

# Second International Workshop on the Web of Things (WoT 2011)

Dominique Guinard  
Inst. for Pervasive Computing  
ETH Zürich  
dguinard@ethz.ch

Vlad Trifa  
Inst. for Pervasive Computing  
ETH Zürich  
trifa@inf.ethz.ch

Erik Wilde  
School of Information  
UC Berkeley  
dret@berkeley.edu

## ABSTRACT

The Web of Things community explores how to extend the *Internet of Things* vision to the *World Wide Web*. This requires to look beyond establishing mere connectivity, and address the specific issues of loose coupling, massive scalability and heterogeneity in the context of pervasive computing. Specifically, the goal of the second International Workshop on the Web of Things (WoT 2011) is to look at the problems and research issues that can be identified when thinking “out of the box” of most pervasive computing applications, which often assume a homogeneous and centrally managed infrastructure that supports some specific applications scenario. Looking at the Web level, it becomes necessary to consider new constraints and design issues. While certain scenarios might not map well to Web concepts, the opportunities and economies of scale available at Web scale make it very interesting to carefully examine how to eventually build a fully functioning and performant “Web of Things”.

## Categories and Subject Descriptors

C.2.0 [Computer Communication Networks]: General

## General Terms

Algorithms, Design, Languages, Standardization, Theory

## Keywords

REST, HTTP, Web Architecture, Internet of Things, Web of Things

## 1. INTRODUCTION

The world of embedded devices has experienced radical changes; home appliances, industrial machines, cars and other daily objects are being increasingly instrumented with tiny computers, sensors, and network interfaces. As Internet access is becoming a commodity, various computing devices and inanimate objects (wireless sensor networks, mobile phones, embedded computers, RFID tags etc.) can have

an online presence that allows to retrieve data about objects and interact with them. This convergence of sensing, computing and Internet-scale networking provides new design opportunities and challenges, as digital communication networks will increasingly contain real-world devices and allow direct read/write interactions with them. The “Internet of Things” has become a legitimate research domain in the pervasive and ubiquitous computing communities, its main focus has been on establishing connectivity in a variety of challenging and constrained networking environments. Furthermore, developments in the field of *IP for Smart Object (IPSO) Alliance*, clearly illustrate the need and benefits to be gained from making embedded devices part of the Internet. However, these trends illustrate only connectivity at the TCP/IP level with limited consideration for what goes on top, at the application level, where a standard protocol is lacking, yet necessary. In consequence, this workshop targets exactly how to bridge this gap.

The Web of Things (WoT) explores the layer on top of connectivity with Things and addresses issues such as fast prototyping, data integration, and interaction with objects. Because the Web is omnipresent and flexible enough, it has become as an excellent protocol for interacting with embedded devices, and the Web of Things is a vision where things become seamlessly integrated into the Web - not just through Web-based user interfaces of custom applications, but by reusing the architectural principles of the Web for interacting with devices. The International Workshop on the Web of Things solicits contributions in all areas related to the Web of Things, and invites researchers and application designers to get together to think beyond sensor networks and Web applications, and to imagine, design, build, evaluate and share their thoughts and visions on what the future of the Web and networked devices will be.

## 2. FROM WOT 2010 TO WOT 2011

The first International Workshop on the Web of Things *WoT 2010* [1] was held successfully at the PerCom 2010 conference. Thanks to the large amount of high-quality submissions and the motivated attendance of the workshop, an influencing community of Web of Things researchers emerged.

*WoT 2011*, held in conjunction with the *Pervasive 2011* conference in San Francisco, aims to reinforce this nascent community by discussing important challenges and especially tackle real-world impediments among practitioners in this field. We received 22 papers from 11 different countries and accepted 10 papers. As last year, we will also feature a demonstration session where researchers and companies

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will be invited to show-case their latest WoT products or prototypes, as this format suits well to generate engaging discussions and a greater bonding among participants. In addition, a pre-workshop hackathon will bring together programmers and other practitioners in a relaxed environment to learn and try the latest tools and techniques for the Web of Things.

