Impact of undesirable traffic on electrical power consumption in ICT rooms

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1. ABSTRACT

Advances in green technology and its overall impact on the environment brought to attention not only the pollution of our planet but excessive consumption of limited resources as well. In the IT world this is reflected in several ways. It can be a simple solution, like a simple warning in e-mail messages regarding the unnecessary consumption of paper ("Do not print this e-mail, save the forest.") or a more complex one, requiring financial investments and changes in the current technical infrastructure.
This paper describes research results in the field of monitoring power supplies and energy consumption in ICT data centers. We explored two ways of power consumption monitoring: by monitoring UPS (Uninterruptible Power Supply) and by monitoring specialized PDU (Power Distribution Units). The idea was to collect information on power consumption in RCUB (University of Belgrade Computer Center) ICT center using already available equipment, which is often present in ICT rooms. Results of the measurements taken on both type of devices, UPS and PDU, are compared and main conclusions are presented. We analyzed the measurement accuracy and usability of this approach to electric power consumption measurement, the impact of the amount of network traffic on power consumption and the prediction of electrical power consumption behavior based on network traffic throughput. Using collected information we have also tried to calculate the impact of undesirable traffic on electrical power consumption.

2. INTRODUCTION

The parameter traditionally used to measure energy efficiency of an ICT rooms is called PUE (Power Usage Effectiveness). PUE is expressed as a ratio of power that is currently used for the IT equipment in data center and the power used by the infrastructure which keeps that data center operational (cooling, power supply, etc.). PUE provides us with information on overall behavior of electrical energy in a data center and by just using PUE no specific details of electric power consumption can be learned. This paper provides us with a tool that can be used for further, deeper analysis and prediction of electrical power consumption in ICT rooms.
First part of the paper is describing testing environment and different variables that where collected from network equipment during the experiment. Second part of the work describes correlation between collected results and idea that could be used for prediction of power consumption in ICT rooms. Experiment was performed on the production equipment that is located in the RCUB.

Research was inspired by the “Campus Best Practice” task (Task 4) in the Network Activity “Status and Trends” (NA3) of the GN3 project. Objective of the NA3T4 task is to address key challenges for European campus networks, organize working groups and create quality set of best-practice documents for the community.

3. TESTING ENVIRONMENT

Devices that were used for testing are located in RCUB, main node of AMRES (Academic Network of Serbia). RCUB is providing internet connection to the AMRES and all web traffic from institutions connected to AMRES is passing through RCUB.

The next list contains devices that were used during the testing:

- six Ironport web security appliances S670
- one Ironport management appliance M16
- one Cisco 2960 switch
- one Cisco ASR1002 router
- four Fujitsu-Siemens Servers RX200 S5
- one Fujitsu- Siemens Servers RX300 S5

Testing enviroment has two APC Metered rack PDU’s and two APC Smart-UPS 5000VA devices. Although not all power distribution devices in AMRES support management cards in this test we did use UPS and PDU with network management card support. Every device that was used for testing, except Cisco ASR1002 router and Cisco 2960 switch, have two power supplies. Dual power supplies are connected to separate PDU units, and every PDU unit is connected to a separate UPS device. Figure 1 shows the testing enviroment.

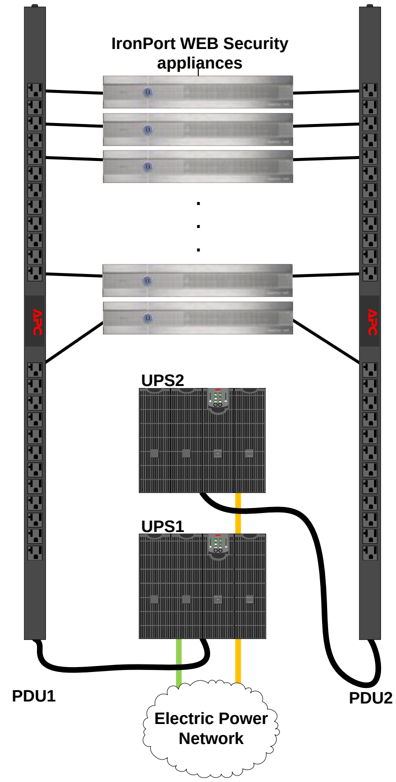


Figure 1 – Testing environment

Because of AMRES policies all end user web traffic must pass through Ironport web security appliances (Proxy servers). Figure 2 shows flow of web traffic through RCUB devices.

