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Green Cloud Computing: Redefining the future of Cloud Computing

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Abstract

The idea behind the word “Green Cloud Computing” is to minimize the energy consumed by the hardware that are used in the process of Cloud Computing. It not only achieves efficient processing but also utilizes the computing architecture and also minimizes energy consumption. This concept of going green ensures that growth of cloud computing in the future doesn't affect the environment in a big scale. There has been an enormous increase in energy consumption by data centres and other infrastructure. The aim of this paper is to call attention to some of the effective ways to attain Green Cloud Computing that include Virtualization, installing solar PV arrays and some energy saving techniques. Despite its positive impacts, green cloud computing still faces challenges which are also discussed. This paper also concentrates on the solutions that can be opted for greener clouds.

Keywords: Data centre, PV array, Nada, Virtualization, Green IT, e-waste, TCM (Temperature Control Mechanism), Thermal aware management, multi-Tenancy

1. Introduction

Green Cloud Computing involves steps such as designing, producing and using the digital spaces in such a manner that mainly focuses on minimizing the unfavourable impact on the environment. It is all about finding and producing energy-saving digital ways to minimize carbon emissions to the ecosystem. It does save energy but it also brings down enterprise costs that are required for operations. Green Cloud Computing allows users to employ the benefits of cloud storage while decreasing its untimely effects on the environment, thereby affecting human well-being. Green Cloud Computing techniques can be used for many purposes such as allocating the resources and improvising the performance of communication protocols such as TCP/IP etc. The communication protocols allow multiple kinds of communication systems for exchanging various

messages. They also help in high performance of network infrastructures. It's necessary to optimize the data centres resources because the availability of the resources is turning down rapidly and there's exponential increase in the energy costs. Green Cloud Computing also means changing the rules and policies by the government to uplift the recycling and minimizing energy use by humans. Deployment of Virtual technologies is one of the common approaches for green cloud computing. [1-5].

2. Approaches for Green Cloud Computing

2.1 NaDa- Helps in reducing Heat Dissipation

The Nano Data Centers also known as NaDa are harmonized and managed by an ISP (Internet Service Provider). The computing platforms that are newly developed uses ISP which is controlled home gateways to offer computing and storage devices. They are efficient when compared to conventional data centres. They help in reducing

heat dissipation and they have the capacity for self-adaption. NaDa centres also provide storage services. The data centres consist of clusters of NaDa which are interconnected to each other and are widely spread across different locations. [6-10].

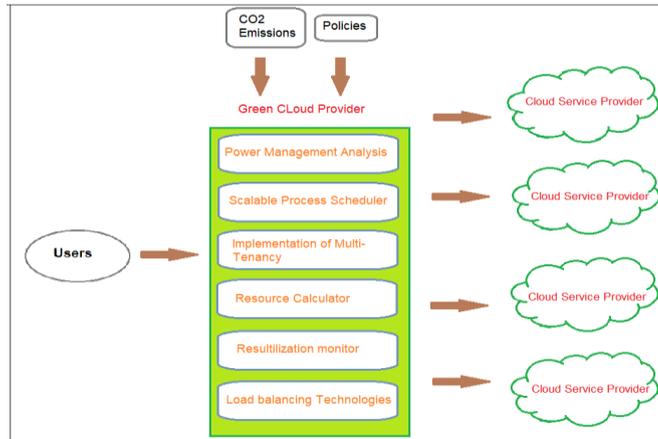


Fig 1: Green Cloud Computing Architecture

2.2 Virtualization- To reduce the power consumption in data centres

Data centres consume an enormous amount of power and environmentalists look for the ways to cut down the power consumption and they engage in making the data centres more energy-efficient than they are. Virtualization is nothing but digging out multiple uses from a single piece of hardware. It provides the means to create new perspectives of services that are available to different users.

Nowadays, data centres don't usually use traditional stand-alone servers, instead they use virtualization techniques. This is because the management using this technique is much simpler and cost-efficient. And the important benefit is that the security is strengthened and the performance is much better. A virtual machine can consist of multiple operating systems and they all can be put together on same server hardware. Natural consolidation is the term used when multiple servers are turned into virtual ones and they are mounted on a single physical server. By doing this, the space can be minimized that are used up by multiple servers. Thus, the power consumption and cooling are also reduced. This technique lets multiple workloads to integrate into lesser number if servers, thereby raising the utilization levels. This increases the energy efficiency. This helps to

facilitate the dynamic allocation of resources within a server, which makes it possible to reallocate the loads from one server to the other.

