Tutorial: Linked Data Techniques for the Web of Things

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MODEL OR TECHNOLOGY COVERED BY THE TUTORIAL

The tutorial covers web technologies for specifying and executing applications involving networked sensors and actuators based on a logical representation of world state and application behaviour.

MOTIVATION

Interoperability is a major challenge on the Internet of Things. Different system vendors follow different paradigms in system architecture and data modelling, which makes the combination of heterogeneous devices into applications difficult. As web technologies have been designed for large-scale interoperability, both people from industry and academia have started to use web architecture to address the interoperability challenge on the Internet of Things. The effort has led to W3C standardisation activities: the Semantic Sensor Network Ontology W3C Recommendation [11] provides a vocabulary for describing the domain of systems, sensors, actuators, observations and actuations and the Web of Things (WoT) Thing Description W3C Working Draft [15] provides a vocabulary for describing device capabilities, along with a JSON-LD serialisation. Schema.org, an industry-led effort for creating and maintaining structured data online, is working on consolidating the various standards with the Schema.org IoT extension[1]. These standards provide means to describe data from the IoT domain in logic-based languages, even if data providers can surface syntaxes which hide the underlying logic-based formalisms.

In this tutorial, we cover light-weight semantic web technologies, commonly dubbed as Linked Data, for the Internet of Things community to fully exploit the standardisation efforts. We present the technology stack of Linked Data, address conceptual differences with other technology stacks for the Internet of Things, and show how to use Linked Data-based access to build applications on the Internet of Things.

[1]http://iot.schema.org/

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The Linked Data community has been active for over ten years. The term Linked Data has been coined around 2006 and is, roughly speaking, the combination of the communication protocol HTTP (of which REST is the architectural style) and the data model RDF, which are well-established web technologies developed in the 1990s. Starting in the early 2000s, people from embedded systems have started to use HTTP/REST for accessing small-scale sensor-equipped devices [6, 17, 25]. The semantic technologies around RDF are a more recent addition to the Internet of Things, see e. g. [22, 18]. The corresponding communities gather around, e. g. the "Schema.org IoT Sync" discussion list (sdo-iot-sync@googlegroups.com) with 100 subscribers, and the "W3C Web of Things Interest Group" with close to 200 group participants.

DETAILED DESCRIPTION

We now present an outline of the content together with the schedule, describe the learning outcomes, explain the presentation style and tutorial format, and detail the prior knowledge required by the attendees.

Content

Session 1: Introduction

In the first session we introduce the topic and outline various architectures for implementing systems in the Internet of Things: Web of Things technologies, Linked Data technologies, message broker technologies, stream reasoning technologies. Also part of the introduction will be a brief overview of techniques from artificial intelligence (cognitive architectures) and cyber-physical systems (control loops).

Session 2: Accessing and Querying the Web of Things

In the second session we introduce the Linked Data abstraction and cover query processing methods on dynamic Linked Data that take into account account the semantics of URIs.

1. Introduction and Overview, Linked Data abstraction [1] [7] [8] [9]
2. Query processing on live Linked Data [10] [14]
3. Repeated evaluation of queries on dynamic Linked Data [16]
4. Evaluation of SPARQL queries on sensor data (practical session)

5. Overview of reasoning for data integration, Notation3 and derivation rules [3] [4] [5]

Session 3: Read-Write Linked Data for the Web of Things
In the third session, we add writing access to the picture and also consider the unsafe methods of HTTP [8] for Linked Data [23, 2]. We cover different ways of composition on the Read-Write (Linked Data) Web for building applications.

1. Read-Write Linked Data abstraction, REST [9]

2. Conceptual differences between approaches for automation and composition on the Web and the Internet of Things, e. g. [21, 24]

3. Overview over a model of computation for Linked Data [19]

4. API design and data modelling for RESTful interaction with Linked Data

5. Using the model for computation to build rule-based applications for the web of things (interactive demo and showcases)

Session 4: Summary and Closing
In the fourth session we summarise the topics covered during the tutorial and give an overview of open issues [12, 13, 20]. We also address questions that attendees still may have.

Presentation Style and Tutorial Format
The tutorial is split into four sessions, with blocks of fifteen minutes allocated for a topic. The style will be a mixture of traditional teaching with interactive elements and practical examples to support the theoretical topics covered.

Learning Outcomes
After completing our tutorial, the participants are able to:

- apply the idea behind query processing on dynamic Linked Data in their projects and research;
- explain how reasoning supports the integration of sensor data on the Web of Things;
- outline and compare different formalisms for representing application behaviour; and
- explain how application logic can be encoded and executed in a rule-based formalism.

Additional outcomes include the ability to point out related research in the area of cognitive systems and cyber-physical systems, and the ability to give an overview of ongoing initiatives around structured data on the Web of Things.

Required Prior Knowledge
The participants should know the fundamental technologies of the web architecture such as URIs and HTTP. Basic knowledge of first-order logic and the Semantic Web technology stack, especially RDF, is beneficial but not required.

TUTORIAL MATERIAL
The tutorial material consists of slides and handouts created by the presenters. The material will be made available on a public tutorial website[2].

AUDIENCE
Our intended audience are practitioners and theorists interested in using Semantic Web Technologies for the Internet of Things. Hence, our natural audience would be from the Web of Things and Semantic Web community, but we assume that also people with a background from ubiquitous and pervasive computing will find the tutorial interesting.

ORGANISERS
Andreas Harth is professor of technical information systems at the University of Erlangen-Nuremberg. He worked as a post-doctoral researcher at Institute AIFB at the Karlsruhe Institute of Technology (KIT) after pursuing a Ph.D. at the Digital Enterprise Research Institute (DERI) at the National University of Ireland, Galway. Andreas has over seven years of teaching experience and gave tutorials at the ISWC, ESWC, SIGMOD, and WWW conferences.

Tobias Käfer is a Ph.D. student at the institute AIFB at Karlsruhe Institute of Technology (KIT) in Germany working under the supervision of Andreas Harth and York Sure-Vetter. His research is centered around the formalisation, observation, and execution of behaviour for the Linked Data Web applied to the Internet of Things. He was visiting researcher at the University of Chile and worked as an intern at DERI, IBM, and Siemens. Tobias was a tutor for various computer science lectures at KIT and gave a tutorial at ESWC.

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[2]http://harth.org/andreas/2018/iot-tutorial/

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