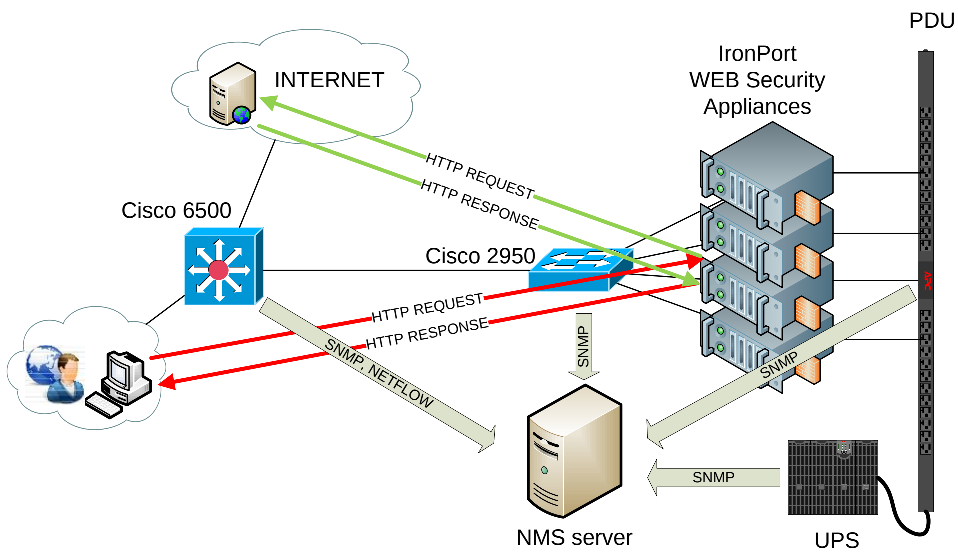


Figure 2 – Flow of web traffic and export of SNMP and NetFlow information

Figure 2 also shows places where we collect information via SNMP and Netflow protocol. Apart from Cisco 6500 and Cisco 2950 switches we also collect information from UPS and PDU management cards. Netflow information is gathered from central Cisco 6500 switch. Because all web traffic passes through Ironport proxy servers we used measurements from UPS and PDU in order to make correlation between amount of web traffic and electrical power consumption.

4. DATA COLLECTION

4.1. SNMP

Information on power consumption can be collected via SNMP in two ways. It can be collected from a UPS device or from a PDU device, since UPS provides power relying on the PDU device. SNMP variables that have been used during testing are APC propriatery variables defind under the APC (.1.3.6.1.4.1.318) private node in the MIB database.

List of used OID values:
APC UPS 5000VA SNMP variables:
- .1.3.6.1.4.1.318.1.1.1.4.2.3 - The current UPS load expressed in percent of rated capacity.
- .1.3.6.1.4.1.318.1.1.1.4.2.4 - The current in amperes drawn by the load on the UPS.

APC PDU SNMP variables:
- .1.3.6.1.4.1.318.1.1.12.2.3.1.1.2 - Getting this OID will return the phase/bank load measured in tenths of Amps.
- .1.3.6.1.4.1.318.1.1.12.1.16 - Getting this OID will return the Power in Watts.

Interface IN/OUT traffic counters
- .1.3.6.1.2.1.31.1.1.1.6 - The total number of octets received on the interface including framing characters.
- .1.3.6.1.2.1.31.1.1.1.10 - The total number of octets transmitted out of the interface including framing characters.

In order to perform collection of SNMP data from the UPS and PDU devices we created a Linux script on the NMS server. The script generates SNMP_GET queries to the UPS and PDU devices every five seconds. Results from the pair of connected UPS and PDU devices should be nearly identical, because all electric power is traversing from the UPS device, through the PDU device, to the network devices.
In order to compare received results we used SNMP data for the time interval of five days.

