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Green Data Centres through Power Management of Underutilized and Idle Resources

Madiha Akhtar[1], Dr. Muhammad Nabeel Talib[2]
[1]School of Computer Science and Info Tech, RMIT University, Melbourne, Australia
[2]Department of MIS, School of Business, King Faisal University, Al Ahsa, Saudi Arabia

Abstract*— Cloud computing proved to be that promising technology which enabled the world to bring resource sharing to a new level by turning the internet into a cloud. With the rise of Internet-scale systems and cloud computing services, there is an increasing trend towards building energy-hungry, massive, and geographically distributed data centres. Due to their enormous energy consumption, data centres are expected to have major impact on the electric grid and potentially the amount of greenhouse gas emissions and carbon footprint. The aim of this research is to make data centres - the heart and core of cloud computing - energy efficient and green. For this purpose the main focus is on achieving this through the management of idle and underutilized resources. In an attempt to do so a new approach - termed Wholesome Green Approach - is presented and analysed.

***Keywords*— Cloud Computing, Power Usage Effectiveness, Resource Allocation, Virtual Machines, Resource Scheduling, CPU Utilization.**

I. INTRODUCTION

Cloud provides a solution to the ever growing, more competitive and cost-effective IT industry to cope with the fast market. Within the cloud a data centre is the location for servers hosting and the client applications [1]. Data centres are the hub of servers, telecommunication/storage devices and other technical and supporting hardware. It generally includes redundant or backup power supplies, redundant data communications connections, environmental controls (e.g., air conditioning, fire suppression) and security devices. Due to this heavy hardware nature of data centres they are also referred as server farms. Components in a data centre can be broadly classified into two types- IT infrastructure and Physical infrastructure.

Energy efficiency can be seen as the percentage of total energy input to the data centre that is consumed in productive task. Ideally a data centre should consume only as much energy as is needed to process incoming requests.

Consider a request for a data item; given the application logic on the data centre servers, this request translates to some number of CPU instructions, memory accesses, disk accesses, and network flow. These requests require some amount of energy to execute, which can be computed given the IT resource specifications of the data centre.

In reality, however, processing the request would additionally incur number of energy overheads; energy used by idling resources, by air conditioners that cool the servers processing the request, and energy wasted in inefficient power delivery to the servers among many overheads. The amount of these overheads depends on the energy efficiency of the data centre.

An ideal data centre would minimize these overheads [2]. This brings the need of finding new ways to minimize the overheads and increase the efficiency.

To search for a solution, which is energy efficient and yet green? This research takes into account different techniques, technologies and products available in the market and widely accepted to be helpful to find better solutions. The main focus of this research is based on the three fundamental questions which are

1. How to reduce the energy consumption of idle IT equipment?
2. How to maximize the utilization of the energy provided to IT equipment?
3. How to gain a solution with no or minimal hardware changes?

The focus is on energy saving by resource utilization i.e. to define a framework where one can minimize the idle resources energy consumption and achieve maximum performance for computing to utilize it optimally for the job allocated.

II. LITERATURE SURVEY

Examining the cause of inefficiency in data centres one can broadly classify the factors as energy consumption by idle resources, energy consumption by supporting infrastructure. To further understand the inefficiency of the current system, need to quantify the energy usage in some form in order to measure and improve it. One such measure is called PUE (power usage effectiveness)

PUE= Total facility energy/ IT equipment energy

Disk management ensures efficient storage and access of data. Many techniques are proposed to make it efficient and less power consuming using software and hardware platforms. One method is to trade between high power mode and low power mode of disks while keeping in mind the power consumption and performance.

Popular data concentration is another solution which divides disks into two sets. One set is composed of high powered disks and other is composed of low power disks. Along with disks, data is divided into categories where one is frequently accessed data and other is less used data. Then the most accessed is stored on high powered disk and rest on low powered disks.

Thus ending up with multiple speed disks which means the each disk is allocated a different speed [19]. Theses disk speeds are optimally calculated. Each disk maintains its speed for a fix time. If performance drops then all disks runs on high speed and then disk speed is calculated and adjusted again [17].

Good caching makes disk read outs reduced to a very few number but for disk write, the disks are accessed. If caching is combined with LFS (log file structured system) to control the write function of disks then energy can be reduced. The write function incurs latency and this latency can be tackled using LFS. The main cause of latency is seek time, this can be eliminated by using append only function and avoiding write function all together. For this append purpose secondary disks are used. To reclaim the space, disks are divided into segments. When a segment is filled the next segment is used. This system also proves to be self-cleaning as the system keeps track of the segments and the data validity of each segment. When the invalid data in a segment increases to a certain threshold then the valid data is moved and the segment only contains invalid data and thus it can be considered free again. Over time the disks get naturally divided into stable, volatile and free segments. The same principle is applied at disk level thus combining valid segments on one and rest on others. Eventually it results in separate level of disks. The free disks can now be cleaned once.

