1 Introduction

Embedded tiny sensors are increasingly deployed around the world, measuring with high precision environmental conditions such as temperature and humidity or physical events such as pressure and motion. Sensor networks are used in the industry and in modern residences to provide advanced automation solutions.

Technological advancements such as sensor networks, short-range wireless communications and radio-frequency identification (RFID) are becoming largely common, allowing the Internet to penetrate in embedded computing. An Internet of Things (IoT) (Gershenfeld et al., 2004) is becoming feasible, where everyday objects are uniquely addressable and interconnected.

Recent efforts for porting the IP stack on embedded devices (Dunkels et al., 2004b), (Hui & Culler, 2008) and the introduction of IPv6, which provides extremely large addressing capabilities, are expected to facilitate the merging of the physical and the digital world, through the Internet.

The Web of Things (WoT) (Wilde, 2007), (Guinard et al., 2010b) is a notion inspired from the IoT where physical things are connected by fully integrating them to the Web. Based on the success of the Web 2.0, this concept is about reusing well-accepted and understood Web standards to interconnect resource-constrained devices. The WoT tries to address the issues that appear in the process of enabling embedded devices to the Web, including their local/global discovery, description of their functionality and interaction patterns with them.

The next big challenge for the Web, after its massive utilization 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 (Weiser, 1999). 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, QR codes). Directly embedding Web servers on sensors is a recent development (Schor et al., 2009), (Yazar & Dunkels, 2009).

Online social networking sites (SNS) constitute suitable Web-based platforms for sharing physi-
cal devices and environmental services among friends and groups of people that share common interests. Through SNS, social relationships between people can be extended to social relationships with their physical environment and things. 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 Web applications, permits these applications to become more effective, enriching them with advanced functionalities.

Thus, SNS could become extremely dynamic, by representing real-time information about the physical world. This expected future dynamic nature of SNS may unveil new perspectives in social network analysis. This chapter investigates the potential revealed when blending online social networking with pervasive computing. The term *pervasive online social networking* includes all ubiquitous real-world applications that exploit online social networking to enrich their functionalities with social elements. The benefits acquired from enhancing SNS with Web-enabled physical devices and Web-based, real-life environmental services are demonstrated by examining various relevant case studies.

The rest of the chapter is organized as follows: in Section 2 the most important efforts for enabling pervasive computing to the Web are introduced while in Section 3 the practice of enabling smart spaces to online social networking platforms is explained. Then, in Section 4 different case studies are presented that deal with extending online social networking with ubiquitous computing and in Section 5 the general benefits and the overall potential are discussed. Finally, Section 6 concludes the chapter.

### 2 Web-enabling the Physical World

Embedded devices and their services need to be enabled to the Web, before being utilized by online social networking applications. This enablement would trigger the seamless interconnection and interaction with SNS.

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). By means of these tokens, a limited virtual representation of the physical world could be achieved. In the Cooltown project (Kindberg et al., 2002), every thing, place and person had a Web page with information about it. The Web presence of these physical entities was performed by sensing identifiers that pointed to associated URLs.

Web-based middleware solutions appeared in the last decade, exploiting Web 2.0 services to integrate embedded devices to the Web. Prehofer et al. (Prehofer et al., 2007) proposed a Web-based middleware for smart spaces, which strongly relied on technologies used in Internet services. This included not only browsers and Web servers, but also development tools, scripting languages and content management.

After researchers and engineers realized the benefits of enabling the physical world to the Web, they observed that high heterogeneity existed between physical devices and pervasive services. Interoperability between Web-enabled machines was crucial in order to allow flexible composition and reuse of Web-based physical resources. Hence, Web services were proposed as a mechanism to address heterogeneity.

Web services tend to fall into one of two camps: Big Web services and REpresentational State Transfer (REST). Big Web services or WS-* (Alonso et al., 2004) are a set of complex standards and specifications for enterprise application integration. They form the foundational elements for the building of service-oriented architectures (SOA), which introduce new possibilities for large-scale software design and software engineering. Nevertheless, WS-* are not very efficient for embedded computing. The work in (Groba & Clarke, 2010) quantifies this statement in terms of time and energy.

