Reconsidering the Social Web of Things. Position Paper.

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Abstract
The notion of a Social Web of Things (SWoT) appears in recent works at the convergence of the Social Web and the Web of Things. In our vision, a third dimension is needed: pro-activeness. We propose to extend and transform social networks by integrating autonomous and proactive things. In this paper, we discuss the evolution of the Web on several dimensions, leading to our vision for the SWoT. We discuss the challenges that need to be addressed, a possible approach for addressing them and we illustrate the applicability of the SWoT through a motivating scenario.

Author Keywords
Web of Things, social networks, multi-agent systems, normative organizations

ACM Classification Keywords
I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—*intelligent agents, multi-agent systems*.

Introduction
The Web is expanding at a rapid pace in multiple directions. Sir Tim Berners-Lee refers to a *Web of People* [3] that enables social interactions among people. More recently, the *Web of Things* extends to everyday objects, making them *"first-class citizens of the Web"*[5].

Meanwhile, the *Semantic Web* [4] aims at a Web of machine-readable content that supports machine-to-machine interaction. However, the different projections of the Web are not silos, they are tied and weaved together as the Web evolves.

Recently, the *Social Web of Things* (SWoT) appeared at the convergence of the *Web of People* and the *Web of Things*. The SWoT has already been discussed in several forms, as we elaborate in the following section. Nonetheless, regardless of its definition, the core idea is the same: to capitalize on the properties of social networks, such as the trustworthiness implied by connections among people, the strongly connected social graphs or the straightforward user interface they exhibit once implemented as *social networking services*. We go a step further. Our aim is to enable things as *proactive* participants in existing social networking services.

In this paper, we start by offering an interpretation of the evolution of the Web from several perspectives. The discussion leads up to our vision for a SWoT and identifying the challenges that need to be addressed in its pursuit. We then continue with discussing a possible approach towards achieving this vision. Before concluding, we illustrate the applicability of the SWoT through a motivating scenario for student housing.

On the Evolution of the Web

There are several perspectives from which one could discuss the evolution of the Web. In this section, we focus on two dimensions, *socialness* and *pervasiveness*, and their convergence. We then discuss a third dimension, *pro-activeness*, and how it could influence the Web.

Socialness

The ways in which people interact over the Web have changed dramatically since its beginnings. The role of the common Web user shifted from a *consumer* of content to a *contributor*, both *consuming* and *producing* Web content. The content and information produced by a particular user are, in most cases, tied to a virtual identity or profile of that user. With the development of *social networking services*, such as Facebook, Google Plus or Twitter, users are able to connect their profiles to the ones of other users. The emerging *social graph* is then leveraged in sharing and retrieving content. In recent years, social networking services opened their social graph to integrating *Web resources*, such as Web pages, that are outside of the social network itself. As a consequence, sharing buttons appeared all across the Web, in order to facilitate the dissemination of information. The role of the social graph in managing, sharing and retrieving information is thus increasing. The Web evolved from a content-centered model to one that is centered around its users, connections among them and sharing of information.

Pervasiveness

The vision of ubiquitous computing, according to which computing devices become seamlessly integrated into the world at large, has been around even before the creation and large-scale adoption of the Web [8]. In recent years, the *Internet of Things* (IoT) emerged as a paradigm that is rapidly gaining ground [1]. While there is not yet a universally agreed upon vision for the IoT, one common understanding of this paradigm is as a world-wide network that interconnects things and objects around us through the use of unique addressing schemes and standard communication protocols.

In more recent work, ubiquitous computing and the Web tend to converge [5]. The *Web of Things* (WoT) is defined as a refinement of the IoT: while the IoT is mostly concerned with interconnecting everyday objects in a unique addressable way at the *Network* layer, the WoT is focused around the *Application* layer and integrating things into the Web by reusing and extending current Web standards and protocols. Such Web-enabled devices can then be interconnected through the use of physical mashups, a concept similar to Web mashups. Several mechanisms for building physical mashups are described in detail in [5].

When Social meets Pervasive
In the WoT vision, the Web becomes pervasive, in the sense that everyday objects become connected, accessible and searchable through the Web. In fact, we are already seeing Web-enabled devices making headlines in the media: toasters and houses that are able to *tweet*[1,2]. Not surprisingly, this convergence of *socialness* and *pervasiveness* attracted the attention of researchers as well.

