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Comparison of the energy, carbon and time costs of videoconferencing and in-person meetings ☆

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ABSTRACT

While video conferencing is often viewed as a greener alternative to physically traveling to meet in-person, it has its own energy, carbon dioxide and time costs. In this paper we present the first analysis of the total cost of videoconferencing, including operating costs of the network and videoconferencing equipment, lifecycle assessment of equipment costs, and the time cost of people involved in meetings. We compare these costs to the corresponding costs for in-person meetings, which include operating and lifecycle costs of vehicles and the costs of participant time. While the costs of these meeting forms depend on many factors such as distance traveled, meeting duration, and the technologies used, we find that videoconferencing takes at most 7% of the energy/carbon of an in-person meeting. This comparison changes when the time cost is taken into account, with videoconferencing potentially costing more than in-person meetings in a worst-case scenario. We also analyze the sensitivity of the energy and carbon costs to various factors and consider trends in energy and carbon usage to predict how the comparison might change in the future.

1. Introduction

Information and communication technology (ICT) is often seen as an attractive mechanism for reducing our environmental impact. In particular, ICT substitutes physical processes with virtual ones, thus providing a greener alternative to conventional activities. A good example is the increasing use of videoconferencing, which replaces physical travel with transferring information across a network. However, videoconferencing is not entirely green with zero environmental impact. The many devices involved in the capture, processing and transmission of information in a videoconference consume electricity, and the generation of electricity has a considerable carbon footprint. Significant environmental impact also arises from the lifecycle of these devices, including their production, deployment and disposal stages. Depending on the magnitude of these effects, the actual carbon savings of videoconferencing over in-person meetings might be reduced or even negated. Furthermore, meetings impose a time cost on participants, and while videoconferencing may save on travel time, videoconferences can take longer than in-person meetings in order to achieve the same outcome, so the overall time cost of the different ways of meeting is also uncertain.

This paper presents a comprehensive study to evaluate the actual energy, carbon and time savings of videoconferencing solutions over in-person meetings. The scope of our study includes the operating and lifecycle (embodied) energy cost of the end terminals, videoconferencing equipment, and network infrastructure. In addition, we also factor in the time overhead caused by the lower efficacy of video communication in completing tasks. These are then compared with the costs of the common modes of transportation taken by participants to attend meetings, such as the direct fuel consumption and the lifecycle energy cost of vehicles, corresponding transport infrastructure and travellers' time cost. We also evaluate how varying travel distance and meeting duration affect the overall carbon savings brought about by videoconferencing.

While claims that videoconferencing has lower carbon, energy and time costs than in-person meeting are often asserted and may seem "obvious" to many people, there is scant literature that tests these claims. To the best of our knowledge, our work is the first to provide a holistic estimate of the energy and carbon cost of a videoconference that includes both the direct and embodied

☆ Previously published in the *IEEE GreenCom 2012 Conference Proceeding*. In this paper we have broadened the scope to cover the time dimension, which is the third factor in addition to the previous two factors (energy and carbon cost) considered previously. We have also considered more cases, and enhanced the presentation by including graphs that demonstrate the impact of multiple factors on the results. We have attached a copy of the previous paper as part of our submission.

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energy of all devices involved in videoconferencing. While the results of our work are not particularly surprising, their value is in the fact that they provide evidence to confirm widely held opinions. This paper extends our previous work [1] in this area by also considering the time costs of the different meeting modes.

Our work focuses on substituting videoconferencing for travel for in-person meetings. That is only one use of videoconferencing, and videoconferencing is also widely used as a substitute for audio-only technology such as teleconference and phone calls. However, to limit the scope of this paper, we will not further consider the costs of audio-only meetings, and instead compare videoconferencing with in-person meetings.

This paper starts by reviewing literature that has examined the carbon costs of videoconferences and in-person meetings (Section 2). Because the carbon costs of running videoconferencing equipment arise from electricity consumption, and electricity generation systems (and so corresponding carbon costs) vary radically by geographical location, most of this paper (Sections 3–4) expresses running costs in terms of energy, and we translate these to carbon costs in Section 6. Considering energy as the unit for operating costs has the added benefit of facilitating comparison to other lifecycle costs (e.g. manufacture and disposal) which are typically expressed in terms of energy rather than carbon emission, enabling a total lifecycle comparison of the energy costs of videoconferencing vs. in-person meetings. In Section 3 we consider the costs of videoconferencing, covering network operating costs (3.1), videoconferencing terminal operating costs (3.2) and lifecycle assessment of network and terminal equipment (3.3). We then consider the transportation costs of in-person meetings in Section 4, and time costs for both meeting modes in Section 5. Total costs of video conferencing and in-person meetings are calculated in Section 6. In Section 7 we extrapolate trends in energy/carbon usage to predict how these costs may change in the future, and offer conclusions in Section 8.

