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Research paper

Energy Conservation and Controlling Co2 Emission using WEC Algorithm in Datacenters

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Abstract

Around the global, extended dryness threatens the reliable electricity production which is critical for data center operations. Therefore the quantity of water consumed by the data centers is been increasing day by day ultimately leading to more CO_2 emission which forms the major environmental threat. Hence, there arises a necessity of a load balancing factor with optimized time complexity for electricity production. To achieve this, an energy and workload management algorithm called WEC is proposed. This algorithm reduces the data centers long-term water consumption and dynamically dispatches the workload among distributed data centers. This algorithm also aims at reducing CO_2 emission and time taken to complete the work.

Keywords: *Water, Energy, Carbon-di-oxide constrained workload scheduling, Virtual Machine, Physical Machine, Natural Resource Management.*

1. Introduction

In Today's world, Cloud Computing gives various computing utilities like networking, abide as servers, software, analytics, storage and databases above the internet. These services are provided with the help various data centers, where energy productivity is determined by the quality of their services and performances. At present, performance is evaluated on the basis of resource management, energy consumption, load balancing and cost. Data centers are growing exponentially in terms of both number and in size leading to huge amount of electricity consumption. Hence, it raises major environmental issues like CO_2 emission and so on. Hence there arises a need for proposing technique to reduce these problems without degrading the performance of that particular system.

Resource management is a process of maintaining system's natural integrity without degrading it. Some of the examples include reducing the air pollution caused by CO_2 emission, avoiding soil pollution, maintaining the forestry, wildlife protection and water management during droughts. The term for the management of resources is natural resource management (NRM)

For any Organization, the available resources should be managed efficiently and effectively for their development and sustainability. The resources may include financial sources, human skills, and use of raw materials for the continuous supply of electricity. These resources should be used in such a way that they do not cause any threat or destruction to the environment. The development of resources can be made possible only when they are managed properly. Also, the amount of money invested on those resources can be gained back by adding some other investments that may develop a new state of capability which might be in demand later. Also, the overall investment can be reduced by disposing the used resources in an reusable way or by exchanging those resources with some other resource that has the particular demand capability.

2. Literature Review

Federico Larumbe and Brunilde Sanso proposed an algorithm called Tabu search algorithm that reduces the CO_2 emission and optimizes the performance in the data centers. This algorithm optimizes the network performance, quality of service and reduces the capital cost of the entire performance cycle. It is a heuristic algorithm that is designed using a programming model using integers and is solved by using an optimization technique. The first step in this algorithm is locating the total number of servers present in a particular data center. With the help of World Wide Web, user interfaces and web servers, the process is carried out where each user system has its own access node and they represent the client component which is executed on the other side in the user system. Web services will respond to the requests made by the access nodes and may also require a large number of servers to handle the requests more efficiently. All these steps will take a lot of time because of which the CO_2 emission is more and the performance of that particular data center is been drastically reduced. A solution to this problem is provided in the Tabu algorithm. Hasan Mahmud, Mohammad A Islam, Xiaorui Wang and Shaolei Ren studied on reducing the carbon emission in colocation data centers by using an online technique called GreenColo.

Colocation data centers consumes huge amount of energy causing more carbon emission. This problem leads to "split incentive" meaning that the carbon efficiency is not managed properly by the tenants. So, an online carbon aware technique is followed where biding is done by the tenants with their own prices on energy reduction and rewards will be provided if their bids are accepted dynamically. This method reduces the carbon emission by 24 % with no extra cost. A set of bids along with the estimated reward and the energy consumption of that a particular tenant is given, which is then processed in an online optimizer and the winning bid is provided with financial rewards. The biding and the number of bids are all voluntary in this approach. As a result this is more energy efficient in the process along with the reduction of carbon emission.

Fahimeh Farahnakian and Adnan Ashraf studied on energy consumption in data centers. Since the virtual machines are being corrected dynamically, it has been given a great area in saving energy in those data centers. This method uses the live movement of VMs so that the under-loaded physical machines can be easily either switched off or put in low power mode. Otherwise it will be harder for the cloud providers and users to achieve the expected level of Quality of Service. So, the main the goal is the reduction in energy consumption of data centers with respect to Quality of Service requirements. Distributed system architecture is used here to implement dynamic VM consolidation inorder to minimize the energy efficiency in data centers thereby it maintains the expected QOS requirements. An algorithm called as Ant Colony System [6] is been used here to solve all the NP-hard problems and VM consolidation is one of those. The ACS based VM consolidation technique finds an optimal solution according to a specified objective function. The implementation result shows that they are actually minimizing the energy efficiency among data centers while managing the basic requirements of execution levels in cloud data centers. The "dynamic VM consolidation is a far better way to increase the resources utilization and their energy efficiency". Ant Colony Optimization is implemented considering the foraging behavior of real ant colonies. Ants act as agents to find a way for indirect communication called stigmergy to find the easier path between their nests and food. Thus, it helps them to find the shortest path.

