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A Study on Green Cloud Computing – An Overview

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Abstract

Cloud computing provides computing power and resources as a service to users across the globe. This scheme was introduced as a means to an end for customer's worldwide, providing high performance at a cheaper cost when compared to dedicated high-performance computing machines. This provision 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 CO2. Since energy has been a prime concern of late, this issue generated the importance of green cloud computing that provides techniques and algorithms to reduce energy wastage by incorporating its reuse. In this survey we discuss key techniques to reduce the energy consumption and CO2 emission that can cause severe health issues. We begin with a discussion on green matrices appropriate for data-centers and then throw light on green scheduling algorithms that facilitate reduction in energy consumption and CO2 emission levels in the existing systems. At the same time the various existing architectures related to green cloud also discussed in this paper with their pros and cons. 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 study, we discuss various elements of Clouds which contribute to the total energy consumption and how it is addressed in the literature. We also discuss the implication of these solutions for future research directions to enable green Cloud computing. The study also explains the role of Cloud users in achieving this goal.

Keywords : Cloud Computing , Technology, Cloud, Telecommunications

1.0. Introduction

According to Wikipedia [wiki], Cloud computing is a collection of a variety of computing concepts in which thousands of computers communicate in real-time to provide a seamless experience to the user, as if he/she is using a single

huge resource. This system provides multiple facilities like – web data stores, huge computing resources, data processing servers etc. The concept of cloud computing is around since the early 1950s, although the term was not coined back then. Time sharing systems was how it was addressed back then. During the period of 1960-1990, a host of experts did hint the era of cloud computing in their books or quotes. The term dumb terminal attached to the mainframes was more famous in this period, in-lieu of the term cloud computing. In the early 1990s, even the telecommunications companies began offering VPNs (Virtual Private Networks) instead of dedicated connections, which were decent in QoS but were comparatively cheaper. In 1999, Salesforce.com was among one of the first to provide enterprise applications via a website. This move aided the advent of cloud computing which was introduced around 2002 by Amazon, the organization which can be considered as one of the pioneers in the field with their Amazon Web Services (AWS) and Elastic Compute Cloud (EC2). Since 2009, after the introduction of web 2.0, other big shots in the web industry viz. Google, Yahoo *etc.* have also joined the club.

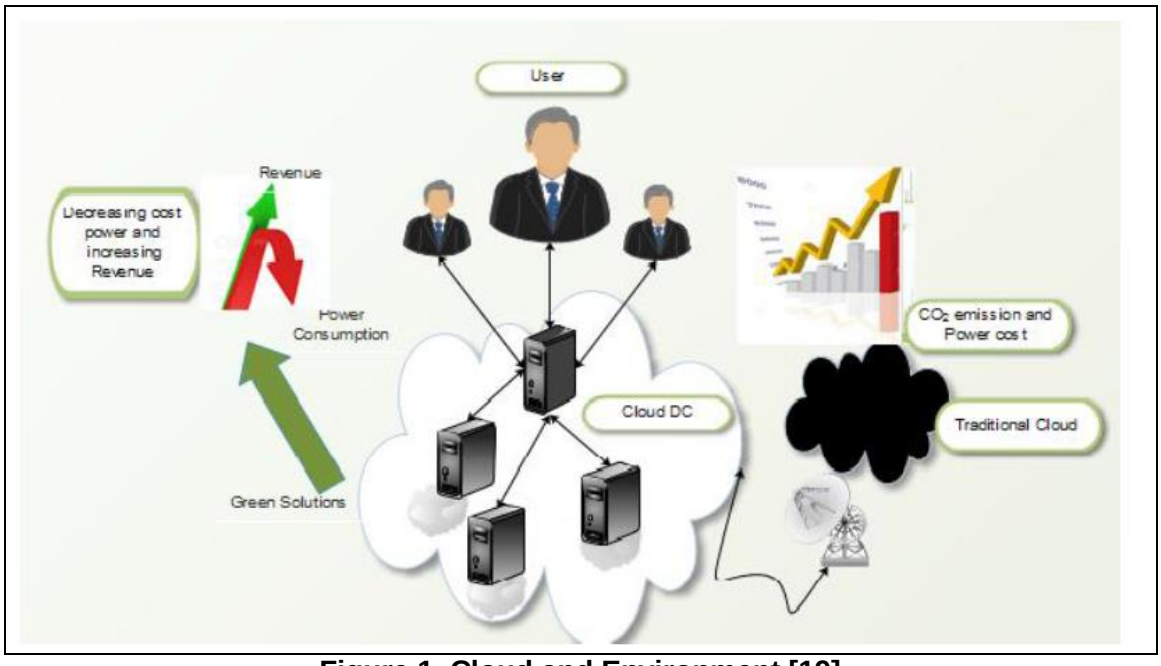

Figure 1. Cloud and Environment [19]

Cloud computing can be considered as a hierarchy of concepts, which comprises of several models. The first model is the Service Model [11] which further includes three models namely – software as a service, platform as a service and infrastructure as a service. Second is the Deployment model [11]

which further comprises of public cloud, private cloud, community cloud and hybrid cloud.

According to National Institute of Standards and Technology (NIST) – "the major objective of cloud computing is to maximize the shared resources and at the same time the disadvantage is its high infrastructure cost and unnecessary power consumption."

According to National Institute of Standards and Technology (NIST) – "the major objective of cloud computing is to maximize the shared resources and at the same time the disadvantage is its high infrastructure cost and unnecessary power consumption."

Global warming has been a big concern of late, with high power consumption and CO2 emission acting as a catalyst to increase the same. The world has become highly protective about the environment with inputs from contributors such as – Greenpeace, Environmental Protection Agency (EPA) of the United States and the Climate Savers Computing Initiative to name a few. With the continuously increasing popularity and usage of cloud computing and the increasing awareness of the people across the globe towards the use of eco-friendly resources has forced the researchers to devise concepts towards an eco-friendly energy efficient flavour of cloud computing called green cloud computing. According to the previous works green cloud computing facilitates the reduction of power consumption and CO2 emission along with the reutilization of energy in an efficient way.

Cloud uses thousands of data-centers in order to process the user queries and to run these data-centers bulk amount of power is used for cooling and other processes. Every year this power consumption is gradually increasing and green cloud computing endeavors to reduce the same thus playing a helpful role to curb these issues. There are various techniques and algorithms used to minimize this expenditure [13]. Among various avenues, one area of research focuses on reduction in energy consumption by computer servers, whereas the

other lays stress on dynamic cluster server configuration to reduce the total power consumption by balancing load and effectively utilizing only a subset of the resources at hand. Similarly Dynamic CPU clock frequency scaling [22, 23] again incorporates some form of load balancing to save power during different load conditions. In addition to these, some more techniques are used to measure the power consumption in data-centers. The first one was developed by the Green Grid called Power Usage Effectiveness (PUE) metric to measure the effectiveness of data centers. PUE tells about the amount of extra power required for cooling IT equipment.

It is clear from Figure 1 that in cloud scenario power consumption is very high with high carbon emission whereas at the same time in green cloud this is very less as compared to traditional cloud. Green clouds avoid power wastage and this is the reason for adoption of this technology by IT companies like Google, Microsoft, Yahoo!, *etc*. According to a survey done in the year 2007 IT industries contribute to 2% of the total carbon emission every year [19]. European Union (EU) is also of the view that severe reductions of the order of 15%-30% is required to maintain the global temperature and stop it from increasing drastically before 2020.

The remainder of this article is organized as follows. Section II reviews previous research in the field of green cloud computing. In Section III we briefly describe the approach used to address the problem. Section IV examines the proposed work with the existing method. Finally, we summarize the study and give way for future research in Section V.

1.2. Existing Work

The use of Green Cloud Computing has increased substantially in the recent past. A lot of research has been done to incorporate and enhance the applicability of Green Cloud in real life scenarios with these help of various parameters. Usage of energy is dramatically increases in data centers. Cavdar *et al.*, [1,2] introduced for improving the energy efficiency of the running data centers, the Green grid is proposing some parameters like Power Usage

Effectiveness (PUE)[7] and Data centre Efficiency (DCE) metrics [10], TDP (Thermal Design Power) [2], *etc*. PUE is the common parameter.

According to Wikipedia "PUE is a measure of how efficiently a computer datacenter uses its power "The range of PUE is varies from 1.0 to infinity. If the value of PUE approaching 1.0 it means efficiency is 100% and full power is used by IT equipment's. In recent years some companies achieved low PUE levels, like Google PUE with 1.13 [9]. If the value of PUE is 1.5 it means that energy consumed by IT equipment in 1kWh, by data centre 1.5 kWh and 0.5 WH energy has wasted as fruitless work like cooling, CPU dissipation and other work. Table I explain some parameters proposed for data centers. In many data centre the value of PUE reached to 3.0 or more but by using correct design 1.6 values should be achievable [5]. This calculation is done in Lawrence Berkley National Labs [8] which illustrate that 22 data centers 22 datacenters measured had PUE values in the 1.3 to 3.0 range [8].

