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Comparative Analysis of Green Cloud Computing

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Abstract: Today it is globally accepted that mankind is the major reason for global warming. Data Centres, computers, and other gadgets are the main causes and sources of greenhouse gasses, especially CO2. Data centres use thousands of processors and other computer elements, that generate heat which requires a large amount of cooling equipment, cooling equipment again generate a large amount of heat. Thus, we need such ideas and techniques that reduce the energy consumption and emission of CO2. In this paper, we have compared different techniques of green cloud computing and show the approximate results of each technique.

Keywords: Green Computing, Power Consumption, Cloud Computing, Power Efficiency, Greenhouse Gases.

I. INTRODUCTION

Green computing is making data center and electronic devices environmentally friendly and eco-friendly, in other words, it is described as the inspection of engineering, designing, manufacturing, disposing and using of computing peripherals in a way that curtails their environmental brunt. In 1992, the Environmental Protection Agency (EPA) introduced the Energy Star program, it was a very first time when the term Green Computing came into light [1].

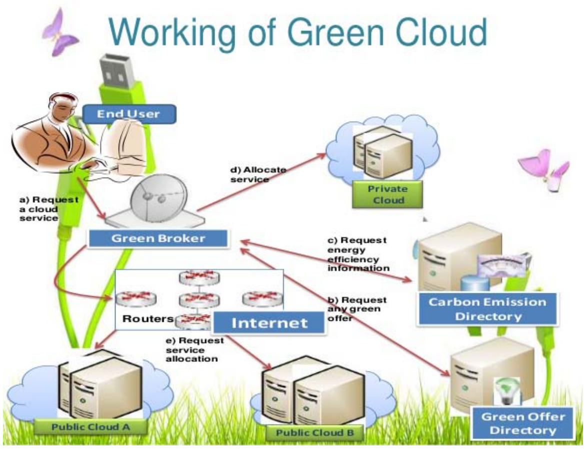

Figure 1. Working of Green Cloud Computing [2]

To see the growing demand for cloud computing in every field it is necessary for the environment that we take one step ahead towards green computing so that electricity consumption and CO2 emissions can be cut down and recycled. Usually, cloud data centers span in more than thousands of feet of area that contain ultimate computing power like servers, networking devices, hard disk racks, cooling fans, console, big screens etc. along with cooling machines, air conditioners, lights and backup generators. So that they can fulfill their day to day costumer's demands. All these things require a great amount of power. In 2012 electricity consumption by these data centers was measured around 38 Giga Watts that is sufficient to almost all united kingdom's residential households, in comparison to 2011, it was 63% more, and it is continuously increasing every passing year [3]. As the demand of Cloud Computing is on peak now a day due to its tremendous capabilities of bringing on-demand services, many organizations and companies are migrating towards the cloud, as a result many data centers coming into light, only one data center occupies a massive amount of area, 50,000 square feet approx. that needs 5 megawatts (mv) electricity that can fulfill the need of the power of 5000 households for one year. So now these data centers require cooling also to cool down their giant servers because these servers provide their services and run 24/7 and 365 days continuously without break, yes, it's true that all servers are not in use all the time but it is also true that they can't be turned off. According to a recent study only US data centers consumed about 70 billion kilowatt-hours of electricity in 2014 [4], that was 30 billion watts in 2012 all over the world, now we can see that how much these data centers are consuming electricity and discharging CO2. There are more than three billion active internet users worldwide that are continuously surfing the internet through google, google runs 1000 servers just for one query, that's why it takes only 0.2 seconds for query results to come up [3], in a single day sixty million searches hit the google search engine [5]. Figure 2 and 3 will demonstrate how much CO2 is dissipated and how much electricity is consumed in one google search as well as in one month respectively.

