Comparison of energy efficiency in PSTN and VoIP systems

Comparison of Energy Efficiency in PSTN and VoIP Systems*

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ABSTRACT

The importance of deploying energy efficient networks has vastly increased due to the rapidly growing nature of power consumption of ICT industry. This requires redesign of networks or modification to existing networks that could prove to be energy efficient. In this paper, two telephone networks namely traditional Public-Switched Telephone Network (PSTN) and Voice over Internet Protocol (VoIP), are extensively examined in terms of energy consumption by means of measurements on our University Campus systems, modeling and actual experiments. Results show that the VoIP system is more energy hungry with respect to traditional PSTN. We then devise possible solutions which are more efficient in terms of energy than current technology.

Categories and Subject Descriptors

K.6.2 [**Computing Milieux**]: Installation Management—*Performance and usage measurement*

General Terms

Management, Measurement, Performance

Keywords

PSTN, VoIP, energy efficiency, measurements

1. INTRODUCTION

There has been a wave of keen interest in saving energy due to increase in consumption by ICT industry [1], which leads to increased operational costs and higher CO_2 emissions. Continuous rising trend in energy consumption essentially depends on new services being offered, as well as on an increase of the number of devices and traffic.

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Previous works dealt with power consumption of copper and fiber-based systems where different states of telephone systems are analyzed theoretically [2]. In our paper, we focus on the comparison of two common architectures deployed in large voice communication infrastructures, that are: traditional circuit-switched technology used in PSTN and the VoIP technology. Many companies are moving away from the PSTN technology to obtain more functionalities for their voice systems while lowering the operational costs due to shared data-voice infrastructure as well as using IP to transfer long-distance calls. Switching from PSTN technology to VoIP technology could lead to an increase of power consumption, so the question is which architecture out of these two alternatives is more energy efficient? The two technologies follow two opposite design choices: on the one hand, complex structured circuit-switched technology utilizes centralized switching and group switching among Private Branch Exchanges (PBX) that implements all intelligence interconnecting very simple phone devices; on the other hand, the VoIP technology uses simple Ethernet switches and a gateway to interconnect intelligent phones that implement all advanced features.

Studies have shown a swift increase of the number of VoIP users over the past few years [3, 4]. With this constant growth of VoIP users and power consumption being a critical issue, the question would be, how much energy efficient are these VoIP systems as they require continuous consumption of energy [5]. And, can VoIP replace the traditional circuit switch technology without increasing operative cost due to higher energy consumption?

The road map of this paper is the following. We start by providing some essential background of already implemented PSTN and VoIP architecture of our university campus. These two are then compared in terms of energy consumption by means of real time power consumption data. We then highlight how energy is wasted and build energy consumption models for both systems in order to predict the per user power consumption. Afterwards, steps are taken to figure out the possible ways to improve energy efficiency.

2. PRIVATE VOICE SYSTEMS

2.1 Traditional Circuit Switched System

We consider the telephone system of our university campus as reference to compare VoIP and PSTN architectures. The configuration implemented at Politecnico PSTN consists of 14 PBXs, serving 3120 phones. These phone lines

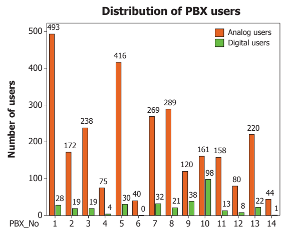

Figure 1: Number of users at Politecnico's PBX

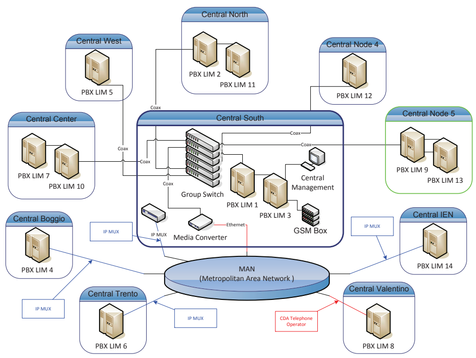

Figure 2: Interconnection of Politecnico's PBXs

are divided into 2787 analog and 333 digital lines. The already known distribution of number of lines at all 14 PBXs is shown in Fig. 1 and the basic view of Politecnico's telephone network is shown in Fig. 2. All 14 PBXs are connected to the Group Switch (GS) located at Central Node. The Group Switch provides connection between all 14 PBXs and the external telecom network.

The maximum capacity of each PBX is around 500 phones with flexibility to increase the number of phones by inserting new line cards. Each line card can handle up to 16 phones. There is a different line card for analog or digital phone lines with different power consumption values.

