IoT 2016

Florian Michahelles, *Siemens Corporate Technology*
Alexander Ilic, *University of St. Gallen*
Kai Kunze, *Keio University*
Mareike Kritzler, *Siemens*
Stefan Schneegass, *University of Stuttgart*

The 6th International Conference on the Internet of Things (IoT 2016) attracted approximately 120 researchers from all over the world with academic as well as industry and practitioner backgrounds. Held in Stuttgart, Germany, the three-day conference was kicked off by four separate workshop streams on IoT value creation for industry, seamless integration via web technologies, semantic interoperability, and open source solutions (see Figure 1). The workshops aimed to foster collaboration among IoT researchers and encourage them to build loosely coupled architectures for seamless cooperation among various systems around the world. There were also various tutorials on specific IoT technologies.

Figure 1. The conference program chairs opening the program by displaying a word cloud of the topics covered in the accepted papers.

The general chair and host, Albrecht Schmidt of the University of Stuttgart, started off the second day by telling participants that we don't know the business needs of the next five years, so the best we can do is keep developing new technologies and researching IoT applications. The goal of the conference was to help further such developments and research.

IOT DISRUPTION AND INTEROPERABILITY

Guido Stephan, head of the research technology field of networks and communication at Siemens Corporate Technology, emphasized in his keynote the disruptive paradigm of IoT for industry, explaining that by using IoT technology, we can implement technological discontinuity. Web technologies let companies offer functionality while hiding the implementation details (see Figure 2). This creates commercial opportunities for companies to provide features to customers while keeping their intellectual property hidden from competitors. Furthermore, web technologies have been widely adopted and easy to use. IoT has the potential to create ecosystems built on physical devices using the features of those devices and descriptions of the device characteristics. To illustrate his point, Stephan presented two examples.

First, Stephan discussed the development of electric buses running on rechargeable batteries and how this brings together stakeholders from fleet management, grid operation, and battery manufacturing. All stakeholders

1536-1268/17/$33.00

CONFERENCES

have different incentives and revenue streams. However, they are dependent on each other, because they all coexist in one ecosystem tied together by a joined IoT architecture. They all benefit from the ability to improve their service through continuous measurements and system monitoring. They can work together because their provided functionality doesn't require them to reveal their intellectual property.

Next, Stephan introduced an intelligent power grid substation. Traditionally, the power grid has been controlled in a top-down manner. The advent of renewable energy generation, providing energy provision with a decentralized setup, requires new models of control. In order to be flexible for upcoming demands, Stephan introduced an app-store-based approach. This way, even after commissioning, new functionality can be uploaded to the hardware. This doesn't just provide more technical adaption but also more continuous revenue by charging for apps downloaded from the app store.

Because the future is difficult to predict, Stephan conjectured that more adaptive machine-readable models and descriptions will be needed, especially for long-living infrastructure investments, such as transportation or electric grids. Instead of trying to anticipate and implement future needs, he proposed providing machine-readable resources, letting machines integrate and implement new features as they become apparent. This would also let us apply machine-reasoning to implement new machine behavior.

The ultimate goal would be to achieve the interoperability of IoT systems with various apps implementing emerging standards. Thus, even systems that were never designed to work together could start collaborating. For example, a traffic light system offering a machine-readable API could grant ambulances priority signaling in an emergency. As entire domains become prepared for this interoperability, new ecosystems might arise and generate novel cross-domain-cutting applications. Stephan suggested that important topics to address will be payments in ecosystems, the convergence and performance of collaborating systems, and the management of machine-readable domain descriptions.

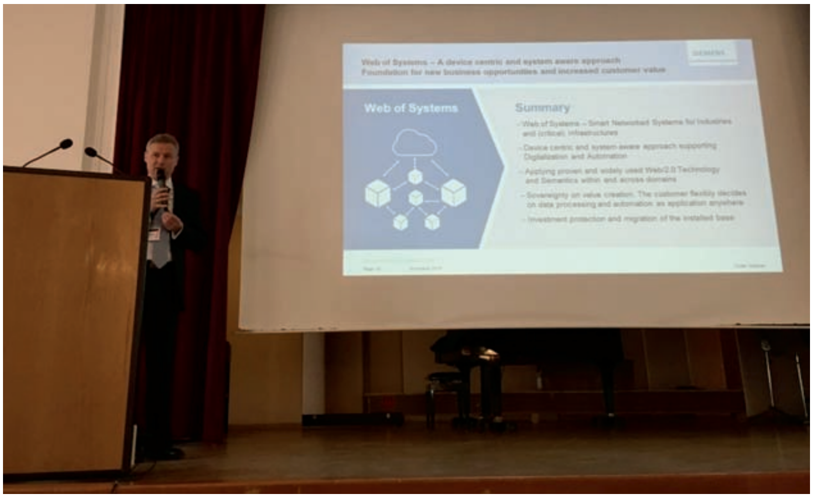

Figure 2. Guido Stephan's keynote about the Web of Systems.

