Temperature Responsive Monitoring System for Smarter Energy Consumption in Data Centers

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Abstract

The need for energy savings in companies, especially in developing countries, encouraged the execution of this study, which presents an analysis of how the integration of free software and hardware with sensors can monitor and manage electric energy consumption in a responsive thermal system in a Data Center. In this way, the developed system can reduce energy input costs and improve the availability of the services offered by the Data Processing Center. The experiment was made using a temperature sensor, a non-invasive current sensor, Arduino Uno, Raspberry PI and Zabbix. Therefore, using the proposed system, it was possible to save an average of 20% of energy in a monitored environment when compared to an uncontrolled environment.

1. Introduction

Nowadays many scientists and societies are concerned about environment degradation inflicted by men, with energy production and consumption being one of the main causes of this negative impact in ecosystems. In addition to environmental concerns, companies in many countries are also concerned about higher energy costs derived from rising energy consumptions.

Regarding technology and data processing, one of the greatest consumers of energy are Data Centers. According to Corrêa (2014), Data Centers are basically a physical structure that was designed to house a variety of resources that provide network equipment, servers and telecommunication storage and management.

The wide use of the Internet and the new ways of storing data generate large amounts of data, which in turn needs to be stored and processed in Data Centers, thus causing an increase in requirements related to these structures. According to Dayarathna et al. (2016), of all the energy consumed in a Data Center, 50% is due to its cooling systems, used for maintaining the equipment in certain preset temperatures.

Bottari (2014) states that Data Centers cooling systems are necessary because of the equipment sensitivity to high temperature and the need to dissipate heat is high. Higher temperatures can shorten the useful life of equipment and also lead to failures. Besides hardware damage, information technology (IT) service interruption can be extremely costly for the companies.

According to Brown (2008), "more than 70% of the Data Center operators have identified the cooling system as the main cause of installation management problems". Bottari (2014) also highlighted that the probability of failures due to higher temperatures entails an increase in Data Center's cooling capacity and results in additional energy expenditure. It is common that the cooling system is designed to withstand possible failures of the equipment responsible for temperature control, thus creating an exorbitant structure that ends up generating an increase in the energy expenditure in Data Centers.

On the other hand, companies are pressured to save energy, not only due to financial reasons but also to environmental impacts related to energy generation. Therefore, companies have the challenging task of worrying about the impact caused in nature and remaining competitive in the market, reducing the cost of operation.

These circumstances encouraged the execution of this study that aimed to integrate free software, free hardware and a set of sensors in order to obtain a responsive thermal monitoring system to manage consumption of electrical energy in a Data Center in order to reduce energy consumption. The following section will address how information technology can be more efficient and assist in meeting efficiency goals.

2. Sustainable Information Technology

Nowadays, awareness that societies must preserve the environment is increasing. The energy consumption is directly linked to the environment, because the more energy is consumed, the more CO_2 is released into the atmosphere generating problems such as greenhouse effect and human and animals related health issues.

According to Cavalcante et al. (2012), environmental and economic aspects are leading corporations to think in more efficient and sustainable ways in relation to the use of IT resources. According to IBM (2007), "for most CEOs, whose sights are firmly fixed on business growth and expansion, energy consumption and environmental concerns can take on a whole new meaning when they begin to impede the company's ability to grow".

In this way, besides the financial benefits, "Green IT" practices also help companies improve their market image since companies with environmental concerns are better viewed by society (Vieira et al. 2009). In addition, international standards such as ISO 14001 encourage institutions to make their processes more efficient concerning environmental impacts. In this scenario, one of the first steps towards implementing more environmentally friendly processes is the reduction of energy consumption.

Just to highlight some successful cases, IBM started a behavioral environmental change in 2006 and managed to reduce 5.72% of electricity consumption and 14% of water by using simple attitudes such as turning off the lights and closing faucets. Also in that year the company was able to recycle 85% of its waste (Vieira, et al., 2009).

Real Bank (Brazil) won the Banker Technology Awards of 2008 due to the results achieved by its efficiency program. They replaced 180 conventional computers with 160 Blade PC, which obtained an estimated reduction of 62% in consumption of electric energy by computers and 50% reduction in the consumption of air conditioning used in the operating tables. Besides the reduction of costs, the project also improved the management and maintenance of these structures (Yuri, 2008). Real Bank also replaced four physical servers with virtualized servers and achieved estimated savings of 40% in the electric consumption of air conditioning in its Data Centers, in addition to the estimated space gain of over 70% (Renner, 2008).

