Contribution of Cloud Computing in the Reduction of Carbon Dioxide Emission

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ABSTRACT

The Information Technology industry is rapidly expanding and as a result its contribution to carbon dioxide emission is also rapidly increasing. Fortunately, the cloud computing industry is perceived by many to be a viable solution for reducing carbon dioxide emissions. Accordingly, there are numerous studies which try to prove that cloud computing can reduce carbon dioxide emissions up to more than half of the current carbon dioxide emissions. In this paper, two of such studies where reviewed to assess whether cloud computing is indeed a viable candidate for limiting and reducing the amount of carbon dioxide emitted by the IT industry. All the information gathered in this paper prove that; cloud computing is a promising technology which could reduce carbon dioxide emissions. The percentage of decrease can range from 10% to 90%. The effectiveness of the carbon dioxide emission reduction process is highly dependent on the size of the business organization. Accordingly the size of the organization is negatively correlated to the efficiency of carbon dioxide reduction. This means that as the size of the organization increase, carbon dioxide emission reduction decrease. This paper also presented the four reasons why cloud computing can reduce carbon dioxide emissions, which are: dynamic provisioning, multi-tenancy, server utilization, and data center efficiency.

Keywords: Carbon dioxide emissions, Green computing, Cloud computing.

I. INTRODUCTION

Advancements in different industries pose great threat to the environment. The Information Technology industry is not an exemption from such. In fact, the said industry grows so fast that its contribution to the overall carbon dioxide emission is predicted to reach 1, 430 metric tons by the year 2020 [1]. Fortunately, numerous studies have shown that such contribution can be reduced by 50% or more, if the new IT invention called cloud computing will dominate the industry in the near future [2].

II. THE IMPORTANCE OF REDUCING CARBON DIOXIDE EMISSION

When carbon dioxide is in excess in the atmosphere it can cause significant damage to the environment. This is because carbon dioxide is a greenhouse gas, which means it absorbs light from the sun and turns it into molecular vibrations. These molecular vibrations produce heat causing the environment to heat up. Too much carbon dioxide will lead to the increase in the average global temperature. When this happens, different catastrophic events such as relatively strong typhoons, desertification or the increase in desert areas, etc., take place. Such events can then pose adverse effects to the economy and to the lives of people all around the world [3].

Reducing carbon dioxide emission takes a concerted effort from the public, private & public industries, and businesses; hence, the IT industry is not exempted, despite the fact that it contributes relatively lower direct

carbon dioxide emissions compared to other industries, such as the energy or mining industries. In fact, the total carbon dioxide emission of the IT industry is only approximately 5.6 billion metric tons equivalents during the year 2011 – the IT industry contributes only 0.000014% of the total carbon dioxide emission worldwide [4]. Nevertheless, it should be pointed out that the only the direct carbon dioxide emissions were included in this computation. Note that the majority of IT infrastructures need electricity to run and metals, semiconductors and plastics are needed to create hardware. The IT industry is growing at a very high rate which would mean a greater demand for energy, and hardware materials [3].

Table 1: Increase in energy consumption of the IT industry

	Electricity Consumption (Billion kWh) 2007	Forecast Electricity consumption (Billion kWh) 2020	Corresponding carbon dioxide Emissions (MtCO2e) 2020
Data Centers	330	1, 012. 02	533
Telecoms	293	951. 75	501
Total Cloud	623	1, 963. 74	1034

Note: MtCO2e = Metric Tons Carbon Dioxide Equivalent; Data Source: Greenpeace.org

Based from the information in table 1, the amount of carbon dioxide emitted from the production and consumption of electricity of the IT industry will continue to increase despite the project increase in use of the cloud computing technology up to year 2020.