Next list presents information about output current received from UPS and PDU devices.

First pair of UPS-PDU devices returned the following set of discrete values:
- UPS1: 5A
- PDU1: 5.8A, 5.9A, 6.0A, 6.1A, 6.2A, 6.3A, 6.4A

Second pair of UPS-PDU devices returned the following set of discrete values:
- UPS2: 6A, 7A
- PDU2: 5.7A, 5.8A, 5.9A, 6.0A, 6.1A, 6.2A, 6.3A

Results recieved from the PDU devices have discrete values with a resolution step of ΔI_p=100mA, while UPS devices returned discrete values with a discrete step of ΔI_u=1A.
The Figures 3 shows results for output current, collected from two UPS and PDU pairs for the time inteval of five days. During this test we have used five seconds time period between SNMP queries.

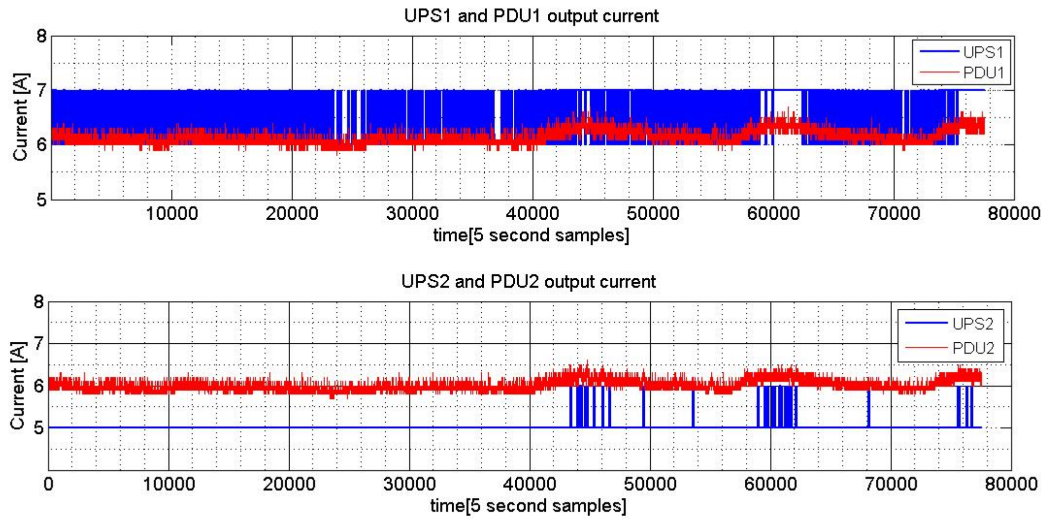


Figure 3 – Output current from SNMP queries to the UPS1 and PDU1 devices

Results show that data collected from UPS and PDU device is different. Because PDU devices have better measurment resolution we can conclude that it is better to use results received from PDU.
The second approach for getting information about power consumption was to generate SNMP queries asking for output power from UPS and PDU. We collected SNMP data every five seconds and it was used for further analisys.
The UPS is returning SNMP data in the form of percent of nominal output power, and PDU is returning SNMP data expressed in watts. Nominal output power of Smart-UPS 5000 device is 4kW.
Figure 4 shows results of SNMP queries for the output power from pairs of UPS and PDU devices.