Truong Duy, Sato and Inoguchi *et al.*, [3] implement the green scheduling algorithm combines with neural network predictor for reducing the energy consumption in cloud computing. In this algorithm, the server predicts the load from time t to the time it takes for restarting and calculates the peak load. According to the peak load the number of server state is decided. Let, No is the number of server in ON state and Nn is the number of necessary International Journal of Grid and Distributed servers. If the Nn > No then, choose server in OFF state, signal them to restart and if Nn < No choose server in ON state and signal them to shut down.

Fumiko Satoh *et al.*, [4] also focus on reducing the usage of energy in data centers. But for the future energy management they develop an energy management System for cloud by the use of sensor management function with an optimized VM allocation tool. This system will help to reduce the energy consumption in multiple data centers and results shows that it will save 30% of energy. This system also used to reduce the energy in carbon emissions.

Table 1. Green metrics power measurement [1, 2]

Metric	Explanation	Formula
Power usage Effectivenes (PUE)	It is the fraction of total energy consumed by the service of a data centre to the total energy consumed by IT equipments.	$PUE = \frac{\text{Total facility energy}}{\text{IT Equipme nt energy}}$
Carbon Usage Effectiveness (CUE)	It is a calculation of green house gases (CO_2, CH_4) release in atmosphere by the data centre	$CUE = \frac{(\text{Total } CO_2 \text{ emission from total energy used for service of data centre})}{\text{Total energy consume by IT equipment}}$
Water Usage Effectiveness (WUE)	It is calculation of yearly water used by data centre like for cooling, energy Production.	$WUE = \frac{\text{Annual usage of water}}{\text{Total energy used IT equipment}}$
Energy Reuse Factor (ERF)	It calculates the reusable energy Like hydro power, solar power etc used by data center.	$ERF = \frac{\text{used of reused energy}}{\text{Total energy used IT equipment}}$
Energy Reuse Effectiveness (ERE)	It is a parameter for measuring the profit of reuse energy from a data centre.	$ERE = \frac{\text{Total energy - reused energy}}{\text{Total energy used IT equipment}}$
Data centre Infrastructure Efficiency (DCiE)	This factor is used to calculate The energy efficiency of a data Centre.	$DCiE = \frac{\text{Total IT equipment power}}{\text{Total facility power}} * 100\%$
Data Centre Productivity (DCP)	It calculates the amount of useful work done by data centre.	$DCP = \frac{\text{Total Usefil woik}}{\text{Total resource used to do this woik}}$
Compute Power Efficiency (CPE)	It determines the total amount of power is truly used for computing.	$CPE = \frac{\text{IT equipment utilization energy}}{PUE}$

Green Energy coefficient (GEC)	It measure the amount of green energy used to provide services to data centre.	$GEC = \frac{\text{Green energy consumed}}{\text{total energy consumed}}$
Space, Wattage and Performance (SWaP)	It is used for work out the space and energy required by the data centre.	$SWaP = \frac{\text{Performance}}{\text{Space} * \text{power}}$
DataCentre Energy Productivity (DCeP)	It calculates the quantity of useful work done by data centre as compare to total energy consumed to make this work.	$DCeP = \frac{\text{Total Useful work done}}{\text{Total energy used to do this work}}$

Cooling is other major issue that consumes huge amount of energy in data centers. Previously, the cooling is done by using mechanical refrigerator that supply chilled water for the IT equipments. Now a day's pre cooling also called as free cooling is used. Free cooling minimizes the use of mechanical cooling. Like Face book deploys their data centre in Sweden which has cold and dry climate. Microsoft leaves servers in open air in order to cool the servers easily. Also Google uses river water to cool their data centre [1]. There are different hardware technologies like virtualization and software technologies like software efficient algorithm used to decrease the consumption of energy.

Rasoul Beik *et al.*, [6] proposes an energy aware layer in software –architecture that calculate the energy consumption in data centers and provide services to the users which uses energy efficiently. Bhanu Priya *et al.*, [11] gave a cloud computing metrics to make the cloud green in terms of energy efficiency, different energy models has been discussed in this paper to reduce the power consumption and CO2 emission to make cloud more green. This survey takes three major factors under consideration; any cloud can be green by following these factors, first cause to make cloud greener is virtualization, Second is Work load distribution and third is software automation, some other factors are also discussed like pay-per-use and self-service which is proved as a key for reduction of energy consumption.

According to Kliazovich and Pascal Bouvry [12] expenses on cloud data centers maintenance and operation done in cloud are gradually increasing. In this paper author has focused on the work load distribution among the data centers so that energy consumption can be calculated in terms of packet level. By this technique packet level communication is achieved. Packet level simulation of energy has been done through the simulator, like for green cloud NS2 simulator and for cloud only one existing called "cloudsim". This simulation is done at three levels: "two -tier, three-tier, and three-tier high-speed data center architectures". Kaur and Singh *et al.*, [13] performed the different challenges in the field of energy in cloud computing, a model is proposed by author to calculate the energy wasted by producing various gases in environment. The proposed model contains various fields Data, Analysis, Record, Put on guard, restrain along with the virtualization concept in green cloud to make it energy efficient and for healthy environment.

Hosman and Baikie *et al.*, [14] gave a new challenge in the field of cloud computing, datacenters consumes a lot of energy and energy is available every time is not necessary, so the author is discussing in his paper about the solar energy. How the solar energy can play a vital role in data centers energy consumption is the hot topic of discussion. In this paper author proposed a small level cloud data center which is the combination of three technologies are "less power consumption platform, energy efficient cloud computing and DC power distribution". Owusu *et al.*, [17] performed a survey to establish the current state of the art in the area of energy efficiency in cloud computing. They beautifully mention the field of energy efficiency as a controversial area to cloud computing. This paper discusses one area of controversy; the energy efficiency of cloud computing.

Yamini *et al.*, Introducing the key approaches like virtualization, Power Management, Recycling of material and telecommuting of green cloud computing very beautifully. The major focus of this paper is the consolidation or scheduling of task and resource utilization in green cloud computing to reduce the high consumption of energy. The decent results shown in the paper not for the direct drastic energy reduction but applies possible saving of electricity in

huge cloud data centers. According to Buyya [19] the demand of cloud is drastically increasing now a day and the consumption of energy and excretion of harmful gases is also extreme which is very harmful and a big issue in the field of health care and also a big reason of the increase in cost of operations in cloud. Buyya gave a presentable and evidential literature survey of the various different members of cloud which participate in the total energy consumption. Structure of cloud are discussed in this paper which turn on the use of green cloud computing.

Buyya *et al.*, [24] Contributes carbon green cloud architecture which points on the third party concept, consist of two types of directories named as green offer and carbon emission. These directories help us to provide and utilize the Green services from users and providers both. Green brokers access the services from green offers directory and scheduled services according to least CO2 emission. Beloglazov and Buyya *et al.*, [25] focuses on virtual machine for the reduction of the energy consumption. An author proposes the dynamic reallocation technique for VMs and toggles off the unused servers which results, considerable energy saving in the real Cloud Computing data centers.

Nimje *et al.*, [28] addressed the security of the cloud data centres in order to achieve green cloud environment by using virtualization concept. Various methods are involved in the paper to address the security and reduction of power consumption. Virtualization here came in to picture because it reduces the load from the data centres and provides deployment, management and delivery of resources in simple manner. Nimije included hypervisor environment to provide the virtualization and works as a security tool to achieve high level of security in green cloud computing.

1.4. Existing Approaches

Buyya *et al.*, Contributes carbon green cloud architecture which points on the third party concept, consist of two types of directories named as green offer and carbon emission. These directories help us to provide and utilize the Green services from users and providers both.

The services of the providers are registered in the "Green offer Directory". The Green Broker accessed these services and organized it according to the price, time and the service that offer least CO2 emission. The Carbon Emission Directory keeps and stores the data which contains the information of energy and cooling efficiency of cloud services and data centers. The green broker used the up to date information about services.

Whenever the user request for the services, it contacts with the Green Broker. The Green Broker uses these directories and chooses the green offer and energy efficiency information and allocates the services to the private cloud. And finally give the result to the users. This directory idea is beautifully used by the Hulkury *et al.*, and Garg *et al.*, and proposes a new architecture called as integrated green Cloud architecture (IGCA) shown in Figure 2. It smartly includes client oriented in the Cloud Middleware that verifies the cloud computing is better than the local computing with QoS and budget.