Aujla, G. S., & Kumar, have "proposed MEnSuS algorithm for energy management with sustainability of Cloud Data Centers". This uses Edge-Cloud Environment with the help of Software defined Networks(SDN).In this proposed scheme, a workload classification approach using support vector machine is presented. In Addition to that, workload scheduling is designed for a two stage game which provides sustainability for the data centers (DCs). "In order to achieve optimal utilization of network, computing resources and energy efficiency are also presented".

3. Research Objectives

Data centers which allocate task and perform various processes are made energy efficient and the water usage along with CO_2 emission during these processes are reduced considerably using WEC algorithm. The entire process is done using simulation, where the performance of the systems are improved using new metrics and load balancing among the virtual machines are done comparatively more efficient and effective than the existing systems. Also, energy utilization is reduced which automatically reduces the cost and electricity used for the entire process.

4. Research Methodology

The proposed algorithm is implemented using available online information.

4.1. Main Challenge

Considering the data center water footprint where long-term effort is needed creating challenges since the desired water capping constraint increases the time slots for different workload management decisions. Power proportionality decisions and GLB has to be made without considering the future which in turn makes the current decision implicitly affect the future decisions. For example, when more water is used in one timeslot, it will affect the water budget for another time slot or for the future use. If the accurate prediction of certain challenging offline information like non-stationary workload arrival is not possible, then the online approach becomes necessary. To overcome this challenge the sample-path Lyapunov technique is implemented. GLB and power proportionality decisions algorithms are made only based on the information available currently. The technique Lyapunov was initially used for control system stability but later extended to achieve long-term queueing stability in networks.In addition to that control decisions are made without considering the future.

Here

Data center water footprint - "job arrivals"

Desired water usage - "job departures".

To achieve long-term water footprint capping, the virtual queue length is made as zero.

A water budget deficit queue which replaces the long-term constraint and a queue with an initial value of zero $q(0) = 0$ is defined as,

$$+m(s+1) = \{m(s) + \sum_{j=1}^{N} w_i(s) - a(s)\} \quad (1)$$

where $m(s)$ is starting time slot t of queue length ,$\sum_{j=1}^{N} w_i(s)$ is the joined together water consumption of all the data centers and a(s) is the reference water budget for time slot s. The a(s) is taken as a constant of reference budget (e.g. $a(s) = Z/K\, fort = \{0,1,\ldots,K-1\}$) or estimated based on projected workload which can be an inaccurate value such that $\sum_{s=0}^{K-1} a(s) = Z$.However, based on simulation studies $, if the total water budget is the same then z(t)$ is having the cost efficiency to negligible impact on the outcome of WEC .The working of this algorithm which does not affect the reference value of z(s).

Queue length=total reference water usage-actual water usage

As the deviation of actual water usage from the total reference water usage is defined as the queue length at any time.This information is used in the optimization so the deviation can be reduced. Instead of optimize the original objective function a new objective function is constructed

$$X.\,h(\lambda(s), l(s)) + q(s).\sum_{i=1}^{N} w_i(s),$$

- This new objective function is obtained by Scaling the original objective function by X
- Added to the water usage multiplied by the water budget deficit queue q(s)

With the help of this new function, the decisions are not integrated with different time slots and it can be solved online having only the information like workload of the current time slot.
The “water budget deficit queue acts as a feedback which collects data from past decisions to the current decision, so that there will be a considerable reduction in the long-term water footprint constraint”. The new objective function

$X.h(\lambda(s),l(s)) + q(s).\sum_{i=1}^{N} w_i(s)$ is changed in such a manner that the reduction gradually occurs so that the obtained feedback does not affect the cost minimization’s main objective. In specific, the parameter X acting as a control parameter inorder to determine the amount of emphasis that should be applied on cost minimization in comparison with the long-term water footprint constraint. “Larger the value of X, greater the cost minimization in data centers than meeting the long-term water budget, and if the value of X is less, it implies that the data center cares less about cost minimization than meeting the long-term water budget”.

4.2 Algorithm

Input $\lambda_j(s), \in_{j,E}(s), \in_{j,J}(s) \wedge u_i(s)$ at the beginning of each time, $s = \{0,1,\ldots,K-1\}$, for $j = 1,2,\ldots,N$

Choose $\lambda(s)$ and $m(s)$ subject to constraints to minimize

P2: $X.h(\lambda(s),l(s)) + q(s).\sum_{i=1}^{N} w_i(s)$ (2)

Update $q(s)$ according to (1).