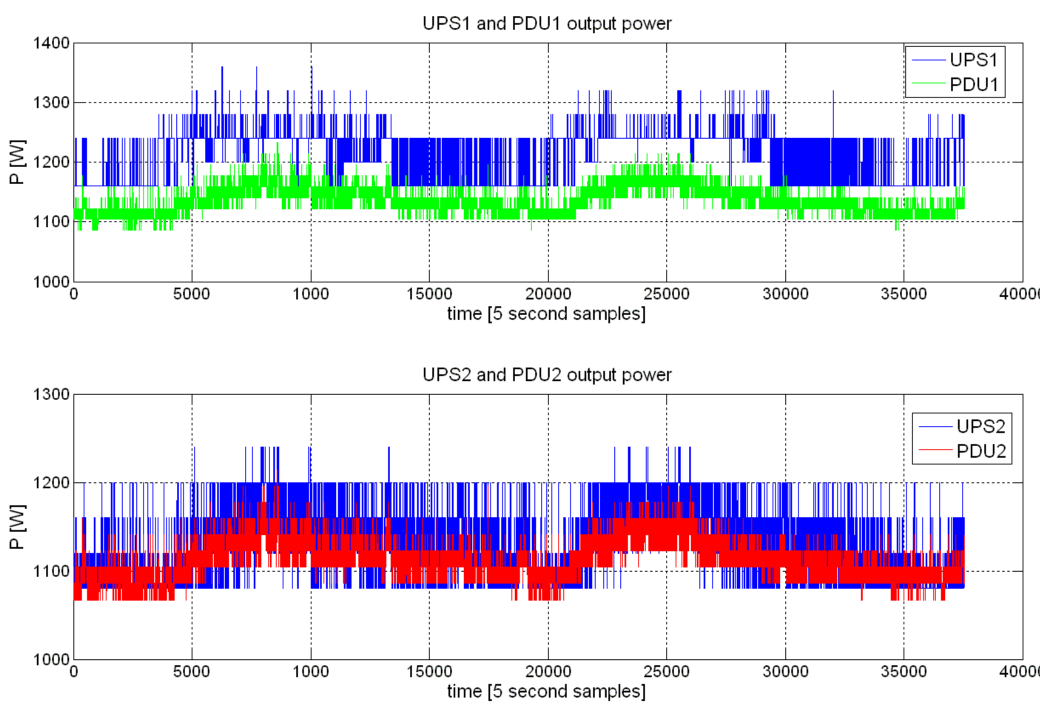


Figure 4 – Output load from UPS and PDU devices

From the graphs we can conclude that UPS2 and PDU2 are overlaping and showing approximately same values, but UPS1 and PDU1 are not overlapping and they have small differences.

During the SNMP data collection devices returned the following values:

- PDU1: 1357W, 1380W, 1403W, 1426W, 1449W, 1472W, 1495W, 1518W, 1541W
- PDU2: 1334W, 1357W, 1380W, 1403W, 1426W, 1449W, 1472W, 1495W, 1518W
- UPS1: 29%, 30%, 31%, 32%
- UPS2: 27%, 28%, 29%, 30%, 31%

Results recieved from the PDU devices have values with a discrete step of ΔW_p=23W, and the UPS devices are returning values with a descrete step of 1%, which is eqvivalent to the ΔW_u=40w.

Since the results received form PDU units have better resolution we decided to use SNMP values received from PDU devices for further analysis.

4.2. NETFLOW

NetFlow protocol was used in this analysis in order to separate traffic based on source or destination subnet, protocol or AS. This information is used later, in order to calculate power consumption caused by specific type of traffic. NetFlow is collecting and exporting information on central Cisco 6500 device.

4.3. IRONPORT LOGS

Ironport log files were used in order to caculate the amount of web traffic that was blocked on the Ironport devices because of AMRES policies. This can either be traffic to forbiden sites or traffic caused by malicious software. This information is used further in the analysis to calculate electric power consumption caused by malicious traffic.

5. ANALYSIS OF COLLECED RESULTS

Since it was concluded that PDU devices return better results for electrical power consumption measurements another Linux script was made in order to perform the second set of tests. The script was generating SNMP_GET queries to the PDU1 and PDU2 units, asking for information on power consumption, and SNMP_GET queries to the Cisco 6500 asking for information on input and output traffic that passed trough the interfaces that connect Ironport proxy servers. In this testing SNMP queries were generated on every 10 seconds. This way we collected results that we used to analyze dependency and correlation between those two processes.

Correlation coefficient between the two processes is given by the following mathematical formula:

$$r = \frac{n\sum x_i y_i - (\sum x_i)(\sum y_i)}{\sqrt{n\sum x_i^{\,2} - (\sum x_i)^2}\sqrt{n\sum y_i^{\,2} - (\sum y_i)^2}}$$

If we calculate the coefficient of correlation for measured results we get the value:

$$r = 0.7967$$

This shows that there is a linear relation between the two processes. Since correlation coefficient r is a positive number it means that if one parameter increases (throughput of network traffic) the other parameter (power consumption) will also increase. Scatter diagram on Figure 5 shows the dependency between electrical power consumption and web traffic throughput.