The application of more sustainable IT focuses on some tools and technologies, as pointed out by Cavalcante et al. (2012): energy management, green data center projects, server virtualization, cloud computing, responsible disposal and recycling of electronic waste and the use of renewable energy sources.

Among these, virtualization procedure does not require large investments because it normally uses hardware resources already in place in the companies. The main goal of virtualization is to increase productivity, management and high availability (Silva & Júnior, 2013) without incurring additional energy expenses.

Server virtualization provides reduction in equipment acquisition, power and space. This operation allows a single server to store various operating systems and applications. The concept is basically the existence of several computers in one. These virtual computers do not differ in any aspect to real computers as far as performance is concerned; the only situation is that they do not exist in a physical form.

In turn, the application virtualization allows running an application and protects the operating system from potential problems that could compromise its performance. In this arrangement, applications do not have access to system information, such as registry keys, system libraries, etc. In application virtualization the resources used by applications are fully managed by the virtual machine (CITRIX, 2015).

With virtualization it is possible to provide remote access to applications and data from any device, and thus maintain the productivity of mobile users. It is also possible to highlight that security is enhanced with this technique, such as controlling and encrypting access to data and applications (CITRIX, 2015).

Another way for energy-saving and service automation is to use nano-computers and microcontrollers. Due to their small size and low power consumption, these technologies are often used in home automation, automotive and monitoring systems. They have become a great alternative to control environments and take actions, being possible to find these technologies present in thousands of devices like, washing machines, microwaves, telephones, keyboards, monitors, etc. (Rodrigues, et al. 2013).

Some of the most common usages for this type of IT equipment are network servers, where instead of using an appliance or dedicated server, generating higher costs, energy and maintenance, a nano-computer is allocated to accomplish this task, reducing costs, space and maintenance (Henes, et al. 2008).

In the next section, the methodology of this work is presented with the aim to show in details how the experiment was made.

3. Methodology

This research has an exploratory character. According to Yin (2005) an exploratory research aims to provide more information on a given subject. The exploratory nature of this study is confirmed due to the need to obtain more information about the real energy consumptions of the Data Center. This research presents a case study, which according to Yin (2005) is a unique experiment, planned and designed for an exclusive event. Since this survey has a sample and a unique environment, it meets these conditions. This study uses an appliance called Arduino and the data analysis collected by it in a real production company environment (Data Center).

This is an applied research in which "it aims to generate knowledge for immediate practical application in the solution of real problems" (Yin, 2005). Particularly in this case, in which the application of the developed solution is supposed to reduce the energy expenditure of the Data Center.

In order to do so, the company studied in this paper is a Data Center of an information technology company based in the city of Passo Fundo in the state of Rio Grande do Sul, Brazil. The company operates on logistics software and Linux. In these two segments, the company has created advanced expertise and tools to support its clients from most varied branches and regions of the country.

The Data Center owns a 9000 Btus air conditioner, three HP servers (ML350-G6, ML310e - Gen 8 and ML310e - Gen8 V2), an OmniPcx telephone system, two modems (TG862 and V5471-002), two Switches (D-Link DES-1024A and Dell Powerconnect-2848), a Unifi AP router, two Storage IBM V7000, a Cyberoam CR35iNG and a T5700 router.

To contemplate the development of the appliance that aims to promote responsive thermal monitoring of electricity consumption in the Data Center, the steps made in this study are presented as follows. Data were collected by a temperature sensor (DHT11) and a non-invasive current sensor (100A SCT-013), as shown in figure 1 and figure 2, in which the temperature sensor is settled in the Data Center environment and the electric current sensor is connected to the electrical equipment power cable of the Data Center.

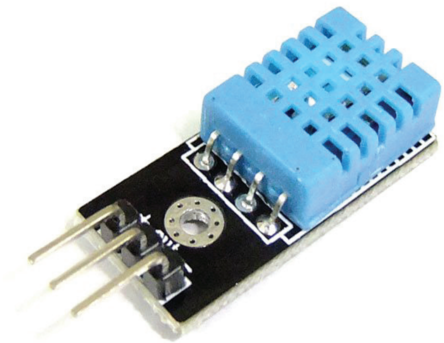

Figure 1 – Temperature sensor DHT11.