2.2 VoIP System

We consider as a reference the VoIP system deployed at Istituto Superiore Mario Boella (ISMB), a laboratory close to Politecnico campus. Its architectural view is shown in Fig. 3. Interestingly, the architecture is simple and does not need large scale infrastructure like in the case of the traditional phone system. We can observe 4 Power over Ethernet (PoE) switches (3 switches with 24 ports and one with 48 ports) and a PC with Asterisk software[1] to act as a communication server. The referenced architecture serves around 120 users with the ability to make phone calls, and also provide data services. This means that the VoIP architecture utilizes shared infrastructure of Ethernet that provides data services, which seems to be a good option in terms of energy saving.

3. MEASUREMENT AND MODELING

The power consumption values of PBX or VoIP switches are measured locally at regular intervals by local devices.

[1]http://www.asterisk.org/

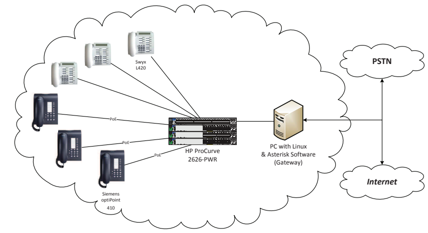

Figure 3: VoIP architecture at ISMB

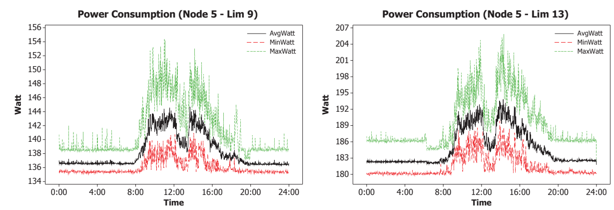

Figure 4: PSTN: Power consumption - Weekdays

Later, the measurement data is transmitted to a central server (youMeter) through a wireless transmitter connected to the measurement device. The collected data is then stored in a database for statistical analysis. This measurement activity involves the collection of certain parameters like Real/Reactive Power, RMS Voltage/Current.

3.1 PBX Measurements

Two PBXs (LIM 9 and LIM 13) are under power measurement[2] present at central node 5. The monitoring of power consumption of these two PBXs collected over the span of two weeks $(4 - 15/04/2011)$ is shown in Fig. 4; Fig. 5 shows the power consumption during weekends. The three curves with green, black and red color represent, respectively, the maximum, average and minimum power consumption samples for 24 hours collected over a span of working days and weekends. Power consumption is constant during weekends and its around 137 Watts in case of LIM 9, even if there is no user activity. During weekdays, and when the system is carrying phone calls, the system consumes around 10% more of the overall consumption. Note that the measurements are vendor specific (Ericson model in our case), so the results we provide may not be representation for every scenario, but rather could be generalized to provide good estimates. For example, similar experiments were conducted over *AASTRA*'s new generation PBX, where empty PBX (no phones or line cards connected) resulted with 66 Watts of consumption.

3.2 PSTN Power Modeling

We extrapolate a simple mathematical model from the acquired real measurements to estimate the per user consumption. Using this estimate, one can approximate an overall consumption for a given number of users in any campus or corporate scenario. Considering minimum power consumption when the system is in idle state, we assume that the power consumed by analog/digital line cards, as well as

[2]Power measurement of PBX includes power consumed by UPS/transformer that transforms 220 Volt to 48 Volt DC (which is part of PBX).

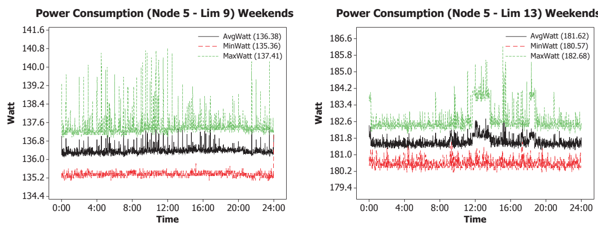

Figure 5: PSTN: Power consumption - Weekends

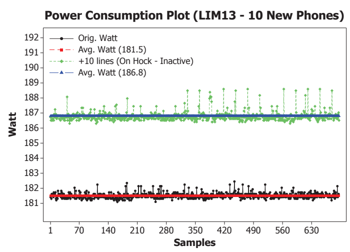

Figure 6: PSTN: Effect of adding 10 new lines

phones, is approximately the same;

$$P_{PBX} + X \cdot P_{lc} + K \cdot P_{ph} = P_{TOT_{PBX}} \tag{1}$$

The above expression divides total power consumption as the sum of minimum constant PBX power consumption, P_{PBX}, plus the power consumed by line cards P_{lc} and phone lines P_{ph}. X and K represent respectively the number of line cards and phone lines connected to specific PBX. Based on the number of interfaces and phone lines connected to each PBX, we obtained the following two equations,

$$\begin{cases} LIM9, & P_{PBX} + 11P_{lc} + 158P_{ph} = 135.10\,\mathrm{W} \\ LIM13, & P_{PBX} + 18P_{lc} + 242P_{ph} = 180.06\,\mathrm{W} \end{cases} \tag{2}$$

