The energetic implications of decentralized infrastructures for data hosting and delivery

Yoann Ciabaud[1] after the study of Arman Shehabi[2], Ben Walker[3] and Eric Masanet[4]

This document is an adaptation from the study by **Arman Shehabi** of Berkeley Lab and **Ben Walker** and **Eric Masanet** of Northwestern University. Their study, **"The energy and greenhouse-gas implications of internet video streaming in the United States,"** was published online in Environmental Research Letters in 2014.

The researchers used a life-cycle assessment approach to estimate energy usage and greenhouse gas emissions associated with streaming video and/or audio content using a traditional commodity based infrastructure (datacenters and Content Delivery Networks), and compared it to the energy and emissions associated with streaming video and/or audio content using a decentralized infrastructure based on existing computing assets (i.e.the Social Cloud).

The research used an open-source model developed at Berkeley Lab with funding from Google. Called the Cloud Energy and Emissions Research (CLEER) Model, it is open to the public and allows anyone to analyze the energy and carbon impacts of cloud computing.

This documents aims to replicate this approach in order to estimate energy usage of the social cloud for the use case of video streaming.

To achieve this purpose, I will evaluate what would have been the results of such a study if the social cloud existed at this time. This document will focus on comparing classic streaming video systems to our decentralized streaming video system to compare the energy efficiency. This study will have to starts on the same basis so it will be based on the US video streaming market data from 2011 and other metrics revised in 2013.

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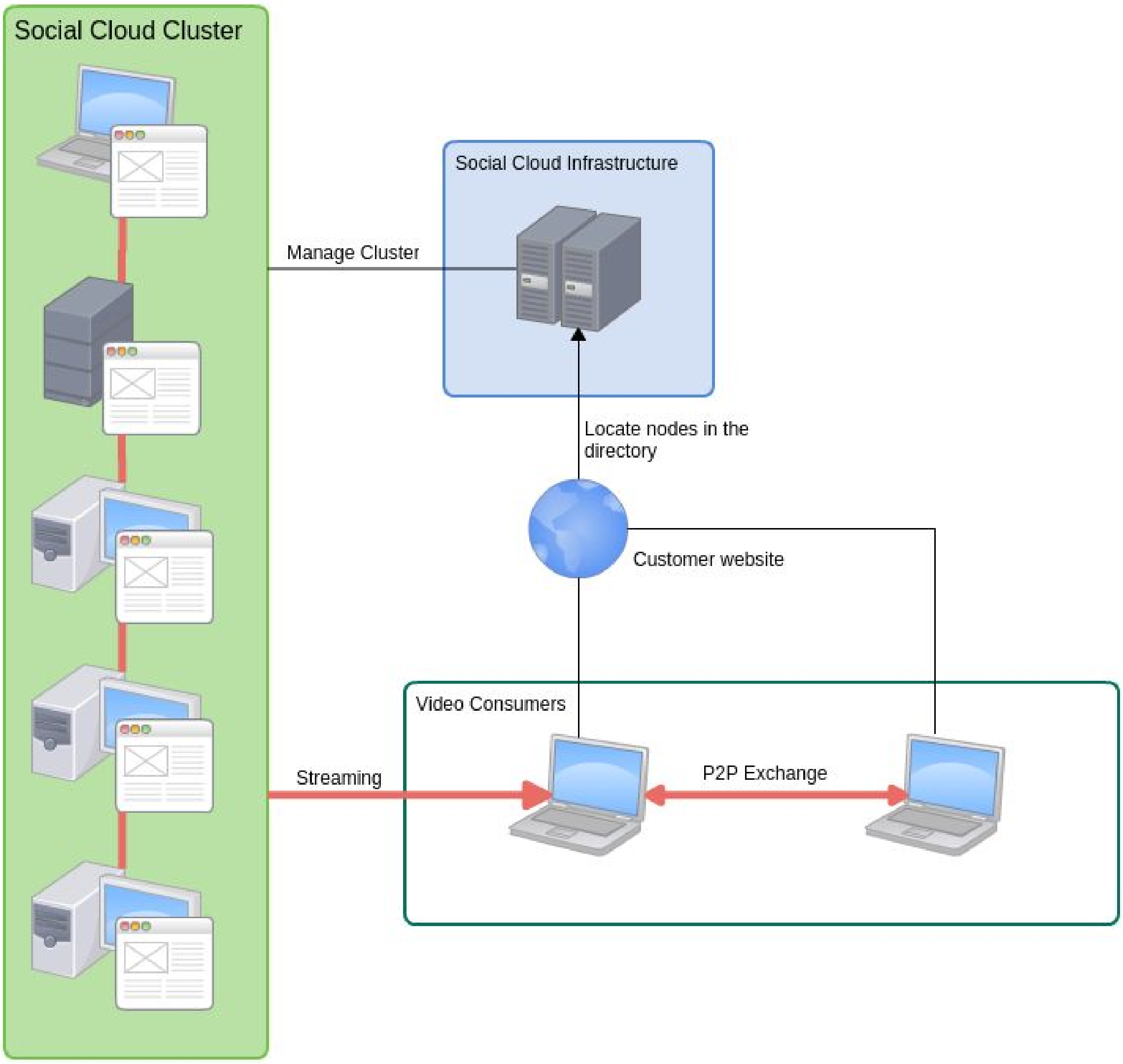
Introduction