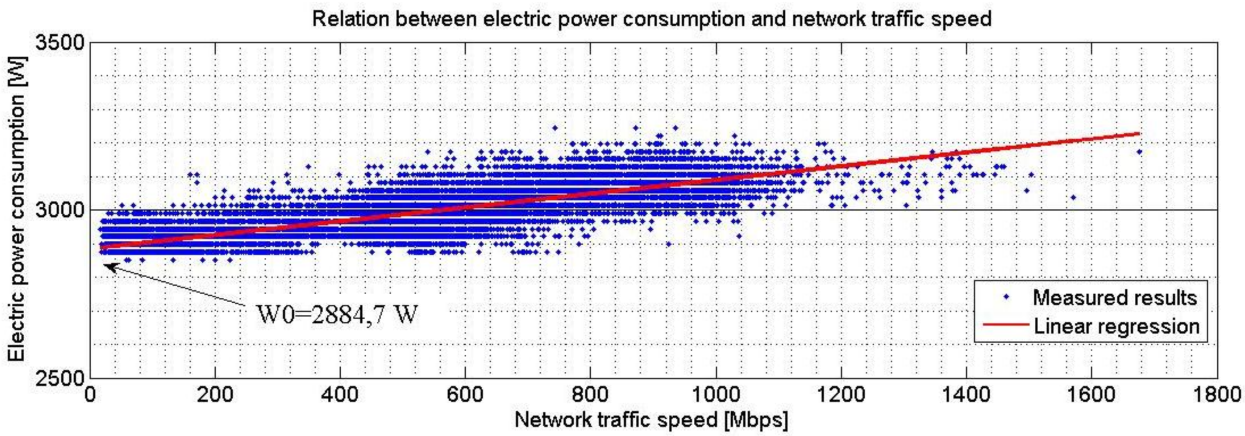


Figure 5 - Dependency between power consumption and the throughput of network traffic

In the next step of our analysis we used linear regression in order to model the relation between electrical power consumption and throughput of network traffic. This resulted in a linear function presented on Figure 5 in red color.

Linear function corresponds to the equation:

$$y = 0.2047x + 2884.7$$

$$k = \frac{\Delta y}{\Delta x} = 0.2047\left[\frac{W}{Mbps}\right]$$

$$W_0 = 2884.7[W]$$

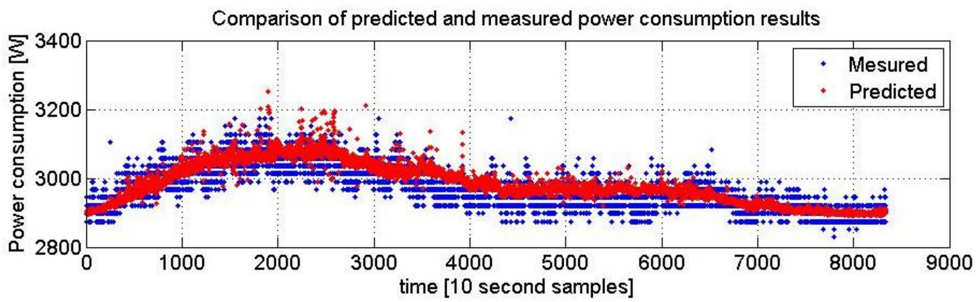
Slope k present the value that tells us how fast electrical power consumption will grow under the influence of network traffic throughput and value W_0 present electrical power consumption during the absence of network traffic (initial power consumption of the working devices). When network devices are turned on they will consume electrical power regardless of the presence or absence of network traffic. Now, we can calculate maximum variation of electrical power consumption that is caused by the throughput of network traffic.

$$\Delta y_{max} = \frac{\max(y) - W_0}{\max(y)} = 11.05\%$$

The result is calculated during the time when the network traffic throughput was highest. We can conclude that, at a certain moment in time, network traffic was consuming approximately 11% of total electric power consumption.

