Introduction to Cloud Computing

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Abstract—Green Computing concept cover a list of technologies, laws, protocols, standards, regulations, initiatives, certifications, company groups, computing style and lifestyles applied to IT (*Information Technology*). In this paper we do a little introduction of this concept plenty of meanings to make a better understanding of it. We focus on the technologies applied from top to bottom, from datacenter to the inside of the servers and the humans.

Keywords—Green Computing, Datacenter, Energy Consumption, Money, Environment.

1 Introduction

The environment is the first thing that come to your mind when you heard "Green Computing". But this concept was caused not only by the environment, by the money also. In the 90's common and IT people start to think how IT affect to enviromental sustainability. It started with advices and news and in few years conferences and groups came up.

In this paper we will explain briefly how Green Computing affect to current technologies in each layer of the IT. Firstly we will start with the reasons (Chapter 2), secondly we will explain what exactly is Green Computing (Chapter 3) and finally we will develop how Green Computing is applied in the datacenter, computer systems, hardware, software and humans(Chapter 4) with conclusions(5) and clarification(Appendix A and B) of answers that came up in the presentation.

2 Why Green Computing

As we said in the introduction1, the money and the enviroment were the main reasons to create Green Computing. In the latest decades, facts such as global warming, ozone layer destruction or energy wasting are (or should be) in the news and in our mind. But when the money come into play is when the people start to think and research in saving money and natural resources. The following data help us to understand how important is the meaning of Green Computing nowadays.

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2.1 Some data

A server spend around 120W [1], so each rack of servers spend around 10kW(each rack contains up to 80 servers [2]). If we include the infraestructure (cooling system, UPS...) it reach around 10MW. This amount of energy cost per month around 1500$, only one server. If we focus on the datacenter, it is stimated [1] that in 2006 all the 6000 Datacenters in USA spend 61 billion kW/h (1,5% of total U.S electricity consumption that year) which cost around $4.5 Billion in electricity cost. This was costs-equivalent to 5.8 million average U.S. households. Actually is not only money, we can see in this infographic the cost of one or all monthly Google searches in terms of kW/h and CO2 carbon footprint. The total carbon footprint of ICT is 2% of total in the world, the same than aviation.

3 What Green Computing is

In this chapter we will see theorical definitions given by researchers that tried to do an approach to the meaning of Green Computing.

San Murugesan in [4] explain green computing as "the study and practice of designing,

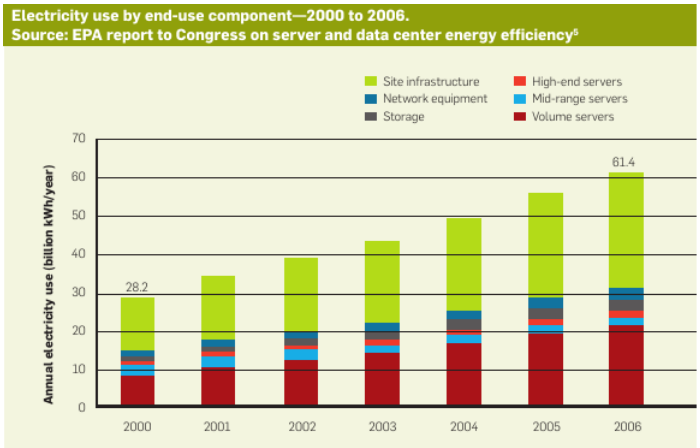

Fig. 1. Graph:Electricity use by end-use component-2000 to 2006. Source [1]

Electricity use by end-use component—2000 to 2006.
Source: EPA report to Congress on server and data center energy efficiency[5]

	2000		2006		2000–2006
End use component	Electricity use (billion kWh)	% Total	Electricity use (billion kWH)	% Total	Electricity use CAGR
Site infrastructure	14.1	50%	30.7	50%	14%
Network equipment	1.4	5%	3.0	5%	14%
Storage	1.1	4%	3.2	5%	20%
High-end servers	1.1	4%	1.5	2%	5%
Mid-range servers	2.5	9%	2.2	4%	–2%
Volume Servers	8.0	29%	20.9	34%	17%
Total	28.2		61.4		14%

Fig. 2. Table:Electricity use by end-use component-2000 to 2006. Source [1]

manufacturing, using, and disposing of computers, servers, and associated subsystemssuch as monitors, printers, storage devices, and networking and communications systems efficiently and effectively with minimal or no impact on the environment". As we can see in this definition words such as computers and enviroment are included. Here also talk about the manufacturing process. We will see in Section4 how this process is involved. Andy Hopper in [5] defined Green Computing as "A multifaceted, global effort to reduce energy consumption and promote sustainability." We think that this is a best approach because here mention one of the (or the most) important word of Green Computing: "energy consumption".