The first issue is that the idle time is to short that the effort is not worth the effect. To solve this all writing commands are localized to pre-determined set of disks, combining it with a good cache to minimize the read access.

Another issue is low predictability of idle time that is to find a co relation between idle time durations. This is tackled as LFS as it can easily pre-determine the disks which are being written at all times.

Further finding a solution that abides by the Service Level Agreement (SLA) and is applicable to worthy amount of requests is not easy. The answer lies in making the system application independent.

Lastly directing a large number of requests to few disks in high power mode increases the risk of error and failure. For this reason LFS does not keep the live number of disks constant.

III. PROPOSED MODEL

Virtualization is coupled with strong energy aware scheduling and allocation techniques to provide the new solution. This section aims at explaining the proposed solution to the problem questions defined along with the model analysis in accordance to the objectives.

A. *Wholesome Green Approach*

This proposed model efficiently optimizes the service allocation to Virtual Machines (VMs) and VMs allocation to servers through energy aware method. It works with the help of a green scheduler which assign a VM to the requests by different or same consumer whereas the Green VM allocator provides physical resources to the VMs. It also performs energy management by consolidating or allocating VMs according to work load and energy consumption. Fig 1 shows the architectural structure of the model.

B. *Green Scheduler*

The green scheduler aims at assigning requested services to actual VMs provided. The challenge here is to assign by keeping in view the near future migration chances of the VMs. Thus minimizing the migration and saving energy and increasing efficiency. This scheduler is composed of four components each of them is explained in Fig 2

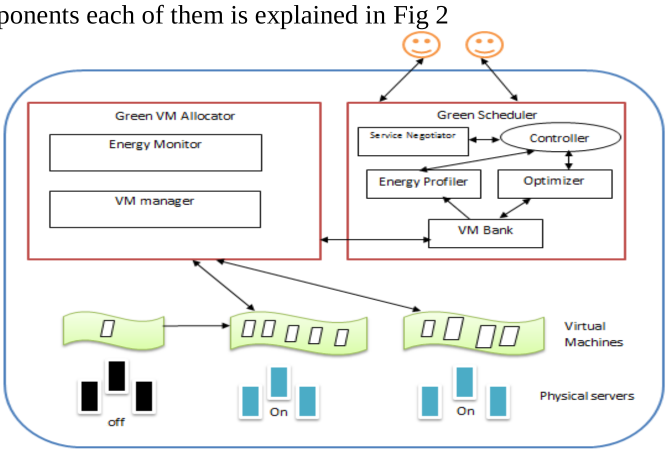

Fig 2 Green Scheduler

1) *Working Green Scheduler:*

The scheduler takes input from the consumer in terms of service requests. These requests are then negotiated with the consumer of Quality of service and SLAs. This request is then send to Energy profiler. The energy profiler analyses the request for its CPU utilization. This CPU utilization is sent to the Optimizer.

Optimizer first takes a list of available VMs along with their CPU utilization from the VM Bank. Then using it uses a trim technique to eliminate the less energy efficient options for the service being allocated. The best VMs are then forwarded to the controller which then assigns the task to the VM.

Trim Technique: Trim technique uses energy aware decision making for choosing the best VM for assigning tasks. It takes the list of VMs from the VM Bank and there CPU utilization it then starts analysing the VMS from top one by one by using the algorithm presented in Fig .3

Algorithm: Trimming Technique

Input: Sorted VMs CPU utilization,
CPU utilization of request
output: Best VM
Foreach VM_c in VM_c list **do**
If $VM_c + R_c > UT$ **then**
Continue
If $VM_c + R_c$ < UT **then**
Flag = allocated