Our intended research on the data center's drought survival is implied in the following ways.

4.2.1. Power Proportionality

Killing the unused servers is the essential standard to change control proportionality (likewise alluded to as "dynamic rightsizing"), as static/sit still servers may expend over 60% of full power. Consequently, killing the servers when the remaining task at hand is low can extensively decrease the utilization of vitality and additionally water impression. We predominantly determine grabbing of Global Load Balancing[6] and power proportionality of server farm's water impression topping: (1) approaches to speeds up the measure of work to geo-circulated server farms (i.e., the level of approaching measure of work distributed to every last server farm) and the quantity of servers to turn over in each datum focus.

4.2.2. Data Center

Data center refers to an on premise hardware which is responsible for storing the data within an organization’s local network. Cloud service providers use data centers to distribute the workloads among several virtual machines.

4.2.3. Workload

A Workload is critical in finding the capacity of the data center. Workload can defined as the processing capacity of the data center at a given particular time. Workload mainly comprises of some amount of program running inside the computer and some users connected to and interacting with the computer’s application.

4.2.4. Problem Formulation

Here, “Operational cost is considered more rather than the capital cost (e.g., building data centers) that can be significantly reduced using individual techniques”. Cost of electricity and delay, are the two costs [12] that are preceding user takes up a more fraction of the operational cost while the later disturbs user revenues and experiences.
As water bill is considerably less comparing to electricity cost and since indirect water consumption is “paid” in energy bills, water cost is not incorporated in our work. The following is the parameterized cost,

$$g(\lambda(t),m(t)) = \sum_{i=1}^{N}[e_i(a_i(t),m_i(t)) + \beta.d_i(a_i(t),m_i(t))] \quad (5)$$

Where
$\lambda(t) = (\lambda_{1,1}(t),\ldots,\lambda_{1,J}(t),\ldots,\lambda_{N,1}(t),\ldots,\lambda_{N,J}(t))$
and $m(t) = (m_1(t),\ldots,m_N(t))$ defines the Global Load Balancing and power proportionality judgements, and $\beta \geq 0$ is the weight factor converting lagging performance to monetary “cost” (adjusting tradeoff between electricity cost and delay performance). Throughout the paper, we use “operational cost” to represent the parameterized cost. Next, we formulate the problem as follows,

$$P1: \min_{A} \acute{g} = \frac{1}{K}\sum_{t=0}^{K-1} g(\lambda(t),m(t)) \quad (6)$$

$$s.t., 0 \leq \sum_{j=1}^{J}\lambda_{i,j}(t) \leq \eta.\mu_i.m_i(t), \forall i,t \quad (7)$$

$$m_i(t) \leq M_i, \forall i,t \quad (8)$$

$$\sum_{i=1}^{N}\lambda_{i,j}(t) = \lambda_j(t), \forall j,t \quad (9)$$

$$\sum_{t=0}^{K-1}\sum_{i=1}^{N} w_i(t) \leq Z \quad (10)$$

Where A represents a sequence of GLB and power proportionality decisions, i.e., $\lambda(t)$ and $m(t)$, for $t = 0,1,\ldots,K-1$. The constraints (7), (8) and (9) indicate no server overloading, over-provisioning and workload dropping respectively, while the constraint (10) specifies the long-term water consumption and the constraint (7), $\eta \in (0,1)$ specifies the maximum server utilization (equivalently, the worst delay performance). The “additional constraints such as that some workloads that can only be routed to certain data centers can also be incorporated into our study later”. Moreover, “onsite water capping for each data center is also considered here (which is more related to regional drought) and carbon footprint capping”. In P_1, the power usage is an affine function of load distribution $\lambda_{i,j}(t)$ and the number of servers to turn on $m_i(t)$, and so are electricity cost and water footprint. The lagging charge is a convex function of $\lambda_{i,j}(t)$ and $m_i(t)$.Thus, P_1 is the convex escalation that can be corrected in polynomial time.

5. Results and Discussion

Energy consumption during load balancing in virtual machines is analyzed by calculating the amount of CO_2 emission, utilization of water, reduction in the time consumption for the entire process.

5.1. CO2 Emission

Data centers are indirectly responsible for the carbon emission in the atmosphere by consuming huge amount of electricity from the power grid which has a significant amount of carbon footprint due to the excessive use of carbon-intensified fuels in the generation of electricity. Since the source becomes indistinguishable when the electricity enters the power grid, we estimate the efficiency of carbon in grids.