In order to solve the equations we need to get the value of one of the variables. For that purpose, we decided to directly measure the power consumption of phones lines by adding ten new phones to the PBX and observe their effect on the PBX power consumption. Figure 6 shows the results of such experiment during night time. We observe the average power consumption by single phone user (ON-hook) to be $P_{ph} = 0.53\,\mathrm{W}$. By solving (2), we get power consumption of line card and PBX,

$$P_{PBX} = 50.6686\,\mathrm{W}, \quad P_{lc} = 0.0629\,\mathrm{W} \tag{3}$$

3.3 VoIP Measurements

Two switches (namely SW-2 and SW-3 which are used exclusively for connecting VoIP phones) with model HP ProCurve are kept under power measurement in the VoIP system. The distribution of the number of phones on SW-2 consists of 12 non-PoE[3] phones and 5 PoE phones. SW-3 has 9 non PoE phones and 12 PoE phones. The monitoring and collection of power consumption data is done as mentioned above. The 24 port switch under measurement can provide up to 370 watts of power to PoE devices, which in turn means all 24 ports deliver at an average of $370/24 = 15.4$ watts per port. Figure 7 shows the actual power consumption behavior of PoE switches observed over

[3]Power is drawn from an adapter locally connected to the VoIP phones.

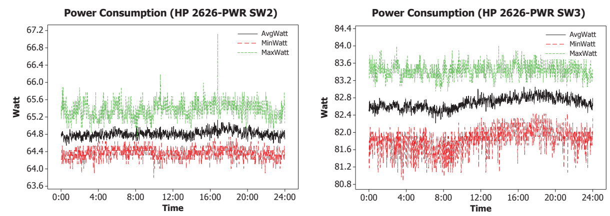

Figure 7: VoIPs Power consumption

the same duration of two weeks $(4 - 15/04/2011)$. Differently from the PSTN system, we observe a constant power consumption, which is independent on user activity (notice the range of the y-axis of the plot).

3.4 Formulation

A similar criterion is used to extrapolate a simple mathematical model to estimate per user consumption.

$$P_{SW} + K_1 P_{PoE} + K_2 P_{\overline{PoE}} = P_{TOT_{VoIP}} \tag{4}$$

P_{SW} is the minimum constant power consumption of the Ethernet switch, K_1 and K_2 represent the number of PoE and non-PoE phones. Lastly, P_{PoE} and $P_{\overline{PoE}}$ represent the power consumption figure of PoE and non-PoE phones. Assuming non-PoE phones do not require power from the switch, we have $P_{\overline{PoE}} \cong 0$

$$\begin{cases} SW-2, & P_{SW} + 5P_{PoE} = 64.81\,\mathrm{W} \\ SW-3, & P_{SW} + 12P_{PoE} = 82.67\,\mathrm{W} \end{cases} \tag{5}$$

Solving the equations, we have $P_{SW} = 51.88\,\mathrm{W}$ and $P_{PoE} = 2.6\,\mathrm{W}$. In order to verify the results, we conducted another experiment in which SW-3 offered connectivity to only 16 PoE phones and SW-2 to only 19 non-PoE phones. The results showed that SW-2 and SW-3 gave 53.2 W and 90.7 W respectively. These numbers complied with the results derived from previous calculations.

4. ANALYSIS

Using the formulation mentioned above for both the architectures, rough estimate of the power consumption values for a generic PSTN system is computed from,

$$P_{PSTN} = \left\lceil \frac{N_{T_{lines}}}{N_{users/PBX}} \right\rceil P_{PBX} + N_{T_{lines}} \cdot P_{ph} \tag{6}$$

where $N_{T_{lines}}$ is the number of phone lines and $N_{users/PBX}$ is the number of phones a PBX can host (500 in our case). Similarly, P'_{VoIP} is the equivalent estimated power consumption of the VoIP system:

$$P'_{VoIP} = \left\lceil \frac{N_{T_{lines}}}{N_{ports/switch}} \right\rceil P_{SW} + N_{T_{lines}} \cdot P_{PoE} \tag{7}$$

where $N_{ports/switch}$ is the number of ports available on a specific switch (24 in our case). Note that (6) and (7) represent a lower bound on power consumption since they assume to fill completely a switch before adding a new one.