On the other hand, REST (Fielding, 2000) is a lightweight architectural style that defines how to
properly use HTTP as an application protocol. It advocates in providing Web services modeled as resources, identified by Unique Resource Identifiers (URI). Resources can only be manipulated by the methods specified at the HTTP standard (e.g., GET, PUT, POST, DELETE), under a uniform interface. REST guarantees interoperability and a smooth transition from the Web to pervasive environments. REST is more appropriate for constrained scenarios and applications due to its simplicity and flexibility.

Following RESTful principles, the work in (Stirbu, 2008) enabled heterogeneous sensor and actuator devices to the Web, focusing mainly on the plug and play discovery of these devices. A scalable discovery mechanism was proposed, augmented with semantic Web elements. TinyREST (Luckenbach et al., 2005) was a RESTful gateway for bridging the Internet with the physical world through the REST architectural style. However, it violated REST by including the SUBSCRIBE verb, through which clients were able to register their interest to specific services that the sensors/actuators could provide.

Erik Wilde (Wilde, 2007) suggested the adoption of REST to make physical objects available to the Web by design, envisioning a Web of physical things. A WoT prototype was presented in (Guinard & Trifa, 2009), where the founding principles of the Web as an application protocol were reused for monitoring the energy consumption of household appliances through smart power outlets. A comprehensive report describing the WoT architecture and some interesting prototypes recently appeared in (Guinard et al., 2010b).

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 & Culler, 2008). Shor et al. (Schor et al., 2009) have showed that IPv6-enabled wireless sensor networks (WSN) may by directly integrated into the future Internet with acceptable performance. Following this concept, Yazar et al. (Yazar & Dunkels, 2009) implemented an IP-based sensor network system where nodes could communicate by using RESTful Web services.

IP-connectivity of embedded sensor devices was also reinforced by operating systems for low-power wireless devices, such as TinyOS and Contiki, which included libraries for IPv6 support. TinyOS (Levis et al., 2005) includes Blip, which is an implementation of the 6LoWPAN stack for TinyOS. 6LoWPAN is an adaptation layer that allows efficient IPv6 communication over the IEEE 802.15.4 wireless communications standard. Furthermore, Contiki (Dunkels et al., 2004a) provides open-source code for embedding a Web server on sensor motes, by means of the uIP TCP/IPv4 stack. An example 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) promoted 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 and objects around the world.

A different approach 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 & Yoo, 2008) and (Foley et al., 2005) extend existing IM infrastructures to support human-to-thing and thing-to-thing communication, for the realization of ubiquitous computing environments.

### 3 Building Pervasive Online Social Networks

The general procedure for transforming existing SNS into pervasive spaces that host embedded devices and pervasive services is explained in this section. At first, the basic elements that allow this transformation are described and then the general architecture is discussed.
3.1 Core Elements

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

- **Online Social Networking Sites** The popularity of SNS has been increased enormously in the last few years. Some of the most popular SNS 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 API** An important feature of SNS that has recently evolved is 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 assist 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 Web sites 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 & Trifa, 2009), using the mashup paradigm to create pervasive Web applications. Physical mashups can use the open APIs provided by SNS, to develop pervasive social applications.

- **Web-enabled Physical Devices** A fundamental part for the enablement of physical devices to SNS is their integration to the Web. This integration procedure is needed in order to access the capabilities of these devices through a Web interface. It 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 may be applied to achieve uniform interaction with heterogeneous embedded devices and ubiquitous services. Their utilization is important for interoperability reasons. From the two main trends for Web services, WS-* and REST, WS-* are preferred in cases when physical devices are behind powerful gateways or when the data produced by these devices are stored in online repositories, while REST is proposed for interaction with resource-constrained physical devices as it is a lightweight protocol.