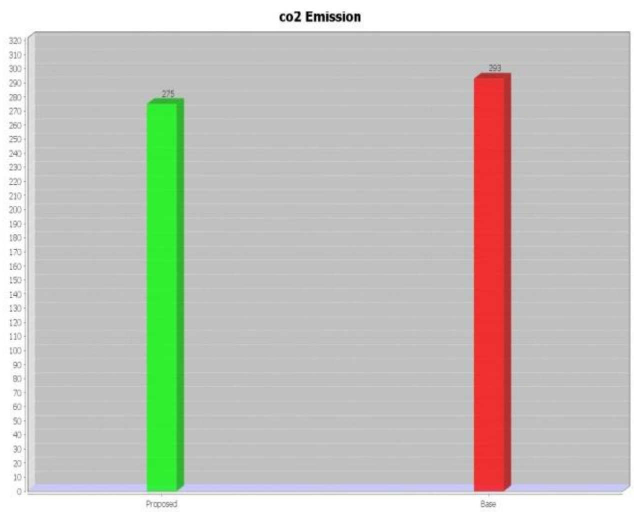

Fig. 5.1.1: CO2 Emission

5.2. Water Consumption

WEC algorithm explicitly incorporates spatiotemporal diversities of water efficiency into its workload management decisions. Also, WEC use water deficit queue for water capping guidance. WEC algorithm can lead to 20% saving of water footprints by successfully meeting the water consumption constraint which, by default, is only 80% of the water consumption by COST while incurring nearly no operational cost. Expectedly, if we set a less aggressive water conservation target (e.g. 15% saving), WEC results in a lower cost implementation.

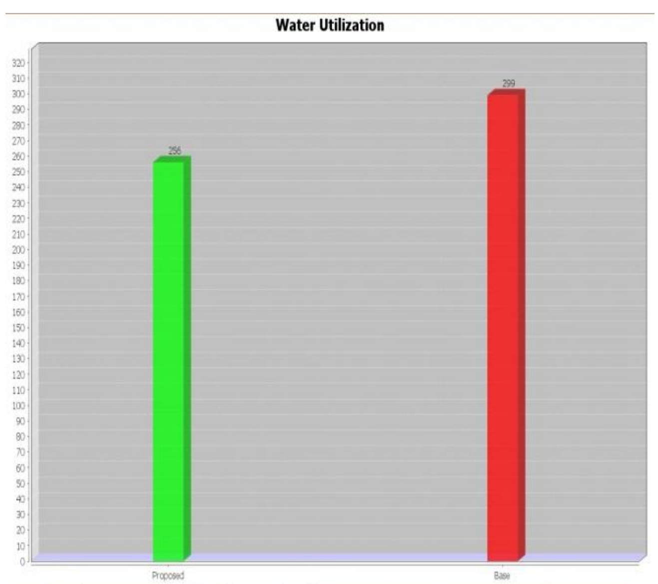

Fig. 5.1.2: Water Consumption

5.3. Time Consumption

The distributed load among different virtual machines when processed should result in less time complexity which improves the performance of the particular data center. Here the time complexity is reduced to half the time taken by the earlier systems.

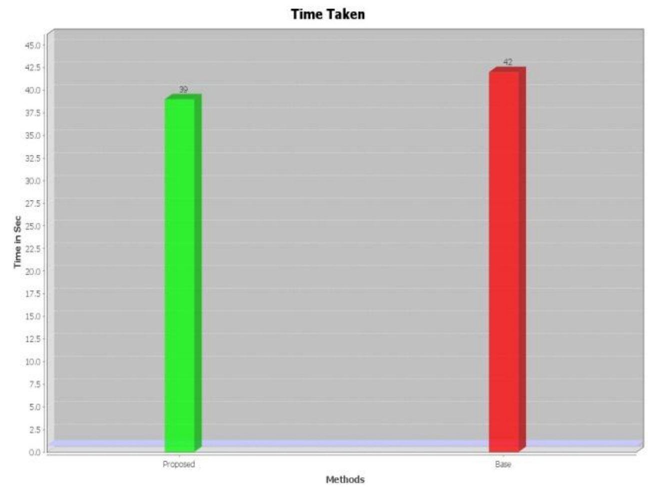

Fig. 5.1.3: Time Consumption

6. Conclusion

Performance of the data centers that are distributed in drought areas and its load balancing is improved by using the WEC algorithm. In the proposed system, the CO2 emission, the water utilization for electricity production and the time consumption is considerably reduced when compared to the previously proposed systems. In the future work, the performance will be improved for large number tasks also. The result obtained using simulation is consistent with the analysis because the reduction in overall reduction in cost of and it is eco-friendly.

7. Limitations and Future Research

The proposed system will work efficiently only if less number of tasks are given and the speed of the system decreases if the number of tasks increases. So as the future enhancement, the performance will be improved for large number tasks also. The result obtained using simulation is consistent with the analysis because the reduction in overall reduction in cost of and it is eco-friendly.

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