Tutorial: Dynamic IoT Data, Protocol, and Middleware Interoperability with Resource Slice Concepts and Tools

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ABSTRACT

Dealing with interoperability in the IoT domain is a complex matter that requires various techniques for tackling data, protocol and middleware interoperability. We cannot solve IoT interoperability problems by just developing (new) software components and (semantic) data models. In this tutorial, we will present interoperability techniques for complex IoT Cloud applications by leveraging dynamic solutions of provisioning and reconfiguring of IoT data processing pipelines, protocol bridges, IoT middleware and cloud services. First, the tutorial will examine cross-layered, cross-system interoperability issues and present a DevOps IoT Interoperability approach for defining metadata, selecting resources and software artifacts, and provisioning and connecting resources to create various potential solutions for IoT Cloud interoperability using resource slice concepts. Second, the tutorial will present techniques for dynamically provisioning data pipelines, middleware services, protocol adapters and custom solutions to address cross-layered, cross-system interoperability for IoT Cloud applications. Such solutions also allow dynamic reconfiguration of resources to add/remove interoperability support. We will present the concepts and techniques with hands-on examples using our research tools **rsiHub** and **IoTCloudSamples**.

ACM Classification Keywords

D.2.2 SOFTWARE ENGINEERING: Design Tools and Techniques; D.2.11 : Software Architectures; D.2.12 : Interoperability

Author Keywords

IoT Interoperability, Resource Slice, Cloud Computing

INTRODUCTION

IoT developers and users deal with a variety type of data collected from different sources and these types of data must be processed or provided to other applications. Many software components for IoT data transformation, data messaging, and processing services are involved in even a single IoT Cloud application. Interoperability arises in many aspects and cross layers and systems, not just data or protocol interoperability. Thus, the IoT community has looked for interoperability solutions intensively. In fact, IoT interoperability is one of the hot topics now for researchers and practitioners in academia and industries. We have seen many calls for papers, analyses, tools and projects centered on IoT interoperability [10, 3, 4, 2, 1, 8, 7, 14, 21, 11, 5].

To understand and solve the IoT interoperability challenge, we must view this challenge from a broad perspective. For different developers and users requirements, there are many issues about interoperability, e.g., data interoperability, protocol interoperability, and middleware interoperability, which prevent them to develop solutions rapidly. However, often researchers and practitioners just look at one aspect, e.g., data interoperability [13] or protocol bridge [12]. This is due to the focus of their work on a specific part, such as the interface and interactions between sensors and IoT brokers. However, this is also due to the lack of knowledge about how to deal with interoperability of IoT Cloud applications in a holistic way. While many IoT developers and users might not be familiar with all complexity of software services involved in IoT applications, they are faced with the interoperability problems from many places of the whole software chains, from IoT data sources to the Cloud backend services to the end-user app. Such chains are cross-layers and cross-systems. Therefore, it is of paramount importance for IoT developers and researchers to be aware of diverse types of interoperability problems, seeking and developing novel interoperability solutions in a holistic way.

We have been dealing with IoT Cloud interoperability since many years from a holistic view of software services, protocols, middleware and data within IoT Cloud applications [18, 19, 17, 16, 15, 20]. We have seen that existing solutions mainly focus on a particular issue, such as data or protocol, at a particular phase/part of the IoT Cloud applications, e.g., message brokering or data transformation. However, in reality IoT Cloud applications are not just dealing with data formats or protocols. Therefore, we believe that a holistic view on interoperability is crucial. To this end, we can address interoperability through the resource slice of IoT cloud systems: resource slices capture involved components for IoT Cloud applications, and through them, we can identify interoperability problems, add and remove software to support in-

IOT '18 October 15–18, 2018, Santa Barbara, CA, USA

ACM ISBN 978-1-4503-6564-2/18/10.

DOI: https://doi.org/10.1145/3277593.3277642

teroperability, and reconfigure existing resources/software to assure interoperability.

Another aspect is that very often we believe that interoperability solution development is static. For example, we identify a problem of interoperability and we spend a lot of effort to build, e.g., a new protocol bridge or a data exchange model. However, we should also see interoperability solutions from another aspect: dynamic and runtime interoperability solutions. This departs from the long-development cycle of standardized components and data models, and leverages existing static, single interoperability solutions. Our interpretation on interoperability is how to quickly solve issues that prevents data and software components to be interoperable in specific contexts. Therefore, we investigate runtime solutions and develop DevOps tasks and tools for IoT interoperability to save time and effort to quickly provide context-specific IoT interoperability solutions. Resource slices also enable the rapid development of custom interoperability solutions for specific contexts.