Data centers and other electronic devices necessary to provide the information and communication technology (ICT) services are pervasive throughout our society. The rapid proliferation of these facilities has received much attention and increased scrutiny, given that their energy demand has grown to about 1.3% of global electricity use. However, great strides have been made recently to reduce the energy associated with providing ICT services by better utilizing data center servers and consolidating those servers in larger, more energy efficient facilities. The methods and results presented in this study illuminate **the decentralized streaming video system can reduce drastically energy use and emissions**, which can be an alternative to actual systems as the video streaming market and data volume are increasing.

The Social Cloud

The figure 1 shows the components involved in the decentralized video streaming system we call “The Social Cloud”. This system is an alternative to the actual video streaming system working with centralized servers in datacenters using a software designed to share unused resources to provide video streaming to the cloud customers.

Figure 1. Schema of the Social Cloud technical architecture



Steps of the streaming process:

- The **consumer** goes on the **customer website**
- The **customer website** provides a specific **video player**
- The **video player** requests nodes to stream from to the Social Cloud **manager**
- The **video player** connects to some nodes directly to get video chunks from them
- The **video player** can provide downloaded data to other instances of the player
- The **video player** plays the content to the **consumer** during the streaming

Approach

This study applies the Cloud Energy and Emission Research (CLEER) model[5] to estimate the energy gain that would have occurred by replacing the actual centralized internet video streaming services with a decentralized infrastructure called "the social cloud".

Input values characterizing present day US home video viewing of internet streaming content were entered into the CLEER model. For many of these inputs, ranges of values were applied to provide a high, low, and base-case input value, and to serve as a sensitivity analysis range. The base-case input values are derived from literature estimates and are intended to represent a typical or median value across a possible range of values within the US. As such, the base-case represents the authors' best estimates of US average energy use per viewing hour. When scaled up by total viewing hours, the base-case provides a best estimate of total national energy use attributable to each viewing method. Given that US average values for each modeling parameter are best estimates with appreciable uncertainties, high and low cases for each modeling parameter were also established. The high and low case values are meant to provide a plausible range for the US average value chosen for each parameter in the base case. As such, the high and low cases should not be interpreted as extreme bounds on the technically-possible values for each parameter; rather, they should be interpreted as plausible uncertainty ranges for the US average point values chosen for each parameter in the base-case. A summary of all high, low, and base-case input values used in this analysis is presented in the Supporting Online Material (SOM).

Results normalized by viewing hour were also compared with a scenario in which all 2011 US streaming video viewing is shifted to a decentralized streaming video service, to shed light on the potential energy use.

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[5] Masanet E, Shehabi A, Ramakrishnan L, Liang J, Ma X, Walker B, Hendrix V and Mantha P 2013 The Energy Efficiency Potential of Cloud-Based Software: A U.S. Case Study (Berkeley CA: Lawrence Berkeley National Laboratory)

Decentralized streaming video system assumptions

Figure 2 depicts the energy using processes and devices associated with providing streaming video service to the in-home viewer on the social cloud. The process steps in figure 2 show video files originating from decentralized nodes (sharing their resources to the social cloud) managed by servers in data centers. The video files are then sent across the network transmission infrastructure; inside the same access network or possibly from one access network connection pathway to another one via a core/metro network connection pathway. At the beginning and the end of the transmissions, the connection involves a router or cable box (i.e., customer premise equipment) within the home before being sent to a playback device (e.g., set-top box) that is coupled with a viewing device (e.g., television) to watch the video.