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```
    Return VM_c
    Break
   endif
  end foreach
  If flag != allocated then
    Get new VM_c
    Flag= not allocated
  Endif
  Return VM_c
```

Fig .3 Algorithm of trimming technique

Here the VM_c stands for the virtual machine CPU utilization. R_c Stand for the request CPU utilization. UT means upper threshold. This algorithm takes the VMs list along with their CPU utilization and form the VM Bank. It then analyse each VM for the possibility of task assignment in order to this task in an energy efficient way it calculates the CPU utilization of VM after assigning the task and see if the results end in violation the upper threshold of VM CPU utilization or not. If the threshold is violated the next VM is analysed until a VM is found who addition does not violate the upper threshold. This VM is then sent to controller which assigns it the service requested. In case no VM is found then the request for creating a new VM is sent to the VM Bank and the new VM is returned to the Controller.

The allocation of services through this method shows an improvement in energy consumption along with the minimization of migration. This module interacts with green VM allocator to get the actual VM data available for use.

C. Green VM Allocator

The green VM allocator helps in allocating VMs to hardware. This module use two components Energy monitor and VM Manager. The module design is presented in Fig .5.

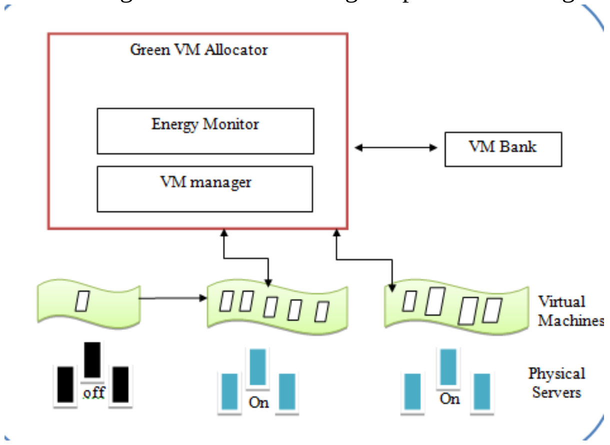

Fig 4 Green VM Allocator

Working: The technology of VMs allows easy movement across platforms which open a big window for consolidation in order to free resources. The freed resources can then be set to sleep mode or turned off thus conserving energy. The issues related are that overly subscribing a server will affect its performance. The Quality of Service also hinders turning the resources on and off dynamically. Ensuring SLA and performance management is difficult in such environments. The VM placement is a two part question one is assigning latest requests for VMS along with their placement on physical machines and second is VM allocation for optimization of the pre-admitted VMs. To solve this, Best fit Decreasing Algorithm is used to sort VMs with respect to CPU utilization. The VMs are placed on the host whose overall power consumption is least changed by the addition of new VM.

The question here arises is which VMS are to be allocated using this technique for among the pre-allocated VMs. The answer lies in assigning utilization thresholds both upper and lower limit. The thresholds aim to keep the utilization of the physical host in a specific range no matter how many VMs are assigned to it. When the lower limit is crossed then all VMs of that host are moved out to others thus freeing this host to be put in low energy mode. If the upper limit is breached then a portion of VMS is to be shifted to keep the utilization in check. For selecting the minimum number of VMs to be reallocated the MM (minimization of migration) policy is used. This policy first sorts the VMS in descending order with respect to CPU utilization then the VMs are selected. First, if the selected VM has a utilization which is more than the exceeded amount of utilization of that host and secondly that the selected VM if removed lowers the overall utilization of the host more than the reallocation of any other VM. This is done in iteration until the utilization of the host is brought back in the range assigned. In case there is no VM found according to the criteria then the VM which has highest utilization among other is removed.

Another policy called highest potential growth policy is used when the upper threshold of number of VM's on a host is crossed then the policy will remove such VM which has the least CPU utilization of the total CPU utilization of the host to avoid an SLA violation.

D. Analysis of Model

The proposed model is in line with three basic questions forming the basis of the research.

The first task was to reduce the power utilization of idle IT equipment this aspect was addressed in the green VM allocator by 1) by defining different threshold to keep the utilization of the hardware in check 2) by consolidating different VMs to free underutilized IT equipment. 3) By turning the idle equipment off and thus saving energy. It also reallocate VMs to different other hosts to free more hosts from underutilization and to reduce power consumption. The energy consumption of idle resources forms a sizeable chunk in the total inefficiency number. Reducing this allows a very safe approach for energy reduction. Another effect of turning the idle resources off is that the cooling budget will reduce as well.