- **Device/Service Discovery** This process involves the discovery of physical devices and their services. Devices should operate in an automated, plug and play way, and their Web-based operation environment may be exploited for developing uniform local and global discovery patterns, such as Dyser (Ostermaier et al., 2010) and the work in (Kamilaris & Pitsillides, 2012). Physical devices may expose their functionality in standardized ways. For example, (WADL, 2005) 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 may be employed for developing pervasive social networks is presented in Figure 1. It consists of the following three components:
Figure 1: General architecture for developing pervasive online social networks.

- 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 local discovery and description patterns. These devices can be sensors, RFID tags, smart electricity meters etc.

- The SNS, which provide Web-based open APIs, supporting the application development from third-party developers. Pervasive SNS applications are developed following the mashup example, extending Web mashups into physical mashups, enabling the physical world to be integrated to the SNS social structures.

- A Web server that hosts pervasive SNS applications, maintaining at the same time connectivity with physical devices/gateways. The Web server needs to have a precise view of the pervasive environments it represents, in order to automatically add/remove mobile ad hoc devices that appear/disappear frequently.

In certain occasions, especially when sensor devices are involved, their sensory readings can be automatically stored in some online repository. In these cases, WS-* can be used, for interaction between the Web server and the repository.

We insist in harnessing Web services, since the majority of SNS offer open APIs that are based on the Web service paradigm. Thus, Web service technology in the whole system assures high interoperability between the pervasive environment of embedded devices and the Web domain of SNS.

4 Bridging Online Social Networking and Ubiquitous Computing

The impact of Web-based social networking was emphasized in (Ben Mokhtar & Capra, 2009), where the notion of pervasive social computing was introduced, focusing on disseminating tasks in a pervasive environment based on users’ common, social preferences and on the Friend Of A Friend (FOAF) ontology.

The need for ubiquitous social networking is highly recognized by the research community. SocialNets (Socialnets FP7 Project, 2008) is a large European project that aims to achieve pervasive adaptation
by harnessing the properties and characteristics of human social networks. The project explores how social networks can be exploited for the delivery and acquisition of content, considering security and trust.

Even though these efforts stress the potential of using the social Web for pervasive adaptation in general, they do not consider ubiquitous applications for the real world and support for the expanding ecosystem of Web-enabled embedded devices and physical services. In this section, we mainly focus on efforts that include real-world applications, highlighting the state of the art in pervasive and physical online social networking.

In the last decade, numerous ubiquitous Web applications have been developed that exploit the functionalities of online SNS, in order to acquire a social perspective. We identify some of these applications in the following subsections, categorized according to their general goal.

### 4.1 Promoting Online Communication in Everyday Life

Bridging the gap between online and physical social networks was the aim of approaches such as the Cityware platform (Kostakos, 2008). In Cityware, Bluetooth-enabled mobile devices were utilized to merge users’ social data, made available through Facebook, with mobility traces captured via Bluetooth scanning. Figure 2 (left) shows the general architecture of Cityware. The authors notice that both the Bluetooth and Facebook social networks exhibit very similar structural characteristics, being rather sparse with similar diameter, and both have low average degree and approximately similar average path length and clustering coefficient (Kostakos & Venkatanathan, 2010). Also, the probability of two face-to-face friends becoming friends on Facebook is an order of magnitude greater than the probability of Facebook-only friends meeting face to face.

![Figure 2: The Cityware platform (left). The Patch device placed on some Facebook user (right)](image)

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. A small case study composed of 22 users for a three-week period indicated the willingness of the subjects to share detailed status and presence information with their friends. Similarly, SenseFace (Rahman et al., 2009) employs wearable sensor devices that can monitor different daily activities of a human body by forming body sensor networks. SenseFace captures the sensory data by sensing the user’s body, processes and stores them in a mobile device, sends them to a remote Internet gateway and finally disseminates them intelligently to a list of his online social networks.

