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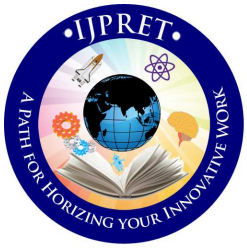

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ENVIRONMENTAL SUSTAINABILITY AND THE GREEN CLOUD COMPUTING

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Abstract

Cloud computing is a highly scalable and cost-effective infrastructure for running HPC, enterprise and Web applications. However, the growing demand of Cloud infrastructure has drastically increased the energy consumption of data centers, which has become a critical issue. High energy consumption not only translates to high operational cost, which reduces the profit margin of Cloud providers, but also leads to high carbon emissions which is not environmentally friendly. Hence, energy-efficient solutions are required to minimize the impact of Cloud computing on the environment. In order to design such solutions, deep analysis of Cloud is required with respect to their power efficiency. Thus, in this chapter, we discuss various elements of Clouds which contribute to the total energy consumption and how it is addressed in the literature

1. INTRODUCTION

With the growth of high speed networks over the last decades, there is an alarming rise in its usage comprised of thousands of concurrent e-commerce transactions and millions of Web queries a day. This ever-increasing demand is handled through large-scale datacenters, which consolidate hundreds and thousands of servers with other infrastructure such as cooling, storage and network systems. Many internet companies such as Google, Amazon, eBay, and Yahoo are operating such huge datacenters around the world.

Clouds are essentially virtualized datacenters and applications offered as services on a subscription basis as shown in Figure 1. They require high energy usage for its operation. Today, a typical datacenter with 1000 racks need 10 Megawatt of power to operate, which results in higher operational cost.

Thus, for a datacenter, the energy cost is a significant component of its operating and up-front costs. In addition, in April 2007, Gartner estimated that the Information and Communication Technologies (ICT) industry generates about 2% of the total global CO2 emissions, which is equal to the aviation industry. According to a report published by the European Union, a decrease in emission volume of 15%–30% is required before year 2020 to keep the global temperature increase below 2 0C. Thus, energy consumption and carbon emission by Cloud infrastructures has become a key environmental concern.

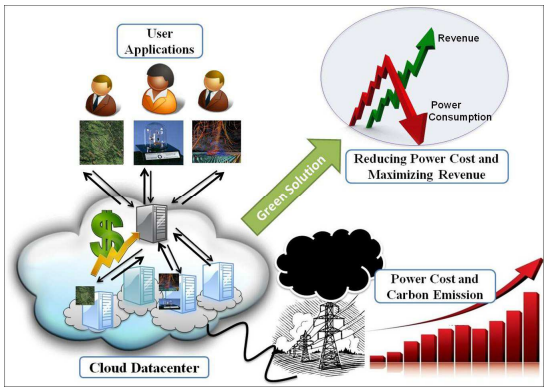

Figure 1. Cloud and Environmental Sustainability

A recent research by Accenture shows that moving business applications to Cloud can reduce carbon footprint of organizations. According to the report, small businesses saw the most dramatic reduction in emissions – up to 90 percent while using Cloud resources. Large corporations can save at least 30-60 percent in carbon

emissions using Cloud applications, and mid-size businesses can save 60-90 percent.

2. CLOUD COMPUTING

As Internet-based computing centralizes in the data center, software technology has advanced to enable applications to be used where and when needed. The term "cloud computing" refers to a computing model that aims to make high-performance computing available to the masses over the Internet. Cloud computing enables developers to create, deploy, and run easily scalable services that are high performance, reliable, and free the user from location and infrastructure concerns. The "cloud" has long been a metaphor for the Internet. When combined with "computing" the definition turns to services. As cloud computing continues to evolve it has increasingly taken on service characteristics. These services include utility computing, software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service

(IaaS)._ Utility computing. The first cloud services were developed by companies such as Amazon.com, Sun, and IBM that offered virtual servers and storage that can be accessed on demand. This is often described as an updated version of utility computing—essentially virtual computing capacity where users pay for what they use when they need it. Early adopters used this service for supplemental and non mission-critical needs. This model could be extended to include virtual data centers as a virtual resource pool.