Recently, the idea that pervasive computing could benefit from social networks is gaining momentum [2]. In [5], the *Social Web of Things* describes an infrastructure that enables users to manage the access to their Web-enabled devices and share them with people they know and trust. To this aim, the sharing infrastructure leverages social graphs encapsulated by social networking services. However, the integration of social networks with the WoT is confined to enabling access control to Web-enabled devices.

[1]http://www.twitter.com/mytoaster
[2]http://www.twitter.com/houseofcoates

The use of social networks as a communication medium is explored by the so-called *socio-technical networks* described in [7]. An observation we find interesting is that Web-enabled devices could use the rich amount of information already available on social networks. However, a general architecture for developing such socio-technical networks is not discussed.

In other work, social networks are pushed as a uniform interface for managing a large number of heterogeneous products and services. This is the case for instance in the work done by Ericsson Research. They also use the term *Social Web of Things* to define their vision on the convergence of the IoT and the Social Web, this time from a *user experience perspective*[3]. The initially successful approach of creating an advanced user interface for interconnecting 10 to 15 multimedia devices, similar to the physical mashup editor described in [5], proved to be impractical when scaling to a large number of heterogeneous devices. The identified limitations are both in terms of scalability of the user interface itself, but also in terms of understandability, or the ways users are able to comprehend such a model. As an alternative for a simplified interaction model, the use of social networks is proposed: users interact with their things, and their things with one another, through common actions in social networking services, such as posts, comments, etc. The insights offered make an appealing case for using social networks as uniform interfaces for managing heterogeneous devices.

Following what has been discussed so far, the *Social Web of Things* seems to be placed at the convergence of *socialness* and *pervasiveness* on the Web evolution

[3]http://www.ericsson.com/uxblog/2012/04/a-social-web-of-things/

timeline, as shown in Figure 1. However, in our vision, things are not just entities present on or managed through social networks, but rather full-fledged users of social networking services, thus interacting with other users (be they humans or things). Therefore, a step is missing from this convergence: *pro-activeness*.

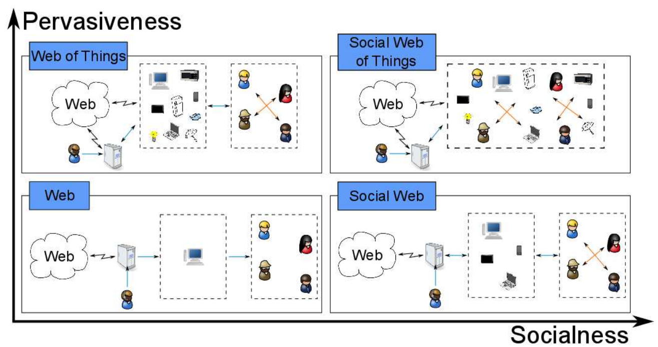

Figure 1: Towards a Social Web of Things.

For instance, the *Social Internet of Things* [2] brings *autonomy* to things in managing their relationships with one another by following rules given by a small set of predefined categories of relationships (*e.g.* objects from the same production batch, objects belonging to the same user, etc.). At the same time, things are compliant to any privacy policies imposed by their owners. The main problem being tackled is creating a unified *navigable* global network of all products and services.

Autonomy can be defined as the ability of operating without the intervention of humans or others. We take a step further and we look at *pro-activeness*, which refers to goal-driven behavior.

Pro-activeness
Web user's role shifting from a consumer of content to a contributor has had a major impact on the Web as an ecosystem. Users changed from having a passive status to becoming *proactive* in expanding the Web. Therefore, we could say that in some sense people are now the ones weaving the Web (*e.g.* Wikipedia, YouTube).

This pro-activeness perspective should also spread to Web resources. As new standards and technologies were defined, the Web metamorphosed into an application platform, exposing available resources as services. The active development of semantic Web technologies pushes the Web further by creating machine-readable Web content and thus transforming the Web into a medium suitable for highly dynamic machine-to-machine interaction.