4.1 Energy Saving Schemes

Current Scenario - The power consumption of PBX and equivalent VoIP architecture for certain number of users is computed using (6) and (7). The results consider the total average consumption of the system during 24h period of

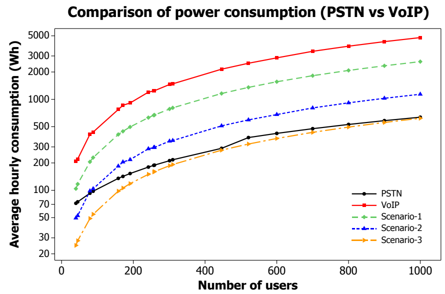

Figure 8: PSTN and VoIP energy consumption

time. They are reported with the solid black and red lines in Fig. 8 (*notice the ylog-scale*); They clearly indicate that VoIP solution consumes more power for the considered architectures, but this is strongly dependent on the devices used for implementing the phone infrastructure. Yet, VoIP systems have the flexibility to be made energy efficient by adding some sort of energy-wise schemes. For example, one possibility to save energy would be to put VoIP phones into sleep mode when there is no user activity using the standard Wake-on-LAN (WOL) Ethernet feature; a second possible space to save energy would be during inactivity period of ongoing call [6]. In the following text, we describe various scenarios to save energy along with their results.

Scenario-1 - We use the already deployed LAN connection infrastructure along with VoIP phones that are powered through Ethernet, thus eliminating the need to add and power up extra Ethernet switches ($P_{SW} = 0$). The power consumption is shown with a green line in Fig. 8.

$$P_{VoIP_1} = N_{T_{lines}} P_{PoE} \tag{8}$$

Scenario-2 - Smart VoIP is the option where we put both the VoIP enabled Ethernet switches and phones into sleep mode when there is no user presence. Assuming 8 hours of working time, 5 days per week. P_{VoIP_2} is calculated using the values of P'_{VoIP} from (7) as:

$$P_{VoIP_2} = P'_{VoIP}\,(8/24)\,(5/7) \tag{9}$$

Scenario-3 - The combination of VoIP phones and already deployed Internet connection infrastructure with power saving scheme defined in (9). The power consumption P_{VoIP_3} is computed.

$$P_{VoIP_3} = P_{VoIP_1}\,(8/24)\,(5/7) \tag{10}$$

Scenario-4 - Use of softphones, i.e., devices connected to the user's PC that consume virtually no power, and existing Internet connection to set up voice communication. We assume softphones do not consume any power consumption. In this case, power consumption is zero ($P_{SW} = 0$, $P_{PoE} = 0$).

4.1.1 VoIP at Politecnico

In practice, it may not be possible to offer all user a softphone. For example, some users may be reluctant to have a softphone to be connected to their laptop. Given certain number of users, an interesting question is then to find how many VoIP phones can be accommodated so as to not exceed the power consumed by the equivalent PBX system

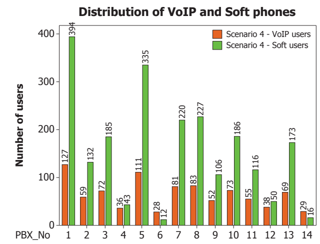

Figure 9: PBX equivalent no. of VoIP/Soft phones

deployed at our campus. The rest of the users are accommodated with softphones that consume no power. We assume to use the same LAN switches as in (8). The results of such distribution shown in Fig. 9 show that about 1/3 of lines could be real VoIP phones at each switch.

$$P_{VoIP_{ph}}(x) \leqslant P_{PSTN}$$
$$P_{VoIP_{ph}} = \begin{cases} 2.6\,\mathrm{W} & VoIPphone : (x) \\ 0\,\mathrm{W} & Softphone : (N_{T_{lines}} - x) \end{cases} \tag{11}$$

4.1.2 Comparison

Figure 8 illustrates graphically the power consumption of PBX and the equivalent VoIP architectures along with the comparison between energy saving VoIP scenarios. Results show that VoIP solutions are more energy expensive, unless aggressive power saving schemes are in place. For example, noticeable difference in power consumption is due to the fact that scenario 3 uses power consumption of VoIP phones only (not the switches) and sleep mode is aggressively exploited.

5. CONCLUSION

In this paper, we have identified the main lines of intervention to introduce energy efficiency in two architectures for telephony, namely a traditional architecture and a VoIP solution. The analyzed results suggest that the VoIP architecture is energy hungry and thus requires, to be competitive in terms of energy efficiency, the implementation of aggressive energy saving schemes. Newer generation of PBX and switches might lead to completely different results. To have a deeper analysis, we intend to differentiate the power consumption of analog and digital phones and compare the results with newer generation of PBXs, switches and VoIP phones. For this purpose we are currently measuring power consumption of *AASTRA*'s new generation PBX, which are replacing Ericson's PBXs installed in our university campus.

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