Enhancing social interactions at the Web by means of wearable sensor devices is investigated in Patches (He & Schiphorst, 2009). Patches is a wearable social network which recreates physically the
social interaction of a poke. When a user pokes some friend through Facebook, a Patch, which is a physical
device placed on the friend’s clothes is triggered to vibrate. A Patch can be observed in Figure 2 (right).

The concept of social devices is introduced in (Vázquez & de Ipiña, 2008). Everyday objects are
transformed into autonomous, augmented artifacts that use the Internet/Web/SNS to promote socialization,
collaboration and better serve their users. The authors demonstrate this concept through various prototypes.
For example, Aware-Umbrella obtains the weather forecast for the next hours from the Internet and reacts
when the user leaves home without taking it by issuing a synthesized voice alert. Aware-Umbrella is
displayed in Figure 3 (left).

Social devices can also interact with online social networks in order to monitor some information
on behalf of their users. For example, a Flickr-enabled digital photo frame can periodically check whether
new photos from the user’s buddies have been published, download them and start a slideshow. Bubblino
(MCQN Ltd, 2011) is a bubble-blowing Arduino bot. He watches Twitter for a chosen keyword and every
time he finds a new mention then he blows bubbles. Bubblino can be observed on the right side of Figure 3.

![Figure 3: The Aware-Umbrella social device (left). The Bubblino device (right)](image)

### 4.2 Sharing Physical Devices and Services through Online Social Networks

Converting existing SNS into smart environments that host embedded devices is a challenging, novel issue.
SenseShare (Schmid & Srivastava, 2007) targets exploiting online social networking infrastructures for
sensor data sharing, focusing mostly on privacy. According to SenseShare, each individual has his own
policies of which data he wants to share with whom. For example, one might want to share his current
location with all his family members, whereas he does not want to share this with the general public. Or
he might be collecting the data from a small weather station in his backyard and want everybody to know
about this data.

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 favorite SNS. More specifically, a Web platform called Social Access Controller (SAC) acts as
an authentication and sharing proxy, permitting owners to define the interaction possibilities with their
physical devices. Access control is based on the existing social structures of several online social networks,
in order to enable the owners to share their devices only with people they trust. SAC is illustrated at the left
side of Figure 4. Friends and Things (FAT) is a graphical application, built on top of SAC, through which
device owners can easily share real-world resources with some of their trusted connections. A screenshot
of FAT is displayed in Figure 4 (right).

In the future, smart homes will offer new automation possibilities to their residents. Information pro-
cessing will be thoroughly integrated into everyday objects, extending the home environment into a shared space that pervasively interacts with its habitants. Online social networking could enhance smart homes with social characteristics. Family members would interact with their home through SNS, transforming the interaction with their home appliances into a social experience. Therefore, social relationships between people may be extended to social relationships with their household devices. Following this vision, Social-Home (Kamilaris & Pitsillides, 2010) is a social application that allows family members to fully manage their smart home through Facebook.

SocialHome hosts 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. The capabilities of these physical devices are exposed as RESTful Web services, as shown in Table 1. Sensor motes are transformed into embedded Web servers by means of Blip, which is an implementation of the 6LoWPAN stack for TinyOS. Ploggs are enabled to the Web indirectly by means of a gateway, since they operate with a proprietary firmware that does not allow software modifications.

<table>
<thead>
<tr>
<th>No.</th>
<th>Resource URI</th>
<th>Description</th>
<th>Method</th>
<th>MIME Type</th>
<th>Parameters</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temperature</td>
<td>Temperature in Celsius Degrees</td>
<td>GET</td>
<td>text/plain</td>
<td>-</td>
<td>Telosb</td>
</tr>
<tr>
<td>2</td>
<td>Humidity</td>
<td>Percentage of Humidity</td>
<td>GET</td>
<td>text/plain</td>
<td>-</td>
<td>Telosb</td>
</tr>
<tr>
<td>3</td>
<td>Illumination</td>
<td>Lighting in the house</td>
<td>GET</td>
<td>text/plain</td>
<td>-</td>
<td>Telosb</td>
</tr>
<tr>
<td>4</td>
<td>Electricity</td>
<td>Electrical consumption in Watts/kWh</td>
<td>GET</td>
<td>application/json</td>
<td>-</td>
<td>Plogg</td>
</tr>
<tr>
<td>5</td>
<td>Switch</td>
<td>Switches on/off an appliance</td>
<td>PUT</td>
<td>text/plain</td>
<td>mode(on/off)</td>
<td>Plogg</td>
</tr>
</tbody>
</table>

Table 1: A list of the RESTful Web services offered by embedded devices at the smart home.