There are various benefits of virtualization:

- It comes handy during emergency planning where the virtual machines can be moved from one location to another thereby providing a better availability of services present. The space required is less and as the consolidation is done to run many applications on fewer number of physical components, this also minimizes the energy consumption. Also, the resource pool can be automatically managed by creating and configuring a Virtual Machine.

But this technique also comes with some drawbacks such as it may create security risks and it takes extra time to generate the desired result. Several knots in the chain should be put together and they must work together to make this technique compatible.

2.3 Thermal Aware Management Techniques

These approaches are the solution for heating problems in data centres. Heat re-circulation is improved for achieving this goal. This includes two aspects that are related to Temperature Control Mechanism (TCM):

- TCM for the central processor, storage devices etc.
- TCM for Computer Hardware which includes servers, storage medium etc.

When certain activities like changing of application of loads are hindered, it uplifts the heat dissipation. When the temperature increases for these reasons, the cooling of hardware becomes important. [11-15].

2.4 Minimizing the power dissipated by CPU

The central processor utilizes its energy consumed for various activities, one of which is cooling. The important component of power consumption is drawn by the central processor. It dissipates energy in the form of heat to the environment. Hence, free cooling technique is adapted so that the power dissipation is reduced. CPU consumes some part of the total power while preserving the capability to execute programs. Multi-core processor is adopted for reducing the power consumed by the CPU. They are very efficient than the conventional methods. One of techniques that is used in green

cloud computing is that when desktops are not in use, they are placed in low power state. This helps in minimizing the power consumption. The energy consumed by the servers and data centres spread throughout the nations is notable. More is the number processor chips; more is the heat dissipated and more is the cooling required.

2.5 Solar Photo voltaic Systems

The power consumption can be reduced by integrating the solar power and battery power. It's an efficient way of using renewable energy resources. The rack design can be powered using the solar charge controller and batteries into the rack. For eg: 20KW of solar PV can provide the fundamental energy source and the electric grid. Solar technologies save the initial investment if the smaller ones are used. They harness the software to improve the conditions and even balance out the load when the weather condition doesn't favour. Now, it is up-to the companies if they wish to install big-budget photo voltaic systems or the systems that are cheaper but do the work according to the daily load, prioritizing the necessary operations. Certain estimations show that the use of Solar PV arrays have resulted in 94% less energy consumption in the racks. This is technique is both feasible and affordable.

2.6 Energy Saving Techniques

Cloud Computing is a platform, where better results can be obtained if some techniques are applied that help in energy management. Some techniques focus on the planning of network environment that helps in minimizing the energy consumption. These techniques of energy management can be applied to certain algorithms and protocols. Many network protocols like TCP, CSMA/CD etc are wireless and some of the algorithms don't meet the requirement of energy saving. There are two ways to resolve that:

- Sleep Modes: A simple technique that puts the components that are not in use in sleep mode.
- Adaptive Link Rate: According to the traffic requirements, this technique allows to regulate and balance the data rate of the link.

2.7 Multi-Tenancy

When a common cloud-based infrastructure is used, multiple units from the same can be benefited. It ensures that lesser machines are

required for operations. This is the concept involved in multi-tenancy.



Fig 2: Characteristics of Green Cloud Computing

3. Challenges faced

It's a fact that tons and tons of natural resources are used up to make desktop computers. A huge amount of energy is supplied to them, but half of them is wasted and only the other half of the energy is used up the computers. Power management techniques should be implemented to make the maximum use of the energy supplied to them. The principal limitation is the high cost of the components that are required to make cloud computing more efficient. The efficiency illustrated by the simulator is tough to implement in reality. Plus, the maintenance of the devices included in the data centre is another limitation. The infrastructure of the data centres is one of the difficult challenges to IT environment. With the advancement in technology, the need of managing resources and cooling the equipment is a necessary concern to focus on. Another major issue is carbon footprints that is provoked by the huge amount of energy and power required and simultaneously the cooling devices required that are needed for the servers to cool down. There are considerable number of ways of going green in cloud computing. But convincing the service providers to employ those methods and invest in them is an issue. This happens because the service providers expect immediate results which is generally not possible right after employing the green cloud computing methods. It takes some amount of time for results and benefits of it to be visible.