4 How Green Computing is

Once we know the reasons (2) and the meaning (3) of Green Computing, in this chapter we will do a route through all the IT layers. We will start on the datacenter and we will gradually go down finishing in Green Computing applied to humans. We will explain firstly the problems that we had or we have currently, then we will explain the solutions reached and we will finish with the "Green Computing technologies" used.

4.1 in the datacenter

As we see in Figure 1, the huge global electricity use of the datacenters was growing during the years. This growing was faster than the earning or clients of each company, so eventually this would turn into financial loss.

The table in Figure 2 helps us to know the first main problem:50% of electricity consumption belong to site infrastructure. Then the volume servers are around 30% and the remainder is shared between network equipment, storage, high-end servers and mid-range servers. Another problem is that in some USA regions such as Manhattan are physical limitations on power availability to make another datacenter [1]. Big companies want to have their datacenters in the best possible location to have a better QoS (Quality of Service). To solve these problems, companies such as Google built datacenters outside USA (this is the trend [3]), for example in Finland or Belgium. Google's Hamina Datacenter is well know in Green Computing world because its special energy sources and cooling system. This datacenter take some of the energy with wind turbines. Also is designed as we see in Figure 3. The datacenter take water from the Gulf of Finland, then with sea water pumps it pupms water in cooling modules which chill inside the datacenter (datacenter workload). This kind of technologies are constantly developed to get a better performance of the datacenter.

4.2 in a computer system

We saw above the energy cost of infrastructure, but also the computer system spend huge amounts of energy. Traditional designs focus primarily on system performance [6] but did not think in the power consumption. We think that there are two kind of solution to these

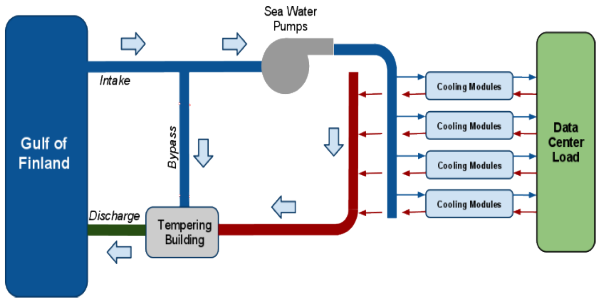

Fig. 3. Hamina's internal structure

problems: change the system or control the system.

changing the computer system

When we talk about "changing the computer system" we mean another ways to process a task. There are two main "Green Computing ways": Cloud Computing and Grid Computing.

- Cloud Computing: thanks to the Internet we can spend someone else's power [6] doing the computation in "the Cloud" and giving the result in mobile devices, which consume less power.The most recent study [7] in this filed set that Cloud Computing can save up to 87% of IT energy.
- Grid Computing: we can save energy distributing effectively compute-intensive parallel applications on grid [8].

controlling the computer system

Another solution is to take a better control of the system. The main goal is to consume the minimum amount of energy required to perform any task [6]. There are plenty ways to do it, the following is a list with some solutions:

- Virtualization: using virtualized enviroments we can save energy because the resources are better used. We can virtualize in many layer, and solutions such as LiteGreen [9] helps to save around 70% of energy compared to manual power management.
- Power Management: doing this with technologies such as *ACPI* [1] we can do a optimal energy use. We have to take in account that the system must be prepared for the changing demand. Another energy-aware solution is power off or sleep idle servers. To have enough technology to do and control these garantee do not waste energy.

4.3 in Hardware

In Hardware field we have the following problems. As we said, the systems (that is, the hardware and software) are made to give the best performance. Also sometimes one CPU is too much to do a small task, so when we have a CPU to do small tasks we are wasting resources. Finally the fact that each PC is made from 1.8 tonnes of chemicals is not a good fact for the environment. To solve last problem, manufacturers are fighting for creating the most earth friendly computers with recycled components,materials and trying to extend the expected life-cycle of the Hardware [5]. With sensor networks and embedded systems [10] we can deal with small task in a Green Computing way. Finally improving the hardware circuits, and with technologies such as power efficient CPU cores (*turbo boost*), memory bank partitioning or SSD hard drives we can have an efficient energy consumption [6].

4.4 in Software

In Software field the main problem is that algorithms do not care about energy consumption. This is related with one of the main problems in Green Computing: long time ago the researchers and manufacturers did not care about the energy, only they tried to give the best performance. Also we have few energy-aware software technologies. To solve these problems, we bet for energy efficient coding (*The Evolution of Application Software [1]*) and of course we have to try optimize software such as DataBase Management Systems, Operating Systems and applications to do the same output with a balance between time consumption and energy consumption.