In Figure 5 (left), a snapshot of the SocialHome Facebook application can be observed. The application is enriched with a 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 exam-
ple, the user can subscribe for events of type Temperature, when it exceeds 30 degrees Celsius for a specific timeframe. When a new event is triggered, the user can be notified by Facebook 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 email. In the right side of Figure 5, the publication of a new event is shown, 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 5: A snapshot of the SocialHome Facebook application embedded to the user’s profile (left). A snapshot of the user’s Wall with a notification about an event (right).

The concept of a social home was generalized for a working environment in (Kamilaris et al., 2011), to achieve online, real-time area monitoring by workers. The equipment of SocialHome was deployed in RiverLand Dairy Farm, which is an organic farm in Cyprus, involving biological procedures to produce animal and vegetable food products. The equipment was installed in one of the farm’s greenhouses, in which tomatoes are grown. Monitoring the environmental conditions inside the greenhouses is crucial for the proper growth of vegetables.

The farm employed eleven workers and it was asked from them to participate in the experiment by utilizing for two weeks the SocialFarm Facebook application. Nine workers accepted to participate, from whom five already owned a Facebook account and four of them had never used a SNS.

To achieve access control to the farm environment, Facebook groups were harnessed. The group FarmWorkers was created, which operated privately. Only the farm owner could approve join requests. An eventing infrastructure permitted workers to get notified when something abnormal happened at the greenhouse.

After the two weeks, the workers were asked about their overall impressions. Those who already owned a Facebook account were excited with the perspective of controlling the greenhouse while amusing online with their friends. Those who did not have previous Facebook experience found it difficult to understand the notification methods and, in general, were not so enthusiastic with this approach. Some of them complained that the notification methods were not very effective since the user needs to be online in order to be informed. However, all the workers noted that SocialFarm helped them increase their monitoring activity, making them more aware about the farm in general.
4.3 Social Norms for Energy Conservation

Undoubtedly, energy conservation is a tremendous global issue with huge implications in the environment, the society and the politics. Leveraging online social networking for environmental awareness is a recent practice.

Generally, the social influence of the community has been recognized as an important factor in decision making (Cialdini, 2001), and may as well be applied in sustainability-related initiatives. In particular, considering online social networking, users tend to be influenced by their online friends.

One of the best examples was the Green Patch Facebook application. Green Patch simulated a small garden on a user’s profile. By maintaining their and their friends’ gardens, the Facebook users were able to raise money for Nature Conservancy to save the rain forest. The number of users was reported at 6.3 million in 2008 and the application was ranked as one of the five most popular in Facebook. The area of Costa Rican rain forest that had been saved at that time was up to 70 million square feet.

StepGreen.org (Mankoff et al., 2010) tried also to exploit social influence to promote energy-saving user behaviors. Through its Web site, the project intended to motivate people to make energy-reducing changes to their lifestyles. StepGreen.org combined features such as committing to and reporting on actions, and served information to a person’s social network profile page. During this project, a field study suggested that motivating factors like public commitment and competitions are effective, and better leveraging these factors will likely lead to greater effectiveness in motivating people to participate in green activities.