The second task of utilizing the energy provided to the IT equipment to maximum is done by both green VM allocator and the green scheduler. The green scheduler strives to fully utilize each VM in order to achieve maximum utilization. This is done by using the trimming technique which keeps assigning new tasks to VM until the maximum utilization is

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achieved. Green VM allocator also fulfils this criterion by consolidating VMs on lesser hosts to increase the utilization of servers and reduce power issues by turning the other hosts off.

The last criteria of minimum hardware changes is achieved by using the virtualization technology as it enables a solution which is both hardware and even platform independent thus is easy to use and maintain. The cost of designing, testing and implementing hardware based solutions is also very high along with that more hardware usage means more energy will be in turn required to remove the heat built up thus the amount effort used does not result in satisfying results. Keeping solution hardware independent made the solution applicable on many different forms of data centre environment.

IV. ANALYSIS AND RESULTS

Model analysis in terms of validation and verified is discussed and analysed in this section. Resource allocation with and without sorting is tabulated and then presented in graphical view. With CPU Utilization threshold, four cases are discussed and analysed whereas in resource allocation section two cases are defined.

A. Resource Allocation

As the Green Scheduler component uses the module of Virtual Memory (VM) bank from where the sorted list of VM is generated. In this section, resource allocation with and without sorting is analysed.

1) ***Resource Allocation without Sorting:*** CPU utilization of 5 VM is tabulated as 68 units, 33 units, 47 units, 54 units and 76 units respectively. Point to be consider in this tabulation is the unsort nature of VM listing. Considering three resource offers in parallel where CPU Utilization is 30 units for the first case, 15 units for second case and 37 units for the third case. For the first case, CPU utilization in the 1 to 5 VMs is 98 units (68+30 = 98), 63 units, 77 units, 84 units and 106 units respectively. For the second case, CPU utilization in the 1 to 5 VMs is 83 units, 48 units, 62 units, 69 units and 91 units respectively. For the third case, CPU utilization in the 1 to 5 VMs is 105 units, 70 units, 84 units, 91 units and 113 units respectively. Table 1 shows the Tabulated Resource Allocation without Sorting.

	Resource Offer	30	15	37
S.No	VM CPU Utilization	VM CPU Utilization + Resource Offer	VM CPU Utilization + Resource Offer	VM CPU Utilization + Resource Offer
1	68	98	83	105
2	33	63	48	70
3	47	77	62	84
4	54	84	69	91
5	76	106	91	113

Table .1 Tabulated Resource Allocations without Sorting

Fig 5 shows the graphical representation of Resource Allocation without Sorting. There are five sets of bar charts where each of the set represents the CPU Utilization for a VM depicting the four cases. First bar in cyan color shows the CPU Utilization of the VM without adding the Resource Offer's CPU Utilization and this is the reason that the cyan bars are the smallest ones among all. Second bar in pale orange shows that the CPU Utilization of the VM after summing up the CPU Utilization made by the Resource offer i.e., 30 for the first case. Third bar in navy blue shows that the CPU Utilization of the VM after summing up the CPU Utilization made by the Resource offer i.e., 15 for the second case. Forth bar in brown shade shows that the CPU Utilization of the VM after summing up the CPU Utilization made by the Resource offer i.e., 37 for the third case.

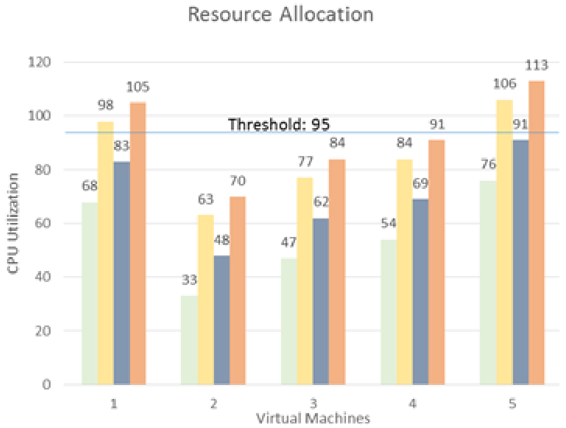

Fig 5 Graphical Resource Allocations without Sorting

Threshold is defined to be 95 units and the need of setting threshold appears by keeping in consideration the avoidance for the over utilization or over subscription. For first VM, first and third cases are trimmed. For second, third and fourth all of the CPU Utilization either initial or after adding the new resource CPU Utilization, remains acceptable and thus not trimmed. But for fifth VM, first and third cases are trimmed.

