After that 5 VM migration policies are suggested and MIMT [Minimization of Migrations Policy Based on TESA] is selected for comparison with other algorithms. Energy Consumption and SLA violation comparison between 5 VM migration schemes as shown in Table 10 and Figure 4[6].

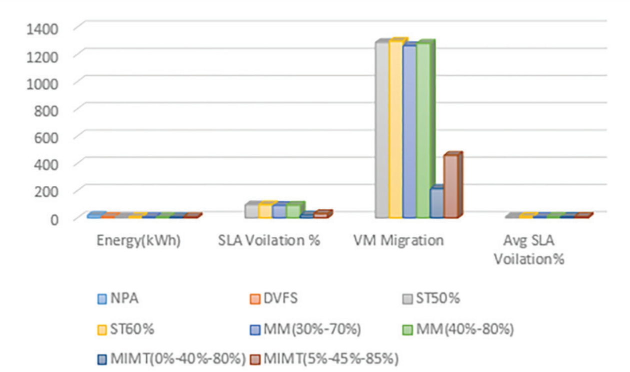

Figure 4. Performance comparison of the selected algorithm.

Table 6. Comparison of energy-efficient schemes

Parameter	Power consumption (kW h)			
	No energy-saving	DVFS	DNS	DVFS+DNS
Data centre	503.4	486.1 (96%)	186.7 (37%)	179.4 (35%)
Servers	351	340.5 (97%)	138.4 (39%)	132.4 (37%)
Switches	152.4	145.6 (95%)	48.3 (32%)	47 (31%)
Energy cost/year	$441k	$435k	$163.5k	$157k

Table 7. Processor types with δ values

Processor type	δ
Intel Xeon dual-core E5502	0.942
Intel Xeon quad-core E5540	0.728
Intel Xeon hexa-core X5650	0.316

Table 8. Comparison of the values of reduction factor for different cores

Processor type	F[GHz]	Voltage	δ		
			2 cores	3 cores	4 cores
Intel Xeon	2	1.104	0.94	0.93	0.92
quad-core E5540	2.5	1.104	0.7	0.71	0.72

Table 9. Idle power consumption of components

Component	Consumption (Watt)
Processors	33 Watt
Memories	14 Watt
Hard Disks	3 Watt
Main board	70 Watt
Total	120 Watt

Table 10. Performance comparison of selected algorithm with other popular algorithms

Algorithm	Energy (kWh)	SLA Violation %	VM Migration	Avg SLA Violation%
NPA	18.47			
DVFS	9.38			
ST50%	8.92	95.72	1288	10.24
ST60%	8.72	96.52	1297	10.82
MM (30%-70%)	8.58	92.49	1264	10.11
MM (40%-80%)	8.47	94.15	1281	10.14
MIMT (0%-40%-80%)	7.62	19.53	215	10
MIMT (5%-45%-85%)	7.66	31.78	460	10

Here a new service migration algorithm is proposed to reduce energy consumption at the IDC[7].

Green Monster protocol is proposed which makes use of Evolutionary Multi-objective Optimization Algorithm [EMOA] for service migration. In this simulation IDC's located at Denmark, Germany, Greece, Ireland, Italy, Netherlands, Spain, UK and Portugal. Green Monster is then compared with two benchmark algorithms Static Placement & Random Placement as shown in Figure 5, 6 and 7. Tables 11, 12, 13 and 14 are adopted from[7] and show the configuration of EMOA and IDC used for simulation.

Here Green Cloud architecture is proposed which helps us in achieving significant energy saving for cloud computing environment along with real time performance for performance-sensitive applications by consolidating workload with the help of live virtual migration technology. Workload Simulation of Green Cloud. Energy consumption Comparison with and without Green Cloud as discoursed in Table 15 and 16 and Figures 8, 9 and 10[8].

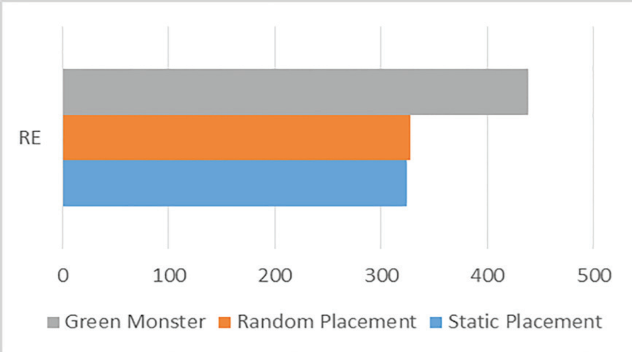

Figure 5. Renewable energy consumption comparison.

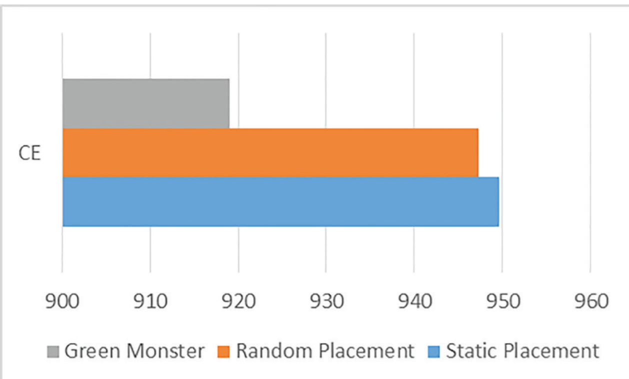

Figure 6. Cooling energy consumption comparison.