Social norms are capable of motivating people to question their behavior, if they discover it is not normal. Residents generally learn from their neighbors and may receive encouragement and support. As an example, OPOWER company exploits social norms to influence people conserve energy, by sending energy report letters to residential utility customers, comparing their electricity use to that of their neighbors (Allcott, 2011). According to the company, this practice has reduced consumption by 2.0%. OPOWER has also developed a Web site (OPOWER, 2011), allowing people to compare their household consumption against homes that share similar physical characteristics (e.g. number of residents and bedrooms, home area in square meters).

In general, people are willing and capable to adapt their behavior 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 electrical consumptions, has the potential to drive residents towards a more persistent behavioral change.

To motivate people become more aware about energy and reduce their consumption, SocialNeighborhood (Kamilaris et al., 2012a) was developed as a social competition between neighboring flats in large residential blocks. The 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 winning flat was 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.

The project employed Ploggs, 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 meter of every flat, communicating wirelessly in frequent intervals (every minute) the electricity data to a laptop computer that forwarded them to a Web server and a Microsoft SQL Server 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 6.

Through the Web server, residents could 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 at the block. All information about electricity were translated to money costs, based on the current tariffs of the electric utility.

The total energy performance of the two blocks, as a summation of the electrical consumption of all the participating flats, is depicted in Figure 7 on a daily basis. Obviously, temperature is strongly correlated to the energy consumption of the buildings. This is clear evidence that a considerable percentage of consumed electricity is utilized for heating. By comparing the first two weeks of the study with the last two, the energy consumption in the last two weeks is reduced by 260 kWh or 26% at the suburban block and by 1091 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, because 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 also 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). Most of the flats have reduced effectively their consumption. Interestingly, 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), this is an indication 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.

Since each area, city or country has different tariffs and varied weather and physical conditions, it is difficult for consumers to assess whether their total electrical consumption is low, average or high and to consider quantitatively how much energy they consume. To understand the ”semantics” of consumed energy, SocialElectricity Facebook application (Kamilaris et al., 2012b) enables comparisons between a user’s electricity footprint and the electricity consumed by relatives, friends and neighbors (Kamilaris et al., 2011).
SocialElectricity is supported by the Electricity Authority of Cyprus (EAC), which is the only electrical utility in Cyprus. EAC provides anonymously the sensory measurements of all the electricity meters, which are deployed in residential buildings around the country. Respecting the privacy of Cypriot citizens, the electricity measurements were aggregated at a street level (address, postal code, city). Hence, the analytic consumption of some specific residence was difficult to be derived. However, residents are encouraged to add by themselves their exact monthly electrical consumption, and compare it with their local neighborhood or their friends.

SocialElectricity allows people to compare their electricity footprint with that of their neighborhood, village or town, indicating to them if their own consumption is low, average or high. It promotes sharing of people’s electricity consumption figures with their friends at a street level and it transforms the procedure of saving energy into a social game between friends. Finally, it provides useful statistics about the most energy-efficient streets, villages, areas and cities near the user’s location, helping 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. 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 color while friends with better energy behavior are displayed in green.

Primarily, SocialElectricity has been deployed at the Computer Science department of the University of Cyprus, while a country-scale deployment is about to follow. The initial case study included 72 students of the department, who were asked to use the application. The majority of them already had a Facebook account, since Facebook is popular among the students of the department. Two weeks after the release of the application, the participants were asked about their impressions.

Students found it entertaining to compare their local energy consumption with that of their friends. Some students even teased their colleagues about the poor energy performance at their street. By comparing their own consumption with that of their neighborhood, students could 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, realized after using the application that he had a faulty electricity meter. He contacted EAC immediately to replace it.

5 The Potential of Pervasive Online Social Networking

The case studies presented in the previous section indicate the great potential of enhancing pervasive Web applications with social attributes. From a technical perspective, reusing the Web API of some SNS simplifies and accelerates -in most cases- the development of ubiquitous applications. For example, the authentication mechanisms of some SNS can be leveraged to achieve user authentication with just a few lines of code. User authentication would then allow the creation of authorization schemes for different user categories. Some SNS (e.g. Facebook) even offer the possibility of creating private groups of users. Solely the administrators of these groups can approve requests for new members to join. Hence, role-based authorization mechanisms can be built without much effort. This mechanism was used in SocialFarm, to allow the farm owner to restrict access only to his workers, to fully manipulate the greenhouse through the social application.