III. THE CLOUD COMPUTING TECHNOLOGY

In order to understand more fully how cloud computing can reduce carbon dioxide emissions, it will first be necessary to understand what it is and how it works. Accordingly, cloud computing pertains to the centralization of all the applications, functionalities, databases and servers into one virtual space called the cloud. In other words, it is the internet-based storage for applications, files, and infrastructure. The concept had been in use for several decades now and is being used by numerous people all over the world whether they are aware of it or not. Social networking sites such as Facebook, Twitter, Pinterest, and even emails use this technology. The technology works as follows: when a person saves his documents into his or her email account he or she is not using his computer's memory but is storing it somewhere into a database - an internet-based storage device. The person who stored the documents and others who are given permission to view them will be able to access them almost anywhere at the same time - this is the principle behind cloud computing. Nevertheless, cloud computing is in a much larger scale in the sense that files and documents are not the only things which are stored and accessed but applications and infrastructures [5]. An illustration of how cloud computing works is shown in Fig. 1.

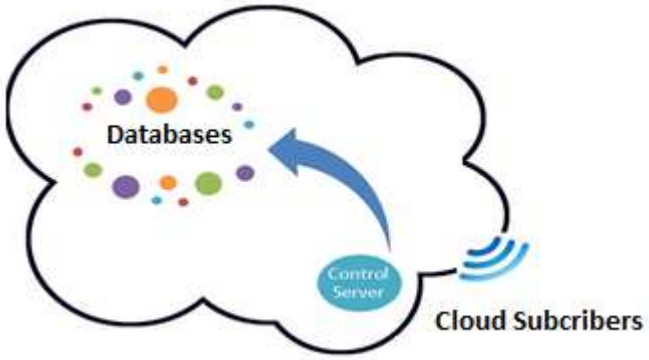

Figure 1: Illustration of the cloud computing technology

Fig. 1 simplifies how the cloud computing technology works. Accordingly, a cloud computing owner controls everything in the cloud. The owner uses the control server to mediate between the databases and the cloud subscriber who requests access to these databases. Note that databases are in different colors to mean that they contain different applications or serve different functions. The control server can gain access to numerous databases which contain different functionalities and different applications, which cloud subscribers need. These databases are contained in one physical place; they are maintained and operated by engineers and programmers in that place. When a cloud subscriber, which may be an individual or an entire firm, wants to gain access to a particular functionality, let us say a programming environment for creating software, the subscriber establishes a connection with the control server. The control server then selects the appropriate database for the subscription and then connects it with the subscriber. The control server will also be engaged in monitoring the use of the database. A cloud computing system may also offer a blank database for data storage where firms can store their data. The control server can then be used a means of controlling who could access the firm's information. Cloud computing technology also uses the wireless internet technology allowing multiple users to access a single database anytime and anywhere.

IV. CONTRIBUTION TO THE REDUCTION CARBON DIOXIDE EMISSION

How this technology contributes to carbon dioxide emission reduction is based on the fact that it uses less physical space for databases, and it can optimize the use of these databases. Accordingly, all the databases can be contained in one physical place. These are super computers connected to each other to store, process, and transmit information. Since they are contained in a single physical place they can be maintained at minimum costs. A single cooling system, for example, can be used to keep the temperatures of all the hardware of numerous databases. What this means is that; cloud computing technology is energy efficient to maintain and to use. Note that energy production and consumption is the number one cause of carbon dioxide emissions. This means that cloud computing has less carbon footprint than the older computing systems or technologies. Moreover, a firm or an individual's need for computing functionalities may vary over time; for example, the number of employees using the subscribed functionality may increase or decrease over time. In the older systems, the change in the number of users, let us say from 10,000 users down to 1, 000 users, will put to waste each computing application installed on the 9, 000 computers. If the computing application was installed using CDs, which would be the most normal medium for transferring applications in the old computing technologies, the process for producing the CDs by itself contribute significantly to carbon dioxide emissions. With the cloud

technology a firm may choose to scale up or scale down on its use of certain applications by simply limiting its access to the cloud through the control server.