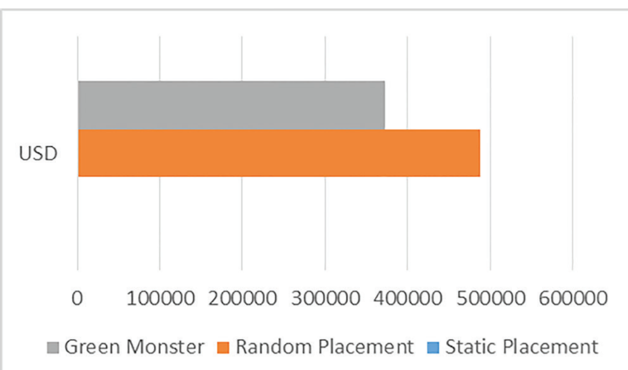

Figure 7. User to service distance comparison.

Table 11. Comparison of migration policies for different values of a, b, c

a	B	c	MIMT	MAMT	HPGT	LPGT	RCT
0	0.4	0.8	19.53	21.30	20.98	20.53	20.48
0.05	0.45	0.85	31.78	35.28	33.88	32.92	32.06
0.1	0.5	0.9	45.65	48.60	47.75	46.89	47.24
0.15	0.55	0.95	59.92	63.42	62.91	60.18	62.22
0.2	0.6	1.0	72.15	74.82	73.98	72.84	73.11

Table 12. EMOA configuration for simulation

PARAMETERS	VALUE
# of generations	100
Population size	100
Crossover rate	0.9
Mutation rate	0.1
Local search rate	0.1
Interval between the proposed EMOA's runs	2 Weeks

Table 13. IDC configuration for simulation

PARAMETER	VALUE
# of IDCs	9
Total # of servers in IDCs	878
# of service types	3
Total # of services	1756
Pmax	400W
Pidle	150W
Per-request CPU utilization for data services	[0.001,0.01]
Per-request CPU utilization for voice services	[0.011,0.024]
Per-request CPU utilization for video services	[0.025,0.039]
Per-request data transmission volume for data services	[0.01,0.05
Per-request data transmission volume for voice services	[0.06,0.15
Per-request data transmission volume for video services	[0.016,0.25
Free-cooling efficiency	1.4

Table 14. Comparison of Green Monster with static and random placement

Algorithm	RE	CE	USD
Static Placement	324.5	949.58	0
Random Placement	327.3	947.34	487378
Green Monster	438.5	919.02	373172

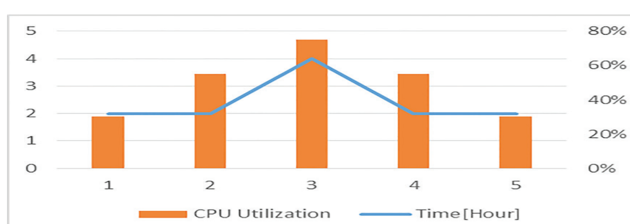

Figure 8. CPU utilisation simulation.

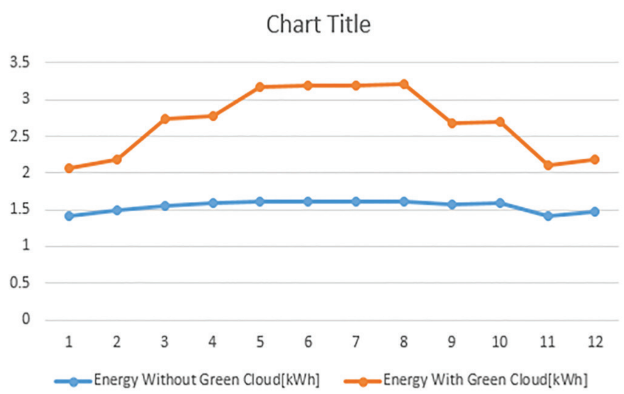

Figure 9. Energy consumption comparison.

Table 15. Workload simulation of Green Cloud

Time[Hour]	CPU Utilization
2	30%
2	55%
4	75%
2	55%
2	30%

Table 16. Energy consumption comparison with and without Green Cloud

Time[hour]	Energy Without Green Cloud [kWh]	Energy With Green Cloud [kWh]
1	1.42	0.65
2	1.49	0.7
3	1.55	1.18
4	1.59	1.19
5	1.61	1.57
6	1.62	1.58
7	1.61	1.59
8	1.62	1.59
9	1.57	1.1
10	1.59	1.1
11	1.41	0.7
12	1.48	0.71

Here a Virtual Machine Power Metering and Provisioning approach is suggested which doesn't require us to modify our hardware or software. This approach also adapts to changes in workload characteristics and hardware configuration[9].

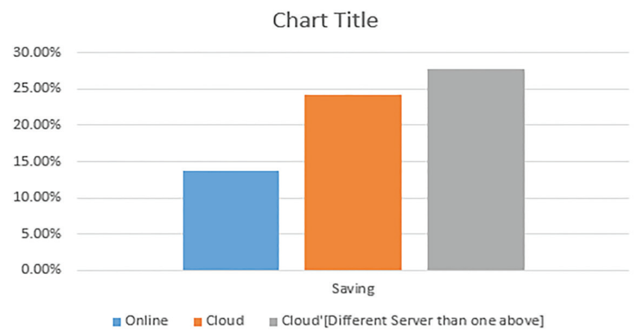

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Figure 10. Energy saving comparison.

3. Conclusion

In this paper, a short survey is done on the current research on Green and efficient dimension of cloud. All the approaches proposed by authors are differentiated on the basis of policies used like manual or automatic (reactive or proactive). Energy efficiency plays an important role in current generation for designing better and efficient algorithms in field of cloud and distributed computing.

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