Figure 3. Wolfgang Wahlster, director of DFKI and creator of the term of Industry 4.0.

USER-CENTRIC IOT

Among the 17 contributions presented at the main conference, there was a strong emphasis on user-centric IoT. For example, George Chernyshov, Jiajun Chen, Yenchin Lai, Noriyasu Vontin, and one of us (Kai Kunze) presented "Ambient Rhythm—Melodic Sonification of Status Information for IoT-Enabled Devices." Ambient Rhythm notifies users using music and ambient music about the status of an IoT system. The presented study showed that most users could distinguish between three priority levels. The authors concluded that alerts using ambient music should mainly be used for noncritical events, because users might overlook an alert.

Also, Mareike Kritzler, Magdalena Murr, and one of us (Florian Michahelles) presented "RemoteBob—Support of On-Site Workers via a Telepresence Remote Expert System." RemoteBob is a tablet on wheels that lets an expert remotely interact with a field worker. In this scenario, IoT works as a mediator and provides more context for understanding a problem and describing the solution by letting expert and field worker communicate through digital objects, gestures, and drawings.

Another example of the user-centric focus came from Miyo Okada, Atsuro Ueki, Niclas Jonasson, Masato Yamanouchi, Cristian Norlin, Hideki Sunahara, Joakim Formo, Mikael Anneroth, and Masa Inakage and their paper, "Autonomous Cooperation of Social Things: Designing a System for Things with Unique Personalities in IoT." The paper presented the concept of social things. Preset conditional statements could be triggered based on information transfer via inter-things communication. The claim was that cooperative functions could be implemented in a more user-friendly way.

INDUSTRY 4.0

Wolfgang Wahlster, director of DFKI and creator of the term Industry 4.0, closed the conference with a keynote focusing on the term, which has finally stuck with the German industry (see Figure 3). Following three industrial revolutions (the steam engine, electrification, and automation), Wahlster argued that the yet-to-follow fourth revolution would be characterized by cyberphysical production systems, a compound of software components and mechanical and electronic physical parts.

Meanwhile, the concept of the fourth revolution has been widely adopted as a paradigm in the Western world by industry, politicians, industry associations, and worker councils as an opportunity to bring back manufacturing jobs. Wahlster explained that so-called "product memories" would become virtual counterparts of physical products and that products themselves would become information containers, actors, and observers. Thus, more personalized, individualized, and feature-rich products can be produced at a lower price due to a faster, more optimized, and more flexible production process, thanks to a seamless flow of information.

Wahlster further extrapolated on hybrids of human and machine collaboration, which would use the synergies of repetitive system precision and human dexterity and creativity. When an audience member asked about adoption, Wahlster replied that society would be convinced by providing a migration path from existing mass production to multipath production to mass customization. This would also provide better experience and satisfaction for workers and more interesting working routines than today's simplified repetitive tasks.

Along these lines, Simon Mayer, Dominic Plangger, Simon Rothfuß, and one of us (Florian Michahelles) presented "UberManufacturing—A Goal-Driven Collaborative Industrial Manufacturing Marketplace." This concept of uber-manufacturing comprises a marketplace for manufacturing services, where product designers can be automatically linked to production resources capable of building the product. The matching could even be optimized along parameters such as price, quality, locality, or sustainability.

Overall, this sixth IoT conference showed a clear departure from the research on data acquisition and sensor management presented at previous series of this conference. IoT 2016 moved toward more commercially applicable implementations and cross-domain applications. The conference community will continue to research machine-readable system models and the convergence of collaboration, semantic integration, and human-machine collaboration, reconvening in Linz, Austria in the fall of 2017.

Florian Michahelles heads the Web of Systems research group at Siemens Corporate Technology. Contact him at florian.michahelles@siemens.com.

Alexander Ilic is an assistant professor at University of St. Gallen. Contact him at ailic@ethz.ch.

Kai Kunze is an associate professor at Keio University, Japan. Contact him at kai@kmd.keio.ac.jp..

Mareike Kritzler is a senior researcher at Siemens Corporate Technology. Contact her at mareike.kritzler@siemens.com.

Stefan Schneegass is a postdoctoral researcher at University of Stuttgart. Contact him at stefan.schneegass@vis.uni-stuttgart.de.