Tutorial: Linked Data Techniques for the Web of Things

Andreas Harth
University of Erlangen-Nuremberg, Germany
Fraunhofer IIS-SCS, Nuremberg, Germany
andreas.harth@fau.de

Tobias Käfer
Karlsruhe Institute of Technology (KIT)
Karlsruhe, Germany
tobias.kaefer@kit.edu

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 extension1. 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.

1http://iot.schema.org/

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).

IOT '18 8th International Conference on the Internet of Things (IoT 2018), October 15–18, 2018, Santa Barbara, CA, USA
© 2018 Copyright held by the owner/author(s).
DOI: 10.1145/3277593.3277641

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 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)

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 au-
tomation and composition on the Web and the In-
ternet 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 interac-
tion 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 sen-
or data on the Web of Things;
• outline and compare different formalisms for repre-
senting application behaviour; and
• explain how application logic can be encoded and ex-
cuted in a rule-based formalism.
Additional outcomes include the ability to point out re-
lated 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 technolo-
gies of the web architecture such as URIs and HTTP. Ba-
sic 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 cre-
ated by the presenters. The material will be made avail-
able on a public tutorial website.

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 sys-
tems at the University of Erlangen-Nuremberg. He
worked as a post-doctoral researcher at Institute AIFB
at the Karlsruhe Institute of Technology (KIT) after pur-
suing a Ph.D. at the Digital Enterprise Research Institu-
tion (DERI) at the National University of Ireland, Gal-
way. 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.

REFERENCES
http://www.w3.org/DesignIssues/LinkedData.html.
2. T. Berners-Lee. Design Issues – Read-Write Linked
//www.w3.org/DesignIssues/ReadWriteLinkedData.html.
W3C Team Submission, 2011.
4. T. Berners-Lee, D. Connolly, L. Kagal, Y. Scharf,
and J. Hendler. N3logic: A logical framework for
the world wide web. Theory and Practice of Logic

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