6. PREDICTION OF POWER CONSUMPTION IN ICT ROOMS

Once the relation between electrical power consumption and traffic throughput is known, it can be used to calculate electrical power consumption if network traffic throughput is known. If we use new SNMP traffic throughput data as input for the modeled linear function we can compare the predicted electrical power consumption results with measured results. Figure 6 shows comparison of the predicted and measured electric power consumption.



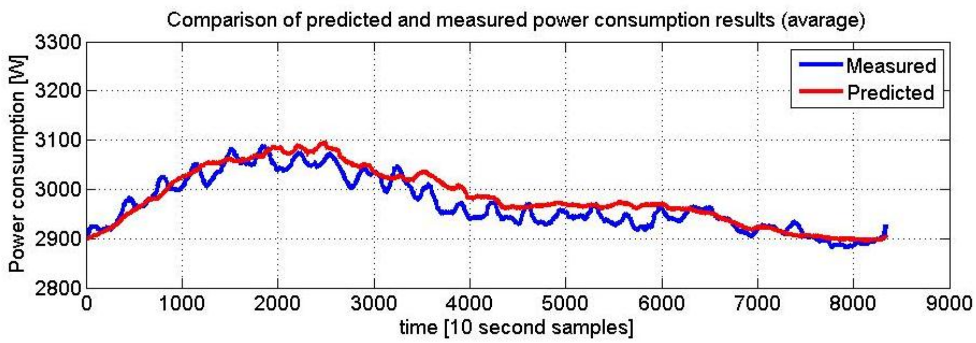


Figure 6 – Comparison of predicted and measured power consumption for one day period

In order to present clearer Figure of comparison, results on the second graph on the Figure 6 are derived as the result of average function on both set of data.

To find prediction error we have used measured and predicted results and calculated energy consumption expressed in kWh for the period of one day.

$$\varepsilon = \frac{|Wh_{measured} - Wh_{predicted}|}{Wh_{measured}} = \frac{|68.7546kWh - 69.0753kWh|}{68.7546kWh} = 0.47\%$$

Error that we introduced during the prediction is very small, just around 0.47%.
This method can be used as very good tool for prediction of power requirement for ICT rooms and billing calculation.

7. MODELING OF POWER DISTRIBUTION CAUSED BY THE NETWORK TRAFFIC

During the next testing phase we used NetFlow data in order to differentiate various types of traffic that passed trough our Ironport proxy servers.

Separation of traffic can be performed using different variables (e.g. AS number, protocol, source or destination ip, subnet, etc.). The linear function used for electric power consumption prediction can be used together with NetFlow data and provide us with information about power consumption specific for this type of network traffic.

Since a lot of users in AMRES use Google and YouTube services we decided to calculate impact of those services on electric power consumption.
Figure 7 shows traffic utilization from Youtube and Google autonomous system. Second graph shows electric power consumption that was made by that traffic.

