The practice of online social networking of the physical world

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Abstract: A big challenge for the web is to become ubiquitous, blended with the everyday life of people. The pervasive web envisions seamless connectivity with the physical world, where embedded devices offer real-world services to the users. Social networking is a core part of the online experience. The Web 2.0 has become a social web, extending users’ social capabilities. Online social networking platforms have the capability to support numerous real-life applications, promoting the concept of sharing environmental services between relatives, friends or more generally groups of people that have common interests. In this paper, we investigate how the social web can be harnessed to facilitate the transit to a pervasive web. We examine this potential through four case studies: a smart home that promotes sharing of household devices between family members; a working environment where employees monitor a common area; a neighbourhood where neighbours compete for energy conservation; and a social application that allows people to compare their electricity footprint with their friends and their community. Through these case studies, we demonstrate the potential benefits of enhancing pervasive applications with social characteristics.

Keywords: pervasive web; social networking; Facebook; web of things; WoT; REST; smart homes; home automation; smart metering; environmental monitoring; energy awareness; social competition; social electricity.


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1 Introduction

Examining the short history of the web, we witness a transition from content publishing to interactive information sharing (O’Reilly, 2007). The Web 2.0 has penetrated deeply in our lives and has enabled collaboration and interoperability on the internet.

An important milestone that has boosted the popularity of the Web 2.0 is the evolution of online social networking sites (SNS). SNS can be defined as web-based social spaces designed to facilitate communication, collaboration and content sharing across networks of contacts.

According to a Nielsen report (Nielsen Online Report, 2009), two-thirds of the world’s internet population visit social networking or blogging sites, accounting for almost 10% of all internet time. Currently, Facebook is the world’s most popular SNS with more than 845 million monthly active users (Facebook Statistics, 2012). Social networking has become a fundamental part of the global online experience, transforming the Web 2.0 into a social web, in which human social capabilities are boosted.

The next big challenge for the web, after its massive utilisation by humans, is to interconnect the physical world. Physical devices, enhanced with embedded microcontrollers, could be an essential part of the future web as they are rapidly being integrated into our lives, justifying Mark Weiser’s vision of the disappearing computer.

This is partly the vision of the pervasive web (Silva et al., 2008), in which users can access information and interact with every connected device and the global community in an ubiquitous way. In the pervasive web, users will be able to know the right content, at the right time, in the right place and on the right device.

 Seamlessly linking the web with physical spaces requires the full web-enablement of physical things and the smooth connectivity and interaction with them. This integration is crucial in order to provide environmental information and ubiquitous services in the future web.

Embedded computing has made tremendous steps to allow the introduction of physical entities to the web. Everyday objects can be blended with the web, either directly by embedding web servers on them (e.g., sensors and actuators), or indirectly by means of gateways, smart readers and mobile phones (e.g., RFID tags, smart cards, and QR codes).

Following this trend, the web of things (WoT) (Wilde, 2007) reuses web principles to interconnect the expanding ecosystem of embedded devices, built into everyday smart things. The WoT tries to address the issues that appear in the process of enabling embedded devices to the web. These issues include local/global discovery of devices, description of their functionality and interaction patterns with them.

We believe that SNS can constitute a driver for the transition to a pervasive web. In the same way as SNS made Web 2.0 technologies popular, they can perform the same task with everyday smart objects, transforming online social networks into shared smart spaces. While waiting for the WoT to effectively solve all the issues associated with the enablement of the physical world to the web, SNS applications can be employed, allowing people to share physical devices and ubiquitous services. In this way, social relationships between people can be extended to social relationships with their physical environment.

Furthermore, SNS offer large possibilities for application developers, as they possess detailed information about the social networks of their users. This social information, when combined with pervasive real-life applications, permits these applications to become more effective, extending them with advanced functionalities. As an example, social norms can be exploited for motivating people to acquire more sustainable behaviours (Allcott, 2011).

This paper investigates the possibilities revealed when blending online social networking with the physical world. We examined a number of real-world scenarios, applied in different social domains, in order to demonstrate the potential for substantial benefits, acquired from the practice of enhancing ubiquitous computing with an online, social perspective.

These scenarios concern a smart home that promotes sharing of household devices between family members, an organic farm in which workers monitor a greenhouse, a block of flats where neighbours compete in a game for energy conservation, and finally, a social application that allows people to understand the ‘semantics’ of the electrical energy they consume, by comparing it with their friends and their community.