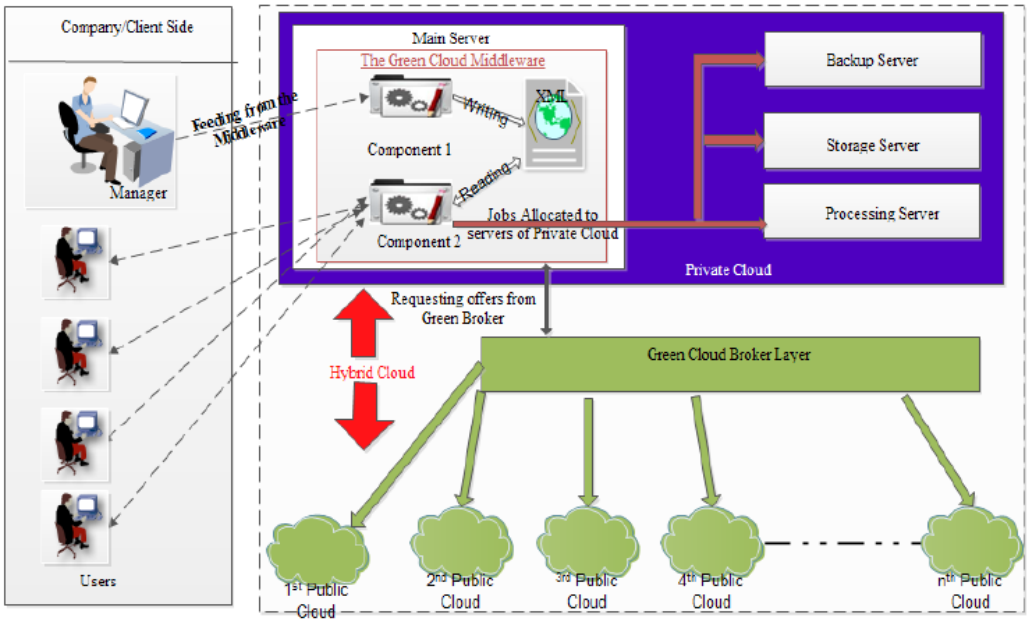

Figure 2. Integrated green Cloud architecture (IGCA) [26]

This architecture has two elements; one is the client and second is the server side. In the client side the manager and the users are present, which deals with the execution destination of the job and in the server side includes the green cloud middleware, green broker and sub servers like processing servers ,

storage servers etc. The directory concept is used in the green broker layer of IGCA for organizing all the information of the public cloud and provides the best green service to the user.

The green cloud middleware has two components. The manager is the main head that deals with one component and stores all the information of the middleware. The usage of the user's PC, the servers present on the private clouds all the information. The frequencies of each sever like high, medium and low. The energy usage, storage capacity [26] and other information also exist in the component of middleware.

When the manager got request from the client. The request is dividing into jobs and distributed among the users meanwhile they also stores the information about job into the component. The carbon emission and energy used for the execution of job on the private cloud by servers, on the public cloud by using green broker or on the client's PC is calculated and show to the users. The best green offer is selected by the manager by taking into consideration the security level of the job also. When the decision is making out by the manager then this information is store in the XML file for future usage.

The second component is accessed by all the users for reading the XML file. This file stocks all the information of the execution of job. The locations of the jobs are registered in the file and according to the addresses, they will execute. If the job entry is not in the file then the job will be executed either on the PC of the client or in the private cloud. The execution of job is takes place in three places. First if the job is executed LOCALLY (on the requester side) then this information is stored in the client side so next time when the request arrives it will not get through will middleware. If the job is executed in the private cloud the location as well as the server name is fetched from the file. Or if it is in public cloud, we will take help from the green broker to know the most excellent green decision for the execution of the job. The middleware know all the information about the three places. Energy used by the workers working in the company is also calculated by the middleware for taking further decisions.

The processing speed, energy consumption, bandwidth or others factors are responsible for deciding the best location for the execution of the job. By considering all the factors the middleware will compute and judge the place from the three places. The IGCA provides the balance in the job execution and provide the security and quality of service to the clients. The manager divides the task and top quality green solution by considering all the places (public, private, local host).

In this architecture the manager plays the central coordinator work which allocates the job to the users and does all decision making. But at the same time the manager is the weakest point in this architecture as it is the central point of failure, as if the manager fails everything in the architecture collapses.

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.

The commercialization of these developments is defined currently as Cloud computing [2], where computing is delivered as utility on a pay-as-you-go basis. Traditionally, business organizations used to invest huge amount of capital and time in acquisition and maintenance of computational resources. The emergence of Cloud computing is rapidly changing this *ownership-based* approach to *subscription-oriented* approach by providing access to scalable infrastructure and services on-demand. Users can store, access, and share any amount of information in Cloud. That is, small or medium enterprises/organizations do not have to worry about purchasing, configuring, administering, and maintaining their own computing infrastructure. They can focus on sharpening their core competencies by exploiting a number of Cloud computing benefits such as on-demand computing resources, faster and

cheaper software development capabilities at low cost. Moreover, Cloud computing also offers enormous amount of compute power to organizations which require processing of tremendous amount of data generated almost every day. For instance, financial companies have to maintain every day the dynamic information about their hundreds of clients, and genomics research has to manage huge volumes of gene sequencing data.

Therefore, many companies not only view Clouds as a useful on-demand service, but also a potential market opportunity. According to IDC (International Data Corporation) report, the global IT Cloud services spending is estimated to increase from $16 billion in 2008 to $42 billion in 2012, representing a compound annual growth rate (CAGR) of 27%. Attracted by this growth prospects, Web-based companies (Amazon, eBay, Salesforce.com), hardware vendors (HP, IBM, Cisco), telecom providers (AT&T, Verizon), software firms (EMC/VMware, Oracle/Sun, Microsoft) and others are all investing huge amount of capital in establishing Cloud datacenters. According to Google's earnings reports, the company has spent $US1.9 billion on datacenters in 2006, and $US2.4 billion in 2007.

Today Information Technology is considered as a heart of our personal and business life. Our both personal and business life are very much dependent upon information technology and it's a true fact that life without Information Technology will become paralyzed (Lamb. J, 2009). Therefore, organizations are continuously investing in information technology for their performance growth and value (Hu & Quan, 2006; Kohli & Grover, 2008) and using the innovative technology for their high performance and to gain the competitive advantage. However this new innovative technology has also increased the cost and complexity (Damanpour & Evan, 1984; Swanson, 1994; Tucker 2002). Yet, if organizations do not invest in the technology they will lose their market place (Geisler & Kassicieh, 1997). Furthermore, IT has raises the environmental issues and problem from e waste disposal, usage and production (Murugesan, 2008). So, the pervasive adaption of information technology has side effects on the environment too. The awareness of this effect has attracted some renowned

organization towards the environmental friendly computing and practices known as "Green IT" (Lamb. J, 2009).

Beside the Green IT practices, information assurance (IA) and information security (IS) is very essential for business success. It is necessary to assure the degree of confidence (i-e Information Assurance) about security features and policies and how security protection are applied to protect the information system (i.e. Information Security) in each Green IT solution. For most of the organization and company, their proprietary and sensitive information is very important asset for them and its protection is as important as protecting a physical asset. In 2009, the Internet Complaint Center, reports nationwide loss of $559.7 million due to cyber-crime. Computer Security Institute also reported that businesses in 2006 loss over $52,494,290 to security related issues. (Esensten, 2011;Harris, 2010). Therefore, there is increasing pressure to assure the information security in all business practices. Now, organizations understand, loss of proprietary and customer information can damage organization's reputation (Russell & Gangemi, 1991).

Apparently Green IT has little to do with information security but in depth it has strong relation between Green IT revolution and information security concerns in IT industry (Grossman, 2011). Here is an opinion from an expert, Simon Mingay, Research vice president for Gartner says, some of the companies may unknowingly giving away information in the reports of their progress on environmental issues (Green IT raises security fears, 2007). Other Green IT practices like mobile computing and telecommuting introduce the risk of information theft and data privacy issues by moving the data outside the local network. Green disposal and paper reduction also has security risk if not properly carried out (Metzler, 2009).. Virtualization technologies and cloud computing brings their own set of security risks (Frangiskatos, Ghassemian and Diane, 2010). This is the objective of thesis to find out how Green IT is strongly connected to security and what are those security risks associated with Green practices.

1.6 Purpose of the Study

The purpose of this study is to identify ways in which Green IT practices and solutions can impact the information assurance and security, while simultaneously supporting green benefits, including energy efficiency, cost reduction and carbon foot print minimization. This master thesis represents the result of systemic literature review to find the impact of Green IT implementation on information assurance. Therefore, the main objective of this thesis is to illustrate how Green IT paradigms and its inherent benefits can affect the information assurance and security.

The focus of the study falls in following area: (a) Green IT dimension and its holistic approach (b) Green IT initiatives (c) Green IT in Information assurance perspective (d) Impact of Green IT practices on information assurance. The intent of this study is to provide the audience with knowledge, which can enables the Green IT solutions more secure to information assurance.

1.7. Background and Motivation

Thesis motivation comes through the background which has been represented in Integrated Model; Green IT from Information Assurance and Security perspective (Figure 1). It shows that increase in CO2 emission enables the Green IT and which motivates the Green IT solutions and Green IT implementation provides the Green benefits which leads to decrease in greenhouse gas emission and lead to safe planet. But Green IT implementation could also have security threats, issues, challenges and vulnerabilities. These issues must need to be mitigated for a safe business. So both green benefits and information assurance and security should be combined at its best level to achieve the both goals of save planet and save business.