This year's goal is to look at real-world challenges where research can provide solutions. This is especially relevant as in the last year an important number of commercial and open source platforms that could be useful for the Web of Things have been appearing. As a consequence, we would like to shape the WoT workshops' series into one of the main venue for researchers and application developers who believe that the world of smart objects has a lot to learn and gain from Web architectures, developments and research.

### 3. WORKSHOP TOPICS

Generally speaking, the WoT workshops explore the use of principles and technologies at the core of the Web such as *Representational State Transfer (REST)*, *syndication* (e.g., Atom) and real-time Web (e.g., Web Sockets, XMPP, Pub-subhubbub, etc.), load-balancing, etc. to provide access to pervasive and ubiquitous computing services. Furthermore, it aims at better understanding and tackling the challenges when building a seamless "Web of Things". The overall workshop themes are as follows:

- Concrete integration of embedded computers, wireless sensor networks and every-day Things using a RESTful and Web-oriented approaches.
- Asynchronous integration patterns of Things into the Web, e.g. by using syndication, streaming databases, or instant messaging.
- Discovery, search, Web mashups and other composition models for the Web of Things.
- Interaction models and paradigms between human and things (mobile interfaces, etc.).
- Challenges, solutions and optimizations for Web-enabling resource-constrained things (e.g. IPv6 lowpan, tiny Web servers, optimized REST, etc.).
- Semantic technologies (e.g. ontologies, microformats, context, etc.) for describing and discovering things and resources on the Web.
- Concrete applications and use-cases of Web-enabled Things.
- Evaluation of Web of Things prototypes and systems.

In particular, the workshop solicited papers addressing two main areas. The *first area* is the question of how to *design and implement back-end systems* (pervasive or ubiquitous computing environments implementing Web services) so that they can be realistically exposed on the Web. The Web is excellent to implement scalable and loosely coupled services, but on the other hand has some limitations when it comes to some of the applications traditionally implemented in tightly coupled and highly optimized systems, such as realtime applications. This means that it is important to

also understand the limitations of Web-oriented architectures, and to understand what and how services pushing the boundaries of Web architecture should be designed and implemented. Examples for issues in this area are:

- *Push vs. Pull.* Pull-based approaches are simpler and scale better than push-based approaches, but they introduce latency and create overhead. How to decide when to push and when to pull? How to best use Web technologies for push?
- *Scalability.* In many cases, sensor networks and similar applications produce vast amounts of raw data. How to manage this volume (such as using filtering and/or clustering) to better match the typical limitations of loosely coupled Web services?
- *Back-End Integration.* The "Web of Things" allows to mix and remix back-ends in a loosely coupled way, but using Web services, important optimization opportunities may be lost. How to build Web-oriented back-ends that allow a more tightly coupled back-end integration with other back-ends, so that combined service implementations can be better optimized (for example for querying and clustering)?
- *SOA for Things.* When designing Web-oriented back-ends, service design and implementation often will focus on REST as the architectural style of the Web. This means that RPC- and middleware-inspired architectures should be avoided in favor of resource-centered approaches. Are there design patterns and frameworks for RESTful Things?

The *second area* is the *design and implementation of Web services that utilize back-end systems discussed in the first area*. These services constitute the front-end of the Web of Things, and the two most important questions in this area are whether there are useful design patterns, service designs, and implementation frameworks that make it easier to design and implement these front-end systems, and whether there are common services that can or should be factored out of individual back-ends.

- *Google of Things.* What does it take to become the "Google of the Web of Things"? Traditional text indexing might be part of the answer, but specific properties of Things such as "location" and "ownership" make it likely that search and discovery of a Web of billions of Things has to work differently from large-scale text indexing.
- *Ownership and Access Rights.* Things often have an owner, but they might change ownership, and access rights to Things (their properties, their services) might be shared among groups of people. Is there room for a general framework for ownership, access control, and Thing management? How would that map to today's Web of information resources?
- *Location Services.* Things often have a location, which can be either spatial (coordinates) or logical (addresses or place names). How to design and use location services to exploit this general property of Things? How to associate located Things with immaterial information resources?

- *Digital Representation of Things*. The Web is centered around the idea of resources, and things introduce physical resources into the Web (which so far mostly focuses on immaterial information resources). How to best represent things on the Web? Are there any common patterns, schemes, or reusable vocabularies for designing representations of things? What are good RESTful representations?