The rest of this paper is organised as follows: in Section 2, we identify related work and in Section 3, we explain the practice of enabling smart spaces to online social networking platforms. Then, in Section 4, we present our experiences from blending online social networking with the physical world, through four different case studies.
Finally, in Section 5, we discuss about future work and conclude the paper.

2 Related work

Embedded devices and their services need to be enabled to the web, before being utilised by an online social networking application. Linking the physical and the digital world by means of online social networking is a recent initiative of the global research community.

Our research efforts span in these two domains: the web-enablement of the physical world and the usage of SNS for sharing web-enabled physical devices and pervasive services.

2.1 Web-enabling physical things

Early attempts for web-enabling physical things included physical tokens such as barcodes and RFID tags, to identify the objects they were attached to Roy et al. (1999). In the Cooltown project (Kindberg et al., 2002) every thing, place and person had an associated web page with information about it.

Web-based middleware solutions appeared in the last decade, exploiting Web 2.0 services to integrate embedded devices to the web (Prehofer et al., 2007). The work in (Stirbu, 2008) enables heterogeneous sensor devices to the web, focusing mainly on the discovery of these devices. TinyREST (Luckenbach et al., 2005) proposes a RESTful gateway to bridge the internet with the physical world.

Wilde (2007) suggests the adoption of RESTful principles (Fielding, 2000) to make physical objects available to the web, envisioning a web of physical things. A comprehensive report describing the architecture of the WoT and several interesting prototypes, is provided in (Guinard et al., 2010b). A prototype of the WoT is presented in Guinard and Trifa (2009), where the founding principles of the web as an application protocol are reused for monitoring the energy consumption of household appliances through smart power outlets.

A technological advancement that boosted the research efforts towards the web-enablement of embedded devices has been the integration of the IP stack on sensor motes (Dunkels et al., 2004b; Hui and Culler, 2008). Schor et al. (2009) have showed that 6LoWPAN-enabled wireless sensor networks (WSN) can by directly integrated into the IPv6-based future internet with acceptable performance. Following this concept, Yazar and Dunkels (2009) implemented an IP-based sensor network system where nodes communicate using RESTful web services.

Contiki (Dunkels et al., 2004a) provides open-source code for embedding a web server on sensor motes. An example Contiki application allows IPv6-enabled sensor devices to directly interact with Twitter and update the user’s status with sensory measurements.

SenseWeb (Kansal et al., 2007) promotes the idea of sharing sensory readings through the web. In SenseWeb, users use web services to transmit their sensory readings on a central server. Pachube (Haque, 2007) offers a similar infrastructure, allowing users to store, share and discover in real-time sensory data from devices around the world.

A different direction proposed for interacting with physical devices on the internet, is through instant messaging (IM). IM is a form of real-time, text-based communication between two or more machines using shared clients. Approaches such as Choi and Yoo (2008), and Foley et al. (2005) extend existing IM infrastructures to support human-to-thing and thing-to-thing communication, for the realisation of ubiquitous computing environments.

2.2 Pervasive social networking

The impact of web-based social networking is recognised in (Ben Mokhtar and Capra, 2009), where the notion of pervasive social computing is introduced, focusing on disseminating tasks in a pervasive environment, based on users’ common, social preferences and on the friend of a friend (FOAF) ontology. SocialNets (Socialnets FP7 Project, 2007) is a large European project that aims to achieve pervasive adaptation by exploiting the properties and characteristics of human social networks, towards ubiquitous social networking.

Some approaches tried to bridge the gap between online and physical social networks. For example, the Cityware platform (Kostakos, 2008) utilises Bluetooth-enabled mobile devices to merge users’ social data, made available through Facebook, with mobility traces captured via Bluetooth scanning. The CenCeMe system (Miluzzo et al., 2008) collects users’ present status or context information using sensor-enabled mobile phones and exports their status automatically to SNS.

Some other projects propose the enhancement of social interactions at the web by means of wearable sensor devices. Patches (He and Schiphorst, 2009) is a wearable social network which uses Facebook to promote online communication in everyday life.

A different direction is followed in Vázquez and López de Ipiña (2008). Everyday objects are transformed into autonomous artefacts that communicate on the internet presenting advanced behaviour. A number of prototypes are demonstrated where augmented objects use the internet to look smarter.