In case of first case where the Resource offered utilizes 30 units of CPU Utilization, 1st and 5th VM will be trimmed from the availability list and thus 4th VM is the appropriate choice for the new resource allocation as the technique focuses on power usage efficiency and thus ensuring at most usage made by VMs. For second case 5th VM is the appropriate choice and best choice for third case is 4th VM.

Resource Allocation with Sorting: CPU utilization of 5 VM is tabulated as 76 units, 68 units, 54 units, 47 units and 33 units respectively. Point to be considered in this tabulation is the sorted nature of VM listing. Considering three resource offers in parallel where CPU Utilization is 30 units for the first case, 15 units for the second case and 37 units for the third case. For the first case, CPU utilization in the 1 to 5 VMs is 106 units (76+30 = 106), 98 units, 84 units, 77 units and 63 units respectively. For the second case, CPU utilization in the 1 to 5 VMs is 91 units, 83 units, 69 units, 62 units and 48 units respectively. For the third case, CPU utilization in the 1 to 5 VMs is 113 units, 105 units, 91 units,

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Volume 4, Issue 12, June 2015

84 units and 70 units respectively. Table 2 shows the Tabulated Resource Allocation with Sorting.

	Resource Offer =	30	15	37
S.No	VM CPU Utilization	VM CPU Utilization + Resource Offer	VM CPU Utilization + Resource Offer	VM CPU Utilization + Resource Offer
1	76	106	91	113
2	68	98	83	105
3	54	84	69	91
4	47	77	62	84
5	33	63	48	70

Table 2 Resource Allocation with sorting

Fig 6 shows the graphical representation of Resource Allocation with Sorting. There are five sets of bar charts where each of the set represents the CPU Utilization for a VM depicting the four cases. First bar in blue colour shows the CPU Utilization of the VM without adding the Resource Offer's CPU Utilization and this is the reason that the blue bars are the smallest ones among all. Second bar in brown shows that the CPU Utilization of the VM after summing up the CPU Utilization made by the Resource offer i.e., 30 for the first case. Third bar in grey shows that the CPU Utilization of the VM after summing up the CPU Utilization made by the Resource offer i.e., 15 for the second case. Forth bar in pale orange shows that the CPU Utilization of the VM after summing up the CPU Utilization made by the Resource offer i.e., 37 for the third case.

Threshold is defined to be 95 units and the need of setting threshold appears by keeping in consideration the avoidance for the over utilization or over subscription. For first and second VM, first and third cases are trimmed. For third, fourth and fifth VMs all of the CPU Utilization either initial or after adding the new resource CPU Utilization, remains acceptable and thus not trimmed.

In case of first case where the Resource offered utilizes 30 units of CPU Utilization, 1st and 2nd VM will be trimmed from the availability list and thus 3rd VM is the appropriate choice for the new resource allocation as the technique focuses on power usage efficiency and thus ensuring at most usage made by VMs. For second case, VM 1 is the best choice and for third case VM 3 is the best choice.

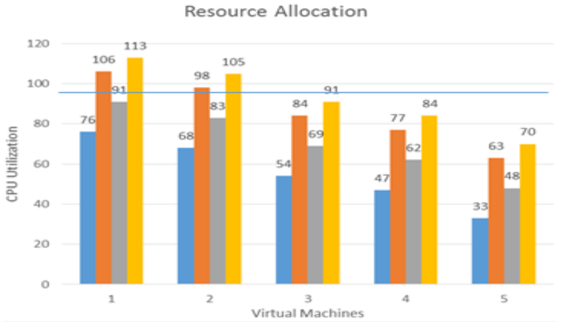

Fig 6 Graphical Resource Allocations with Sorting

Number of trim cases is almost same in both with and without sorting scenarios but the sequence of allocation of VM is in order and need to explore all bars for every case.

B. VM Allocation with variable policies

Power policies can be one among the two:

1. Non Power Aware Policy (NPA Policy)
2. Power Aware Policy (PA Policy)

In PA Policy, some considerations bound the upper limit for the CPU Utilization like setting the threshold to be 95 units as the at most CPU Utilization whereas in NPA Policy, being unware of Power Policy, it promises 100 units of CPU Utilization. Whereas PA Policy is further divided into different policies depending upon the threshold defined.

1) Non Power Aware Policy