V. RELATED STUDIES

The next question which would probably enter one's mind is: are there any proofs for carbon dioxide emission reduction in using cloud computing technology over the old computing technologies? The answer to this question is, "yes." One proof is the research conducted by Accenture, Inc. Accenture is an outsourcing company, which is involved in conducting software-related research for many prestigious firms. One of its recent clients was Microsoft, Inc. The latter hired Accenture and another firm called the WSP to conduct a research which aims to determine how much carbon dioxide can be reduced in using cloud computing technology compared to using old computing technologies. Accordingly, Accenture, Inc. and WSP Environment and Energy created a quantitative model which allowed them to calculate the energy consumption and carbon footprint of a business organization's IT applications which were used in two different set-ups: the first uses the cloud while the other uses an old computing technology called on-premise deployment. Note that on-premise deployment simply means that the servers used for the computing task are owned and operated by the business organization. The said model was created to quantify energy and carbon consumption is a "per-user" basis. The model also assumes that on-premise server counts do not necessarily follow a linear scale in energy and carbon consumption as user the numbers of users increase. Based from these assumptions three different sizes of samples were studied, namely: small, which is composed of 100 users; medium, which is composed of 1, 000 users; and large, which is composed of 10, 000 users. Three Microsoft applications where used for each user, which includes: Microsoft Exchange, Microsoft SharePoint, and Microsoft Dynamics CRM. Results of the study revealed that cloud computing technology relative low carbon dioxide emissions in a per user basis on all samples and set-ups. Figure 2 illustrates this difference.

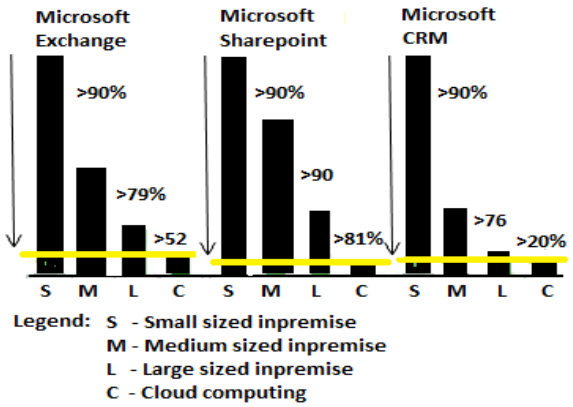

Figure 2: Percentage carbon dioxide emissions of Cloud Computing-Based vs. On-Premise Delivery of Microsoft Exchange, Microsoft SharePoint, and Microsoft Dynamics CRM [6].

It is evident from figure 2 that cloud computing could reduce carbon dioxide emission up to 90% - the lowest reduction rate is 20%, which is for the large-sized sample. Another interesting finding in the study was; that as the size of the cloud increases its efficiency in utilizing energy and carbon consumption decreases. This means that as the size of the cloud or the number of users using the cloud increases, the degree of carbon dioxide reduction decreases. Accenture, Inc. also identified four (4) key factors which allowed cloud computing to lower energy and carbon consumption. The first key factor was Dynamic Provisioning, which pertains to the decrease

in the amount or number of wasted computing resources made possible by better matching of the capacity of the servers with actual demands. The second key factor was Multi – Tenancy, which pertains to the flattening relative peak loads made possible by providing service to large numbers of users and organizations on shared infrastructure. The third key factor was Server Utilization which pertains to the high utilization rate of operating servers. Finally, the fourth key factor was Data Center Efficiency, which pertains to the utilization of advanced data center infrastructure designs which could help in the reduction of power loss through improved power, conditioning, cooling, etc. [6].

In another study conducted by the Carbon Disclosure Project, they have shown similar results to that of the aforementioned research. In their experiment, however, the range of carbon dioxide emission reduction is from 10% to 70%, which is a little lower by the average to the results of the aforementioned study. Nevertheless, the average carbon dioxide reduction rate for both studies is still significantly large (more than 50%) proving that the cloud computing technology is a greener IT system compared to the traditional computing technologies [7]. Numerous other studies have shown similar results [8] [9] [10] [11].

