

Integrating Existing IoT systems: LA smart parking use case

By Georgios Bouloukakis

boulouk@gmail.com

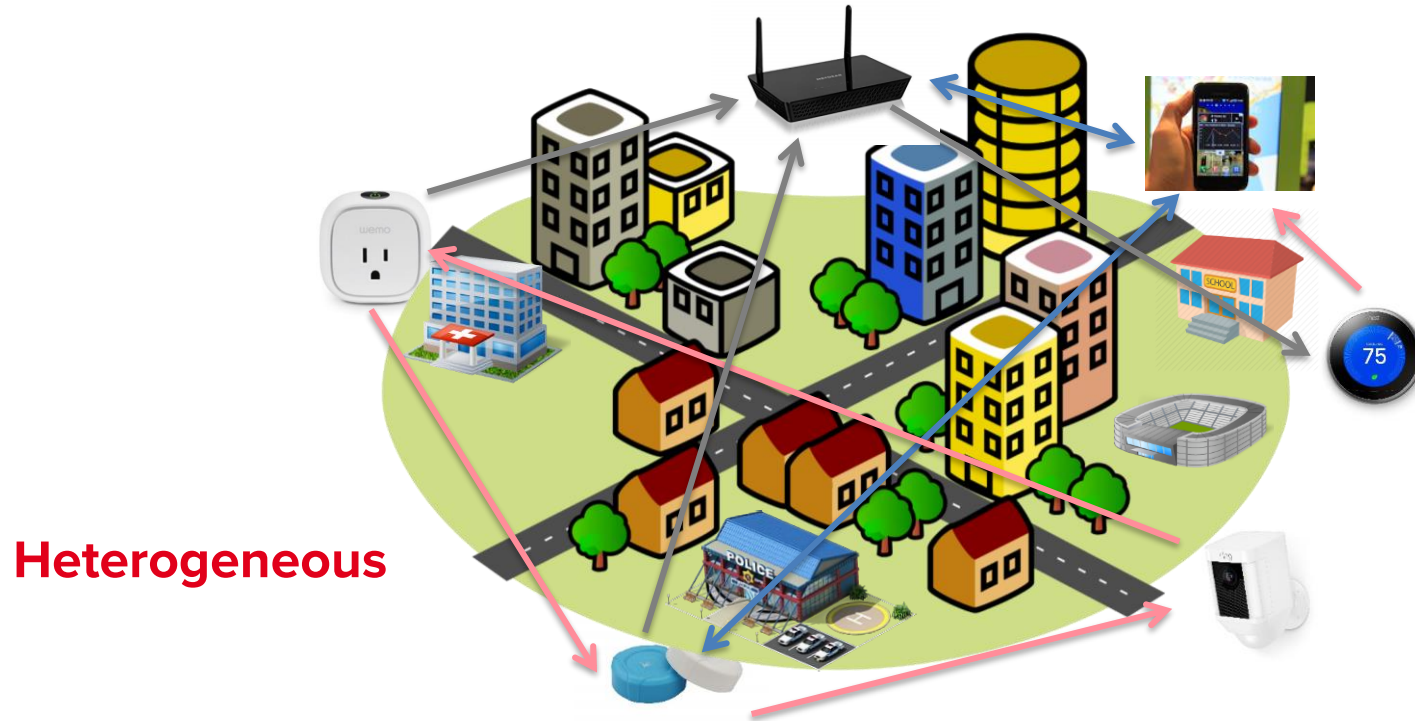
Joint work with: Pierre-Guillaume Raverdy,
Patient Ntumba, Nikolaos Georgantas & Valerie Issarny

