WoT 2017 - The Eighth International Workshop on the Web of Things

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ABSTRACT

The *Web of Things* has become mainstream: REST (though sometimes interpreted liberally) and Web best practices today constitute the de-facto application layer of smart physical objects within Internet of Things deployments. **WoT Mission Accomplished!**

However, the WoT workshop series was never only about technology, but rather enabled us to establish a community of academics and practitioners who are on the forefront of research fields from real-time communication with physical objects to discovery and search, and from the composition of services provided by smart devices to resource-constrained smart environments. In this year's eighth iteration of the International Workshop on the Web of Things, we therefore invited the WoT community to discuss about our *Next Big Thing*.

KEYWORDS

Web of Things; Internet of Things

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1 BACKGROUND

The *Internet of Things* has become a well-known brand for a set of research issues in the pervasive and ubiquitous computing communities. The focus of this research theme has mostly been on establishing connectivity in a variety of challenging and constrained networking environments. Our hypothesis is that the *Web of Things* is the next logical step in the ongoing evolution of how pervasive and ubiquitous computing have enabled new applications and provided new opportunities. The Web of Things takes the next step from establishing connectivity and thus the ability to communicate with Things, to a vision where things become *seamlessly* integrated into the Web – not merely through Web-based user interfaces of

specific applications, but by blending into the hypermedia information space that is created by the Web and its architectural principles [4]. On top of the seamless integration of things into the Web, we are witnessing the increasing integration of devices and their functionality on a *semantic level* which holds the potential of creating autonomous environments of smart devices that make use of one another's functionality to achieve higher-level goals, for instance in the smart home and manufacturing domains [9]. With novel protocols such as CoAP, Web technologies and patterns – until recently reserved for connecting rich servers and clients – also apply to resource-constrained devices; in the extreme case, as part of a “Thin Server” architecture that connects atomic device components directly to the Web and has them interact through application logic that can be hosted and run anywhere on the planet [5].

Continuing the successful Web of Things workshop series at PerCom 2010 (Mannheim, DE), Pervasive 2011 and 2012 (San Francisco, US / Newcastle, UK), UbiComp 2013 (Zurich, CH), and at the Internet of Things 2014, 2015, and 2016 conferences (Cambridge, US / Seoul, SK / Stuttgart, DE), we changed tack for this iteration of the WoT workshops: over the past eight years, the WoT has evolved as the de-facto application layer for connecting smart physical devices – testimony to this is given by Matthias' Kovatsch talk about the WoT at the IoT 2017 workshop *Connected World and Semantic Interoperability* (see Fig. 1). Beyond the application of REST to physical devices, the more general adoption of core Web principles and patterns such as modularity and the establishment of well-defined and well-described interfaces for devices in smart environments has driven Internet of Things deployments and research in this time: **the Web of Things has become mainstream!**

Consequently, for WoT 2017 we embarked on a quest for the “Next Big Thing” for the WoT community. We solicited short position papers that were briefly presented, discussed, mashed up, and elaborated on in a breakout session during the workshop. These discussions formed the basis of a joint manuscript that was submitted as a community paper and accepted in Wiley's *Internet Technology Letters: Hypermedia to Connect them All – Autonomous Hypermedia Agents and Socio-Technical Interactions* [8]. The WoT 2017 call for papers thus included the classical WoT topics, but we asked participants to focus on the *future* Web of Things, rather than emphasizing their past work:

- Integration of embedded computers, wireless sensor networks, every-day appliances, smart gateways, and things using a Web approach
- Real-time communication with physical objects
- Web-based discovery, search, composition, and physical mashups

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Figure 1: The Web of Things has become mainstream: Matthias Kovatsch gives a keynote on the WoT and its role in establishing semantic interoperability for IoT systems at the IoT 2017 workshop *Connected World and Semantic Interoperability*.

- Use of semantic technologies to facilitate the interaction with and between things on the Web
- Models, paradigms, and systems that enable the interaction with physical things for humans
- Security, privacy, access control, and sharing of physical things on the Web
- Application of Web tools and techniques in the physical world (e.g., REST, HTML5, 6lowpan, social networks)
- Cloud platforms and services for the Web of Things
- Concrete applications, use-cases, deployments, and evaluations of Web-enabled Things in contexts such as smart homes, connected cities, and Web 2.0 enterprises

2 WOT 2017 IMPRESSIONS

WoT 2017 took place on the campus of the Johannes Kepler University in Linz, Austria, where it was co-located with the 7th International Conference on the Internet of Things.¹ Our primary goal in this context was to foster collaboration among researchers in pervasive and ubiquitous computing, and to encourage them to build loosely coupled architectures to allow the various systems and architectures devised by researchers and engineers around the world to cooperate seamlessly.