Figure 2 – Non-invasive current sensor 100A SCT-013.

The treatment of the information collected by the temperature sensor and the noninvasive current sensor was made by an Arduino Uno (figure 3), which sent the data using a serial port to communicate with the Raspberry PI (Figure 4). The data collected was processed by the Zabbix network administrative tool (Version 3.0.1) and the information generated by it was analyzed through its dashboard.

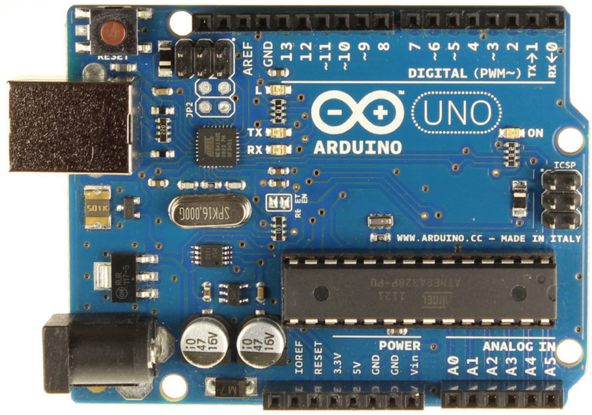

Figure 3 – Arduino Uno.

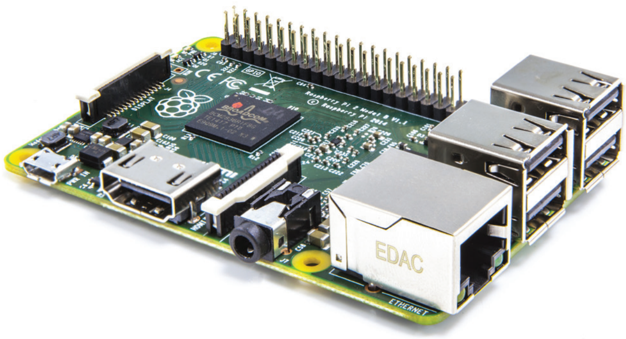

Figure 4 – Raspberry PI.

The Arduino Uno was responsible for the thermal responsiveness of the Data Center, which performed temperature control through the air conditioning via infrared. According to Geng (2014), to ensure the proper operation and durability of equipment at the Data Center's environment temperature, it should not exceed 25ºC. Additionally, according to Pereira (2015) good practices values for environmental temperature in a Data Centers must be between 18ºC and 22ºC. Thus, in this work, the Arduino will ensure that room temperature does not exceed 22°C. If for some reason the limit of 22ºC is exceeded, the Arduino will configure the air conditioner to operate at the minimum temperature (16ºC) to bring down the temperature and stabilize it between 18ºC and 22ºC. If the temperature is equal to or lower than 20ºC, it will turn off the air conditioning system to save energy, and under normal conditions the air conditioner will operate at 20ºC.

In order to analyze the results obtained by the implementation of the appliance, a comparison will be made with the energy consumption prior to the project implementation and the new consumption data after the project. Figure 5 shows the sensor collecting data from the Data Center. Figure 6 presents the developed system.

Figure 5 – Non-invasive current sensor (100A SCT-013) collecting data from the Data Center.

Figure 6 – Developed system collecting data from the Data Center.

During data collection, Zabbix monitored the temperature and power data readings hourly. In the following section, the data collected will be analyzed.

4. Results Discussion

In order to perform the data analysis, the data obtained by the collections made on two consecutive days were compared. The first day is the business as usual case, without the thermal response appliance and it is presented in table 1.

Table 1 – Hourly Temperature and Energy Consumption in the Business as Usual Scenario.