Converting existing SNS into smart environments that host embedded devices is a challenging, novel issue. SenseShare (Schmid and Srivastava, 2007) targets exploiting social networking infrastructures for sensor data sharing, focusing mostly on privacy. The work in Guinard et al. (2010a) proposes sharing of physical devices between people that know and trust each other. Trust is delegated from the device owner to his online contacts, which are discovered from his favourite SNS.

Evrythng (Murphy et al., 2011) is a new software company aiming to enhance individual things with unique online profiles. When every product and other physical objects are part of the web, novel dynamic digital services could be developed. It is a radical new initiative for globally connecting people and things together, by means of the web.
Leveraging online SNS for environmental awareness is a recent practice. The social influence of the community has been recognised as an important factor in sustainability-related initiatives (Cialdini, 2001). For example, StepGreen.org (Mankoff et al., 2010) exploits online SNS for promoting energy-saving behaviours of users.

Following the direction of transforming online SNS into pervasive spaces, our contribution is among the first, to our knowledge, that demonstrates the potential of sharing physical things and pervasive services through SNS, by means of four different case studies, each applied in a different real-life scenario.

3 Building pervasive online social networks

In this section, we summarise our earlier experiences (see Kamilaris and Pitsillides, 2010) in transforming existing SNS into pervasive spaces that host embedded devices and pervasive services. At first, we describe the basic elements that allow this transformation and then we provide the general architecture.

3.1 Core elements

The core elements needed for developing pervasive social networks are listed below:

- **SNS**. The popularity of SNS has increased enormously in the last few years. Some of the most popular SNS widely used worldwide are Facebook, Twitter, MySpace and LinkedIn. A SNS essentially consists of a representation of each user (Profile), the social links that represent his friendship relationships (Friends) and additional services that promote content sharing.

- **Open web APIs**. A very important feature of SNS that has evolved recently is their support for open application programming interfaces (APIs). These APIs provide access to the internal structures of SNS, allowing one to acquire the social networks of their users. They contribute in designing rich integrations that help make the web more social.

- **SNS applications**. Through their open APIs, SNS support the development of social applications from third-party developers. According to Facebook Statistics (2012), there currently exist more than seven million applications and websites, integrated with Facebook. More than 70% of Facebook users engage with some of these applications every month.

- **Web mashups**. Mashups are web-based resources that include content and application functionality through reuse and composition of existing resources. When web mashups employ physical devices, they can be extended into physical mashups (Guinard and Trifa, 2009), using the mashup paradigm to create pervasive web applications. Physical mashups can use the open APIs provided by SNS, to develop social, pervasive SNS applications.

- **Web-enabled physical devices**. A fundamental part for the enablement of physical devices to SNS is their discovery to the web. This integration procedure is needed in order to access the capabilities of these devices through a web interface. This integration can be performed either by embedding web servers directly on the physical devices or by employing gateways. Gateways are employed when embedded devices are not able to directly connect to the internet (e.g., RFID tags).

- **Web services**. Web services can be applied for achieving uniform interaction with embedded devices and ubiquitous services. Their utilisation is important for interoperability reasons. There exist two main trends for web services: WS-* and REST. WS-* (Alonso et al., 2004) are mainly used for enterprise application integration. They are preferred in cases when physical devices are behind powerful gateways or when the data produced by these devices are stored in online repositories. REST (Fielding, 2000) is an architectural style that defines how to properly use HTTP as an application protocol. It is proposed for interaction with resource-constrained physical devices as it is lightweight.

- **Device/service discovery**. This process involves the discovery of physical devices and the services they offer. Devices should operate in an automated, plug and play way, exploiting their web-based operation environment for developing uniform local and global discovery patterns. Physical devices can expose their functionality in standardised ways. For example, (WADL, https://wadl.dev.java.net/) provides a machine-readable description of HTTP-based web applications. Concepts of the semantic web can be also employed for understanding the semantics of pervasive services.

3.2 General architecture

The general architecture that can be employed for developing pervasive social networks is presented in Figure 1. It consists of the following three components:

- The physical devices that are web-enabled, directly through embedded web servers or by means of gateways. The devices/gateways offer RESTful web services for interaction with them and web-based device/service discovery patterns. These devices can be sensors, RFID tags, smart electricity metres, etc.

- The SNS, which provide web-based open APIs, supporting the application development from third-party developers. Pervasive SNS applications can be developed following the mashup example, extending web mashups into physical mashups, enabling the
Blending online social networking with the physical world

To demonstrate the real-life benefits, acquired when combining online social networking with pervasive applications, we examined four different case studies.