1.8 Audience

The study is primarily written for the IT business environment in which Green Computing solutions are being implemented and those who are very much concern about the information assurance and security. This study can make a significant contribution to the knowledge of Chief Information Officer (CIO), Chief Information Security Officer (CISO) and security managers and to whom it

may concern. This thesis has not conducted for the interest of a particular organization.

2.1 Research Design

A systematic effective literature review approach has been chosen to conduct this study because the goal of this study is similar to the goal of the literature review, filling the gaps of previous research work and extending preceding studies (Creswell, 2009, p. 25). Here it is necessary to give a brief explanation about literature review before applying it. Literature review is much more then reviewing the collection of papers and previous research work. Hart (1998, p.1), defined, meaningful and effective review as "the use of ideas in the literature to justify the particular approach to the topic, the selection of methods, and demonstration that this research contributes something new" (Levy and Ellis ,2006, p.182). He further says that a high quality literature review is deep and broad, rigor and consistent, valid and clear, effective and synthesize. It should not be a simple compilation of related material.

Research on Green Computing has been performed at very certain extent . A very few research and news articles have reported security risk as a problem in Green IT solutions (Green IT raises security fears, 2007). Several Green IT solutions experience the security threat. This study explores and interprets the past literature to establish the link between Green IT and Information Assurance and security. The literature about different Green IT solutions and practices has been analyzed to identify the hidden threat and risk for data security.

The methodology used in this study is, systematic approach for literature review, based on three steps guideline of literature review process for the development of a sound and effective literature, proposed by the (Levy and Ellis ,2006, p.182). The three steps of literature review process comprises of 1) Literature review input 2) Literature review processing and analysis 3) Literature review output. Following figure provides an overall view of three step guideline proposed by Levy and Ellis.

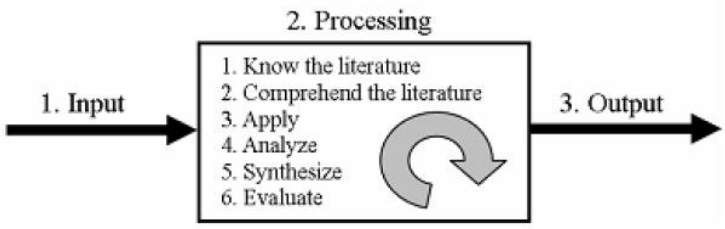

Figure 2: The three stages of effective literature review (Levy and Ellis, 2006, p.182)

The thesis also follows some guidelines and suggestions of Webster & Watson about how to begin your article, how to structure review like concept centric approach to literature review, research techniques of go backward and go forward citation, identifying knowledge gap in theoretical framework, how should be a conclusion (Webster & Watson, 2002, p.15-17).

Although many literature review methodology has been studied but Levy and Ellis' suggested systemic approach has been chosen because, theirs systematic literature review framework follows the traditional data processing model and easy to follow for students and novice IS researchers. The three step approach has made the literature review a manageable task. More to it, Levy and Ellis' has given very important tips about reading the literature and how to manage the searched literature to refer later. They have also given practical examples for how to comprehend, apply, analyze, synthesize and evaluate the literature (Levy and Ellis, 2006, p.193-201).

2.1.1 Why Conduct a Literature Review

Before explaining how the literature has been conducted, it is necessary to justify why literature review has been chosen for this study. Literature review is conducted for variety of reasons, as follows:

- This thesis report must raise the IT community's current understanding and knowledge about Green IT and contribution of exploration in the current Body of Knowledge (BoK) (Levy and Ellis, 2006).
- This literature review brings the attention of IT community where more research work is required and what is needed to be known.

- The literature review methodology is chosen to give collateral evidence of the research problem.
- One of the reasons for doing literature review is to ensure the validity of the evaluated results.
- Furthermore literature review builds a strong theoretical foundation from available resources (See Table 1 for resources) which helps to explain the problem with strong arguments and reasons (Levy and Ellis, 2006).
- Additional reasons for using the literature review are; to justify the significance of the information security problem in Green IT; to develop the relationship between Green IT ideal solutions and actual practices of it.
- This literature review approach also helps to identify the recommendations for future research about how to make Green IT more secured from information security perspective and what controls need to be implemented and what additional care to be taken while implementing practicing Green IT Literature Review Process.
- The systematic literature review has been chosen because it ensures that complete relevant literature about Green IT has been gathered. One of the step of literature review process, known as, literature input process, gives a very good sign about literature gathering completion when you are not finding as new concept and thoughts. Webster and Watson (2002) also say, "A systematic search should ensure that you accumulate a relatively complete census of relevant literature.

2.1.2 Literature Review Input

This section describes how literature has been search and gathered, with the help of specific approaches and techniques, introduced by Levy and Ellis (2006). Literature review input process is the foundation of a quality literature review which is deep and broad, rigor and consistent, valid and clear, effective and synthesize, not a simple compilation of related material (Hart, 1998). If literature input is wrong, or of low quality, impertinent or inappropriate then whatever the data analysis or evaluation method is used, a quality and valid result cannot be achieved (Levy and Ellis, 2006).

Literature Resources

It is true that importance of past literature resources cannot be denied. The previous research work and studies helps the other researchers to take advantage of it while deriving the new knowledge.

To take advantage of previous work, it is necessary to look for literature resources (See Table 1) because a literature from quality resource can be confidently referred in owns new concepts for various purposes for example, to give direction to the reader or to prove the validity of the study.

Table 1 is the list of databases, where the searching has been carried out. Important criterion for searching the relevant material inside and outside the IT/IS outlets, has been followed as discussed in the following sub section "Search Techniques", where searched keywords are searched in all fields including the full text.

Table 1: List of Literature Databases

S.NO.	Literature Databases
1.	ACM (Digital Lab)
2.	EBSCHost
3.	Elsevier (ScienceDirect)
4.	Google Scholar
5.	IEEE (Comp Soc & Xplore)
6.	ProQuest (ABI/INFORM)
7.	SAGE
8.	Springer

Research Parameter

In order to gather manuscripts relevant to the subject matter, under investigation, following different high level keywords of Green IT are used for searching which are as follows:

- Green Computing

- Green IT
- Climate Saver Computing
- Green Threat
- Green Technologies
- Going Green
- Green Grid
- Green IT threat to security
- Green IT and Information security

Levy and Ellis (2006, p.190) and Webster and Watson (2002) suggestion, about the keyword search, has also been followed. Different keyword or phrase has been used to search the literature.

Buzzwords has been avoided as a keyword that appear and disappear in the literature. Search technique is not stick to a specific keyword. Further techniques has been discussed in below sub heading.

Search Techniques

To achieve the high degree of literature quality, following search techniques has been followed:

- Searching has been started from the Journals guided by Levy and Ellis (2006, figure. 2) and Webster & Watson (2002).
- Selected conference proceeding compiled by (Levy and Ellis, 2006, figure. 3) has also searched for the applicable literature.
- The literature input has also been gathered from umber of literature database vendors.
- Backward and Forward search techniques, (Webster and Watson; 2002 and Levy and Ellis 2006) has been used.
- Most the searched worked is carried out electronically. Except the few books which are borrowed from the library or some purchased articles.

Search Result

To represent the search result , the Webster and Waston's (2002) suggested table format has been used.

Below Table 2 display the result for the eight literature databases (mentioned in Table 1) from high level key word of Green IT. In the eight literature databases 876 numbers of studies related to the Green IT were found. Of these 876, 43 literatures were practical screened (practical screening includes reading and reviewing. Skim reading has also been done but only for those articles which were found not related to thesis subject matter) and after practical screening and out of which 7 were found in pure context of information security and assurance issues in Green IT . The remaining 36 only discuss the Green IT and its dimension and different solutions in details.

After extracting the knowledge of different Green IT solutions from the remaining 36 literature studies, further research carried out to find out the information assurance and security issues in each green IT solution. For that purpose each green it solutions is separately searched in context to security issues. Below from Table 3- display the result for the eight literature databases (mentioned in Table 1) for each Green IT solution in context to security issues.