Time	Room Temperature (ºC)	Energy consumption (watts)	AC status	AC temperature (ºC)
0:30	17	1,325	On	16
1:30	17	1,333	On	16
2:30	17	1,335	On	16
3:30	17	1,329	On	16
4:30	17	1,335	On	16
5:30	17	1,337	On	16
6:30	17	1,570	On	16
7:30	19	1,572	On	16
8:30	19	1,569	On	16
9:30	17	1,456	On	16
10:30	17	1,369	On	16
11:30	17	1,356	On	16
12:30	17	1,370	On	16
13:30	17	1,315	On	16
14:30	17	1,377	On	16
15:30	17	1,379	On	16
16:30	17	1,357	On	16
17:30	17	1,367	On	16
18:30	17	1,379	On	16
19:30	17	1,355	On	16
20:30	17	1,326	On	16
21:30	17	1,297	On	16
22:30	17	1,300	On	16
23:30	17	1,365	On	16

In table 1, it is possible to verify that the air conditioning is always turned on in the minimum device temperature. Likewise, the room temperature suffers almost none variation. The energy consumed is always high.

In table 2, the new scenario with the system described and developed in the following day is presented. As it was described in the methods section, an automated smart management of the air-conditioning is made and the results are as follows.

In table 2 it is possible to witness that to maintain room temperature below 25 ºC there are certain periods of the day that the air conditioning is not necessary to be turned on. Therefore, reduced electricity consumption can be attained.

Table 3 presents a comparison of energy consumption between the business as usual scenario and the proposed scenario.

Table 2 – Hourly Temperature and Energy Consumption in the Scenario Using the Developed System.

Time	Room Temperature (ºC)	Energy consumption (watts)	AC status	AC temperature (ºC)
0:30	20	715	Off	–
1:30	20	717	Off	–
2:30	20	725	Off	–
3:30	20	719	Off	–
4:30	20	723	Off	–
5:30	24	1,034	On	16
6:30	23	1,577	On	16
7:30	22	1,573	On	16
8:30	21	1,576	On	20
9:30	22	1,449	On	20
10:30	22	1,379	On	20
11:30	22	1,346	On	20
12:30	22	1,356	On	20
13:30	21	1,342	On	20
14:30	22	1,376	On	20
15:30	22	1,359	On	20
16:30	22	1,352	On	20
17:30	22	1,362	On	20
18:30	21	1,374	On	20
19:30	20	716	Off	–
20:30	19	721	Off	–
21:30	19	726	Off	–
22:30	19	727	Off	–
23:30	20	719	Off	–

Table 3 – Energy Consumption Comparison.

Time	Without Thermal Response (watts)	With Thermal Response (watts)	Difference (watts)
0:30	1,325	715	610
1:30	1,333	717	616
2:30	1,335	725	610
3:30	1,329	719	610
4:30	1,335	723	612
5:30	1,337	1,034	303
6:30	1,570	1,577	-7
7:30	1,572	1,573	-1
8:30	1,569	1,576	-7
9:30	1,456	1,449	7
10:30	1,369	1,379	-10
11:30	1,356	1,346	10
12:30	1,370	1,356	14
13:30	1,315	1,342	-27
14:30	1,377	1,376	1
15:30	1,379	1,359	20
16:30	1,357	1,352	5
17:30	1,367	1,362	5
18:30	1,379	1,374	5
19:30	1,355	716	639
20:30	1,326	721	605
21:30	1,297	726	571
22:30	1,300	727	573
23:30	1,365	719	646
Total	**33,073**	**26,663**	**6,410**

It is possible to verify that between 05:30 and 18:30 the energy consumption is higher, probably because that in these moments occurs a greater use of the servers and the temperature increase, which ends up requiring extra air-conditioning and consequently a greater consumption of energy.
Still analyzing the values of table 3, with the use of thermal responsivity, it was possible to obtain savings of 6,410 watts in one single day. If it is considered a 30-day month, savings could easily reach 190,000 watts, providing significant financial savings for the company and resulting in an enhanced efficiency related to energy consumption.

5. Conclusion

The need for a more efficient and sustainable use of resources in developing countries motivated this research, which aimed to integrate free software, free hardware and a set of sensors in order to obtain a responsive thermal monitoring system to manage consumption of electrical energy in a Data Center.
Using the proposed system, it is possible to verify that a simple automated system as described in this article is capable of saving an average of 20% more energy compared to an uncontrolled environment. In addition, it is possible to highlight a greater reliability of the services offered by the Data Center and the reduction of the problems generated by the lack of an active monitoring in the same one since the Zabbix software could alert real-time problems to company employees. Further experiments could be made to enhance energy efficiency of the system. Other preset temperature values could be tested in order to save even more energy and maintain the room temperature in the desired values.

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