Chapter 14
Green, Energy-Efficient Computing and Sustainability Issues in Cloud

Monica Gahlawat  
L. J. Institute of Computer Application, India

Priyanka Sharma  
Raksha Shakti University, India

ABSTRACT
Sustainability creates and maintains the conditions under which humans and nature can exist in productive accord, that permit fulfilling the social, economic and other requirements of present and future generations. There is a debate that cloud computing is green contributing to sustainability or a risk of climate change. Cloud computing if compared to traditional on-premise computing, is a cost effective, energy-efficient, scalable and on-demand computing. There is no doubt that the expansive power of computing can help us address sustainability challenges, but this technology also draws from the Earth’s finite environmental stocks and biosphere which results in risk of climate change.

INTRODUCTION
The emergence of cloud computing has drastically altered everyone’s perception of infrastructure architectures, software delivery and development models. It is a paradigm shift from CAPEX model (capital expenditure) to OPEX model (operational expenditure), means the organizations shares cloud infrastructure on pay per use instead of purchasing the costly dedicated hardware and software for satisfying the computing needs of the organization. To support the CAPEX model various cloud service providers came into existence like AMAZON, Google, yahoo and SalesForce.com etc. To handle sudden spikes in the demand requires huge data-centers to be tightly-coupled with the system, the increasing use of which yields heavy consumption of energy and huge emission of carbon footprints. Carbon emission leads to climate change and a health related risk to the society.
There is no doubt that the expansive power of computing can help us address sustainability challenges, but this technology also draws from the Earth’s finite environmental stocks and biosphere. In 2013, U.S. data centers consumed an estimated 91 billion kilowatt-hours of electricity, equivalent to the annual output of 34 large (500-megawatt) coal-fired power plants. According to the Natural Resources Defense Council (NRDC), data center electricity consumption is projected to increase to roughly 140 billion kilowatt-hours annually by 2020, the equivalent annual output of 50 power plants, costing American businesses $13 billion annually in electricity bills and emitting nearly 100 million metric tons of carbon pollution per year.

There are troubling signs that data center power use will continue to grow substantially. The pros and cons of the cloud computing leads to a debate that cloud computing is a green opportunity or climate change risk. If compared with on-premise computing the cloud computing is a green initiative. Virtualization also played a great role in optimum utilization of the resources to maximize profit and minimizing the energy consumption. The Carbon Disclosure Project (CDP) found in its research that large US companies that use cloud computing will be able to save $12.3bn in energy costs and 85.7 million metric tons of CO2 emissions annually by 2020. But because of random, unpredictable consumer demand, the resource allocation algorithms in the data centers should be dynamic and intelligent enough to utilize the data center capacity at optimum level so that energy consumption can be reduced.

**Energy Consumption Patterns**

To improve the energy consumption of the data centers, it is first important to understand the energy consumption pattern of the data centers. There are various factors contributing to the total energy consumption of the datacenter. The components can be categorized into 1) Fixed energy consumption components e.g. lighting, networking equipments 2) dynamic energy consumption components e.g. UPS(uninterruptible power supply), PDUs(Power Distribution units), servers etc. The Figure 1 shows the percentage of energy consumed by the components of the data center. The cooling system and the servers are consuming nearly half of the total power consumption. The energy in-efficiencies in the datacenter are because of non-uniformity of the energy consumption of the servers and the traditional cooling and air conditioning units. To attain sustainable energy efficient environment of the data center dynamic energy efficient algorithms are required to be applied on both the components. There are a number of industry initiatives e.g. Climate Savers Computing Initiative (CSCI), Green Computing Impact Organization, Inc. (GCIO), Green Electronics Council, The Green Grid, FIT4Green, ECO2Clouds, Eco4Cloud, International Professional Practice Partnership (IP3) etc. working in the direction of green energy efficient computing.

**Taxonomy of Energy Efficient Computing Techniques**

Environmental sustainability has been a subject of augmented attention over the last few decades. Natural resources are slowly being depleted, a reason for the issue of sustainable development arising. Virtualization has played a great role to achieve improvement in efficiency and eventually reduction in carbon emissions. The energy management techniques can be broadly categorized into 1) Power Management Techniques and the 2) Thermal Management Techniques. The taxonomy of the energy management techniques is shown in Figure 2.