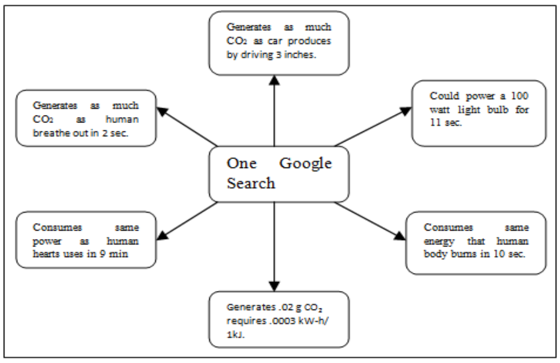

Figure 2. Energy consumption in one Google search [3]

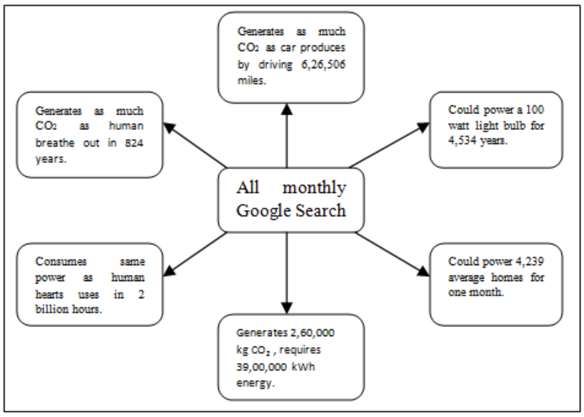

Figure 3. Energy consumption in monthly Google search [3].

Google data centers consist of thousands of servers, these servers demand enormous supply of electricity to working seamlessly, now the consequences come in the form of CO2 emission, thus these data centers are one of the biggest responsible for global warming. So now it is our duty that we find some innovative ways to overcome this problem, it is our responsibility to search such ideas and techniques that help us to reduce electricity consumption and CO2 emission.

II. Green Computing Techniques For Energy Efficiency

In this section, we are presenting various techniques that can help to reduce energy consumption. We have divided this section into two categories, the first category describes such techniques that can be implemented at home, these techniques are basically for normal and average users. The second category is consisting of some advanced techniques that are specially designed for power-hungry data centers.

Ideas that can be applied and implemented at home:

- Hard disk sleep mode: Hard disk and other optical drives are designed to fall asleep after a specific time of inactivity to conserve energy, in this state HDD stays in "low energy consumption" mode and platters have halted to spin [6]. 3.5" Hard disk drive uses the electricity from 6.5 to 9 watts, 2.5" laptop HDD consumes power from 0.7 to 3 watts, and a solid-state drive can use 0.6 to 2.8 watts [7]. After proper configuration Operating System can automatically manage this mode.
- LED/LCD sleep mode: Enable the sleep mode option in the monitor, so that after some time of idling monitor will falls asleep. In sleep mode LED turns off its all emitting pixels and enters "low power consumption state" [6]. For instance, a Fujitsu B27T-7 LED monitor consumes 51.34 (kWh/yr) Total Energy, while in sleep mode it's only a 0.25 watts [8].
- Power off devices when not in use: Shutting down the system in idle period is the most effective, most natural and absolutely the simplest and the easiest way to reduce energy consumption [6].
- System standby mode: In this mode, the computer shuts down all its components and parts except Volatile Memory, the volatile memory remains active and waits for the user command, whenever user press some key, move a mouse or open a LED in laptop case Volatile Memory immediately active the entire system [6]. In standby mode system starts from that stage where the user left it before, in simple words it resumes the system. An average desktop PC consumes electricity between 80 and 250 watts, depending on additional peripherals, while in standby mode a desktop computer uses between 1.1 and 83.3 watts, the average is 21.13 [9]. Table 1 demonstrates standby power summary in detail.

Table I. Standby Power Summery

Computer Desktop	Avg (W)	Min(W)	Max (W)
On, idle	73.97	27.5	180.83
Off	2.84	0	9.21
Sleep	21.13	1.1	83.3
Computer, Notebook			
Fully on, charged	29.48	14.95	73.1
Fully on, charging	44.28	27.38	66.9
Off	8.9	0.47	50
Power supply only	4.42	0.15	26.4
Sleep	15.77	0.82	54.8

- Hibernate Mode: The hibernate mode is an advanced version of standby mode; this mode completely turn off the computer including volatile memory, before shutting down the computer it saves the memory and system state on the hard disk so that it can resume the PC when the user invokes the system. If the computer is unplugged it uses zero power, otherwise, in hibernate mode, it uses 2.3 watts [10].