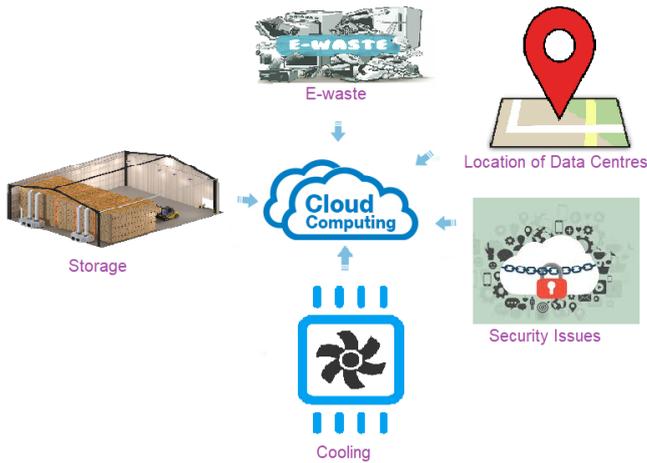


Fig 3: Challenges faced by Green Cloud Computing

3.1 Location of Data Centres

The factors that are important and have to be considered are: Energy supply and efficiency of the data centre. Therefore, Data centres should be constructed in such a manner that energy could be harnessed from sources like solar and wind energy which are renewable. They should also be constructed in SEZ (Special Economic Zones). While choosing a location for the data centres, convenience is not the only factor that should be considered. Microsoft Company alone consumes about 27 megawatts of energy at any given point of time which is generated by hydro-power. Other major companies like Microsoft have also built their data centres near the dams to take advantage of the hydro-power. Another Microsoft data center, located in Ireland, was planned to be air cooled, making it much more environment friendly. It uses less energy and water as compared to other major data centres. This helps in minimizing carbon dioxide emission, energy consumption and boosts the performance. Apart from the location of the data centres, the flexibility of transporting the equipment is also considered.

3.2 Cooling

Data Centres consume an extensive amount of energy for providing power and for the purpose of cooling servers. And cooling consumes about 1/3rd of the total energy consumed. There are 2 ways:

- Water based cooling
- Air based cooling

A way is found that improves the flow air through the server to provide a cheaper, safer and better solution. This improves the temperature distribution and cuts down the down also.

Economizer Cooling is the technique in which the outside air is used to cool the data centre which is used by modern data centres. A key point to be noted is that the cooling equipment should try cool the hot equipment instead of the entire room. Supercomputers consume an enormous amount of electrical energy and release a lot of heat. Hence according to the size of the supercomputer, there has to be cooling technology of that scale also. Nowadays, data centres focus on creative cooling technologies to maintain optimum conditions for computing activities. A lot of complex heat transfer technologies are also employed for this purpose. For eg: external air or water is used in most of the cases as that is the most efficient method. Google’s data centre located in Finland uses the ocean water for the purpose of cooling which reduces the energy consumption. Also, they are now relying on machine learning and artificial intelligence to improve the cooling efficiency. One of the innovative methods is using liquid server cooling system. This method uses pipes to deliver coolants to the specific areas where the cooling is required. Some of the cooling techniques are:

- Free Cooling
- Evaporative Cooling
- Liquid Cooling
- Immersion system
- Raised floor

Chiller plants can be built near the data centres to provide the cold air for the servers to cool down. Providing energy to the equipment is not an incompetent method but not all the power given is used up by the equipment, a lot of it is wasted. So efficient methods should be put to use to make the data centres more reliable.

3.3 Storage

Storage has become a crucial concern for companies all over the world with the exponential increase in IT industry. When there is a collection of disks, only few of them are used at a single point of time, so the rest of them could switch to power saver mode. The storage can also be consolidated. For eg: Building SAN (Storage Area Network).