The figures shows in green the components we have to remove from the analysis since the social cloud is based on existing hardware that were built and are used for another purpose. The study will only have to estimate the increased energy consumption introduced by contributing or using the social cloud.

Figure 2. System diagram of streaming analysis. Various components evaluated within each process step required in providing streaming video service.

<table>
<tr><th>System Management</th><th>Streaming Source</th><th>Provider Premise Equipment</th><th>Provider Access Network</th><th>Transmission Pathway</th><th>Customer Access Network</th><th>Customer Premise Equipment</th><th>Playback</th><th>Viewing</th></tr>
<tr><td rowspan="2">Data Center Building</td><td rowspan="2">Desktop Computer</td><td rowspan="2">Router</td><td rowspan="2">ADSL</td><td rowspan="2">Core/Metro Network</td><td rowspan="2">ADSL</td><td rowspan="2">Router</td><td rowspan="2">Game Console</td><td></td></tr>
<tr><td rowspan="2">Television</td></tr>
<tr><td rowspan="2">Data Center Servers</td><td rowspan="2">Laptop Computer</td><td rowspan="2">Cable Box</td><td rowspan="2">Cable</td><td rowspan="2"></td><td rowspan="2">Cable</td><td rowspan="2">Cable Box</td><td rowspan="2">Set Top Box</td></tr>
<tr><td rowspan="2">Flat Screen Monitor</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="2">Desktop Computer</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Laptop Computer</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Smartphone</td></tr>
</table>

(yellow)	Components included in the analysis
(green)	Component ignored because already built/use for another purpose

Table 1 presents the server and network characteristics assumed as base-case estimates for the 2011 US streaming video delivery system. Total current US streaming viewing hours for full-length movies or television programs are estimated at 3.2 billion h, which is based on the original study[6]. An average streaming rate of 2.33 Mbps[7] is applied to the annual hours of video content to estimate the total bits of streamed content. To allocate server power (including idle power) across data flows, each server managing the nodes is assumed to draw an average power of 300 W.

The nodes hosting the video streaming are assumed to consume an average of 10 W of increased energy consumption due to the use of the social cloud software[8].
They are assumed to stream content at a maximum sustained rate of 80 Mbps based on the average fiber upload rate in France[9].

Data centers hosting the cloud managers are assumed to have the characteristics of cloud data centers, where the number of servers in use scales with the number of nodes to manage. When including an average utilization rate of 40% for the nodes, approximately 26k nodes are estimated to meet current US streaming video demand. As one cloud server can handle approximately 100k nodes, we can assume that 1 server would be enough to manage all the nodes. The nodes along with the server sums up with an average data streaming electricity intensity of 0.69 Wh / GB.

Note that these measurements focus on the infrastructure needed for flux (i.e. data transportation) not on the storage needs to achieve this aim (which will be the subject of a later study).

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[6] 2011 US streaming video characteristics http://iopscience.iop.org/article/10.1088/1748-9326/9/5/054007#erl487799t3

[7] Netflix 2013 ‘The ISP speed from netflix.’ http://ispspeedindex.netflix.com/

[8] Maximum energy consumption measured during a beta test campaign of the social cloud software running on a laptop monitored with a tool measuring energy consumption on the battery. http://manpages.ubuntu.com/manpages/utopic/man8/powerstat.8.html

[9] Fiber average upload rate since 2013 http://www.ariase.com/fr/vitesse/observatoire-debits.html#onglets_moyennesGlobales_fibre

Table 1. 2011 US decentralized streaming video characteristics.