In our vision, Web resources (*e.g.* Web services, Web-enabled devices) become entities able to *autonomously* interact with one another, but which can also exhibit *goal-driven behavior* – be it for the composition of services, the aggregation of some required knowledge, the optimization of a particular process, etc. In this vision, while people still remain in the driver's seat, the future Web is able to weave itself in some sense.

Towards a Social Web of Things (SWoT)

Following our discussion on *socialness*, *pervasiveness*, *pro-activeness* and their relations with the Web, we define and motivate our vision for a *Social Web of Things* at the convergence of these three dimensions.

We envision a Web that is:

- *pervasive*, by extending to the physical world through integrating everyday objects and things in general;
- *proactive*, by embodying a significant number of autonomous and proactive entities, functioning as regular Web users that (i) produce and consume content and (ii) interact with other (possibly human) entities;
- *social*, by centering around its entities, both human and non-human, and the relationships among them.

We call this vision the *Social Web of Things (SWoT)*, complementing and building upon the WoT. In our vision, a *thing* can be both a physical object or an exclusively virtual one, such as a Web service.

In the following sections, we elaborate on our objectives and the challenges that need to be addressed.

Objective and Motivation
Our objective is to develop a platform that enables things to participate in existing social networks as regular users and service providers.

We thus propose to extend and transform social networks into *socio-technical networks* (STN) by introducing autonomous and proactive things. The STN will therefore inherit and extend several properties of social networks, such as an efficient model of interaction among its users, the highly dynamic communication medium, the emerging strongly connected social graph and the information filter it represents. We borrow the STN term from [7], however we extend this concept and we put a stronger emphasis on the STN as an application platform.

Such a STN is suitable for (i) providing a good experience to the WoT user, (ii) extending the perception of things by tapping into the rich amount of information already being published on social networks and (iii) providing a framework for the development of complex WoT applications.

Challenges
Integrating things as proactive entities in social networks raises multiple challenges. First, given there are several social networks with high user adoption, it is desirable to define a *uniform interface* through which things can access an open set of social networking services. Moreover, once the interaction channels are in place, it is necessary to define a reasoning model that enables things to participate in social networks.

Besides enabling things as regular users, we also aim at enabling things as service providers in the STN. Services do not represent a common feature in current social networks, which brings up the challenge of defining a model for the representation, publishing, sharing and composition of services in the STN.

Having things that operate without human intervention seems to be essential in the highly dynamic context of a SWoT. However, it seems equally important to define mechanisms for *enabling control and regulating this autonomy*. *E.g.*, the over-sharing of information is already a controversial issue in current social networks. We can only imagine this issue to get bigger as more entities start publishing content. Therefore, one of the key challenges that needs to be addressed in order to enable things as full-fledged active users of social networking services is developing a reasoning model for placing information in the appropriate context.

A reasoning process however requires *knowledge* to be reasoned upon. To this aim, an issue that needs to be

Figure 2: A Layered Model for the SWoT.

addressed is creating a machine-readable representation of the STN.

A STN also seems to emphasize challenges that are less common in current social networks. *E.g.*, most social networking services impose limitations on the accounts of their users, such as a maximum number of friends. These restrictions are not usually a problem for the regular user, however one can easily imagine how autonomous non-human entities could end up consuming a lot of resources rather quickly. This stresses the problem of performance and resource optimization in social networking platforms.

A Layered Model for the SWoT

To better describe the SWoT platform, we make use of the layered model shown in Figure 2. Each layer in the presented model should be as agnostic as possible to its direct lower layer.

Given that the SWoT builds on top of the WoT, for simplification reasons we illustrate an abstraction layer offering a RESTful API to the WoT. This layer represents the entry point in our model and could enclose APIs for things or for composite WoT applications.

The Agency Layer

The building blocks of a *socio-technical network (STN)* are entities. An *entity* is anything that has an associated URI. An entity can be either *autonomous* (*i.e. human* or *thing*) or *non-autonomous* (*i.e. relationship* or *service*).

Autonomous entities (including humans) are modeled as intelligent agents at the *Agency* layer. An agent exhibits several properties that are of interest for the SWoT, such as *autonomy* (operating without the direct intervention of humans or others), *social ability* (interacting with other agents), *reactivity* (perceiving the environment and responding to changes) and *pro-activeness* (goal-driven behavior) [9]. The goal of the Agency layer is to enhance autonomous entities with the capabilities required for participating in a STN.