Starting from a home environment, we performed a study concerning the technical advantages associated with the practice of sharing household appliances between family members. Moving to a working environment, we observed how the monitoring of an area of common interest could be improved, through online social networking.

Then, we considered a local neighbourhood, creating an online social competition between the residents, targeting energy awareness and electricity conservation. Finally, we extended the application of online social networking in large-scale application scenarios, reaching a city- or even a country-wide scale. We created an application that helps people to question their electricity footprint, by means of comparisons with their online friends.

We selected Facebook as our experimental SNS because it is one of the most popular social networking platforms on the web, with a stable open API that provides rich possibilities to application developers.

In the following subsections, we present these case studies, explaining our implementation and deployment efforts, discussing the first impressions and experiences from the people involved in them.

4.1 Sharing home devices in a domestic environment

In the future, smart homes will offer new automation possibilities to their residents. Information processing will be thoroughly integrated into everyday objects, extending the home environment into a shared space that pervasively interacts with its inhabitants.

Online social networking could enhance smart homes with social characteristics. Family members could interact with their home through SNS, transforming the interaction with their home appliances into a shared, social experience. Therefore, social relationships between people can be extended to social relationships with their household devices.

4.1.1 Implementation

In Kamilaris and Pitsillides (2010), we demonstrated the feasibility of social networking of the smart home. We created a smart home that hosted two types of embedded devices: Telosb sensor motes (Polastre et al., 2005), operating with TinyOS and Plogg smart power outlets (Energy Optimizers, 2010), which are wireless devices with the capability of measuring in real-time the energy consumption of various electrical appliances and control their operation.

In general, smart metering is a crucial element in future smart homes due to the environmental and financial implications of electrical energy today. Timely electrical consumption feedback has the potential to reduce domestic electrical consumption by 5% to 15% (Darby, 2006).

We developed an IPv6-enabled WSN, consisting of the sensor motes, which are equipped with temperature, humidity and illumination sensors. We exposed their sensing capabilities as RESTful web services, transforming them into embedded Web servers. Our implementation was based on Blip, which is an implementation of the 6LoWPAN stack for TinyOS. 6LoWPAN is an adaption layer that allows efficient IPv6 communication over the IEEE 802.15.4 wireless communications standard.

Ploggs are enabled to the web indirectly by means of a gateway, since they are installed with a proprietary firmware that does not allow software modifications. This gateway has been installed on a laptop. It operates in Java and exposes the services offered by the home devices by means of a RESTful interface. REST functionality is supported by Restlet, which is a REST web framework for Java. An Apache HTTP server has been installed on the same laptop, hosting the Facebook application. The Facebook application has been implemented in HTML and
PHP, utilising Facebook open API. The whole system infrastructure is shown in Figure 2.

**Figure 2** System infrastructure in the smart home (see online version for colours)

![System Infrastructure Image]

The RESTful web services we implemented are shown in Table 1. The first three resources sense the environmental state, the fourth transmits the energy consumption of some electrical appliance in Watts and kWh (encapsulated in JSON format) while the last resource controls the appliance, switching it on/off.

The gateway has the responsibility of dynamically discovering physical devices and understanding their functionality. Device discovery and service description of the devices is based on the work in Kamilaris et al. (2011c).

The Facebook application is split into six different interfaces: *Status* presents the latest measurements offered by available sensor devices, deployed at the smart home; *devices* lists all the connected devices; *services* records the RESTful web services offered by these devices; *interaction* provides the means to users to interact with actuators; *eventing* allows the user to subscribe to events; and *profile* is the section where a user can manage his current event subscriptions.

In Figure 3, a snapshot of the Facebook application can be observed, in which the status interface is selected. We can see that the application is embedded into the user profile by design. Whenever the user logs in his Facebook account, with a single click from his main web page (*Wall*), he can connect to his home environment.

We enriched our application with a simple, content-based publish/subscribe eventing infrastructure, taking advantage of the notification mechanisms provided by the Facebook API. Users are able to subscribe to selective events by specifying constraints in the form of service name-value pairs and basic comparison operators. For example, the user can subscribe for events of type *temperature*, when it exceeds 30 degrees Celsius for a specific time frame.

When a new event is triggered, the user can be notified by four different notification methods. He can either be informed through an update of his status, through a new post on his Wall, through a new note or through an e-mail.