- Use a computer and other peripherals in power saver mode: The power saver saves energy by reducing computer's performance where possible. This technique reduces the CPU speed all the time and set the display brightness at minimum possible level.
- Ideas and techniques for data centers:
- Using Clock Gating: Clock gating is an energy conserving feature in semiconductor microelectronic, that is responsible for enabling and disabling the clock. Many electronic devices use clock gating feature to disable bridges, buses, controllers and chunks of processors to reduce power consumption. It saves the electrical power used by the processor. The working criteria of clock gating are if the logic block is engaging in some work then clock of a logic block must be activated, and if there is no task performing then clock gating must be deactivated. Clock gating technique is very popular among many synchronous circuits [3].
- Energy Efficient Processors: Modifying the clock rate of a processor or voltage of a processor is possible, we can do this with the help of "Dynamic Voltage Scaling" and "Dynamic Frequency Scaling". In dynamic voltage scaling, we can modify the voltage as per the need of current situation, whether it is related to hardware or software by increasing and decreasing it. In dynamic frequency scaling, we can set the frequency according to hardware and software need by minimizing and maximizing it. This technique can save a lot of electricity power, also it is already implemented in the following real-time systems: Transmeta Longrun and Longrun2, AMD Cool'n'Quiet, Intel SpeedStep, VIA LongHaul (PowerSaver), AMD PowerNow, IBM Energy Scale [3].
- Renewable Energy sources: For backup purposes, usually data centers need generator powered by diesel, burning diesel come out in the form of exhaust gasses, like CO2, NOx, GHGs, and particulate matter, the diesel generator emissions these gasses into the atmosphere and pollute the nearby air quality substantially. One liter of fuel has 0.73 kg of carbon, so with one liter of fuel 2.6 kg of CO2 released into the air. To overcome this problem there are some other ways to produce electricity, we can use solar energy, wind energy as well as hydroelectric energy instead of diesel generator as a backup plan for data centers [3].
- Energy Efficient Storage: Today energy efficient storages are available in the market that can take place of current storages of the cloud. As the life expectancy of a data center has been measured up to 9 years so while overhauling existing data center renovator can use energy efficient storage like solid state Drive (SSD). As there is no moving part in SSD unlike hard disk drive, so now, SSD requires less cooling and less energy as compared to HDD, as we mentioned earlier a hard disk consumes electricity from 6.5 to 9 watts, while solid state drive consumes electricity from 0.6 to 2.8 watts. Clearly, we can see the differences between two [3].
- Using Free Cooling System: Most of the data centers achieve cooling by refrigerator, in this technique a machine called compressor supplies or pushes the chilly water into the network of pipes made of highly conductive metal, like copper or aluminum, these pipes clamped on top of the CPU and on other equipment, water flows absorbing heat and makes it way to a radiator and so on. Instead mechanical refrigeration technique we can use free cooling, basically it is depended on outside atmosphere and weather condition, if the data center's outside temperature is below or reached specified point then refrigerator start automatically to provide cooling, here one thing is considerable that free cooling is not truly or entirely free, because cooling equipment is still needed, for example, fans, pump etc. [3].

III. Parameters Used For Measuring Power Consumption

Many measurement techniques are available to measure the data center electricity consumption, some of them are listed here: 1. Thermal Design Power (TDP), 2. Power usage Effectiveness (PUE), 3. Data Center infrastructure Efficiency (DCiE), 4. Performance per Watt (PpW), 5. Compute Power Efficiency (CPE), 6. Green Energy coefficient (GEC), 7. Energy Reuse Factor (ERF), 8. Carbon usage Effectiveness (CUE), 9. Water usage Effectiveness (WUE), 10. Data Center Productivity (DCP).

a. Thermal Design Power (TDP)

Also, called Thermal Design Point, this term often use in CPU or GPU, the TDP is the maximum power consumption by a CPU or GPU when running a real application, at this point of time a device dissipate whatever the max power is known as TDP. Table 2 present different TDPs of GPU and CPU: -

Table II. Different GPUs and CPUs. [11] [3].