SaaS: This implementation of cloud computing delivers applications through a browser interface to thousands of customers using a multitenant architecture. Salesforce.com is perhaps the best known of the SaaS companies with applications in sales force automation, CRM, human resources, and supply chain management. More recently, Google has adopted a SaaS model for its GoogleApps and Zoho Office. _ PaaS. An outgrowth of the SaaS model, PaaS delivers development environments as a service. The model provides the required resources to support the entire life cycle for developing and delivering web applications and services over the Internet. Leading PaaS companies are Force.com, Google AppEngine, and Microsoft Azure. The

primary advantages are the speed and low cost that can be achieved for development and deployment.

IaaS. This cloud offering provides basic infrastructure, such as servers, storage, clients, and networking as an on demand service. Leading IaaS companies include Amazon Web Services, GoGrid, and Flexiscale. The advantages include a high degree of flexibility, low cost,

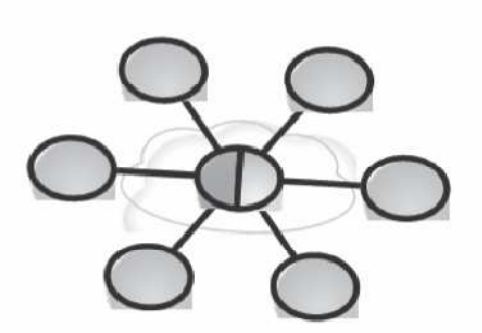

Figure 2 shows the typical configuration of Cloud Computing at run-time when consumers visit an application served by the central Cloud, which is housed in one or more data centers.

3. ENERGY EFFICIENCY

Total power consumption. In a recent study, this metric was the most popular with 68% of IT managers specifying its use. The cost of power and the volume of kilowatts used are typically included in the baseline assessment. This metric can be useful in tracking power usage by facility, function, application, and employee. Making power cost a discrete line item in the IT budget invites action to become more efficient and generate cost savings.

Power usage effectiveness (PUE).

PUE is equal to Total Facility Power/IT Equipment Power. IT equipment power is defined as the load associated with computers, storage, network equipment and peripherals . Total facility power is the total power measured at the utility meter. A PUE of 2.0 indicates that data center demand is twice as high as the power necessary to power the IT equipment. A PUE value of 1.0 would indicate 100% efficiency with all power consumed by IT equipment.

Data center infrastructure efficiency (DCiE). DCiE = 1/PUE. This ratio is equivalent to the PUE. In the above example IT equipment uses 50% of the power in the data center. The other 50% is of power demand is typically required for cooling. As IT equipment uses less energy pay as you go,

access to the latest technology, faster service delivery and time to market.

4. GREEN COMPUTING METRICS

Power-related metrics currently dominate green computing. Several energy-efficiency related metrics have been proposed to help IT organizations understand and improve the efficiency of data centers.

Data center performance efficiency (DCPE). DCPE = Useful Work/Total Facility Power. This ratio is informed by PUE and DCiE. However, it is much more complex to define and measure "useful work" performance as a standard metric.

Other energy efficiency benchmarks. An alternate approach to energy efficiency monitory at the data center level is to build energy efficiency into the initial design of components and systems and to adaptively manage system power consumption in response to changes in workload and environment. These benchmarks include Analysis tool, EnergyBench, SWaP, Energy Star, SPECPower, and JouleSort.

5. ENVIRONMENTAL IMPACT

Carbon footprint. Regulations to reduce green house gas emissions worldwide will likely be forthcoming soon as a carbon tax or cap and trade scheme is being considered by the U.S. government and the Intergovernmental Panel on Climate Change (IPCC). Already some businesses are requesting that their partners provide information on carbon dioxide production. One emerging strategy is to purchase electricity from renewable energy sources such as wind, solar, or hydro. Google has adopted this strategy..

6. SUSTAINABLE IT SERVICES: THE SECOND WAVE

Sustainable IT services are essential to business success. There is increasing pressure to adopt sustainable business practices. Therefore, sustainable IT is about everything an organization needs to do to ensure that IT services delivers superior value to attain a strong market position and to ensure its ability to survive.

Service sustainability. At a minimum, this includes effective and reliable processes for delivering IT services.

Temporal sustainability. To sustain IT services over time an organization has to start with a clear understanding of the value that is to be created.