4.5 in humans

The last years of industrialization, a lot of changes have been made in humans life. Some of these changes have an important effect to some essentials of life such as Earths flora and fauna and the whole environmental system of Earth. Many of the proposed solutions have an engineering orientation and are based on current technologies. Information systems can play an important role in sustainability improvements. More explicitly information systems can help in the promotion of a sustainable environmental information strategy to parallel and complement engineering solutions. Its a fact that many people want to maintain a sustainable lifestyle, but they do not know how. It would be helpful for the society and for the improvement of human life to organize and exploit information systems in order to achieve that. Information systems and people related to computer science can play a critical role in order to adopt and promote this strategy. ACM (Association for computing machinery) members could participate in creation and implementation of such an information strategy. Its a fact that Computing professionals and academics have many of the required skills to help solve the problems of surrounding sustainability. Based on their experience, and knowledge it is possible to design and implement such a strategy for information systems. This article [**?**] focuses on the aspects of this need based on several imperatives. These imperatives arise from two views about human behavior rational and social. The rational view, takes two perspectives Individual rationality and collective rationality. Individual rationality however, does not always lead to collective rationality.

The Role of Information in Rational and Social Behavior

The first problem that arises from the lack of such a strategy is that from a sustainability and societal perspective, prices are not always an effective signal because of the presence of externalities, which represent costs absorbed by society rather than the producer. Moreover one of the problems of the current economic system is that prices are not aligned with sustainability goals. At present, there are no data streams and associated information systems that economists and legislators could use for setting fees and establishing regulations and social interventions to ensure that prices reflect externalities. A proposal to this problem is to create information systems and networks that provide the capacity to incorporate significant environmental costs into prices. Another problem is that many organizations and individuals have a positive attitude toward the environment and seek to make sustainable choices. It is often difficult for them to follow these beliefs because they lack information about the environmental consequences of those decisions. Information, which helps to form perceptions, is critical to the functioning of our social as well as rational side. Three streams of information can influence perceptions about sustainability: organizational sustainability reporting, product information, and feedback on individual environmental impact. This fact implies that the need for sustainability reporting is emergent. Thus a possible solution to this problem can be the design of corporate sustainability reporting systems that achieve the goal of a more sustainable society. Furthermore another problem of the current system is that many products do not include labeling information to provide data on the nutritional value of food and the chemicals in drugs. Computing professionals can play a key role in defining the data standards for consumer environmental calculations and then designing systems for making this data publicly and conveniently accessible. In this way, consumers can be helped to choose greener products and understand the environmental consequences of their purchasing decisions. A possible proposal to this problem is to develop information systems that provide individuals with accurate, meaningful, and actionable information about the environmental impact of personal decisions. Finally its a fact that such an information strategy requires processing and storing more information. Certainly what we should avoid is a situation where the energy required for storing and processing this information to have as a result harmful emissions. A solution to this problem can be the development of professional standards for data processing and storage that minimize their environmental

consequences, while simultaneously helping to create a sustainable society.

5 Conclusion

For now the most important thing is to address all these problems in order to involve information systems to an Information Strategy for Environmental Sustainability. In order to achieve this goal the ACM members, both collectively and individually, must apply their computing knowledge to contribute to the creation and implementation of an information strategy for a sustainable society.

Appendix A
About the Google search carbon footprint

The first question that came up in the presentation was the doubt, the mistrust of data showed in this Google search infographic. There were two options: the data were collected taking in account the diference between instant power consumption when the server is processing the search request less power consumption when the server is idle (as we suggested) and other option is that they only took in account the search request power consumption (so the infographic is not so well). We were looking for an asnwer in numerous sources, and we have not found a clear answer because these kind of researchs are closed for security reasons. But we can add that these data were discussed a lot during these days and a researcher that indicated the opposite had to make a clarificationclarification maybe grant confidence for first option. Furthermore, in another researches such as this one in *Chapter V Experimental Results* (page 7), we read "We call this the active power, which is basically the measured power during query processing less the idle power of the server.", so would be difficult that other researchers do it in another way.

Appendix B
How cloud computing save energy

Regarding to the doubt about the Could Computing energy saving, we explained the fact that in Could Computing one file can be shared by more than one user (by links), different from common computing where if I send you an email with a file both save this file in each mail server. This is an example of resource reduction desired in Green Computing. To make a best clarification of this fact, we send to the reader to Reference [7] where you can find a research of this month that mention up to 87% of energy reduction with Cloud Computing.

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