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Carbon footprint of movie distribution via the internet: a Swedish case study

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ABSTRACT

Peer-to-peer (P2P) has been suggested as an energy-efficient means of movie distribution, indicating potential environmental benefits. An alternative option for the user would be to stream the movie from an internet protocol television (IPTV) solution. This paper presents an assessment of the carbon footprint of these two alternatives. When studying the environmental impacts of a product (goods or services), it is important to adopt a life cycle perspective in order to avoid moving the potential impacts from one part of the life cycle to another. Therefore the carbon footprint was assessed with a screening life cycle assessment (LCA).

The results show that end-use equipment and distribution (in both P2P and IPTV systems) are clearly key aspects. Both manufacturing and use are important. In the use phase, the electricity for using the end-use devices and for distribution is the main contributor to the carbon footprint. For the distribution, another major contributor to the carbon footprint is the construction work involved in installing cables.

Downlink/uplink bandwidth and movie size have a major influence on the environmental impact related to watching a movie by P2P, as the total time for which end-use devices need to be used is critical. Movie size determines the impact related to the distribution.

In terms of the carbon footprint from the two systems, the P2P system has a higher impact, mainly caused by the end-use devices. Downlink–uplink bandwidth and movie size determine the overall impact of the P2P system. The carbon footprint from P2P systems could be lowered either through higher uplink bandwidth or through decreased movie size.

1. Introduction

Today, rapid changes and a range of alternative solutions for communication and distribution are provided by the information and communication technology (ICT) sector. The media sector has been a pioneer regarding use of ICT (Lindqvist et al., 2003), with new platforms for media users and producers and new ways of distributing media being some of the arenas for ICT solutions. A major difference has occurred for printed media, where newspapers, books and magazines are electronically available to an increasing extent. This has had a considerable impact on businesses in this field, including increased competition. Regarding television (TV) media, this was long perceived strictly as (terrestrial) broadcast media content (also called telecast) accessed on cathode ray tube (CRT) TV sets in the home. However, today broadcasting is also carried out via satellite and cable. Most EU countries have switched to digital terrestrial TV (deVries ed., 2010). Webcasting, streaming content, is another way of distributing TV content that is becoming increasingly popular. In addition downloading of specific content by choice of the user is an alternative content transmission route. With the broad penetration of broadband internet, the opportunities for distributing TV through this channel have increased in Sweden. In 2009, 75% of the Swedish population had broadband access (Nordicom-Sverige, 2010). The change to digital solutions has decreased the costs for production and distribution of TV (deVries ed., 2010). However, at the same time the competition has increased as regards the distribution of TV (deVries ed., 2010), or perhaps more correctly audiovisual material of different kinds. In addition, the opportunities for file sharing have increased. According to Findahl (2009), file sharing in Sweden increased every

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year during the period 2004–2008, since when it has stagnated. File sharers are predominantly young men, aged 16–25. Of these, approximately 50% are currently sharing files, while 72% have shared files over the internet at some time.

ICT solutions are often considered as potentially providing benefits from an environmental perspective. For TV this is perhaps not as relevant as for other media that were previously mainly delivered on paper or discs, for example books, newspapers and music. In these cases there are opportunities for dematerialisation, as use of the paper or disc materials can be avoided through digital delivery and access (e.g. Moberg et al., 2011; Moberg et al., 2010; Weber et al., 2010). In the case of TV, analogue TV distribution was already 'non-material'. However, major changes are also going on for TV and the environmental implications of the different alternatives available are not well studied. Considering that all TVs in use and their peripherals were estimated to contribute to 0.8% of total global greenhouse gas emissions in 2007 (Malmodin et al., 2010), the environmental impacts related to watching TV should not be neglected. Operation of the end-use equipment was the main reason for these emissions, followed by manufacturing of the end-use equipment. According to a rather rough estimate, the distribution of media content contributed a smaller proportion (Malmodin et al., 2010). There have also been product-related studies on the environmental impacts related to TVs, mainly focussing on the manufacturing and use of the end-use devices (e.g. Hischier and Baudin, 2010; DCE, 2007; Fraunhofer Institute for Reliability and Microintegration, 2007a). In their preparatory study on TV consumer behaviour and local infrastructure within the research programme on Energy-using Products (EuP), the Fraunhofer Institute for Reliability and Microintegration (2007a) suggested that there is a need to further study the environmental impacts of extended TV broadcasting and access infrastructure. When studying the environmental impacts of a product (goods or service) it is important to adopt a life cycle perspective in order to avoid moving the potential impacts from one part of the life cycle to another.