For the evaluation purpose, resources offers are considered for 8 VM allocations. CPU Utilization for the resources under observation is 11 units, 57 units, 23 units, 19 units, 26 units, 6 units, 35 units, 63 units, 41 units, 8 units, 62 units, 45 units, 29 units, 54 units and 77 units respectively. For the very first resource request when all virtual machines are available, according to the algorithm Service 1 will run on VM 1. For Service 2, VM 1 is considered first and the calculations shows that out of 100 units of CPU Utilization only 11 units are yet utilized so Service2 will also run on VM 1. For Service 3, VM 1 is considered first and the calculations shows that out of 100 units of CPU Utilization only 68 units are yet utilized so Service3 will also run on VM 1. For Service 4, VM 1 is considered first and the calculations shows that out of 100 units of CPU Utilization 91 units are already utilized and adding 19 units of Service 4 into the already CPU Utilization of VM 1 i.e. 91 will force the VM exceeding CI, so Service3 will run on VM 2. For Service 5, VM 1 is considered first and the calculations shows that out of 100 units of CPU Utilization 91 units are already utilized and adding 26 units of Service 5 into the already CPU Utilization of VM 1 i.e. 91 will force the VM exceeding CI, so Service5 will run on VM 2. For Service 6, VM 1 is considered first and the calculations shows that out of 100 units of CPU Utilization 91 units are already utilized and adding 6 units of Service 6 into the already CPU Utilization of VM 1 i.e. 91 will keep the VM within CI, so Service6 will run on VM 1 and the same algorithm will dry run for all service requests and CPU Utilization with Confidence Interval (CI) equals 100 is tabulated below in Table 3.

Last row of the Table 4.3 computes the total CPU utilization of the Resources in first column and in remaining eight columns total CPU Utilization is mentioned which are 97 units for VM 1, 88 units for VM 2, 92 units for VM 3, 86 units for VM 4, 62 units for VM 5, 54 units for VM 6, 77 units for VM 7 and VM 8 is still free as all service offers are addressed.

As total CPU Utilization required is 556 and it seems like 6 VM will be enough to facilitate the requests but some stack remains empty due to resource CPU utilization unit. This is the reason, iterations are being performed that to

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Volume 4, Issue 12, June 2015
check if the coming resource get adjusted in any of the stack that is still empty in previously trimmed VM.

	CPU Utilization	100							
S. Id	Resource's CPU Utilization	VM 1	VM 2	VM 3	VM 4	VM 5	VM 6	VM 7	VM 8
1	11	11							
2	57	57							
3	23	23							
4	19		19						
5	26		26						
6	6	6							
7	35		35						
8	63			63					
9	41				41				
10	8		8						
11	62					62			
12	45				45				
13	29			29					
14	54						54		
15	77							77	
Total	556	97	88	92	86	62	54	77	0

Table .3 CPU Utilization with CI equal 100

VM 1 can still facilitate resources up to 3 units of CPU Utilization. VM 2 can still facilitate resources up to 12 units of CPU Utilization. VM 3 can still facilitate resources up to 8 units of CPU Utilization. VM 4 can still facilitate resources up to 14 units of CPU Utilization. VM 5 can still facilitate resources up to 38 units of CPU Utilization. VM 6 can still facilitate resources up to 46 units of CPU Utilization. VM 1 can still facilitate resources up to 23 units of CPU Utilization. And VM 8 can facilitate resources up to 100 units of CPU Utilization.

Fig 7 shows that the VM 1 is running 4 service requests (i.e. Service Id 1, Service Id 2, Service Id 3 and Service Id 6), each represented by a colour code. VM 2 is running 4 service requests (i.e. Service Id 4, Service Id 5, Service Id 7 and Service Id 10). VM 3 is running 2 service requests (i.e. Service Id 8 and Service Id 13). VM 4 is running 2 service requests (i.e. Service Id 9 and Service Id 12). VM 5 is running 1 service request (i.e. Service Id 6). VM 6 is running 1 service request (i.e. Service Id 14). VM 7 is running 1 service request (i.e. Service Id 15). And VM 8 is running 0 service requests, that's why it in the idle state and can be moved to stand by state to save power utilization.

After running the VM Manager Allocation algorithm on the CPU utilization in terms of PUE per VM is visualized in Fig 7.

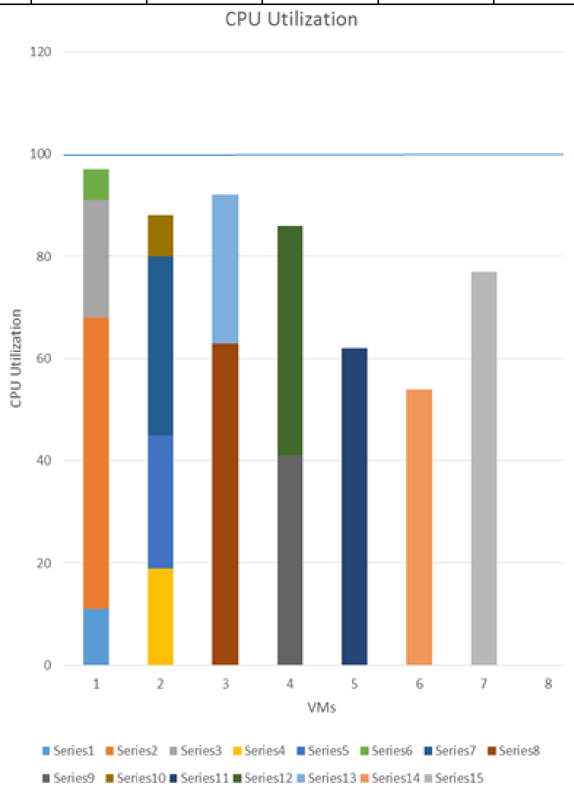

Fig 7 CPU Utilization with CI equals 100

Table .4 CPU Utilization with CI equals 95

	CPU Utilization	100							
S. Id	Resource's CPU Utilization	VM 1	VM 2	VM 3	VM 4	VM 5	VM 6	VM 7	VM 8
1	11	11							
2	57	57							
3	23		23						
4	19	19							
5	26		26						
6	6		6						
7	35		35						
8	63			63					
9	41				41				
10	8			8					
11	62					62			
12	45				45				
13	29						29		
14	54						54		
15	77							77	
Total	556	87	90	71	86	62	83	77	0

2) Power Aware Policy: Keeping in consideration the power related factors and consumptions, threshold value is being defined so that to track the effect of Confidence Interval (i.e. threshold) on the VM allocation and CPU Utilization per VM.

a) Case I: CPU Utilization with CI Equals 95

Setting the CI to 95 and to run the same algorithm as for CI equals 100, Table 4.4 got the resource allocation details in term of depicting the CPU Utilization per VM.

