Journal of Network and Computer Applications ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

Making social networks a means to save energy

Juan López-de-Armentia, Diego Casado-Mansilla, Diego López-de-Ipiña

Deusto Institute of Technology - DeustoTech, University of Deusto, MORElab Envisioning Future Internet Avda. Universidades 24, 48007 - Bilbao, Spain

ARTICLE INFO

Article history:
Received 13 November 2013
Received in revised form
1 July 2014
Accepted 23 September 2014

Keywords:
Collaborative eco-aware everyday things
Eco-aware everyday things
Social devices
Energy-efficiency
Coffee machines
Predictive models

ABSTRACT

Energy consumption in the world has increased significantly in the last few decades, becoming an important issue nowadays. The eco-aware everyday things were devised to prevent the waste of energy resources in common areas where people often elude their responsibility about the energy consumption when using appliances of collective use, like printers, coffee makers, beamers and so on. These eco-appliances are able to improve their energy efficiency dynamically adapting their operation according to their usage patterns. This work proposes a further step, also aligned with devices' automation, where everyday consumer devices are transformed into collaborative eco-aware everyday things. Taking advantage of the evolution of the Internet towards the Internet of Things and the Web as a universal communication mechanism both among humans-to-things and things-to-things, it is proposed to use Twitter as a communication channel for eco-aware appliances to share their usage patterns. Thus, other newly deployed similar devices in comparable environments can alleviate the cold-start problem, which is common in scenarios where usage learning is needed. To assess the effectiveness of this approach, a collaboration between three of these eco-aware devices has been simulated, giving place, encouragingly, to a higher energy reduction efficiency when compared with non-collaborative objects.

1. Introduction

Over the past few years we are witnessing an exponential growth of information technologies in the form of consumer devices. Most of them are smart everyday objects. These, together with the new capabilities to link Internet with everyday devices and the new forms of identification and communication among people, are defining the so-called Cyber-Physical Systems. Such a substantial increase of electrical devices must be absolutely followed by government guidelines and policies to restrain the ecological footprint that these appliances will cause in their overall life-cycle (from design to disposal). Our society should also take a pivotal action-role in such a major concern. Thus, we have to become more aware of energy waste in all its forms and everywhere.

Common area settings, such as workplaces, have remained rather unexplored despite its great potential for energy savings. The workplace is a very relevant case of study inasmuch as our society spends at work more than half of the day, and this sector is now responsible for roughly the 10% of the overall energy demand in the world (DECC, 2013). A good example is the United States where commercial buildings account for 36% of all U.S. electricity consumption (Efficiency and Energy, 2008). Focusing in the office environment, the energy consumed by work-appliances of common use (coffee-makers, printers, screens, kettles and so on) represents more than 15% of the total, and it is expected to rise above 20% in 2020 (Carbontrust: Employee awareness and office energy efficiency [Online], 2013). In this article we devise means to face up to such energy consumptions.

In a previous research (López-de-Armentia et al., 2014) we proposed to reduce the energy consumption of devices of shared use within common areas through the eco-aware everyday things concept. These eco-appliances were able to improve their energy efficiency adapting their operation according to their usage pattern. To perform accurate usage predictions, these devices required a learning period (30 days in López-de-Armentia et al., 2014). In that work, it was demonstrated that the energy saving potential of learning the usage pattern and making usage predictions upon them was about 15%. In the reported experiment (López-de-Armentia et al., 2014), the first week energy consumption was 928 Wh. After the learning phase, the coffee-maker saved 15% per week, that were around 140 Wh per week. This amount of energy, according to `carbon.to`,[1] is equivalent to completing the

E-mail addresses: juan.lopezdearmentia@deusto.es (J. López-de-Armentia), dcasado@deusto.es (D. Casado-Mansilla), dipina@deusto.es (D. López-de-Ipiña).

[1] http://www.carbon.to/

http://dx.doi.org/10.1016/j.jnca.2014.09.020
1084-8045/© 2014 Published by Elsevier Ltd.

Please cite this article as: López-de-Armentia J, et al. Making social networks a means to save energy. Journal of Network and Computer Applications (2014), http://dx.doi.org/10.1016/j.jnca.2014.09.020

charge process of 140 mobile phones. This means that any reduction of the aforementioned period, will lead to a reduction of energy consumption.

This paper presents a new iteration in our quest for eco-aware everyday things. Now, eco-aware everyday things collaborate with similar eco-aware devices by sharing their usage patterns through Twitter. This similarity among appliances is reflected in the profile of each eco-aware everyday thing, which encompass information, such as the device type, its location, the users that share it, the activity developed in its deployment setting, the schedule, etc. Eco-aware devices' usage patterns are collected and shared through the social network, so that other similar newly deployed eco-aware devices can acquire them alleviating their cold-start problem. That means to reduce the learning time (30 days in previous work López-de-Armentia et al., 2014), as much as possible and therefore, to start saving energy earlier.