Cost sustainability. This includes acquisition and operating costs such as the choice of low cost hardware and software that also offer benefits such as low power consumption and ensure high levels of resource utilization.

Organizational sustainability. Organizational change is inevitable. Whether it derives from personnel changes or major changes in technology, markets, or mergers and acquisitions, IT services must continue to operate and innovate.

Environmental sustainability. In an ecological context, IT services must be able deliver customer and business value while ensuring that the Earth's resources are being used at a rate that ensures replenishment. In essence, the goal for environmental sustainability is for IT services to be able to meet the needs of the present without compromising the ability of future generations to meet their needs.

6.1 Toward a Framework for Sustainable IT Services

Although the need for the development of strategies to address the environmental sustainability of IT services has been apparent for many years, there is no extant body of literature on strategies or best practices. The issues surrounding the first wave of green computing are clearer and focused on reducing energy costs through new data center designs, architectures, facility and server density, and virtualization. Beyond that, companies are approaching sustainability through a fragmented incremental "greener IT" approach. When developing IT services, few IT organizations consider the full environmental impact of their product and

Service designs. One reason for this is the short-term orientation that puts emphasis on costs and business value. If reducing costs also has a beneficial environmental impact, such as the relationship between reducing power costs and carbon emissions; that will be given priority. However, organizationally, it is unlikely the IT

organization itself can drive the sustainability priorities of other departments without the full support of top management. An integrated corporate wide sustainability strategy is necessary for IT services to be truly sustainable. Then, it is possible for IT, facilities, supply chain management, manufacturing, finance, and marketing to all be acting in an integrated fashion. Cost optimization was the primary emphasis of the first wave of green computing. Problems and solutions associated with green computing are well known. The second wave, which we call sustainable IT, or more appropriately, sustainable IT services, has a much broader focus on the role of IT in the society. The primary driver of sustainable IT is corporate social responsibility (CSR), especially as it applies to firm's impact on the economy, environment, and society at large. These are three areas of responsibility are associated with "triple bottom line" or TBL reporting.

6.2 Developing a Sustainable IT Strategy

Few companies have developed a sustainable IT strategy that rises to an enterprise-level or focuses on social responsibility goals A sustainable strategy should be one that is complementary to both the business and the environment. The following topics should be considered for developing a strategy for sustainable IT services

Sustainable organizational culture. The creation of an organizational culture that is based on environmental sustainability is an important step to driving sustainable solutions through the organization.

Sustainability goals. Setting clear enterprise-level sustainability goals and objectives will enable the IT organization to align decisions with corporate business strategy.

Products and services. The products and services of a sustainable IT organization should, at a minimum, not adversely affect the environment. Product and service design should take the following factors into account:

- Clean technology.
- Design for environment (DfE).
- Design for recycling (DfR).

- Asset decommissioning.
- E-waste minimization and disposal.
- Sustainable processes.
- Corporate social responsibility (CSR) road map. The IBM Institute for Business Value has developed what they call the CSR Value Curve. The curve is essentially a road map to CSR-driven business growth. IT depicts the milestones on the maturation curve as businesses move up the CSR continuum from low-value compliance activities to the high-value CSR growth platform. The major steps along the curve are:
- Legal and compliance.
- Strategic philanthropy.
- Values-based self regulation.
- Efficiency.
- Growth platform.
- Reporting.

7. CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

Sustainable IT has been a major focus for IT organizations for the past decade as the cost of power for data centers has risen rapidly. The focus of sustainable IT initiatives has been on strategies to increase data center efficiency. Therefore, infrastructure, power and workload management, thermal management, product design, virtualization, and cloud computing strategies have assumed primacy in terms of both strategic and tactical focus. Then of sustainable IT services is nascent and much more difficult to define and implement. It will involve establishing a roadmap and baseline metrics, redesigning business processes, encouraging participation, and adapting the organization's culture to new ways of doing things. IT governance and decision making will likely be substantially impacted. This paper offered a review of current thinking and suggested factors that should be considered for a sustainable IT strategy. Future research is needed to fully understand the market impact of a sustainable IT services strategy. Beyond cost savings are there benefits from sustainability oriented business strategies that customers are willing to pay for? Does sustainability for IT services create competitive advantage? Finally, a model for the development and implementation of

sustainable IT services needs to be developed.

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