For CI equals 95, VM 1 has 4 more CPU Utilization units available; VM 2 has 1 more CPU Utilization unit available etc.

Fig 8 shows that with CI equals 95, VM 1 is facilitating Service Id 1, 2 and 3. VM 2 is handling Service Id 4, 5, 6, 7 and 10. VM 3 offers services Service Id 8 and 13. Service Id 9 and 4 are catered by VM 4. Service Id 11 is catered by VM 5. Service Id 14 is catered by VM 6. Service Id 15 is catered by VM 7. VM 8 is still in standby mode.

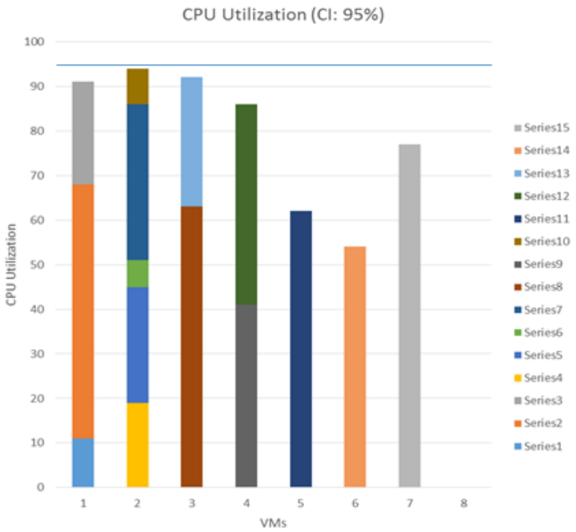

Fig 8 CPU Utilization with CI equals 95

b) Case II: CPU Utilization with CI Equals 90

Setting the CI to 90 and to run the same algorithm as for CI equals 100, Table 4.5 got the resource allocation details in term of depicting the CPU Utilization per VM.

For CI equals 90, VM 1 has 3 more CPU Utilization units available; VM 2 has no more CPU Utilization unit available, etc. Fig 4.5 shows that with CI equals 90, VM 1 is facilitating Service Id 1, 2 and 4. VM 2 is handling Service Id 3, 5, 6 and 7. VM 3 offers services Service Id 8 and 10. Service Id 9 and 12 are catered by VM 4. Service Id 11 is catered by VM 5. Service Id 13 and 14 are catered by VM 6. Service Id 15 is catered by VM 7. VM 8 is still in standby mode.

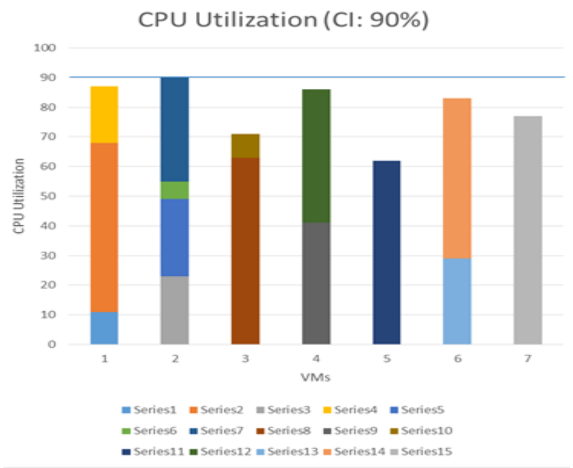

Fig 9 CPU Utilization with CI equals 90

c) Case III: CPU Utilization with CI Equals 80

Setting the CI to 80 and to run the same algorithm as for CI equals 100, Table 4.6 got the resource allocation details in term of depicting the CPU Utilization per VM.

For CI equals 80, VM 1 has 6 more CPU Utilization units available; VM 2 has 4 more CPU Utilization units available etc.

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Volume 4, Issue 12, June 2015

Table 5 CPU Utilization with CI equals 80

	CPU Utilization	100							
S. Id	Resource's CPU Utilization	VM 1	VM 2	VM 3	VM 4	VM 5	VM 6	VM 7	VM 8
1	11	11							
2	57	57							
3	23		23						
4	19		19						
5	26		26						
6	6	6							
7	35			35					
8	63				63				
9	41			41					
10	8		8						
11	62					62			
12	45						45		
13	29						29		
14	54							54	
15	77								77
Total	556	74	76	76	63	62	74	54	77

Fig 10 shows that with CI equals 80, VM 1 is facilitating Service Id 1, 2 and 6. VM 2 is handling Service Id 3, 4, 5 and 10. VM 3 offers services Service Id 7 and 9. Service Id 8 is catered by VM 4. Service Id 11 is catered by VM 5. Service Id 12 and 13 are catered by VM 6. Service Id 14 is catered by VM 7 and Service Id 15 is catered by VM 8.

Confidence Interval has a crucial impact on the resource allocation on the VMs. Usage of some or all of the VMs depend upon the CI allowed to be used for the CPU Utilization. As in case of CI equals 100, 95 and 90, starting 7 VMs from VM 1 to VM 7 were utilized and if the VM is set to be 80, then with VM levelling as per defined CI, VM 8 is also in active state. Thus, PUE is directly related to the CI, refers to higher the CI more likely the PUE. Number of VM under CPU Utilization is inversely proportional to the PUE, more VMs in use refers to unlikely PUE and optimized VMs in consideration leads to promising PUE.

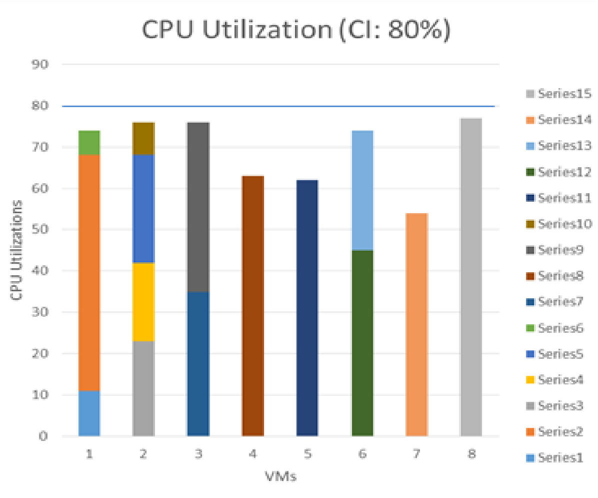

Fig 10 CPU Utilization with CI equals 80

C. Results

Two of the main contributions of this research are about reducing the energy consumption by using Virtual Machines and offering a strong competitive Cloud Computing Market. Main inputs of the proposed Wholesome Green Approach are the resource offers that are the requirements or requests offers and the policy of power consumption. None of the power aware assumption and optimization is linked with NPA as it works for maximum power usage and holds 100% CPU Utilization. Results shows that the best CPU Utilization is ensured with NPA policy but keeping the policy unaware of the power factors is not a good choice so the PA policy with the threshold of 95 % is the one ensuring promising results with efficient and optimized VMs allocation to the requested resource offers.

Additionally the optimizer is adding to the efficiency of the data centre resources and thus providing the best VMs to the resource by appropriate resource levelling. Sorting involved in the VM bank adds up to the performance conformance by saving the effort of searching all VMs to extract the one that is suitable. Significant decrease in energy consumption is noticed in the PA Policy with maximum threshold i.e. 95%. As the VM allocation with the threshold of 80% leads to more VMs allocation (eight instead of seven), so the crucial task is setting the optimized threshold.