Additionally, notification mechanisms can be easily created, when using a SNS that supports no-
tification triggering through its API. This possibility was demonstrated in SocialHome, through the publish/subscribe eventing infrastructure. With little effort, family members were able to subscribe to selective events by specifying some constraints, and be notified through a variety of notification methods supported by the SNS. For urgent notifications, users may even be informed through SMS, in case they register their mobile phones to the SNS.

From a psychological point of view, the integration of pervasive applications to SNS helps people to 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 lifestyles. SNS users could find it easier to accept and use such applications, as they become blended with their overall online experience.

The general practice of creating pervasive applications with a social context (e.g. Friends and Things), promotes sharing of physical devices and services between people. Furthermore, by giving awards and social incentives to residents (e.g. StepGreen.org, SocialNeighborhood), initiatives that concern environmental awareness may be more effective.

Presented studies such as the OPOWER example and SocialElectricity denote that social influence has the potential to boost the energy-saving efforts towards a greener world and SNS may constitute suitable platforms in such efforts. 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, while promoting these applications would be a time-consuming and expensive process.

Bridging together the presented real-life social applications would be an interesting task. For example, SocialElectricity could constitute a platform for energy competitions among local neighborhoods. SocialFarm 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. It would be more than welcome to see other case studies that exploit the capabilities of the Social Web to extend Web applications into more valuable tools for people. For example, other real-life scenarios such as health monitoring could be enabled, where doctors would interact through SNS with their patients monitoring, at the same time, their vital signs.

Recently, the business sector showed interest for the social-enablement of the physical world. Evrythng (Evrythng, 2011) is a new software company aiming to enhance individual physical things with unique online profiles. Their idea is that when every product is 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. Evrythng works towards this vision, aiming to design a Facebook for everyday devices and physical objects.

Publishing open, Web-based API from online service providers is the current trend on the Web. According to (Programmable Web, 2012), more than 5,500 Web API have been already added to their API directory, including numerous SNS. Technologies such as OpenSocial (OpenSocial, 2012) try to provide interoperability between SNS, through publishing a common API across multiple platforms. These initiatives have still a long way to go to prove themselves effective facing, during their efforts for moving the social Web forward, the unwillingness of some major SNS (e.g. Facebook, Twitter) to participate. Clearly, a common API would enable the propagation of social pervasive applications across the whole social Web.

Enabling physical devices to the Web and defining a social Web API for everyday objects and real-life services, would boost the functionality and effectiveness of current Web-based pervasive applications. The idea of sensors and actuators having social identity, behaving like "normal people" in SNS would provide enormous capabilities to developers and users. Perhaps in the future such efforts could lead to
a Devicebook, in which relationships between people would be extended to relationships with physical objects and real-world services.

6 Conclusion

Online social networks would become much more dynamic, powerful and challenging, by integrating and supporting pervasive computing. This chapter scratched only the surface of the possibilities that arise by the Web-enablement of physical objects. Future social network analysis efforts need to take into account the Web presence of massive amounts of sensors and actuators that offer pervasive services. It would be interesting to analyze how people react with environmental information, especially when this information is blended with their online social experience. How this abundance of environmental information would affect people’s everyday lives, assisting them to take decisions is a hot research question.

The presented social Web applications and case studies 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 may become truly 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 Web applications. For example, social norms may help people to acquire environmental awareness while comparisons between friends may help them 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 socialization of sensory readings and real-time interaction with embedded devices. Physical things may become social entities just like human beings and their socialization could enable them to blend smoothly with the future Web.

Evidence indicates that the future Web will be social and pervasive, connected to the physical world. Perhaps online social networking will be the cornerstone in this vision. Dynamic analysis of online pervasive social networking may reveal new drivers towards a real-time, digital, social, sustainable world.

References