After a brief opening presentation by Simon Mayer, we bootstrapped the discussion on the future of the Web of Things with the help of four impulse talks on the accepted position papers: Alessandro Ricci introduced the *Web of Augmented Things* [3] where the Web of Things enables the development of open and interoperable pervasive systems that integrate IoT and Mixed Reality technology to mash up physical things and MR-based augmented things – in the paper, they also present a prototype platform that enables the development and execution of Augmented Worlds [10]. Next, Simon Mayer advocated the creation of *Open APIs for the Rest of Us* [7] and talked about how manufacturers might be persuaded to

¹See www.iiot-conference.org/iiot2017

Figure 2: WoT 2017 Impressions: Talk by Alessandro Ricci on the paper *Beyond Physical Mashups: Autonomous Systems for the Web of Things*.

equip their devices with such APIs since open APIs carry a number of substantial advantages for consumers and society as a whole – as part of his talk, Simon also revived the idea of the *Thin Server Architecture* [5] and hinted at cases where API openness forms part of antitrust regulation (e.g., with UBER’s API restrictions). In the third talk of the session, Manuel Wimmer presented an approach to augmenting smart WoT devices by mashing up their exposed APIs within their augmentation framework, *Domoto* [6]. The session was concluded by Alessandro Ricci who stood in for Andrei Ciortea and presented their paper on *Autonomous Systems for the Web of Things* [1] (see Fig. 2). In the paper, they derive a coherent set of abstractions that ease the design, programming, inspection, and debugging of autonomous systems for the WoT and bring together research in the WoT and by the research community on Autonomous Agents and Multi-agent Systems (AAMAS) – from the AAMAS perspective, that line of thinking is laid out and continued in a paper on *Repurposing Manufacturing Lines on the fly with Multi-agent Systems for the Web of Things* [2].

After the workshop, a subset of the workshop participants and organizers continued their discussions on the future of the Web of Things in the context of Mixed Reality environments and (re)emerging distributed AI technologies that would enable smart, Web-enabled devices to become more autonomous in their behavior and interactions: we agree that using hypermedia as the underpinning for socio-technical systems of people and autonomous agents can have broad impact on a range of research areas within and beyond computer science and laid out our deliberations in an article – titled *Hypermedia to Connect them All* [8] – that discusses the main challenges to achieve that vision and possible avenues for overcoming them, with the goal of enabling the development and deployment of world-wide, open systems of autonomous agents and people.

3 WOT 2017 PROGRAM COMMITTEE

The Program Committee of WoT 2017 was composed of researchers and practitioners in the fields of pervasive computing and Web technologies that have a clear understanding of the Web of Things.

We would like to thank all members of the WoT 2017 PC for their support, in particular for their help with the reviewing of workshop contributions:

- Michael Blackstock, University of British Columbia, CA
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4 WOT 2017 ORGANIZERS

- **Simon Mayer** is leading the research group on *Cognitive Products* at Pro²Future, an Austrian research center that focuses on next-generation products and manufacturing machinery with embedded cognitive capabilities and works with the Institute of Technical Informatics at TU Graz as a postdoctoral researcher. Before, Simon was part of Siemens' *Web of Things* research group in Berkeley, California in the role of a Senior Key Expert for Smart and Interacting Systems. His main research topics are aspects of integrating smart things into the Web, their semantic description, and infrastructures that support human users and machines in finding and interacting with the information and services provided by such devices. As visiting researcher at the Laboratory for Manufacturing and Productivity at MIT in the year 2012, he was also working on bringing live data from automobiles to the Web. Simon graduated with a PhD in computer science from ETH Zurich.
- **Dominique Guinard** is the CTO of an Internet of Things related startup called EVRYTHNG. He is also the co-founder of the Web of Things initiative and workshop series. During his PhD at ETH Zurich, he researched on the foundations of the Web of Things and especially focused on facilitating application development in the form of physical mashups. He was also a visiting researcher at the Auto-ID Labs of MIT, working on bringing global networks of tagged objects to the Web. Before this he worked 4 years as a research associate for SAP Research, building a service oriented architecture to enable real-world device integration into business software. Dominique had further experiences

with several research institutions and companies in the Internet of Things domain such as with Lancaster University, Nokia research or Sun Microsystems. He graduated in computer science from the universities of Fribourg and Bern, and holds a PhD in computer science from ETH Zurich.

- **Matthias Kovatsch** is an Internet of Things researcher at Siemens Corporate Technology in Munich, with a focus on Web technology for highly resource-constrained devices. He is active in the Internet Engineering Task Force (IETF), the IoT Industry Working Group by the Eclipse Foundation, and the Contiki OS community. His background is rooted in electrical engineering and computer science through an interdisciplinary study course. Matthias created the Erbium (Er) REST Engine, the Californium (Cf) CoAP framework, and the Copper (Cu) CoAP user-agent. In 2011, he was also a visiting researcher at SICS Swedish ICT in Kista, Sweden. Matthias graduated with a PhD in computer science from ETH Zurich.

THANK YOU ALL FOR HELPING TO MAKE WOT 2017 A SUCCESS!

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