Table 2: Search Result from Literature Databases

Literature Databases	# of unique hits from high level keywords	# of studies remaining after the practical screening	# of studies concerning Green IT in information security context	Studies concerning Green IT in information security context
ACM (Digital Lab)	20	2	0	-
EBSCOHost	9	3	1	Green IT raises security fears, 2007
Elsevier (ScienceDirect)	21	8	4	Grossman, 2011 Arnfield, 2009 Goucher, 2009 & Gorge, 2008
Google Scholar	542	9 (found only in Google Scholar)	1	Esensten, 2011
IEEE (Comp Soc & Xplore)	17	12	0	-
ProQuest (ABI/INFORM)	30	1	0	-
SAGE	193	1	0	-
Springer	44	7	1	Frangiskatos, Ghassemian and Diane, 2010
TOTAL	**876**	**43**	**7**	

Table 3: Search Result for "Green Cloud Computing" from Literature Databases

Literature Databases	# of unique hits from "Green Cloud Computing"	# of studies remaining after the practical screening	# of studies remaining after the practical screening in information security context	Studies in information Assurance & security context
ACM (Digital Lab)	23	1	1	Ristenpart, 2009
EBSCOHost	2	0	0	
Elsevier (ScienceDirect)	112	5	4	Zissis and Lekkas, 2010 ; Svantesson & Clarke,2010; Li, 2011; Lombardi, 2010
IEEE (Comp Soc & Xplore)	30	10	6	Sabahi, 2011; Kaufman, 2009; Greer, 2010; Chakraborty, 2010; Ren, 2012; Carroll. M, Kotzé & Paula, 2011
ProQuest (ABI/INFORM)	2	0	0	
Springer	12	0	0	
TOTAL	**181**	**16**	**11**	

Table 4: Search Result for "Thin Client" from Literature Databases

Literature Databases	# of unique hits for "Thin Client" in Green IT context	# of studies remaining after the practical screening	# of studies remaining after the practical screening in information security context	Studies in information Assurance & security context
ACM (Digital Lab)	42	0	0	
EBSCOHost	2	0	0	
Elsevier (ScienceDirect)	13	4	2	Marc Hocking, 2011; Vlissidis, 2010;
Google Scholar	11	3	1	Intel Information Technology, 2010;
Springer	14	1	0	
TOTAL	**82**	**8**	**3**	

Table 5: Search Result for "Virtualization" from Literature Databases

Literature Databases	# of unique hits for "Virtualization" In Green IT context	# of studies remaining after the practical screening	# of studies remaining after the practical screening in information security context	Studies in information Assurance & security context
ACM (Digital Lab)	12	6	1	Ray, 2009
Elsevier (ScienceDirect)	82	8	1	Li, 2011
Google Scholar	13	6	4	Reuben, 2007; Chaudhuri, 2011; Williams, 2010; Rhodes, 2005
IEEE (Comp Soc & Xplore)	45	12	6	Carroll. M, 2011; Mahalingam, 2009; Karger, P.A, 2008; Cleeff, 2009; Sahoo, 2010; Vaughan-Nichols, 2008;
TOTAL	**152**	**32**	**12**	

Table 6: Search Result for "Computer Recycling" from Literature Databases

Literature Databases	# of unique hits for "Computer Recycling"	# of studies remaining after the practical screening	# of studies remaining after the practical screening in information security context	Studies concerning Green IT in information security context
EBSCOHost	50	7	5	Smits & Cain, 2010; Hope, 2007; Liam,

				2007; Dubie, 2009; Filipek, 2007
Elsevier (ScienceDirect)	28	11	7	Hinde, 2003; Jones, 2006; Jones, 2005; Jones, 2009; Jones, 2006; Mathieson, 2007; Nicho, 2000; Jones, 2009 (November)
IEEE (Comp Soc & Xplore)	17	5	1	Bennison & Lasher, 2004
Springer	22	5	2	Venter, 2007; Kwon, Lee & Moon, 2006
TOTAL	**117**	**28**	**15**	

2.1.3 Data Analysis Plan

Searching of relevant literature is certainly necessary part of the literature review but it is not enough to obtain the desire results. For the accomplishment of new theory and ideas, analysis and evaluation of the gathered data is also needed (Levy and Ellis, 2006).

The data analysis process involves series of steps which provide the researcher plan to extract the relevant concept and meaning in their research work. Webster and Watson (2002) " A review succeeds when it helps other scholars to make sense of the accumulated knowledge on a topic" (p. 18).

There are many theories available regarding the literature analysis process. This study is analyzed according to the guidelines recommended by Levy and Ellis (2006) i-e, know the literature, comprehend the literature, applying the literature, analyze the literature, synthesize the literature and evaluate the literature which has been explained later in the section. This study also follows the suggestion of Creswell (2009), of organizing the literature into segments or theme based on common categories, then process of bringing information is applied. Here themes means three areas of Green IT's dimension covering, Green design, Green use and Green disposal. So the theory of organizing data into themes is applied on Green IT dimensions where different Green IT approaches and solutions are analyze separately one by one.

The literature review flows like as shown in the below diagram, increase in greenhouse gas emission enables the Green IT, Green IT motivates the Green IT solutions and its implementation which provides the green benefits lead to decrease in greenhouse gas emission and save the planet.

3.1 Green Design and Manufacturing in Information Assurance Perspective

The green design and manufacturing process is not new concept it has been started from the time when human has realized that advancement in science and technology has start effecting on the natural resources and environment has been started polluted but now there is much more growing awareness of environmental impact of IT and increasing new demand of customer for energy and cost effective electronic equipment, computer, and other related sub system and which has led the design and manufacturing enterprises to review their design and manufacturing strategies and processes (Deif, 2011). Therefore, the design and manufacturing enterprises are working on more objective to produce the electronic equipment, computers and system with minimal or no impact on environment.

The green manufacturing is the modern strategy which comprehensively considerate on environmental impact and resource utilization and resource consumption. Its aim is to a produce the product which has minimal impact on environment, maximum utilization and facilitate harmonious development of enterprise economic benefit and social benefit in its whole lifecycle from design, manufacturing, packaging, transport, use to scrapping and disposal (Jin-ying, 2011). This aim of green manufacturing can be achieved by employing green strategies, objective, principles and techniques and innovations to turn into eco efficient. In nut shell, as the word green is associated with the manufacturing process, then manufacturing becomes more aware about its production's impact on environment and consider such impact on its production planning and control (Deif, 2011).

Now if we talk about the green design, then green design deals with maintaining the environmental sustainability in its electronic design construction.

The salient example of green design and design are Thin Client which do not have large memory and processing power as example which aims to reduce the power consumption of the IT resources (Joumaai, Kadry, 2012, Info-Tech Research Group, 2009 and Murugesan,2008). Second is cloud computing based on the characteristics of Grid technology, billed by consumption (Vykoukal, Wolf, Beck, 2009).

As presented in Figure 9, few of green design and manufacturing initiatives are the cloud computing and thin clients. In rest of the chapter each initiative which will be illustrated in further details to analyze its impact on the degree of information assurance and security.

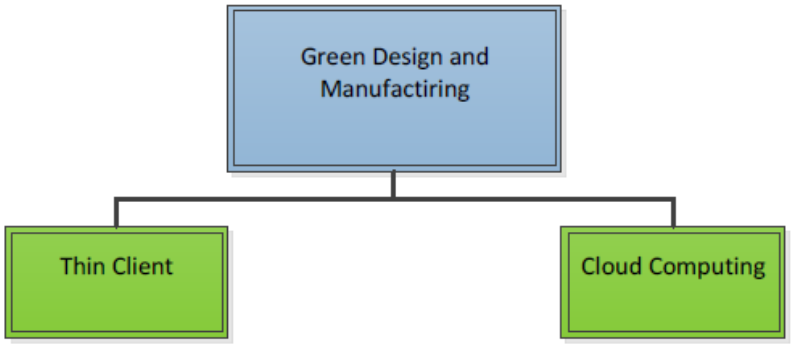

Figure 10: Green Design and Manufacturing Initiatives

3.1.1 Cloud Computing: A Green IT solution and its assessment from IA and security perspective

The availability of high speed internet connection and ip deliveries has shift the paradigms of the way IT world works. Today the small and medium size business companies instead of constructing IT infrastructure are relying on access to the shared computer resources, software, hardware and data storage resources, business application 'as a service' using internet technologies. These services are offered by external services providers to both corporate and individual over internet on use-on-demand and pay-per-use basis, called cloud computing.

Cloud Computing is derived from the Grid Computing technology in around 2007 that includes deployment of computing utility, SaaS, storage resources, applications and computation power by external service provider and obtaining them as services (Lamb, 2011 & Zissis and Lekkas, 2010).

There are many definition of cloud computing based on the services currently offered and on discussion about service offering in future (Baliga, Ayre, Hinton, and S. R. Tucker, 2011, p-150).

Below is the summarized definition of cloud computing covering its scope:
"Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of con-figurable computing resources that can be rapidly pro-visioned and released with minimal management effort or service provider interaction." (Baliga, Ayre , Hinton, and S. R. Tucker, 2011, p-150).

The main area of cloud computing service model are infrastructure as a service (IaaS), software as a service (SaaS) and platform as a service (PaaS) and it can be deployed in private, public, community and hybrid model (Jamil and Zaki, 2011; Carroll. M and Kotzé, 2011 & Baliga, Ayre, Hinton, and S. R. Tucker, 2011). Here we will not go into details of cloud computing services and deployment model. NIST (U.S. National Institute of Standards and Technology) have summarized the cloud computing definition in visual form in Figure -11.