In Figure 4, we can examine the publication of a new event, posted on the user’s Wall, for the previous subscription example. A new temperature measurement of 33 degrees Celsius, caused the triggering of the appropriate notification mechanism.

**Figure 3** A snapshot of the smart home Facebook application embedded to the user profile (see online version for colours)

![Facebook Application Image]

**Figure 4** A snapshot of the user’s Wall with a notification about an event (see online version for colours)

![Wall Notification Image]

### 4.1.2 Technical benefits

This scenario gave us the opportunity to identify numerous benefits, obtained by exposing the functionality of a smart home through a SNS application.

Firstly, the authentication mechanisms of the SNS can be leveraged, to achieve user authentication with just a few lines of code. User authentication would then allow us easily to derive authorisation schemes for each user category. Some SNS even offer the possibility of creating private groups of users. Solely the administrators of these groups can approve requests for new members to join. Therefore, a role-based authorisation mechanism can be built without much effort. In this scenario, we exploited this functionality to allow the owner of the smart home to restrict access to his family members, in order to fully manipulate their house through the SNS application.
Additionally, notification mechanisms can be easily created, when using a SNS that supports notification triggering through its API. We demonstrated this possibility through the content-based publish/subscribe eventing infrastructure we developed. With little effort, family members were able to subscribe to selective events by specifying some constraints.

Users can be notified through a variety of notification methods, depending on the notification mechanisms of the SNS. For urgent notifications, users can even be informed through SMS, in case they register their mobile phones to the SNS.

In general, the practice of creating pervasive applications with a social context, promotes sharing of physical devices and services between family members. Such applications could increase the awareness of residents about their home environment, helping them to acquire more sustainable behaviours.

SNS users could find it easier to accept and use such applications, as they become blended with their overall online experience. We demonstrate this statement in the following closely-related scenario.

### 4.2 Area monitoring in a working environment

RiverLand Dairy Farm is the first organic farm in Cyprus, involving biological procedures to produce animal and vegetable food products. The farm has numerous greenhouses. Monitoring the environmental conditions inside the greenhouses is crucial for the proper growth of vegetables.

#### 4.2.1 Implementation

The equipment described in the previous scenario (see Section 4.1), was deployed in one of the farm’s greenhouses, in which tomatoes are grown (Kamilaris et al., 2011a). The intention was to monitor through Facebook in real-time the temperature, humidity and illumination levels at the greenhouse as well as the electricity footprint of a lamp that is placed inside it. Thus, we reused the web services, offered by the Telosb sensor motes and Ploggs, which are displayed in Table 1.

<table>
<thead>
<tr>
<th>Index</th>
<th>Resource URI</th>
<th>REST Verb</th>
<th>MIME type</th>
<th>Parameters</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temperature</td>
<td>GET</td>
<td>Text/plain</td>
<td>-</td>
<td>Telosb</td>
</tr>
<tr>
<td>2</td>
<td>Humidity</td>
<td>GET</td>
<td>Text/plain</td>
<td>-</td>
<td>Telosb</td>
</tr>
<tr>
<td>3</td>
<td>Illumination</td>
<td>GET</td>
<td>Text/plain</td>
<td>-</td>
<td>Telosb</td>
</tr>
<tr>
<td>4</td>
<td>Electricity</td>
<td>GET</td>
<td>Application/json</td>
<td>-</td>
<td>Plogg</td>
</tr>
<tr>
<td>5</td>
<td>Switch</td>
<td>PUT</td>
<td>Text/plain</td>
<td>mode(on/ff)</td>
<td>Plogg</td>
</tr>
</tbody>
</table>

Concretely, the Facebook application developed for the smart home scenario, was only slightly changed to adapt to the requirements of this working environment. Therefore, the status of the greenhouse was displayed as shown in Figure 3.

The farm currently employs eleven workers. We asked from all the workers to participate in our experimental deployment by utilising for two weeks the SocialFarm application. Two workers who were quite old, kindly refused to participate as they had zero experience with computers. From the rest nine workers who accepted to participate, five already owned a Facebook account and four of them had never used a SNS. We created accounts for the workers who did not have and we configured our application in their accounts.

We harnessed Facebook groups as the mechanism to achieve access control. We created the group *FarmWorkers*, which operated ‘privately’. Only the farm owner could approve join requests. Hence, only authenticated Facebook users, members of that group could fully use the application. We also included the eventing infrastructure developed in the previous scenario, to permit workers to get notified when something abnormal happened at the greenhouse.