GPU	TDP (in Watts)
Radeon HD 4870	160
Radeon HD 4870 X2	286
Radeon HD 3870	105
GeForce GTX 295	289
GeForce GTX 280	236
GeForce 9800 GTX	156
CPU	
Core Duo T2xxx	31
Core Duo L2xxx	15
Core Solo T1xxx	27-31
Atom 330 (Dual core)	8
Core Duo U1xxx	5.5-6
Core Solo T1xxx	77
Phenom II X3 740	95
Core i5-2xxx	95
Athlon II X4 650	95
Core i3-21xx	65

b. Power usage Effectiveness (PUE)

Power usage Effectiveness (PUE): PUE is a calculation matric, used to determine the energy efficiency of the data center, it is calculated by measuring the ratio of total energy consumption, PUE describe as the ratio of overall consumed power by the data center to the total consumed electricity by IT devices, like servers, routers, storage networking devices etc. It is defined as:$PUE = \frac{\text{TotalDatacenterPower}}{\text{ITDevicesPower}}$

$$PUE = \frac{\textit{Total Data center Power}}{\text{IT Devices Power}} \quad (1)$$

Excellent efficiency has been measured for the data center as PUE of 1.0. PUE lies between 1.3 to 3.0 for most of the data centers.

c. Data Center infrastructure Efficiency (DCiE)

DCiE is the reciprocal of PUE, these tow electricity measurement techniques are very much popular between most of the data centers. It is defined as:

$$DCiE = \frac{1}{\text{PUE}} \quad (2)$$

$$= \frac{\text{IT Devices Power}}{\text{Total Data center Power}} \quad (3)$$

d. Performance per Watt (PpW)

It computes the energy efficiency of an individual and computer hardware or computer architecture. According to Wikipedia" it measures the rate of computation that can be delivered by a computer for every watt of power consumed" [12]. Usually, it is measured in Floating-point operations per second (FLOPS) and Million instructions per second (MIPS).

e. Compute Power Efficiency (CPE)

CPE is a measurement of computing efficiency of a data center. It's not fundamental all the time that we get effective work by each watt consumed by the server, some devices are power-hungry, they consume power even in idle state, yes, it is also true that 100% data center capacity will never be used but still we want as much output as possible from the electrical power. CPE defined as:

$$CPE = \frac{\text{IT Devices Utilization}}{\text{PUE}} \quad (4)$$

$$CPE = \frac{\text{IT Devices Utilizatipon X IT Devices Power}}{\text{Total Data center Power}} \quad (5)$$

f. Green Energy coefficient (GEC)

GEC is a measurement of how much green energy is used by the facility of the data center from green providers like hydroelectric energy, wind energy or solar energy. All these energies come from renewable energy sources that make data centers environmentally friendly. GEC defined as:

$$GEC = \frac{\text{Green Power}}{\text{Total Facility Power}} \quad (6)$$

g. Energy Reuse Factor (ERF)

How much energy is reused from outside of the data center, the ERF is measured that. For example, the energy that produces from renewable energy sources. ERF is defined as:

$$ERF = \frac{\text{Energy Reused}}{\text{Total Facility Power}} \quad (7)$$

h. Carbon Usage Effectiveness (CUE)

A measurement of CO2 emission is called Carbon Usage Effectiveness. CUE defined as:

$$CUE = \frac{\text{Eco 2}}{\text{EIT}} \quad (8)$$

Where

Eco2 = Total CO2 emission from total energy consumed by the data center.

EIT = Total energy consumed by IT Devices.

i. Water Usage Effectiveness (WUE)

How much water is required for cooling by a data center yearly, it is measure that. It is defined as:

$$WUE = \frac{\text{Water Used Yealy}}{\text{EIT}} \quad (9)$$

j. Data Center Productivity (DCP)

It is a measurement of the amount of valuable work done by the data center. It is defined as:

$$DCP = \frac{\text{Valuable Work Done}}{\text{Tresource}} \quad (10)$$

Where

Tresource = Total resource which was taken to done this valuable work.

It's like DCeP, but the main difference is it deals with both software and hardware resources, and DCeP compatible only with software resources [3].

IV. CONCLUSION

In this paper, we have presented some innovative ideas for home users as well as for cloud data centers to reduce power consumption and CO2 emission, we have also discussed a different kind of power measurement techniques that measure the power and electricity of a data center. Green computing is the need of current time, it provides environmentally friendly computing power that believes on energy efficient computing, mainly it is focused on the reduction of CO2 emission to make IT industry pollution free.

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