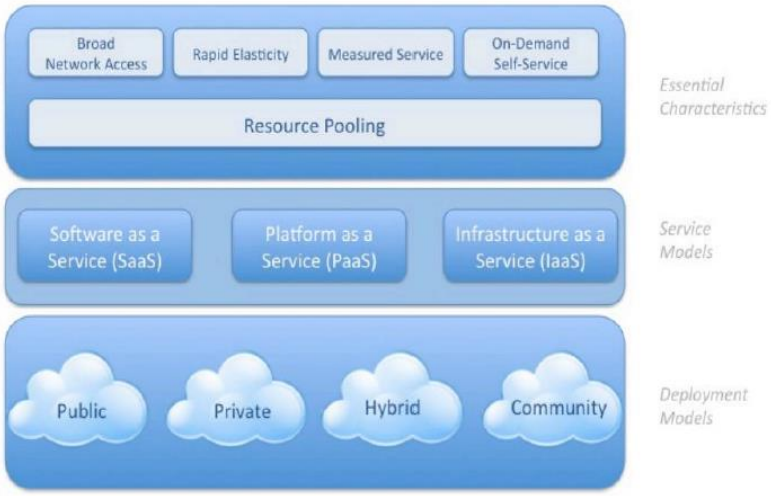

Figure 11: NIST Visual Model of Cloud Computing Definition (P. Mell and T. Grance, 2009)

3.1.1.1 Cloud Computing and Green IT

The growing awareness of global warming and contribution of IT in global CO2 emission has force the IT world to think about going green in IT . Today the major challenge of many organizations is to work and operate in going green manner. There are various solution that are working for the purpose of making IT Green, which has be discussed in this paper one by one.

Although Cloud Computing has not been dreamed up as a Green IT solution but cloud computing inherently has the green benefits in it and it also provide the Green IT benefits to the organization that are using it, which has been discussed in Table 1. Furthermore the increasing importance of energy efficiency in information and communication technologies (ICT), has given the call to reduce the greenhouse gas emission in ICT and to migrate towards the energy efficient computation, storage and communication technologies. Recently cloud computing has been given wide attention in this respect. It is growing as a promising approach to use the computation and storage resources and communication technologies in energy efficient manner with improve utilization of data centre. Now cloud computing is evolving as green cloud computing.

As we know that Green IT is refer to practice of using computer resources in energy efficient manner to minimize the environmental impact and reduce the power consumption while maintaining or increasing the overall performance and the same analogy is found in cloud computing where computing, storage and communication resources are used in energy efficient ways. It also incorporates the natural extension of virtualization technologies where two or more logical computer is run on a single physical machine with equal sharing of resources and enables the scalable management of virtual machines, thus allow the maximization of energy efficient resource utilization and resource sharing which incurs the energy saving architecture/model of Is Green IT Threat to Security? Cloud services (Li. J, Li. Bo, Wo. Tanya, Hu. Chunming, Huai. Jinpeng, Liu. Lu & Lam. K.P, 2011).

3.1.1.2 Green benefits in Cloud Computing

The integration of IT and green management to reduce the CO2 has given the call to the government and enterprises to adopt the low CO2 gas emission technology and industries, to encourage them for more sustainable environment. So in this order to save energy and reduce carbon emission, ICT is helping by multi user sharing of resources and reducing the IT related cost, power consumption and global warming. In the same regard to make IT industries and enterprises more green, cloud computing has moved from a fast-growing information technology (IT) fields to the carbon reduction of high technology and high efficiency green management industry. Cloud computing architecture can also help meet the carbon reduction and environmental goal, the saving from the elimination of redundant and overlapping data center and server applications can save about 112 megawatts of electricity, reduce carbon emissions by more than 70 million metric ton(Liang Dung, Liang Dong & Chang, 2012).

The following table describe the green benefits associated with the cloud computing. The benefits listed are only those which have been found in the literature and further benefits may exist. The inspiration of presenting the green benefits in tabular form has been got from Esensten (2011) report.

Table 8: Green Benefits of Cloud Computing

Table 8: Green Benefits of Cloud Computing

Green Benefit	Description	References
Saving energy	Cloud computing is saving the energy by moving towards cloud virtualization in the form of server virtualization, network virtualization and storage virtualization. Server virtualization can increase the hardware utilization from 5 to 20 times and gives the opportunity to decrease the number of server consuming power.	Yamini & Vetri, 2010
Improve utilization of data center resources	Data center has moved towards the energy efficient IT infrastructure through virtualization and consolidation. Virtualization is promising technology, address green utilization of resources, facilities, space, power and cooling. Virtualization combines the more than two virtual machine on a single physical server thus maximizing the energy efficiency and minimizing the idle hardware time and hence the overall power consumption. Moreover, virtualization can assist in energy efficient self-management manner by distributing work load in such a way that servers are either busy, or put in a low power sleep state or turned off the server the unused server to save the energy. This	Lamb, 2009 Berl, Gelenbe, Girolamo, Giuliani, Meer, Dang & Pentikousis, 2010 Li. Jianxin, Li. Bo, Wo.

(TCO) for client	buy, deploy, own and maintain their own applications, IT infrastructure and system. Cloud computing providers take the responsibility to provide the infrastructure, platform and storage as a service to its customers.	, Hinton, and S. R. Tucker, 2011
Lower total cost of ownership (TCO) Of cloud computing	In cloud computing, cloud service provider (CSP) takes the responsibility to run the servers, backups, operating system, software, databases, cooling, power, space etc. They manage the users to share the pool of resources, on a single instance of the software, they can amortize Costs over thousands of customers. This yields the reduced TCO	Lamb, 2009
Energy efficient utilization of resources in cloud computing system	Energy consumption and resource utilization are highly coupled in the cloud computing. Recourses underutilized or over utilized still consume the high energy as compare to efficient utilization of resources. Task consolidation is an effective technique to increase resource utilization which is enabled by virtualization to perform several tasks concurrently on single physical resource. Task consolidation not only contributes in energy efficiency but also make the resources free which sitting idle and drawing power.	Lee.Y.C & Y. Zomaya. 2010
Reduce number of hardware equipment	One of the objective of cloud computing is efficient utilization of resources which yields in less number of hardware equipment and potential reduced global CO_2 gas emission	Chang.R.S and Wu. Chia-Ming,
Saving in IT related cost	Cloud computing provides compelling savings in IT related costs including lower implementation and maintenance costs; less hardware to purchase and support; the elimination of the cost of power, cooling, floor space and storage as resources are moved to a service provider; a reduction in operational costs; and paying only for what is used (measured service). Cloud	Carroll. M, & Kotzé, Paula, 2011
More sustainable environment	Cloud computing helps organizations to reduce power, cooling, storage and space usage and thereby facilitates more sustainable, environmentally responsible data centers. Moving to the cloud further frees up existing infrastructure and resources that can be allocated to more strategic tasks.	Carroll. M, & Kotzé, Paula, 2011

3.1.1.3 Assessing the IA and Security Challenges in Green Cloud Computing

Today modern computing technologies is not only facing the technical challenges but also facing the challenge of environmental sustainability in term of high power consumption. As the size of IT infrastructure grows the effective green IT solutions and initiatives also required to develop for minimization of the global carbon gas emission. Going green and saving cost are the key objectives of an organization and Cloud computing helping its consumer organization to reduce cost, power consumption, hardware, storage, cooling and space usage and facilitating more environmental sustainable green data centre. Hence the cloud computing is fast moving to less carbon emitting green cloud

computing. As green cloud computing is massively extension of virtualization technologies and consists of virtualization-based platform so it also raises the serious security issues and data privacy with in the cloud environmental general and in particular extensive virtualization techniques in particular. So before taking the entire advantages of green IT, it is necessary to assess the security assurance mechanism of green cloud computing architecture.

In Cloud computing there are set of principles and policies includes privacy, governance, reliability, surveillance, telecommunication and capacity but among all of them the most important of all cloud consumers is information assurance and security. These security concerns are originated from the fact that customer store their data at remote server under the control of service vendor, residing at any location and rely on the software application to store and execute it (Svantesson & Clarke. 2010).

This section analyses the information assurance in green cloud computing. Here, we discuss the assessment of the IA and security issues which are arise due to energy efficient technologies and practices to make cloud computing green. This study outline the several critical security issues found in the literature and point out the importance to motivate the future investigation and research of security solutions that will help the growing adoption of trust worthy green cloud computing.
Here, we do not consider the general security issues associated with cloud computing.

Trust

Trust is the new topic in the field of computer science. It measure the degree of confidence that consumer have on computer system or model. It is used in convincing the observer and user that process, system, design or model is correct and secures (Zissis & Lekkas, 2010). The concept of trust is move around the parties like in cloud computing, cloud computing users believe that cloud infrastructure will behave as expected and required and ensure the strong security mechanism. In cloud computing trust has become the biggest

concern for the cloud consumer. This certainty of trust in cloud computing can be expressed in customer's faith in integrity and soundness operation, and successful implementation of security control and measures where all security risks is eliminateor reduced to minimum level.