#### 4.2.2 Evaluation

After the two weeks, we asked the workers about their impressions in using our social application. All of them found the application easy to use. They all agreed that the integration of embedded devices in SNS would promote sharing of sensory services. One worker even suggested a Facebook application that targets health monitoring, in which doctors would interact with their patients monitoring, at the same time, their vital signs.

The workers who already owned a Facebook account were excited with the perspective of controlling the greenhouse while amusing with their friends. The workers who did not have previous experience in Facebook found it difficult to understand the notification methods and, in general, they were not so enthusiastic with our approach. Some of them complained that the notification methods are not very effective since the user needs to be online in order to be informed. However, all the workers stated that SocialFarm increased their monitoring activity, making them more aware about the farm in general.

The owner of the farm, although he was one of the workers that did not previously possess an account, was really satisfied with the SNS application and showed interest to learn the costs needed in order to fully automate
his farm. He was excited with the possibility of delegating access, through the FarmWorkers group to his friends/workers, in order to observe the status of his greenhouse.

Summing up our experiences from this deployment, we believe that the integration of pervasive applications to SNS can help people engage in beneficial activities, such as monitoring a greenhouse for abnormalities. Blending working tasks with online social entertainment can give strong incentives to people in order to adopt sustainable living.

4.3 A social competition in a neighborhood

Buildings consume a large proportion of the world’s total electrical energy (Europa Press Release, 2008). More than 30% of all greenhouse gas emissions can be attributed to houses and buildings. Predictions denote that by the year 2030, the global energy demand will more than double, rising up the energy-related greenhouse gas emissions by 55% (International Energy Agency, 2007).

In general, people are willing and capable to adapt their behaviour to energy-saving lifestyles if given the necessary feedback, support, and incentives. Especially the influence of the community by means of comparisons with other people’s consumptions, has the potential to drive residents towards a more persistent behavioural change (Cialdini, 2001). Social norms can motivate people to question their behaviour, if they discover it is not ‘normal’ (Allcott, 2011). Residents generally learn from their neighbours and receive encouragement and support.

4.3.1 Implementation

To motivate people become more aware about energy and reduce their electrical consumption, we created a social competition between neighbouring flats in large residential blocks. Plogs were employed, equipped with external current transformers for loads up to 100 Ampere, for acquiring the electrical consumption of each flat in real-time.

A Plogg was attached to the mains metre of every flat, communicating wirelessly in frequent intervals (every minute) the electricity data in JSON format to a laptop computer that received them by means of a Telegesis USB stick.

We installed on the computer the smart home application framework described in Kamilaris et al. (2011b, 2011c), which was implemented by using web technologies. The framework was responsible to parse the electricity-related data, extract the important information and forward them to a web server and a Microsoft SQL Server database. The web server was developed in C# and ASP.NET, tightly coupled to the online database. A Facebook application was created to show real-time information about the competition, as well as a Facebook group, in which residents were encouraged to discuss about the study. The system infrastructure is illustrated in Figure 5.

Through the web server, residents could authenticate themselves and get informed in real-time about their overall ranking in the competition, according to their electricity footprint. They could also view their historical electrical consumption at the previous days of the competition, as well the overall electricity consumed by the block. All information about electricity is translated to money costs, based on the current tariffs of the electric utility.

The winning flat would be the flat that reduced most effectively its electrical consumption in the one-month competition. The award to the winning flat was a real-time energy monitor.

Our case study included two blocks of flats. The first is at a suburb, with six flats participating and the second in an urban area, having 20 flats. The duration of the competition was one month for each block and it was performed in winter period.

4.3.2 Evaluation

The total energy performance of the two blocks, as a summation of the electrical consumption of all the participating flats, is depicted in Figure 6 on a daily basis. Obviously, temperature is strongly correlated to the energy consumption of the building. This is clear evidence that a considerable percentage of consumed electricity is utilised for heating.

Because of the high dependencies to temperature, ‘safe’ conclusions about the energy savings due to the competition can not be extracted. However, by comparing the first two weeks of the study with the last two, we can observe that the energy consumption in the last two weeks is reduced by 260 kWh or 26% at the suburban block and by 1,091 kWh or 33% for the urban block. Furthermore, in days with similar temperature, the electrical consumption of the blocks towards the end of the month is reduced.
Comparing the block at the urban location with that at the suburb, average energy savings in the urban case were 2.4 times more. People at the suburban block consumed in average 11% more energy compared to the urban block, however, temperature affected this fact. Residents at the urban block were more excited about the competition and took it more seriously. As a large proportion of them were highly educated students, it was easier for them to understand and accept the motivation and terms of the competition, and more convenient to use the Facebook application as a feedback tool for reducing their energy consumption.