3.4 Security Issues

There are four types of issues raised while discussing the security of the cloud:

- Data Issues
- Privacy Issues
- Security issues
- Infected application

Solutions to these security issues are:

- Control the consumer access devices
- Security checks events.
- Share demanded records and verify the data deletion

3.5 E-Waste Management

Green Cloud Computing must take certain things into consideration such as from production, operation and recycling for better results. There many simple methods for adopting recycling e-waste. For eg: recycling equipment such as mercury and lead enable to replace equipment that otherwise would have been manufactured. This reuse helps in saving energy and also helps in reducing the impact on environment. Research on constructive e-waste management and use of green compliant devices should be encouraged. waste have already caused major issues in the environment. Measures have to be taken before it's too late. E-waste should be classified and disposed accordingly to reduce its harmful impacts. If the e-waste is let to accumulate for a long time, it will lead to groundwater pollution and bio-accumulation. Another major concern is that majority of the companies nowadays use nuclear-powered plant or coal-powered plants, for their energy requirements, which release a lot of nuclear waste and this not only pollutes the environment but it also poses a major threat to the people nearby who inhale those nuclear discharges.

3.6 Technical and Non-Technical Issues

There are 2 kinds of challenges encountered:

Technical Issues: These are related to software design and thermal-aware management techniques.

a. Software design is a vital part of Green Cloud Computing. The communications taking place between the software components have to be efficient. This is important because resources reside in this and proper management should be taken care. Load balancing is an important issue

that comes under this. For this, virtualization technique can be used. It helps in balancing out the workload and thereby improvising the software design. The number of physical servers can be minimized which reduces the power consumption.

b. Thermal aware management techniques: These techniques are used for the heating problems. Heat re-circulation is performed to achieve server cooling. Algorithms such XInt can be put into use for heat re-circulation. The motive of these techniques is not only to improve heat re-circulation but also minimize the cooling cost.

c. Non-technical Issues: These include construction of data centres in areas with cooling resources. But there are two problems that can arise.

d. One is that, the international laws mainly focus on the security grounds. And these laws differ from country to country. The issue is that some countries don't have regulations and some don't follow them even if they have.

e. The cost of equipment that are associated with green cloud computing is another drawback of it. The price varies from the cloud provider to the users. For gaining a profit, the cloud providers will expand the costs of equipment and services. Some cloud providers actually have built data centres in locations where renewable energy resources are available or may be easily available during the operational stage.

4. Solutions that can be opted

E-waste is generated day by day in developed countries, so there are some important steps that can be taken towards Green Computing. Firstly, the countries that are in stage of developing must strictly go through the policies which the government have been promised. Another solution is to make educational institutes make Green IT subject compulsory one rather than an optional one, so that new and different can be developed by the students in this field that are cheaper and less hazardous. By doing this, innovative projects and ideas can be invited. More efficient and lower-emitting resources should to employed to reduce the carbon emissions. Pooling up the resources and reducing the number of hardware resources may help with better power consumption. Also, the consumers can contribute by making their choice to purchase those electric products that can be

recycled or reused. For facing problems related to storage issues, companies can use large capacity drives that helps not only in reducing the energy consumption and but also helps in the elimination of redundancy in the system. Cloud Computing is expected to have a healthy relationship between the cloud service providers and the environment. Green ICT rules are supposed to be followed by the service providers and they should be fined if they don't adhere to the regulations. Government should charge extra tax on the companies that aren't adhering to Green ICT rules and also who aren't producing Green ICT products.

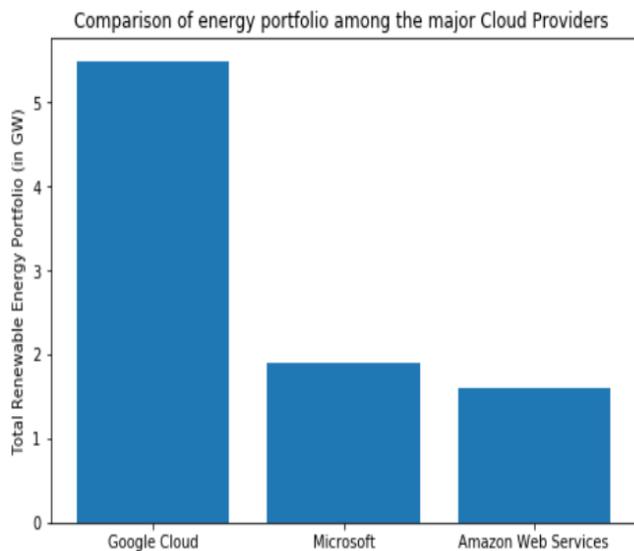


Fig 4: Comparison of renewable energy portfolio among the major Cloud Providers

Major companies claim that their data centres are powered by renewable energy sources like solar, wind energy and by hydroelectricity. But in reality, only a hint of their power is supplied by the renewable sources. The above graph shows that Google Cloud has the highest total renewable energy portfolio (i.e. more than 5GW). Google express that they use machine learning algorithms to make the data centres more efficient by predicting the solar or wind capacity in advance, because the internet never goes off when the sun is down or wind is low. On the other hand, companies like Microsoft Azure say that they have technologies that will have lesser impact on the climate. They invest in researches that make the existing and even future data centres more efficient. Pay-as-you-go is a nature of cloud-based