## 4. ORGANIZERS

- *Dominique Guinard* is a final year Ph.D. candidate at the Institute for Pervasive Computing of ETH Zürich and was a Research Associate for SAP Research. Before this, he was a visiting researcher at the Auto-ID Lab of MIT working on using Web and Cloud blueprints to simplify RFID networks. He also was a researcher at the Information Management group of ETH working on mobile interactions with the Internet of Things for Nokia Research. He served as a scientific collaborator at the University of Fribourg where he worked on scalable service architectures for the Internet of Things together with Sun Microsystems Switzerland. He did his masters at Ubicomp lab of Lancaster University (UK), where he worked with Prof. Hans Gellersen on using sensor networks to support mobile spontaneous interactions with the physical world. Dominique is the co-founder of the *webofthings.com* initiative. His research interest is in Web and Cloud architectures for the Web of Things, especially focusing on the notion of physical mashups with sensors, home appliances and tagged objects.
- *Vlad Trifa* is a final year Ph.D. candidate at the Institute for Pervasive Computing at ETH Zürich working on the Web of Things and real-time data collection, processing, sharing and storage using Web technologies. In 2010, he spent six months as a visiting researcher at MIT SENSEable City Lab where he worked in smart cities and new approaches to urban planning based on the Web of Things. From 2007-2010 he has been a research associate with SAP Research in Zürich where he explored the integration of shop-floor machines and sensors into business applications in the context of logistics and manufacturing. Prior to that, Vlad has done research in bioacoustics at UCLA (2005-2006), and in multimodal human-robot interaction at ATR Research Center in Kyoto, Japan (2006-2007). Vlad received a M.Sc. in Computer Science from Ecole Polytechnique Fédérale de Lausanne (EPFL) in 2006 with a concentration in distributed systems, bio-inspired robotics, and artificial intelligence.
- *Erik Wilde* is associate adjunct professor at the UC Berkeley School of Information. He holds a diploma in computer science from the Technical University of Berlin, and a Ph.D. from ETH Zürich. His general interest is Web architecture and Web-oriented information architecture. His research focus is on XML and related technologies, Web services and REST, and loosely coupled architectures for exposing data and services in easily usable and accessible ways.

## 5. PROGRAM COMMITTEE

The program committee of WoT 2011 has been assembled to thoroughly review all submissions to the workshop. Each submission is reviewed by various PC members in a double-blind fashion, which results in a fair and balanced reviewing process and helpful feedback for the authors. The program committee of WoT 2011 consists of:

- Rosa Alarcon, Pontificia Universidad Catolica, Chile
- Liselott Brunnberg, MIT Mobile Experience Lab, USA
- Adam Dunkels, SICS, Sweden
- Christian Floerkemeier, Auto-ID Labs, MIT, USA
- Gary Gale, Nokia, Germany
- Vipul Gupta, Oracle Labs, USA
- Masayuki Iwai, University of Toyko, Japan
- Artem Katasonov, VTT Labs, Finland
- Tim Kindberg, matter 2 media, UK
- Gerd Kortuem, Lancaster University, UK
- Marc Langheinrich, Università della Svizzera Italiana (USI), Switzerland
- Rodger Lea, University of British Columbia, Canada
- Olivier Liechti, University of Applied Sciences of Western Switzerland, Switzerland
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- David Resseguie, Oak Ridge National Laboratory, USA
- Till Riedel, TecO Karlsruhe Institute of Technology, Germany
- Albrecht Schmidt, University of Duisburg Essen, Germany
- Vlad Stirbu, NOKIA, Finland
- Inaki Vazquez, University of Deusto, Spain

We would like to extend our thanks to our colleagues who agreed to served on the committee and helped the organizers, the authors, and the community for making WoT 2011 happen.

## 6. MORE INFORMATION

For more information we invite the readers to visit the workshop's official Web page on <http://www.webofthings.com/wot/2011>, as well as the community blog on <http://www.webofthings.com/>.

## 7. REFERENCES

- [1] DOMINIQUE GUINARD, ERIK WILDE, and VLAD TRIFA, editors. *First International Workshop on the Web of Things (WoT 2010)*, Mannheim, Germany, March 2010.