Figure 7 presents the electricity footprint of each flat during the competition, as well as that of the previous month (acquired from the electricity bills of the flats). As we can see, most of the flats have reduced effectively their electricity footprint. Flats located on higher floors needed more heating and consumed more electricity.

The average reduction of energy is 11.90% at the suburban block and 27.74% in the urban case. Considering that the average monthly temperature patterns before and during the competition were similar (especially for the suburban case), we believe that the social competition has influenced the participating flats to reduce their consumption.

The winners reduced their consumption either because they found this competition as a first-class opportunity to save money, or because they believed they helped protecting the environment.

Our findings suggest that the practice of giving awards and social incentives to residents, can be effective in initiatives that concern environmental awareness. Social influence has the potential to boost the energy-saving efforts towards a greener world. SNS may constitute suitable platforms for such initiatives.

4.4 Energy awareness through social comparisons

Undoubtedly, energy conservation is a tremendous global issue with huge implications in the environment, the society and the politics.

According to scientific studies, such as Darby (2006) and Seligman et al. (1981), energy awareness alone can be capable of reducing electrical consumption by a fraction of 5% to 15%. Smart metering has been introduced for allowing electric utilities to better manage their energy generation to meet dynamic demand. Hence, residential smart metering can provide timely overall electrical
consumption feedback, helping people to manage more rationally their electrical consumption.

However, still people cannot easily assimilate quantitatively how much energy they consume. They do not possess the proper metrics to define whether their total consumption is low, average or high. This happens because each area, city or country has different tariffs and varied weather and physical conditions.

A promising way to understand the 'semantics' of consumed energy is to compare it with the amount consumed by relatives, friends and neighbours. In this case, SNS are the ideal platforms for such comparisons, as they maintain a highly accurate graph of users’ social networks.

### 4.4.1 Implementation

To demonstrate whether energy awareness can be reinforced by social comparisons, we created SocialElectricity, which is a Facebook application that allows people to compare their electricity footprint with their friends in a country-wide scale (Kamilaris et al., 2011a). We collaborated with the Electricity Authority of Cyprus (EAC), which is the only electrical utility in Cyprus. EAC delegated us with anonymous access to the sensory measurements of all the electricity metres, which are deployed in the residential buildings of Cyprus.

Respecting the privacy of Cypriot citizens, the electricity measurements of the country were aggregated at a street level (address, postal code, and city). Thus, it is not possible to derive the analytic consumption of some specific residence. However, residents are encouraged to add themselves their exact monthly electrical consumption, and compare it with their local neighbourhood or their friends.

More specifically, our social application has five broad objectives:

- It allows people to compare their electricity footprint with that of their neighbourhood/village/town, indicating to them if their own consumption is low, average or high.
- It associates electricity with costs, enabling consumers to have a more meaningful view of their energy profile.
- It promotes sharing of peoples’ electricity consumption figures with their friends at a street level. It can transform the procedure of saving energy into a social game between friends.
- It gives useful tips to people in order to reduce their electrical consumption and increase their energy awareness.
- Finally, it provides useful statistics about the most energy-efficient streets, villages, areas and cities near the user’s location. Thus, it helps people to acquire ‘region awareness’, inspired to take actions in order to help the local community maintain a better ranking in the future.

SocialElectricity aims to be extended into a healthy competition, in which each user competes with his friends for less consumed energy. People from the same area are encouraged to cooperate in order to reduce the total aggregated consumption and improve the overall ‘green ranking’ of the area.

The web server hosting the application has been developed using Visual Studio 2010 and Microsoft Silverlight. The electricity consumption data have been stored on a Microsoft SQL server while the connection between the web server and the database server has been achieved using WS-*.

Bing Maps permit people to view their friends on maps, in the current location where they live, together with the average energy consumption at their locations. Figure 8 provides a snapshot of SocialElectricity application, showing the comparison of electrical consumption between friends at Cyprus. Friends with higher consumption are displayed in red colour while friends with better energy behaviour are displayed in green.

### 4.4.2 Preliminary evaluation

Primarily, our application has been deployed locally, at the Computer Science department of the University of Cyprus. After the elimination of all possible problems, a country-scale deployment will follow.