We believe that it is extremely important for IoT developers and users to have a very useful tutorial that considers a holistic, integrated view on interoperability across IoT, network functions and clouds for IoT Cloud applications but also examines further runtime solutions, DevOps tasks to foster the development of interoperability solutions in a short time.

TUTORIAL DESCRIPTION

Content and schedule

The content of this tutorial will include

- IoT Cloud application development overview
- Identification of interoperability problems for IoT data, message brokers, protocols, etc., and review of existing solutions.
- DevOps IoT interoperability model and tools
- Solution approaches to IoT interoperability: static versus runtime solutions
- Resource slice model and how to build resource slice that combine various services from IoT, network functions and clouds for IoT Cloud applications
- Metadata for various types of resources for interoperability solutions.
- Runtime IoT interoperability solutions with resource slices:
  - Key changes in IoT Cloud resources metadata description and discovery.
  - Search for interoperable resources.
  - Dynamic provisioning interoperability solutions.
  - Custom data processing functions for dynamic interoperability.
- Practical hands-on examples and solutions using research prototypes **IoTCloudSamples** and **rsiHub**.

Learning outcomes

We believe that the attendees will achieve the following outcomes:

- Understanding the interoperability problems in a holistic and integrated view of IoT Cloud applications.
- Obtaining a state-of-the-art on current IoT interoperability solutions.
- Understanding the complexity of resources required for achieving interoperability for IoT Cloud applications and systems.
- Bing able to apply, develop and deploy interoperability solutions, especially using existing tools and software, for complex IoT Cloud applications in a rapid and extensible manner.

Presentation style and tutorial format

The tutorial will include presentations and various running examples available in GitHub for hands-on practices. Current examples are available at:

- **rsiHub** [9]: it includes tools and services for resource slices and interoperability solution development
- **IoTCloudSamples** [6]: it includes various IoT, network functions and cloud services as samples for resource slices and interoperability

Based on these examples, this tutorial will present custom examples for interoperability studies.

Prior knowledge required by the attendees

Attendees should have basic knowledge about IoT and Cloud, especially able to understand the basic service model and provisioning and common IoT middleware. Attendees should understand the metadata about IoT data and common IoT data format like CSV and JSON. Common knowledge about messaging systems like MQTT, AMQP, Apache Kafka, and CoAP are expected. It would be a plus if the attendees also knows how to leverage data pipelines and workflows for data transformation. We will use Javascript (with NodeJS) and Python in our examples so basic knowledge about such programming languages are expected.

TUTORIAL MATERIAL

We will utilize existing dataset and virtual machines/dockers to emulate IoT sensors or actually. The software for the tutorial are completely open sources or free. The dataset, tools, etc. are open sources based on our **IoTCloudSamples** and **rsiHub** software, whereas some cloud services can be free for the attendees or the attendees can just register such cloud services free. Our software is open source. Furthermore, we will release tutorial materials (slides, code examples, etc.) as free open sources hosted in Github under the space https://github.com/rdsea/iot2018tutorial.

AUDIENCE

There is a huge demand on learning how to develop interoperable IoT Cloud applications that leverage IoT, network functions and cloud resources. While it is easy to write IoT applications pushing data to clouds, complex applications require a lot of effort and knowledge about IoT, cloud and network functions across layers and systems. Dealing with interoperability is far from just doing data transformation and building protocol bridges. Thus, this tutorial would be a useful source for not only researchers and practitioners working on IoT systems and data but also for people working on IoT middleware and cloud services. We expect that, with this wide and diverse types of cross concerns, this tutorial will attract both researchers and practitioners.

ORGANIZER

Hong-Linh Truong is a Priv.Doz and an assistant professor at TU Wien. He lead the Service Engineering Analytics team (http://rdsea.github.io) in where he concentrates on engineering analytics techniques and tools for designing, monitoring, analyzing, and optimizing functions, performance, data quality, elasticity, and uncertainties associated with systems, software, data and services. He has developed engineering analytics for: Systems (IoT, Cloud, and Edge Systems), Software (Middleware, Protocols, and Tools), Data (Processing Models and Analytics), and Services (Data Marketplace, Service Models, APIs, and Configuration). His work has been contributed to several EU funded and industry projects and been applied to various applications, including smart cities, smart agriculture, enterprises and telcos. In his teaching, he carries out IoT, cloud computing and advanced services engineering and big data.

ACKNOWLEDGMENTS

The work in this tutorial is partially supported by the H2020 Inter-IoT project under the sub-project INTER-HINC. Many people have contributed to the software research and development for IoT interoperability in this tutorial. Among them we are grateful to Lingfan Gao, Michael Hammerer, Duc-Hung Le, and Nanjangud Narendra.

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