infrastructure that uplifts the users to consume what they need and nothing more than that. The users can only consume the resources when they are in the need of it and they will have the ability to turn off the resources with the expiration times set. It's not always necessary to re-build the equipment or infrastructure for improving the performance. They can be re-used for many benefits. It is also cost-efficient. The time used in re-building the infrastructures can also be saved. There some simple ways which one can easily contribute to green cloud computing. These steps include putting the laptop in sleep mode or even better turning it off when it's not in use. One can buy "Energy star" labelled laptops, devices etc. They are internally programmed to power down to a lower power state automatically when they aren't in use. This helps to keep the device to stay cooler and also energy is saved via this. Use of flash drives should be encouraged.

5. Future Scope

Going green is not a new concept for us. Companies are putting efforts in adopting new and innovative to achieve green computing. The challenges discussed in this paper are big and computing performance is hindered because of that. Technologies can be improved and put to use in the future for getting much better results. Cloud Computing is a new model that integrates the already-existing technologies so as to achieve the increase in efficiency of resource use. Nowadays, IT services are shifting from single-server operations to rack-mounted blade servers. Even though Green ICT has many advantages, it still comes with drawbacks. And Green Cloud computing is a vital constituent in this. Future scope in green cloud computing is an emerging discipline. There is need to explore and implement new technologies that can aid in green cloud computing. Analyse should be systematically carried out based on the services provided by cloud computing and the operations that take place. There is a tremendous increase in clouds such as mobile, social clouds etc, even in future it'll keep on growing exponentially, therefore green mobile communications will be a base for green cloud computing.

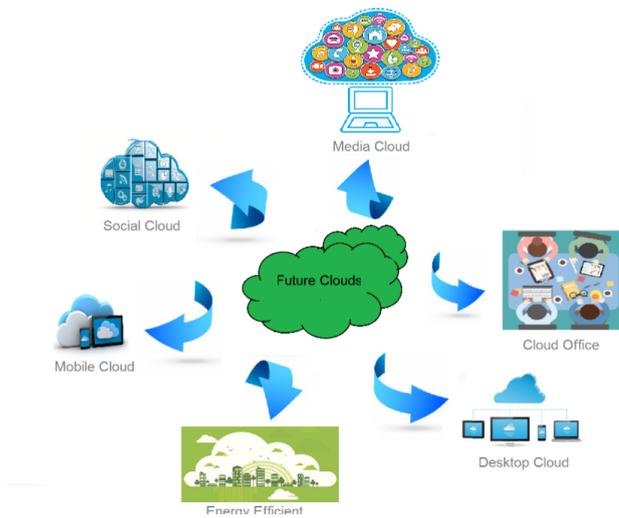


Fig 5: Future clouds

The companies must switch to eco-friendly ways to offer cloud services by using renewable sources of energy. Some of the aspects that the cloud suppliers should consider before offering the cloud services are:

- Green ICT principles must be followed by the companies that provide cloud services for having negative impacts as low as possible.
- While providing the cloud services, the first priority is to reduce the carbon dioxide emissions, reduce the amount of power consumed and minimize the amount of e-waste generated.

Conclusion

This paper explains the approaches that can be employed for greener clouds and the challenges faced the data centres to employ the green cloud computing techniques. Many effective strategies can be implemented in data centres to make them eco-friendly. It is effective only if energy consumed in servers are saved. Energy saving strategies saves a considerable amount of power and cuts down the cloud footprint. Some common approaches for green cloud computing are discussed in this paper, they include generating electricity using renewable sources, managing power consumption, cluster computing etc. Beneficial changes will only be visible when the green computing methods are completely put to use for certain amount of time.

However, cloud computing is exponentially growing, the negative effects of it will be visible in the near future. Green cloud computing still faces

challenges of security and the need of connectivity. There are still many who research about the computing methods that are eco-friendly and cost efficient. But despite the challenges faced, significant number of benefits of using green cloud computing techniques are witnessed.

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