Our initial sample comprised of 80 students of the department, who were asked to use SocialElectricity. The majority of them already had a Facebook account, since Facebook is popular among the students of the department. Only 22 people did not have an account and we kindly asked them to create one. Just eight students refused to do that. Two weeks after the release of the application, we asked the participants about their impressions.

Not surprisingly, people were highly impressed by the capabilities of the application. They found it really entertaining to compare their local energy consumption with that of their friends. We even listened to some students teasing their colleagues about the poor energy performance in their street. We consider this teasing as a positive step towards saving energy in the future.

SocialElectricity becomes useful only when people enrich their Facebook profile with information about their place of stay. Some students complained that their friends did not appear on the map as they did not fill in yet their (general) address details. However, this phenomenon occurred only at the first two-three days, before a large number of students utilised the application.

Comparing their own consumption with that of their neighbourhood, allowed students to quantify their electricity footprint more precisely. 70% of the students reported that SocialElectricity helped them become more aware of the energy they consume. Around 18% admitted they had a high electricity bill and they promised to consume energy more rationally in the future. One student particularly, realised after using the application that he had a faulty electricity metre. He contacted EAC immediately to replace it.
The initial success of SocialElectricity might depend on the young age of the sample, which covers students 17 to 25 years old. A large deployment would include people from other ages, whose friends might not be actively involved with SNS.

Nevertheless, our findings are highly encouraging to proceed with a deployment around the whole of Cyprus. In cooperation with EAC, we plan to monitor the energy behaviour of the Cypriot society to consider how much our approach has contributed in increasing the energy awareness of Cypriot citizens, and whether it has influenced them to save energy and money.

We are also examining the possibility of giving some awards to local communities and villages that effectively reduce their overall electrical consumption. These awards could concern lower billing of the local consumers, prizes and small gifts to people, such as real-time energy monitors.

We need to note that without the existence of SNS, pervasive applications like SocialElectricity, which require social content, would not be practical. It would be extremely difficult to acquire the social networks of people. In addition, promoting the application would be a time-consuming and expensive process.

The SocialElectricity Facebook application can be found online at Kamilaris et al. (2012).

5 Conclusions

In this paper, we investigated the capability of the social Web to support real-life pervasive applications, enabling the transit to a pervasive web.

Our real-life application deployments and evaluation efforts suggest that online social networking platforms have the potential to support the physical world, enhancing ubiquitous computing with a social shape. Physical devices and environmental services can become ubiquitous inside online social networking applications, merged with the everyday social activities of users.

Most importantly, the practice of harnessing the social networks of people through SNS offers advanced functionalities to pervasive applications. For example, social norms may help people to acquire environmental awareness while comparisons between friends may help people to reduce their electricity footprint.

SNS can constitute a key aspect for the transition to a pervasive web, in the Web 3.0 era. The perspective of sharing physical environments through SNS applications, opens new dimensions towards the socialisation of sensory readings and real-time interaction with embedded devices. We envision physical things as social entities just like human beings and we believe that their socialisation will help them to blend smoothly with the future web.
For future work, we plan to enhance our applications with more advanced, social capabilities and extend them into more general and valuable tools for people, in order to support other real-life scenarios such as health monitoring.

Bridging our real-life social applications together would be a challenging task. For example, the SocialElectricity application could be used as a platform for energy competitions among local neighborhoods, in case electric utilities supplied our social application with (near) real-time electricity measurements from residential smart metres.

As another example, the SocialFarm application could be expanded to report the total power consumption of the farm itself. Afterwards, the online social sharing of this information between farms of similar type (dairy, greenhouse, etc.), could be helpful in the collaboration of the local industry to reduce overall power usage.

We currently work on defining a web-based, social API for embedded devices, in order to acquire social identity and behave like normal people in a SNS. Our work could lead to a Devicebook, in which relationships between people would be extended to relationships with physical objects and real-world services. Evrything Company (Murphy et al., 2011) is already working towards this vision, currently designing a Facebook for everyday devices and physical things.

Finally, extending the idea of SocialElectricity application to other natural resources, as for example water or gas, is not expected to require much effort and the benefits for the consumers are obvious.

Evidence indicates that the future web will be social and pervasive, connected to the physical world. Our work constitutes a small contribution towards this trend.

References


Web Applications Description Language (WADL) available at https://wadl.dev.java.net/.