Trust in cloud computing is dependent upon its infrastructure, technology, model and governance. The organization who wants to reduce their IT related cost of floor space, money, power and cooling are moving towards the virtualization-based cloud computing. Where they are basically delegating the all controls of their data to the cloud infrastructure owner and come under the mercy of service provider that they will enforce the sufficient security mechanism and policies and guarantees the implementation of security controls to deal with the all associated risk of cloud computing and virtualized infrastructure. This trust can be expensive when owner is failed to provide the service as expected and required (Zissis & Lekkas, 2010).

Multi-tenancy Security

As we know that green cloud computing is basically virtualization-based cloud computing platform, which offers the deployment of scalable and energy efficient software application and services. It also deals with the energy efficient utilization of resources and hardware achieved through the increased sharing of hardware and multitenant cloud architecture environment (Li. Jianxin , Li. Bo, Wo. Tianyu, Hu. Chunming, Huai. Jinpeng, Liu. Lu & Lam. K.P, 2011).

Multi-tenancy is the fundamental characteristics of green cloud computing, which optimize the resource utilization. Several aspect of multi-tenancy is used to keep the cloud green, including from memory, program, server, storage, network and data. In green cloud computing, users are sharing the resources at the network level, host level and application level. Although users are kept isolated from each other at virtual level. The CSPs is also using the hardware virtualization, where many users' runs the application on the same hardware while application is designed to virtually partition its data and configuration so that each user works with customized instance of application. This multi-tenancy architecture increases use of the underlying hardware resources.

Virtualization eases the management burden for CSPs, allowing for efficient and effective resource provisioning and reallocation without the need for any upfront hardware purchase or setup (Li. Jianxin , Li. Bo, Wo. Tianyu, Hu. Chunming, Huai. Jinpeng, Liu. Lu & Lam. K.P, 2011 and Ren, Wang. C, & Wang. Q, 2012). Despite the many other and green benefits of multitenant cloud architecture, poses a number of severe security threats and vulnerabilities to both CSPs and users. It also impact the assurance of confidentiality and privacy attribute of clouds. Since multitenant virtualized cloud architecture share same functionality of existing operating system and application in non-virtualized physical environmental, so software bugs and newly identified threat are the primary threat to multitenant virtualized environment (Ren, Wang. C, & Wang. Q, 2012). In multi-tenancy, object reusability can also lead to vulnerabilities if not properly controlled (Li. Jianxin, Li. Bo, WO, Tianyu, Hu, Chunming, and Huai. Jinpeng, Liu. Lu & Lam. K.P, 2011). Furthermore, for the proper resource management and utilization, several forms of virtualization must need to consistently monitored and protected. Furthermore the growing size of multitenant cloud environment and use of these virtualization technologies brings additional security concerns and makes the maintenance and security assurance more difficult to achieve (CSA, 2009 and Ren, Wang. C &Wang. Q, 2012).

Privacy and Confidentiality

Amazon EC2 provides it customer the instantiate of Virtual Machine (VM) on demand. These virtualization techniques allow the multi-tenancy of user and maximize the utilization of resources Is Green IT Threat to Security?

under the low capital. In this scenario, customer trust on the cloud owner for the privacy, confidentiality and integrity of their data and computation. However, it is not the case; such cloud infrastructure allows other customers and adversaries' VM on the same physical machine which raises non obvious threats of privacy and confidentiality leakage. Considering the situation where, adversary and victims are on the same physical machine and adversary can penetrate from the isolation of VMs and escape the hypervisor via

vulnerabilities or side channel attacks and violate the other customer's privacy and confidentiality (T. Ristenpart, 2009).

In virtualized environment, the other scenario of data confidentiality leakage is possible when data is nominally erased or removed. The lack of strong access control mechanism and exploitation of application vulnerabilities can also lead into breach of confidentiality (Zissis & Lekkas, 2010). Privacy, confidentiality and multi-tenancy are the biggest challenge of the public cloud computing (Greer, 2010). Due to growing virtualized and multi-tenant infrastructure of cloud, it is very difficult to solve the privacy issue, but it can be merely assured by strong service level agreement (SLA) or through the use of private cloud**.** However, to protect the privacy and confidentiality of data, the strong isolation solution is must require at level of virtualization or to expose the risk and placement decisions directly to users (Subashini and Kavitha, 2010 & T. Ristenpart, 2009).

Integrity

The virtualized based green cloud computing offers the deployment of energy efficient network software application (NetApp) by virtue of improved utilization of resources. It is necessary that NetApp is loaded with out tempered by various malware such as viruses, Trojans, worms and rootkits which are the threat for VM. Issue with malware like rootkit is that it can hide its own process and escape from conventional network security. Although there are several integrity measurement exist like Tripwire, integrity measurement architecture (IMA), policy-reduced integrity measurement architecture (PRIMA) and Google Chrome OS but they have widely known limitations (Li. Jianxin , Li. Bo, Wo. Tianyu, Hu. Chunming, Huai. Jinpeng, Liu. Lu & Lam. K.P, 2011). For example IMA is implemented through Linux kernel LSM which is inherently vulnerable to bypass attack and Tripwire recalculate the hash value of the file when file have been changed but the malware program which change the file keep the hash value same. (Li. Jianxin, Li. Bo, WO. Tianyu, Hu. Chunming, Huai. Jinpeng, Liu. Lu & Lam. K.P, 2011).

However, security isolation at different level is the technique to counteract for NetApp integrity preservation but problem is NetApp can be downloaded from a third party which may contain malicious code (Li. Jianxin, Li. Bo, Wo. Tianyu, Hu. Chunming, Huai. Jinpeng, Liu. Lu & Lam. K.P, 2011).

Access Control

Access control of virtual resources is also a major challenge of virtualization based cloud computing (Greer, 2010). In green cloud computing a large number of user shares the resources and several access control mechanism is there to facilitate the authentication mechanism like oVirt, built on libvirt allows to manage the hosted VMs. oVirt also provide the additional secure Is Green IT Threat to Security?

communication (GSSAPI/SASL2) and authentication mechanism (Kerberos/LDAP) for access of remote resource pools. Li. Jianxin (2011) also mentioned the associated limitation of above mentioned approach, oVirt only provide a simple identity-based authentication mechanism without considering the real-time security policy updating and evaluation for the multi-tenant resource pool

Data Segregation

As mentioned above, multi-tenancy is the fundamental characteristic of green cloud computing. A large number of users store their data through the application provided by SaaS. In cloud computing it is happen that data of many users resides on same location and where intrusion of data can happen in many ways for example by exploiting the vulnerabilities of application or by injecting client code into SaaS system (Greer, 2010) . A client can also inject the masked code into the application, if the application executes this code without verification, then there is a high potential of intrusion into other's data. There is also required to define the user's data boundary not only physical level but also at application level too (Subashini and Kavitha, 2010).

Authorization

The other issue of VMs is the control of administrator on host and guest operating system. Perfect isolation is not found in Current virtual machine monitor (VMMs). There are many bugs founds in popular VMMs where user can escape from the VM although in virtualized guest environment the VMMs should not permit the privileges to interference with host system. Moreover, there are vulnerabilities found in all virtualization software which can be exploited by malicious users to bypass certain security restriction and gain privileges. For example, Microsoft virtual PC and server's vulnerability allows the guest operating system user to run code on host or on other guest operating system. Such vulnerabilities also allow the elevation of privileges. One more example of authorization and privilege issue is in Xen caused due to an input validation error in tools/pygrub/src/GrubConf.py. This can be exploited by 'root' users of a guest domain to execute arbitrary commands in domain 0 via specially crafted entries in grub.conf when the guest system is booted (Subashini and Kavitha, 2010).

This section has assessed the IA in green cloud computing environment. Doubtless there are number of benefits offered by the green it cloud computing (Carroll. M and Kotzé, Paula, 2011 & Subashini and Kavitha, 2010) but green approach of virtualization and multitenancy has its own risk too (Li. Jianxin , Li. Bo, Wo. Tianyu, Hu. Chunming, Huai. Jinpeng, Liu. Lu & Lam. K.P, 2011). So it is highly required for cloud computing community to take proactive measure to assure the IA. Eventually it is also necessary for all users migrating towards the cloud computing who are interested in utilizing the cloud computing products for the purpose of sustainable environment that they must ensure the all associated security challenges of privacy, confidentiality, access control and authorization. They must also ensure that the product they are going to use is of their need and risks are well understood (Svantesson. Dan and Clarke. Roger, 2010). In other way around they must have strong SLA agreement or at least must be aware of it.

4.2 Key Findings

With direct and indirect connection between Green IT implementation and information security, thesis represent the list of IA challenges, security issues and vulnerabilities. Whenever any enterprise adopt the Green IT solution such as virtualization, cloud computing, thin client, reduction of paper, travel reduction, mobile computing, for the reduction of power consumption and cost, they will face the security issues presented in Table 13: Information Assurance and Security Threats, Issues and Challenges in Green IT Solutions.

The following chart is displaying the result of this literature study. These are the main IA and security issues and challenges found in each green IT solutions with respect to Green IT dimension of: Green Design & Manufacturing, Green Use and Green Disposal.