Increasing the threshold of CPU Utilization decreases the power consumption and thus making the data centre more energy efficient but vice versa is not exactly true if the threshold is kept too low (like 80% in this research). Similarly, increasing the threshold to 100% will make it Non Power Aware.

V. CONCLUSIONS

The model presented helps in efficiently assigning the requests from the user to the different Virtual Machines and then smartly allocating those machines on the physical server. Both the process of allocation and assignment is done in an energy aware and green manner. The standard made for achieving energy efficiency and green solution were three fold.

1. The solution should aim at reducing the idle resources.
2. The solution should fully utilize the available resources.
3. The solution should involve minimum or no hardware changes to the existing setup.

All three standards were achieved by wholesome green approach. The reduction and maximum utilization of idle resources is done at two levels; first during service scheduling and secondly during VM allocation.

The reduction of idle resources is done through matching power to load. It was implemented by developing the trimming technique which states that the services should be allocated in a manner that the allocation of the VM to the service ends up in increasing the utilization of it and avoids the need of creating a new VM or filling any idle ones. The next stage was to eliminate these idle resources from consuming energy this is done by the VM allocator. The VM allocator allocates or reallocated VMs to machines as such that it ensures that all the alive machines are utilized close to their maximum ability and according to the work load more machines are made alive or are turned off. For reducing idle resources it also consolidate VMs from lightly loaded VM which eliminating more idle resources.

Wholesome green approach also touches the triple bottom line of green computing which are the people, planet and profit. Through better management of resources in hand the hustle of buying new equipment with every rising change is contained. The better utilization also results in switching the idle resources off thus saving the planet from excessive carbon footprint with no beneficial outcome. Using fewer resources and achieving same goals aids the company in gaining more profit by having less expenses

The two components used for service scheduling and resource allocation use different methods and were governed by two policies

1. Threshold of trimming technique
2. Confidence Interval for resource utilization

These policies were defined and there suggested settings were recommended as well during the validation process of the model. The overall impact of the combined method was greater than using focused optimization of just one aspect of resource allocation.

A. Limitations

Wholesome green approach and its effects are only limited to the inefficient use of computing resources. It doesn't have any effect on other factors like data storage, data writing, data accessing, networking etc. This method in combination with other efficiency methods for data accessing can bring more efficient results. All these variables are constant for our method they have no effect and they are not affected. In short the latency and energy usage specially related to data storage needs to be addressed.

B. Future Work

The wholesome has several different modules all designated with some responsibilities and monitoring. These modules are addressed in the work at a high level of abstraction with the exception of the core modules.

These supporting modules (energy manager, energy profiler, service negotiator) generate values which form the input to the core VM manager, optimizer thus affecting the overall model. The task performed can be optimized and researched for improving the model. Some the tasks are

Calculating CPU utilization: CPU utilization can be calculated through different ways but choosing the way which gave the best closest value and exploring its affecting factors is a question of its own.

Service Negotiation: service negotiation with the consumer is a very core task for better performance as for any set up satisfaction of its consumers comes first. Energy efficiency and green computing seems to be a concern for the data centre organization but not for the consumers. This trend needs to be changed and incorporated in SLA.

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