The Social Layer

While the Agency layer is focused around individual agents, the *Social* layer connects agents by placing them in social structures.

The structure of the STN is given by a directed graph in which nodes represent *autonomous entities* and labeled edges represent the different *relationships* among them. We call this graph the *socio-technical graph* (STG).

The STG is built upon existing social graphs. Therefore, in order to have a consistent representation across the different social networks, there are two categories of relationships supported in the STG: a generic *acquaintance* relationship, which answers the question "who knows whom" and builds the social structure of the STN, and a *localization* relationship, which answers the question "who is where" and better defines the spatial dimension of the STN.

The Social layer deals with creating the STG and defining a uniform interface for accessing an open set of social networking services.

The Organizational Layer

As we get to the third layer, we now deal with a network of agents that can operate autonomously. However, the SWoT should provide mechanisms that enable control over agents. This is the main goal of the *Organizational* layer: placing agents in organizations. An organization of agents represents more than a social structure. An organization includes, among others, behavior-regulating norms that define what is acceptable and what is not, constraining an agent's autonomy for the sake of itself and its peers.

A particular class of *things* are *socio-technical contexts* (STC). An STC, which is thus an autonomous entity in itself, represents an organization of other autonomous entities (*i.e.* agents) and we choose an approach similar to [6] for defining it on 4 dimensions: a *structural* dimension, which expands the generic acquaintance relationship; a *functional* dimension, which defines organizational goals and processes; a *communication* dimension, which defines communication schemes and protocols; a *normative* dimension, which defines organizational policies. Organizational processes and policies are used for enhancing entities with autonomous capabilities, but also for setting ground rules for enabling control in the STN.

The Application Layer
Defining mechanisms for enabling control over agents sets the groundwork for the *Application* layer. The goal of this fourth layer is to provide standards, protocols and mechanisms for managing services, content and social platform resources. Such elements could then be used in the development of SWoT applications.

Illustration

We illustrate the applicability of the SWoT, and in particular of the model discussed in the previous section, through a motivating scenario.

A SWoT App for Student Houses
John Doe is a PhD student who lives in a student house in Saint-Étienne. The administration has decided to improve its services by connecting the student house to the SWoT. The SWoT app has two main goals: to enhance interaction with and among students, and to improve the quality of service of the laundromats.

The building has 6 floors, each floor with 20 studios and 1 laundry room. Each laundry room contains one washing machine and one dryer. In order to satisfy the user requirements of the SWoT app that is to be developed, all studio doors, laundry doors, washing machines and dryers have to be connected to the SWoT. The washing machines and the dryers are Web-enabled and support the recommended standards and protocols for participating in the SWoT. The doors themselves are not Web-enabled, however each door has a virtual counterpart that is accessible through a URI. The URI is encoded in a QR code which is used as tagging technology for creating a link between each physical door and its virtual counterpart.

For simplification purposes, we assume all entities in the student house scenario use the same social networking service and thus are in the same STN.

The STC
The application developer needs to specify the *StudentHouse* STC, which is the core of the SWoT app. The STC is implemented as a multi-agent normative organization. More specifically, the STC is in fact an *instance* of an organizational specification. A formalization of the STC is out of the scope of this paper, however we describe each of its dimensions in more detail for illustration purposes.

The structural dimension. The organization designer needs to specify what are the roles available in the *StudentHouse* STC. For this illustration scenario, it suffices to consider a *role* as a placeholder for the different obligations or permissions an agent enacting that role might have. The deontic modalities are applied to roles through norms.

In this scenario, we can imagine to have a root role *Entity* which is inherited by *Student*, *Administrator* and *Thing*. The latter is inherited by *WashingMachine*, *Dryer* and *Door*. There are two types of doors, specifically *StudioDoor* and *LaundryDoor*. When a role inherits from another, it will inherit all norms that apply to its parent.

We can also imagine to have *groups* of roles declared for each floor. Each group would have an identifier according to its floor and would restrict the cardinality of the roles made available (*e.g.* at most 20 studio doors, 1 washing machine). Similarly, we could imagine to have a group for all washing machines.

