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Energy efficiency in access and aggregation networks: From current traffic to potential savings

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ABSTRACT

Access and aggregation networks account nowadays for a large share of the consumed energy in communication networks, and actions to ameliorate their energy cost are under investigation by the research community. In this work, we present a study of the possible savings that could be achieved if such technologies were in place. We take advantage of large datasets of measurements collected from the network of FASTWEB, a national-wide Internet Service Provider in Italy. We first perform a detailed characterization of the energy consumption of Points of Presence (PoPs) investigating on how factors such as external temperature, cooling technology and traffic load influence the consumed energy. Our measurements precisely quantify how the power consumption in today networks is practically independent from the traffic volume, while it is correlated only with the external temperature. We then narrow down our analysis to consider the traffic generated by each household. More specifically, by observing about 10,000 ADSL customers, we characterize the typical traffic patterns generated by users who access the Internet.

Using the available real data, we thus investigate if the energy consumption can be significantly reduced by applying simple energy-efficient policies that are currently under studies. We investigate energy-to-traffic proportional and resource consolidation technologies for the PoP, while sleep modes policies are considered at the ADSL lines. All these energy-efficient policies, even if they are not yet available, are currently being widely investigated by both manufacturers and researchers. At the PoP level, our dataset shows that it would be possible to save up to 50% of energy, and that even simple mechanisms would easily allow to save 30% of energy. Considering the ADSL lines, it results that sleep mode policies can be effectively implemented, reducing the energy consumption of ADSL modems with little or marginal impact on the Quality of Service offered to users. We make available all datasets used in this paper to allow other researchers to benchmark their proposals considering actual traffic traces.

1. Introduction

The topic of energy efficiency in telecommunication networks has attracted a lot of interest in the recent years. This is due to economical reasons, driven by the ever increasing cost of energy, to the willingness of reducing the environmental impact, and to technical matters, since energy density limits devices scalability.

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In the telecommunications field, researchers were used to consider energy-efficiency as an aside aspect of their investigations. Instead, nowadays several initiatives such as TREND[1] and ECONET[2] European projects, the GreenTouch Consortium[3] and the D-Link Green Products,[4] focus specifically on the energy efficiency of telecommunication devices. Among those initiatives, the TREND project aims at quantitatively assessing the energy demand of current and future telecommunication infrastructures, and designing energy-efficient, scalable and sustainable future networks. In this work we present the results of a collaboration between Politecnico di Torino and FASTWEB,[5] one of the major Internet Service Provider (ISP) in Italy.

We focus explicitly on wired networks. In such scenario, the access and the aggregation portions of the network account for the largest share of the overall energy consumption, and forecasts show that this is expected to worsen in the future [1]. The improvement of the energy efficiency in these network segments is as such an important target.

In this work, we aim at (i) providing a detailed characterization of the actual energy consumption as seen by the ISP and (ii) evaluating the impact of currently studied energy efficient policies when effectively deployed in these network segments. Our goal is to provide a precise quantification of the possible energy saving that policies and technologies currently under development would bring in a real scenario. For this purpose, we leverage a large dataset containing the actual energy consumption, traffic and other important measurements collected by the operative network of FASTWEB. Using these actual data, we analyze how the energy consumption is correlated to the other metrics in order to understand how and where energy efficiency can be improved. The characterization of the energy relationships with other factors represents indeed an important aspect of this work. Even if these relationships are intuitive, it is fundamental to actually confirm and quantify it with actual data. Following the scientific principle of allowing results reproduction, and to allow other researchers to validating their proposals in actual scenarios, we make available all datasets used in this paper on the website of the TREND project.[6]

In the context of access and aggregation networks, we focus our attention on the Points of Presence (PoPs), large network "nodes" that act as both aggregation and traffic switching points, where several thousands of end-users lines are aggregated. This choice is motivated by the fact that the energy consumption of PoPs weights for the 26% of the total energy consumed by FASTWEB, as we computed starting from the data provided by FASTWEB. We next move our attention to each single ADSL access line, i.e., on the modems located at users' home and at the ISP Digital Subscriber Line Access Multiplexer (DSLAM). Being in the order of several millions, it has been indeed shown that the customer premise equipment overall accounts for more than 65% of the energy consumed in access networks [2].

Notice that the PoP and the single-line operate in substantial different traffic scenarios and time scale. The former transports traffic aggregated from thousands of users, while the latter manages traffic generated by a single household. This have to be taken into account when conceiving energy efficient policies. Having this in mind, we investigate some "what-if" scenarios in which we identify possible energy efficient policies that could be deployed if new technologies become available, or if different management procedures are adopted.

We assume the availability of energy efficient policies, based on resource consolidation or sleep mode technologies that are currently being investigated by manufacturers and researchers. We explicitly do not focus on the problems related to their technical implementation and deployment. We rather evaluate if these strategies could offer significant energy savings assuming as benchmark the available measurements. In the case that savings are consistent, manufacturers can be motivated to perform the investment to provide those solutions, and ISPs to deploy them.

By using simple models that we fed by the actual data, we predict the possible energy savings that can be expected when rolling out such technologies. Results show that even simple policies allows to save from 30% to 50% of the energy consumed by a PoP. Furthermore, given the very large burstiness of traffic on each single ADSL line, sleep mode policies would allow to keep the ADSL modes into sleep or low-power state for more than 60–80% of the time with a marginal impact on users' perceived Quality of Service (QoS). Technologies such as the one proposed in [3] would be an excellent means to reduce the energy costs of access networks.

Preliminary results have been presented in [4,5]; in this paper we extend them introducing a more comprehensive analysis of the PoP traffic characteristics and considering different energy efficiency technologies. In particular, we perform a more detailed analysis of the dataset, introducing the analysis of Pearson correlation coefficients in order to better characterize the correlation among the different metrics. Moreover, we perform a detailed analysis of the energy breakdown of the PoPs in order to distinguish between networking devices and cooling system power consumption contributions. Furthermore, we consider the adoption of Dynamic Voltage Frequency Scaling (DVFS) based technologies as PoP strategy to improve the energy efficiency. Achievable savings in term of energy consumption and monetary investments are also quantified for the selected PoPs and the associated ADSL lines.

In the following, Section 2 describes the dataset and the available metrics. In Section 3 we present the energy profiling of the PoPs, evaluating possible correlations among energy consumption and the other metrics, and furthermore we introduce the energy breakdown of the PoPs. We analyze the traffic dynamics of the PoPs and we evaluate the typical activity of ADSL user in Section 4. The energy saving strategies are introduced in Section 5, while the achievable energy savings are estimated in Section 6. Lastly, conclusions are drawn in Section 7.

[1] http://www.fp7-trend.eu.
[2] http://www.econet-project.eu.
[3] http://www.greentouch.org.
[4] http://www.dlinkgreen.com/greenproducts.asp.
[5] http://company.fastweb.it.
[6] http://www.fp7-trend.eu/content/datasets-benchmark-access-networks.