Streaming video characteristics	
Annual video viewing (billion h)	3,2
Average streaming rate per video (Mbps)	2,3
Total bits streamed annually (petabits)	26,2
Average power per server (W)	300
Average power per node (W)	10
Average node utilization	40%
Annual processed data per node (terabits/node)	1,01
Simultaneous node managed per server	100000
Average node streaming electricity intensity (Wh/GB)	**0,69**
Total number of nodes to meet current demand	**25963**
Total number of servers to meet current demand	**1**

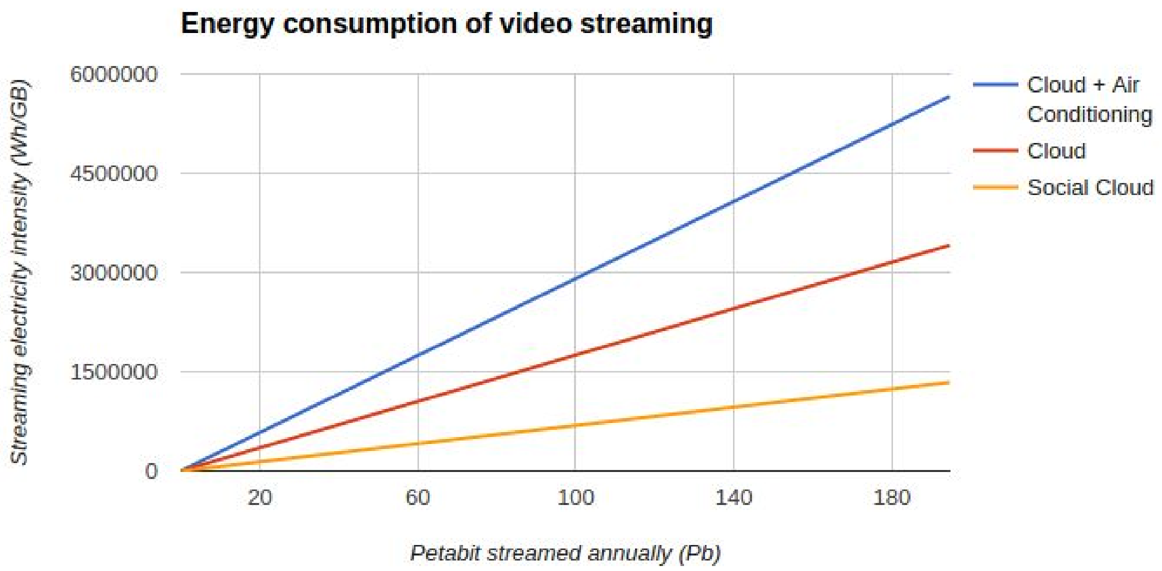
This analysis does not include the data streamed between concurrent users. The social cloud uses an emerging pattern that consist in making the consumer of video a content publisher with P2P technologies. A recent article[10] mentions the efficiency of this method up to 95% of savings when used with a large amount of consumers.
This method is too variable along with the popularity of the video streamed to measure it efficiently but we can tell the number of nodes and their consumption may be underestimated.

Results and discussion

Figure 2 presents estimates of the energy consumption for both centralized and decentralized streaming video systems based on the base-case input assumptions described in the previous sections. These results indicates that decentralized video streaming is significantly more efficient than classical systems as the volume of data streamed increases.

[10] Peer5, a Live Streaming CDN That Leverages WebRTC, Now Makes 1 Server Equal 20
http://finance.yahoo.com/news/peer5-live-streaming-cdn-leverages-160000342.html

Figure 2. Graph of the evolution of electricity consumption for video streaming



This study is mainly focused on the consumption of the computer resources needed to provide video streaming but the infrastructure used by the datacenters to protect and maintain these resources are worth studying. This figures shows the energy cost of cooling the servers with air conditioning according to a study published in 2014[11]. These results demonstrates that a big quantity of energy is used by servers and can be saved in the social cloud model.

Conclusions

This study estimates the energy use associated with video viewing through both traditional video streaming and the system our startup is trying to set up. The results shows a significant gain in the energy use with an infrastructure that uses existing resources instead of building hardware only for this purpose.

In the near future, we will complete this study with a primary energy and greenhouse-gas implications analysis to measure how much CO2(e) emission intensities are involved in centralized and decentralized video streaming to ensure our solution is more efficient.

With our preliminary tests with the CLEER model, we can predict a significant gain in cradle-to-gate primary energy and CO2(e) emission as well as the embodied energy and CO2(e) intensity of datacenter IT due to the reduced amount of servers involved in our solution. These tests needs to be improved to present detailed results in a study but they are relevant enough to give us an encouraging trend of the benefits in term of energy consumption our innovation could provide.

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[11] Jumie Yuventi, Roshan Mehdizadeh. “A critical analysis of Power Usage Effectiveness and its use in communicating data center energy consumption.” Energy and Building 64 (2013) 90-94 : Web. 17 November 2014.