VI. THE AMOUNT OF REDUCTION OF CARBON DIOXIDE EMISSIONS

To have a better picture of how significant the computed average carbon dioxide emission reduction is (>50%), it is necessary to have real carbon dioxide emissions values for the IT industry [12] [13]. Greenpeace, a non-government organization which is concerned with identifying environmental concerns and addressing them has presented the amount of carbon dioxide emitted by the IT industry in the world wide scale [1]. A summary of the computed values for carbon dioxide emissions is given in table 2.

Table 2: Increase of carbon dioxide emission by the IT industry from 2007 to 2020 and its possible reduction through the cloud computing technology

	Emissions 2007 ($MtCO_2e$)	Emissions 2020 ($MtCO_2e$)	Emissions with Cloud Computing 2020 ($MtCO_2e$)	% Reduction
World	830	1430	< 715	> 50%
Server farms or data centers	116	257	< 128.5	> 50%
Telecoms, Infrastructure, and Devices	307	358	< 179	> 50%
Personal Computers, and peripherals	407	815	< 407.5	> 50%

Note: $MtCO_2e$ = Metric Tons Carbon Dioxide Equivalent

It can be seen from table 2 that more than 50% reduction in the carbon dioxide emission through the use of cloud computing could be achieved, which would reduce the carbon dioxide emission to its initial level 13 years back from 2020. In other words, despite the predicted growth of the IT industry, its carbon dioxide

emission will remain low even up to the level that it emitted in 2007. Nevertheless, it should be pointed out that the 50% reduction is only the average of the reduction levels determined by the studies conducted by Accenture, Inc. and Carbon Disclosure Project. It is important to remember that this average reduction level is dependent on the number of small, medium, and large IT infrastructures [14] [15]. Accordingly, if the number of large IT infrastructures is more than that of the small IT infrastructures, then the average carbon dioxide emission will shift downwards approaching the 10% t0 20% levels of reduction. If this is the case then the reduction may become insignificant and the environmental purpose of cloud computing technology will not be met.

VII. CONCLUSION

Heretofore discussed is the information on cloud computing technology; particularly, its potential to be considered a green technology by because of its ability to reduce the amount of carbon dioxide emissions. The reasons why cloud computing technology could indeed reduce carbon dioxide emissions, as well as the reasons why the IT industry should strive to minimize and reduce its carbon dioxide emissions were also discussed. Two studies which experimented on the efficiency of cloud computing to reduce carbon dioxide emissions were presented and analyzed to arrive at the following conclusions: it can be concluded in this study that cloud computing is a promising technology which could reduce the current carbon dioxide emissions by 90% with the average and minimum reduction capacities equivalent to 60% and 10%, respectively. It is also conclude in this paper that the size of the IT organization using the cloud computing technology must be considered in order to optimize the environmental benefits of cloud computing. Accordingly, cloud computing business must avoid large scale use of cloud computing software. Large scale mean above 10, 000 users using the same application at the same time. This is because at this level the carbon dioxide emission reduction begins to decline to 20%. The decline will continue as the scale or size increases until the reduction rates become insignificant. This means that it will be more beneficial for the environment if cloud computing business keep their number of cloud subscribers between medium and small sizes. Doing such will maximize the carbon dioxide emission reduction. Moreover, it should be noted that there are other industries which are strongly linked to the IT industry that contribute to carbon dioxide emission. Accordingly, the hardware manufacturing industries, and the energy industry should also improve their processes so that the indirect carbon dioxide emissions associated with the IT industry could also be reduced. Lastly, it is concluded that reducing carbon dioxide emission requires more than just inventing highly efficient devices or business process concepts; it requires sincere and careful assessment of the strengths and weaknesses of the invention so as to achieve the ultimate aim of protecting the environment.

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