To test the effectiveness of our approach, we performed a one month trial with three augmented capsule based coffee machines. Two of them, placed in two research laboratories, were collecting usage-data during two weeks. After that, a new coffee-maker was installed in the remaining laboratory. The three devices continued collecting usage-data along the next week (the third week). At this point, the new device could acquire two different behaviours: continue operating alone or accept collaboration. To observe the difference in energy terms between the two approaches during the fourth week of the process, we proceeded to perform two consumption simulations with the collected data, obtaining promising results.

The remaining of the article is organized as follows. In Section 2, different strategies to save energy, middleware solutions for Internet of Things, the relation of social networks with Internet of Things and the methods to identify profiles' similarity are reviewed. Section 3 describes the eco-aware everyday things challenges. Section 4 illustrates, by mean of a scenario, how collaborative eco-aware devices interact with each other, unlike the ordinary ones, that they operate alone. In Section 5 the trial performed to compare the energy consumption of eco-aware everyday things, both by means of collaborative and individual operation, is explained. In Section 6, the results are shown and analysed. Finally, Section 7 summarises these paper's contributions and open future perspectives.

2. Background

2.1. Eco-devices

Regarding the commercial deployment of eco-awareness systems, there are several physical gadgets in the market designed to visualize the energy consumption in real-time. For example, *Wattio Solar*,[2] the *Energy Orb*[3] or *Wattio*.[4] Other commercial eco-awareness system is *Nest*,[5] an intelligent thermostat which learns what temperatures user likes and builds a personalized schedule in his/her home. Aligned with this solution, but not commercialised, there is TherML (Koehler et al., 2013). This is an occupancy prediction algorithm that uses GPS data from a user's smartphone to automatically control the indoor temperature of a home.

Most of these devices are designed for people's personal settings. That is, individual or by a very small family group use. The solutions presented represent stand-alone meters, devices or applications. There are solutions which are designed to operate autonomously without any kind of interaction nor cooperation with distant Internet-connected devices. Indeed, most of them are focused on household settings. Furthermore, most of the reviewed solutions are mainly aligned with promoting human behaviour change and people awareness, while our approach is focused on optimising electrical everyday things' performance towards energy-efficiency. We propose a dynamic and automatic collaboration among similar smart eco-aware things deployed in comparable environments, i.e. similar group size and type of work, which would explain that they can import intelligence from each other.

2.2. IoT middlewares

Recently, some architectures for Internet of Things have been proposed by ITU,[6] EPCGlobal,[7] The CASAGRAS initiative,[8] the uID research group[9] or Xively.[10] Analysing them, we conclude that their emerging priorities are:

- Enable full connectivity of things to the Internet.
- Provide middleware and application functionality and protocols to ease the exploitation of things-related services.

One of the main features of the eco-aware everyday things which we promote is that they should collaborate, not only with others devices, but also with people who use them. Hence, we oriented the solution to the social networks, instead of developing a new architecture to connect things between each other and with people by means of Internet.

Twitter is one of the most influential and less intrusive of the reviewed networks. Indeed, with more than 200 million users and roughly 400 million[11] tweets per day, Twitter is the most prominent micro-blogging service available today on the Web. The research community is exploiting Twitter for several purposes, such as trends predictions (Danesh et al., 2010), incidents detection (Klein et al.,) or influential users (Cha et al., 2010). Studying its functionalities, we reckon that Twitter platform can successfully adapt to our needs. These are: (a) to have an identity with an associated profile; (b) to find similar devices; and (c) to send private messages to other devices. Other social networks, such as Facebook, could also cover all the requirements, but Twitter is more open than them and fits better with our system priorities.

There are many libraries to communicate with Twitter.[12] Bearing in mind a Django[13] application deployed in a server, we advocate using Tweepy.[14] It is an open-sourced library which enables Python to communicate with Twitter platform and use its API.[15]

2.3. Introducing social networks

There is scientific evidence that a large number of individuals connected in a social network can provide far more accurate answers to complex problems than a single individual (Surowiecki, 2005). The exploitation of this principle has been widely investigated in Internet-related research (Holmquist et al., 2001; Bleecker et al., 2005; Nazzi and Sokoler, 2011; Guinard et al., 2010; Kranz et al., 2010).

[2] http://www.diykyoto.com/
[3] http://www.orbenergy.com
[4] http://www.wattio.com/
[5] http://nest.com/thermostat/saving-energy/
[6] http://www.itu.int/es/Pages/default.aspx
[7] http://www.gs1.org/epcglobal
[8] http://www.iot-casagras.org/
[9] http://groups.csail.mit.edu/uid/
[10] https://xively.com/
[11] http://cnet.co/KHlg8q
[12] https://dev.twitter.com/docs/twitter-libraries
[13] https://www.djangoproject.com/
[14] https://github.com/tweepy/tweepy
[15] https://dev.twitter.com/docs/api/1.1

Please cite this article as: López-de-Armentia J, et al. Making social networks a means to save energy. Journal of Network and Computer Applications (2014), http://dx.doi.org/10.1016/j.jnca.2014.09.020