The functional dimension. The functional dimension specifies organizational goals and processes. *E.g.*, an organizational process could describe the steps a *Student* and a *WashingMachine* need to go through for doing the laundry. The process has a final goal, such as *finish_laundry*, which can be broken into subgoals, such as *notify_laundy_start*, *wash_clothes* or *notify_laundy_done*.

The communication dimension. Communication regulations in the STC are based on the communication modes and transmission hypothesis given by the communication dimension. *E.g.*, a *transmission hypothesis* could be declared for selecting only studio doors from a given floor as potential recipients of announcements addressed to students.

The normative dimension. We can imagine to have a norm saying that any *Door* entering the *StudentHouse* STC, *i.e.* an agent enacting the role *Door* or any of its descendants, should create connections with all other doors already in the STC. Other norms could be specified to ensure that all agents involved in the laundry process (*e.g.* a *WashingMachine* and a *Student*) see to the defined goals, or that all agents in a particular situation follow the specified communication regulations.

Enhancing Interaction

It turns out the cleaning service will have to be postponed from its regular date. Due to the large number of studios, the cleaning has to be done per floors and on different dates in order to optimize cleaning costs. Using the SWoT app, the administration can notify students efficiently, targeting recipients by floor, and in a non-intrusive way, by posting messages to their doors.

John is connected to his door in the STN, so he can follow its activity or even be directly notified through personal messages. Moreover, John can also use his door for disseminating information. *E.g.*, John is not connected to everyone in the student house, and might not even wish to do so, especially given that residents come and go. Nonetheless, given that all doors are connected to one another (following the specification of the normative dimension of the STC), John can easily disseminate a non-intrusive announcement to everyone on his floor that he is about to throw a dinner party for celebrating his latest paper being accepted. Thus, it is not necessary for John to possess any prior personal contact information.

There is also another form of social interaction that emerges. Jane Doe might not be connected in the STN to John or his studio's door. However, by scanning the QR code posted on the door, Jane can leave a virtual message for John. The door decides if it should forward the message to John or not based on the communication policies that apply (if any).

Laundry Day
It is Saturday and it is laundry day. John is usually caught up with work during the week, but unfortunately so are most people living in the student house. Therefore, weekends can get quite crowded for the laundromats. By having the student house connected to the SWoT, John can announce his intention on doing the laundry by posting a status update on the STN and making the status available for the washing machines group.

All 6 washing machines in the student house *comment* on the status update. It turns out the washing machine on John's floor is busy for the next couple of hours, but there is one available at the 6th floor. John decides it is better to wait and makes a reservation for the washing machine on his floor.

Once John has reserved a time slot, the washing machine has a new goal: to wash John's clothes. To achieve this goal, the washing machine follows the appropriate organizational process defined by the functional dimension of the STC. When it is time to do the laundry, the washing machine will send a reminder message to John in order to fulfill the subgoal *notify_laundy_start*. In this scenario, the washing machine is an *autonomous* and *proactive* entity. It can apply the *plans* it *knows* in order to fulfill *goals* that are part of an *organizational process*. Plans can be programmed on the washing machine by its manufacturer or can be exchanged with other agents in the STN.

Conclusions

In this paper we have offered an interpretation on the evolution of the Web from several perspectives: *socialness*, *pervasiveness* and *pro-activeness*. We have placed the *Social Web of Things* (SWoT), as defined in our vision, at the convergence of these three dimensions. In this vision, the SWoT is focused around social networks of people and proactive things. In a *Web of Things* (WoT) in which everyday objects become Web-enabled, such *socio-technical networks* would offer people an intuitive uniform interface for managing their things, while at the same time expand the perception of things and provide a framework for developing complex WoT applications.

Moreover, we have identified the challenges that need to be addressed and we have discussed a possible approach for implementing the SWoT. In our approach, the *autonomous entities* in the SWoT are modeled as autonomous and proactive agents. We have introduced a layer of normative organizations that uses organizational policies and processes for (i) bringing more autonomy to things, (ii) enabling control over the autonomy of things and (iii) supporting coordinated behavior in SWoT apps. We have illustrated the applicability of the SWoT, and in particular of the described approach, through a motivating scenario.

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