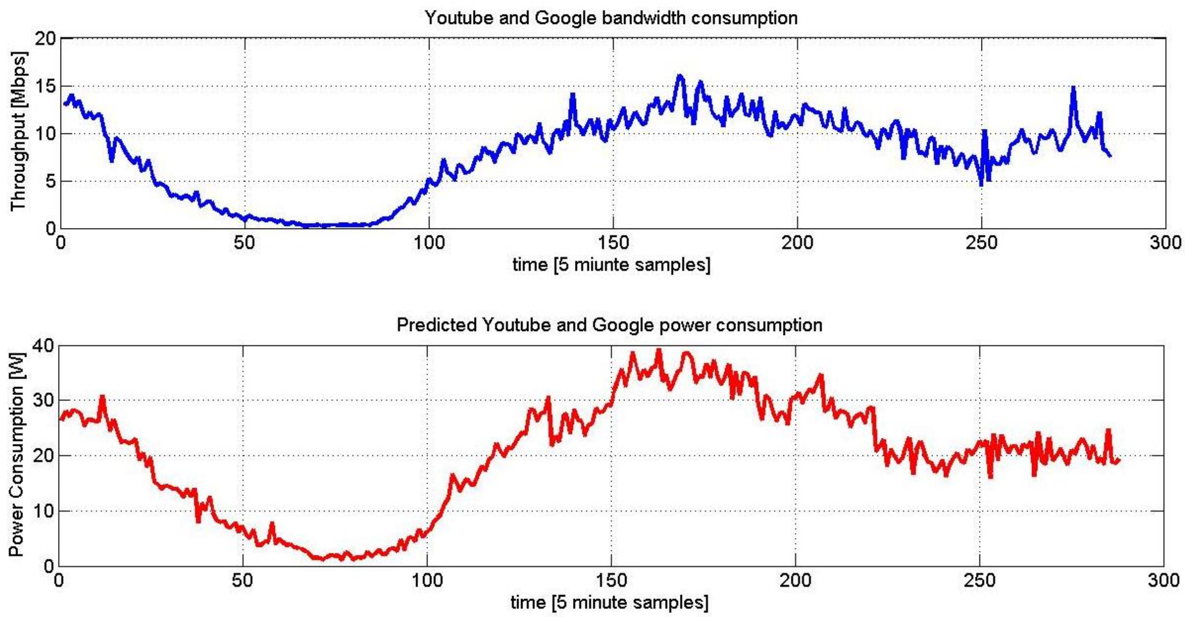


Figure 7 – Power consumption made by YouTube and Google service

By using NetFlow data we can predict power consumption caused by specific service, AS or subnet. This calculation is not totally accurate since the function that was used for prediction of power consumption was made using SNMP data. We are using that same linear function with NetFlow data as input. There is a difference between information that SNMP and NetFlow protocols provide. SNMP provides information about every bit that passes through an interface of the Cisco 6500 device while NetFlow provides information related to data above layer 2 of the OSI model. Since we have information about amount of packets and because we are using Ethernet technology, which have fixed overhead L2 data, we have added additionally 42 octets for every packet that passed router interface for specific time interval. This way we have corrected missing information.

8. POWER CONSUMPTION CAUSED BY BLOCKED TRAFFIC

The final phase of testing involves network traffic that has been blocked by Ironport proxy servers. For this test to be performed we used Ironport log files and search them for specific blocked traffic. We noticed that there are a lot of web requests that are directed to localhost ip address (127.0.0.1). After some research we found out that uTorrent plug-in for Mozilla Firefox web browser and miss configured web browser were causing this behavior. Graphs on the Figure 9 are showing throughput that is caused by uTorrent plug-in and predicted power consumption for time interval of one hour.