All IA issues and security challenges has been assess in aspects of security attributes of confidentiality, privacy, integrity, availability, authentication, authorization, access control, data segregation, trust and multi-tenancy security.

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Information Assurance and Security threats, vulnerabilities and Challenges in Green IT Solution						
	Green Design & Manufacturing		Green Use			Green Disposal
Security Attributes	Thin Client	Cloud Computing	Paper Reduction/ On-line Communication System	Virtualization	Travel Reduction	Computer Recycling
Privacy	–	• Escape of Hypervisor (T. Ristenpart, 2009). • Side Channel attacks (T. Ristenpart, 2009). • Lack of strong access control (Zissis & Lekkas, 2010). • Nominally erased data(Zissis & Lekkas, 2010).	–	–	–	• Organizations unaware of the recycling policies (Andy, 2005). (Venter, 2007 & Jones, 2006) (Kwon, Lee & Moon, 2006). •No check and balance of computer recycling process (Kwon, Lee & Moon, 2006).

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Information Assurance and Security threats, vulnerabilities and Challenges in Green IT Solution						
	Green Design & Manufacturing		Green Use			Green Disposal
Security Attributes	Thin Client	Cloud Computing	Paper Reduction/ On-line Communication System	Virtualization	Travel Reduction	Computer Recycling
Confidentiality	• Threat of eavesdropping activity (Vlissidis & Hickey, 2010)	• Escape of Hypervisor(T. Ristenpart, 2009). • Side Channel attacks(T. Ristenpart, 2009). • Lack of strong access control (Zissis & Lekkas, 2010). • Nominally erased data (Zissis & Lekkas, 2010).	• Laptop theft (Pasquinucci, 2009). • Spying software (Mendyk-Krajewska and Mazur, 2010, p.436). • Trojan horses (Mendyk-Krajewska and Mazur, 2010, p.436). • Threat of backdoors(Mendyk-Krajewska and Mazur, 2010, p.437). • Gumblar attack (Mendyk-Krajewska and Mazur, 2010, p.438-439). •Threat of breaking the existing security of wireless network.	• Introspection feature of VMM can cause confidentiality issue (Cleeff, 2009). • no physical connection between the servers (Frangiskatos, 2010). • isolation among the VMs is not strongly maintained (Reuben, 2007). • VM escape attack(Reuben, 2007). • Guest to guest attack (Reuben, 2007). • Hypervisor hijacking (Reuben, 2007). • Virtual hub between VM (Reuben, 2007). • double encapsulation attack (Esensten, 2011). • VN to VN attack in NV(Natarajan & Wolf, 2012, p.539).	• Worm and viruses through unmanaged pc (Hocking, 2011, p.18). • Laptop theft RAM (Pasquinucci, 2009).	• Organizations unaware of the recycling policies (Andy, 2005). (AVenter, 2007 & Jones, 2006) (Kwon, Lee & Moon, 2006). •No check and balance of computer recycling process (Kwon, Lee & Moon, 2006).

6.2.1 Discussion of Key Finding in Relation to Thesis Question: How Green IT practices can impact the information assurance and security?

The contribution of IT in increasing CO2 emission has push the government and IT business sector to go for Green IT solutions such as cloud computing and thin Client in computer designing and manufacturing. Similarly the way we are using the IT is also getting change via Green IT solutions of virtualization, going paper less, moving towards the internet computing, travel reduction.

Furthermore, recycling schemes of electronic compute is also getting change. Now is Green IT encouraging the recycling of computer hardware and electronic equipment. All these Green IT solutions have their own set of implementation and bring own security challenges as mentioned in Section 6.2 and discussed earlier in section 5. Leading example of the security issues has brought through virtualization, virtualization of data centre which has many security issues such as escape of hypervisor, guest to guest attack, and vulnerabilities in the features of hypervisor, escalation of privileges, compromised of host machine etc. Second example is recycling of large no of computers where the poor polices and process of recycling are followed. Such recycling process is a great threat to privacy and confidentiality of data.

4.2. Research Delimitations

Although the thesis has been successfully accomplished but following are the limitations. The limitation is about the available literature, very few literature are available who talk about the Green IT and security together. Most of the literature only talks about the importance and advantages of Green IT. Few of the articles who speak about Green IT in terms of security. These few articles are based on observations, personal and experts' opinion or either only discuss the virtualization as green it solution threat to security. But this limitation is overcome by identifying the green solutions in all area of design, manufacturing, use and disposal. Than continued the research for each green solution and also combine the scattered literature about Green IT and its associate security threats in Green IT solutions.

4.3. Future work and Recommendation

This thesis employs the literature study to provides the gainful work to address and list the information security threats and vulnerabilities, however this require further studies to elaborate how to tackle these security issues and what security counter measures can be applied to strengthen the security aspect of Green IT. The continued use of systematic literature review could be followed to identify mitigation of found security issues. Beside the literature review, government institutions, IT organizations that encompasses Green IT solutions the environmental sustainability, could be greatest utility, to gain on hand experience and working security measures. In depth, a case study could also be recommended to inform the associated security issues along with the proper guidance how to control and minimize them. Another research idea, A Delphi study , a method of an iterative process used to collect and distill the judgments of experts using a series of questionnaires interspersed with feedback (Skulmoski, Hartman and Krahn, 2006), can be adopted for the accomplishment of thesis. But unfortunately due to the limited number of contact and resources are available to carry out this method. Limited number of judgment is not sufficient to justify the result of thesis.

This thesis and future work can also contribute and help the Green IT sector, how to manufacture computers, design software and hardware, how to use electronic equipment and technology and in last how to proper recycle, to achieve the both goal of information security and assurance and a more sustainable environment.

Thus the significant future work required here to investigate about the security control measure to overcome and minimize the identified security threats and issues. Assure the degree of confidence that security features, architectures and security policies are properly applied on information system. These recommendations allow Green IT to be implemented in a way which leverages

the strengths the green technologies and allows implementation of security controls to mitigate the security weaknesses.

Thesis results also address the security professionals, chief information security officers and managers to plan necessary strategies and policies to make the solution more security immune.

Although going green is becoming necessity of time, not an option (Murugesan, 2008) and have many benefits besides reduction in energy consumption but Green IT implementers should also consider security loop holes in green IT and involve the security experts, and professionals to plan best practices, principles and policies to tackle the security issues. Also use the IA program, to include the risk management, when moving the existing traditional processes and IT solutions to Green solutions. IA and risk management plans ensures the protection of sensitive information while still remaining Green.

4.4. Conclusion

High power consumption data centre, under-utilized IT resources, paper consumption, nonrecycling hardware with dumping on landfill, poor recycling policies are proof that IT is helping to destroy the planet (Webber and Wallace,2009). Therefore government and IT industries are playing their role and are in process of adopting and planning Green IT to save the planet.

Green IT is about incorporation and implementation of new solutions such as thin client, cloud computing, virtualization, paper reduction, mobile computing, travel reduction, computer recycling. All these Green IT solutions have their own implementation procedures and security challenges.

Therefore, Thesis has examined Green IT from a different aspect of information security and assurance.

This thesis had made several contributions to the research on the Green IT field and its security threats. This literature review research links the Green IT technologies on security posture and performance for any organization using it.

Thus it provides additional insight to information security and assurance weaknesses in the field of Green IT. The key findings of the thesis validate the postulate that the going green concept will bring the additional security issues if not properly measured and controlled.

Thus thesis conclude that Green IT practices not only have the common security threats and vulnerabilities but also more specifics security risks and vulnerabilities due to the greening aspects, and techniques, such as, privacy and confidentiality issues of cloud computing due to its growing size of multi-user environment, integrity issues due to malware attack in NetApp loading and many more. Virtualization also has various issues like escape of hypervisor, guest to guest attack, escalation of privileges etc. and in last poor recycling polices and policies also compromised the data confidentiality and security. Surely, Green IT solutions also has many green benefits for the environmental sustainability and business itself but the facts as in section 6.2 speak themselves, that the Green IT solutions also have limitations in terms of information assurance challenges and Is Green IT Threat to Security? information security issues and threats and One cannot ignore them just to avail all the green benefits In nutshell, thesis results and findings are valuable and in the interest of the organization who are planning to take part in the movement of CO2 reduction by ICT while achieving the business and cost reduction benefits from Green IT. Green IT is found suitable to reduce the greenhouse gas emission and to save the planet but also lead to increase in security threats and risks and could bring security threat to business values and information if not properly understood and mitigated. So to win the planet and along with the fulfilling the business need securely, it is necessary not to forget the security aspects in going green. For the successful and secure Green IT implementation, one should completely know about the business and fully

assess it to see how and where we can make the organization business process and system greener. Then make plans about how to incorporate Green IT solutions and practice of virtualization, cloud computing, thin client, green data centre and computer recycling. This will enable the organization to implement Green IT under Information assurance strategies that facilitate a balance level between both, Green IT and security.

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