As stated above, there are many different ways of providing the service TV. An alternative option to internet protocol television (IPTV) for the user would be to download e.g. a movie from the internet. Peer-to-peer (P2P) has been suggested as an energy-efficient means of content transmission, indicating potential environmental benefits. In addition TV content is very diverse. The energy efficiency and carbon footprint from distribution of digital video content has been the object for different studies (e.g. Chandaria et al., 2011; Feldmann et al., 2010; Baliga et al., 2008), however with different scope and system boundaries than ours. In the current study we have focused on movie content and compared IPTV and P2P solutions with the aim of assessing the carbon footprint resulting from watching a movie. The results are based on a study performed in 2009. The parts of the respective life cycles which give rise to most emissions are also identified.

2. Materials and methods

2.1. The studied systems

2.1.1. The IPTV system

The considered IPTV system is a commercial IPTV service. Different alternatives for IPTV, where the signal was distributed from alternative servers, were studied in the project on which this paper is based. These alternative ways of distributing the signal were from storage clusters to centrally placed servers, directly from central servers or from locally placed servers, to the end-users home. Since the material end energy for running these alternatives were in the same order of magnitude, the global warming potential of these different alternatives was similar. Therefore only one case of IPTV distribution is presented here, where content is streamed from a central server to the end-user's home.

The components included in the IPTV system studied are illustrated in Fig. 1. These are:

- Customer premises equipment (CPE) (end-use devices): Residential GateWay (RGW), set-top box (STB) with or without video recording function (STB with PVR 12%; STB 88%) and TV.
- IP access (equipment outside the end-user's home): Digital Subscriber Line Access Multiplexer (DSLAM),
- Distribution and storage: IPTV server, cables and IP network (with many servers, routers, etc).

In the end-user's home, the STB streams content from the IPTV server in the network using IP access and the above-mentioned equipment for distribution and storage. The movie is watched on the TV. The downlink bandwidth is considered to be sufficient for streaming video (at a rate of 415 kB/s). Since the amount of data that needs to be uploaded from the STB is negligible compared to the amount of data downloaded, the estimated carbon footprint is not dependent on the uplink bandwidth.

2.1.2. The P2P system

A simple model of the energy use of a P2P file sharing system can be developed by assuming that the energy use of a computer when uploading and downloading data is proportional to the amount of data uploaded and downloaded. Since a peer downloads every part of the file from some other peer, this assumption implies that the energy use involved in downloading a file (i.e. a set of file parts) is equal to twice the energy use of a single computer downloading the file. Using a similar reasoning, but not accounting for the energy use involved in receiving the file, the model used by e.g. Nedevschi et al. (2008) expresses a direct proportional relationship between the amount of data downloaded and the energy use. Nedevschi et al. (2008) do not consider the electricity use of the computers that they would have anyway just to be powered on. This is however considered in our analysis. Since our study is a descriptive attributional LCA, we needed a model that enabled us to estimate the average computer use attributed to file sharing.

In order to develop a suitable model, consider a P2P file sharing system in which overlay management is implemented in a decentralised fashion, e.g. using a distributed hash table and gossipping, as in modern BitTorrent peers. The traffic related to overlay management is very small compared to the amount of downloaded data, usually in the order of a percent, and therefore we ignore it. Let us consider that in the P2P system the average downlink and uplink capacity of the (average) peer is C_D and C_U, respectively. With a file size of B it takes on average at least B/C_D time for a peer to download the file. If $C_D > C_U$, as is usually the case, then on average downloading the file takes less time than uploading it. Assume now that an average peer leaves the P2P system upon downloading. Then during the B/C_D time that it spent in the P2P system it only uploaded $C_U B/C_D < B$ amount of data, which is insufficient to maintain the file available for newly arriving peers. Therefore, in order for the file to be available in the P2P file sharing system in the long term, peers have to spend on average at least B/C_U time in the system. That is, an average peer would download and upload the file during B/C_D time and then would spend $B/C_U - B/C_D$ more time uploading the file. The model can be interpreted in another way too. In order for a peer to be able to download at rate C_D, there need to be C_D/C_U peers that upload data at rate C_U each. Note that the model is equivalent to the previous model if $C_D = C_U$. The model and the related reasoning are in accordance with the most widely used fluid model of BitTorrent-like P2P systems (Qiu and Srikant, 2004; Lehrieder et al., 2012).