2. Literature review

Although video conferencing has been commonly advertised as a greener alternative to in-person meetings, surprisingly little research has been done in quantifying the actual energy savings and greenhouse gas reductions brought about by video conferences. In this section we review the few papers that have directly considered the carbon costs for videoconferencing, while in subsequent sections we refer to many other papers (e.g. [2,3]) that provide data about energy and carbon costs of components of the complete meeting ecosystems.

Baliga et al. [4] studied the carbon savings provided by telecommuting as a function of the percentage of reduction in car and air travel. Their work focused on the energy consumed by the network infrastructure, in particular the carbon contribution for different access networks. However, they did not study the energy and carbon contribution of end systems such as videoconferencing equipment and LANs, and also omitted the lifecycle cost of the devices involved. Their calculations show that telecommuting and teleconferencing do substantially reduce carbon emissions; e.g., a mere 5% reduction in car travel will save between 50 and 160 $kgCO_2e$ (kilograms of carbon dioxide equivalent) per household (equivalent to 1% of the average household carbon emission), depending on the quality of the video call and the type of access network.

Guldbrandsson and Malmodin [5] studied the life-cycle CO_2 savings of three different videoconferencing configurations for a meeting between Stockholm and Dallas. The total active duration of the video conferencing systems is assumed to be 960 h p.a. and 48 plane trips are assumed to be eliminated per year. For this specific case, they found that using the videoconferencing systems saved roughly 215 $tonCO_2e$/year, which is about 170 times the annual carbon emission of a videoconferencing system.

Another study by Quack and Oley [6] found that substituting meetings by videoconferences reduces carbon emissions by up to 90%. They also presented the tradeoffs between distance and the energy cost – longer travel distances leads to increased carbon savings. However, they did not present details of their derivation and intermediate values in terms of the energy and carbon emission for both meeting solutions. This makes it hard to scale their results to estimate the environmental impact for varying meeting dimensions (distance, duration, configuration of end terminals, number of participants and endpoints).

3. Videoconferencing energy cost

In this section we assess the energy costs of videoconferencing by examining the contribution of the operating expenses (opex) of the network (Section 3.1) and videoconference terminals (Section 3.2), as well as the lifecycle costs of network and videoconference equipment (Section 3.3).

3.1. Network operating expenses

Network opex cover the use-phase energy cost of the network infrastructure including all transmission and switching equipment in the Internet. For our purposes, the Internet does not include networking equipment at end sites (e.g. home routers) but includes ISP equipment. We will separately consider networking equipment at end sites because it can be measured using techniques similar to those used to measure the power requirements for other devices at end sites, which will be addressed in Section 3.2. A common measure for the network opex is the energy intensity of data transfer, which is the energy cost per gigabyte of data transmission (kWh/GB) [2].

The total active power of the Internet is estimated to be between 43 and 72 GW [7]. Also, the global Internet traffic was estimated to be 500 PB per day in 2010 [8]. This is consistent with the value extrapolated from the Minnesota Internet Traffic Studies [9], assuming the growth rate of the Internet data flow is 50% in 2009 [2]. Therefore, the Internet energy intensity is calculated by dividing the operating power of the Internet (Watts) by the Internet data flow (bits per second), as in [2]. The end result is an estimate of the average operating energy intensity of the Internet of between 2.17 and 3.61 kWh/GB in 2010. Videoconference data rates vary widely (as discussed further in Section 6), but typically range between 100 kb/s to 10 Mb/s (or equivalently 0.045–4.5 GB/h), which at around 3 kWh/GB equals 135 W to 13.5 kW to carry video traffic across the Internet.

As a sanity check, we compare our obtained values of the Internet energy intensity to the values estimated in [2]. The analysis of Internet advertising in [2] presented 3 separate estimates of the energy intensity: 24.9, 16.3 and 9.4 kWh/GB. They also found that the Internet energy intensity fell 10-fold in 6 years. Assuming this trend continues, the estimates of energy intensity would be 3.7, 2.4 and 1.4 kWh/GB in year 2010, which are consistent with our range of estimates.

3.2. Videoconference terminal operating expenses

Videoconference devices lie at the outer edge of the network, which include the home or office LAN devices (modems, switches and Wi-Fi access points), computers, displays, projectors and videoconferencing specific equipment and peripherals such as CODECs, microphones, sound systems and cameras. Unlike network equipment, the energy consumed by these devices correlates