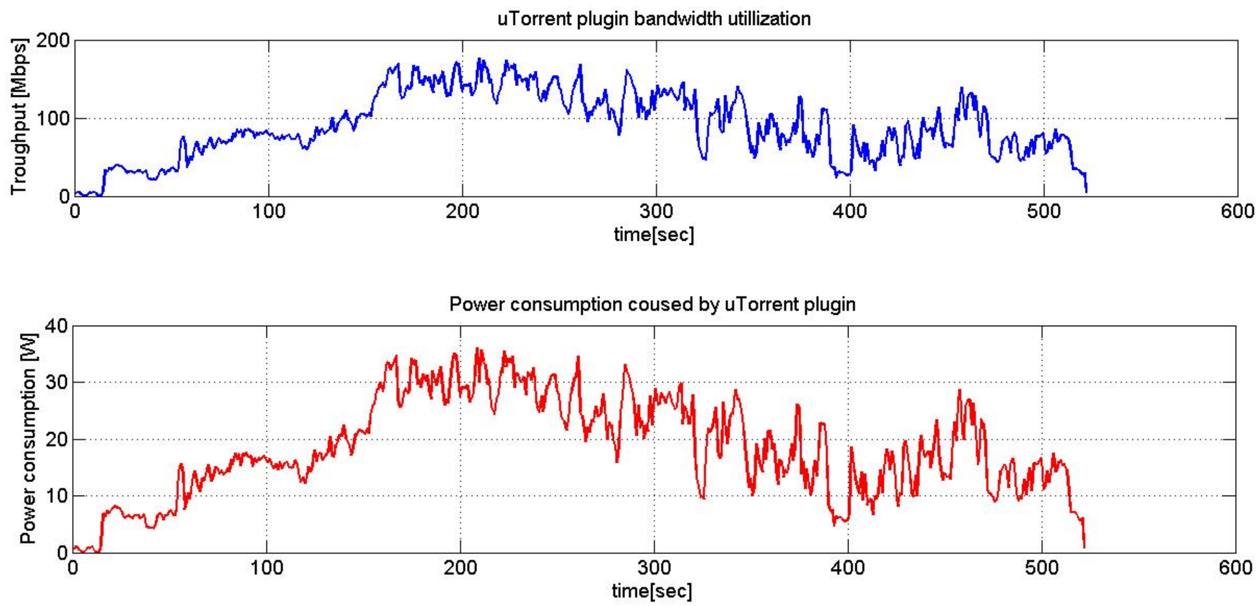


Figure 9 – Power consumption caused by uTorrent plug-in

Although electric power consumption at Ironport proxy servers is not that big, total electric power consumption caused by uTorrent plugin should be calculated not only at Ironport proxy servers but also on every device that connects uTorrent workstation (a desktop workstation) and Ironport proxy servers. This is the only way that the total electric power consumption caused by this problem can be measured.

9. INFLUENCE OF SAMPLING INTERVAL ON RESULTS

If we assume that the sampling interval of 10 seconds is providing good results about electrical power consumption, what will happen if we increase the sampling interval? We tried to calculate total power consumption for one day expressed in kWh for different sampling intervals. Results are shown on Figure 8.

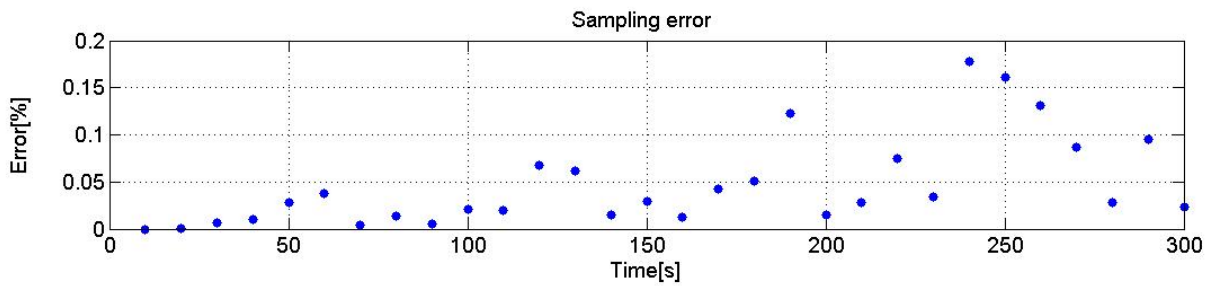


Figure 8 – Sampling error for different sampling intervals

From Figure 8 we can conclude that measurements don't have to be executed too often. Time interval of 300 seconds will introduce error into the results that is less than 0.2%. In order to perform measurements that will later be expressed in kWh, the measurement interval can be increased. This is important information because it is telling us that applications that are used for power consumption measurements could increase their sampling period. This way we are reducing burden on the monitoring application and we are reducing amount of management traffic.

10. CONCLUSION

We presented a simple method that could be used in order to monitor electric power consumption in ICT rooms. We also showed that during collection of electric power consumption data sampling period could be increased without big impact on accuracy of collected results. Paper also provides information about modeling of electric power consumption function. This function could be used in conjunction with throughput information from different types of web services in order to calculate their role in overall electric power consumption. Paper is also showing that electric power consumption in ICT rooms could be decreased by simple policy methods that are blocking malicious traffic as close as possible to the source. Although green technology will always have last word, human behavior could also have impact on green environment.

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12. GLOSSARY

AMRES – Academic Network of Serbia
ICT - Information and communications technology
NetFlow – Network Flow
PDU – Power Distribution Unit
RCUB - Computer Centre of Belgrade University
SNMP – Simple Network Monitoring Protocol
UPS - Uninterruptible power supply