Feb 2020, Los Angeles City Hall



UCIRVINE

Enabling Data Exchange in IoT Smart Spaces



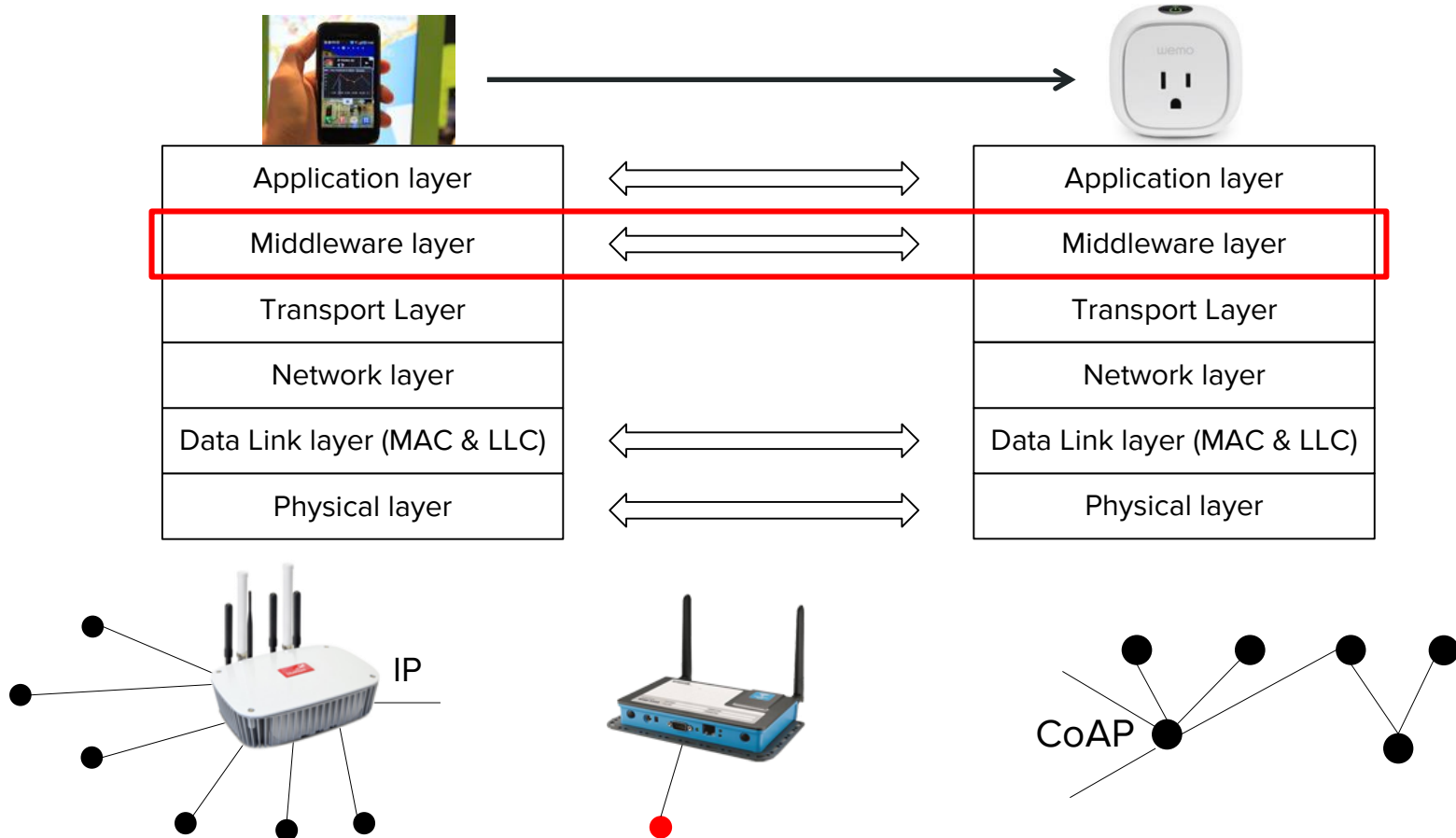
Dynamic

Heterogeneous

“what is the **occupancy** of the room 2065?”

“**decrease** the **temperature** of those rooms with **occupancy** above 50% of their capacity?”

IoT heterogeneity at multiple layers



Middleware protocols in the mobile IoT



DPWS

Client-server



CoAP

MQTT



ZeroMQ

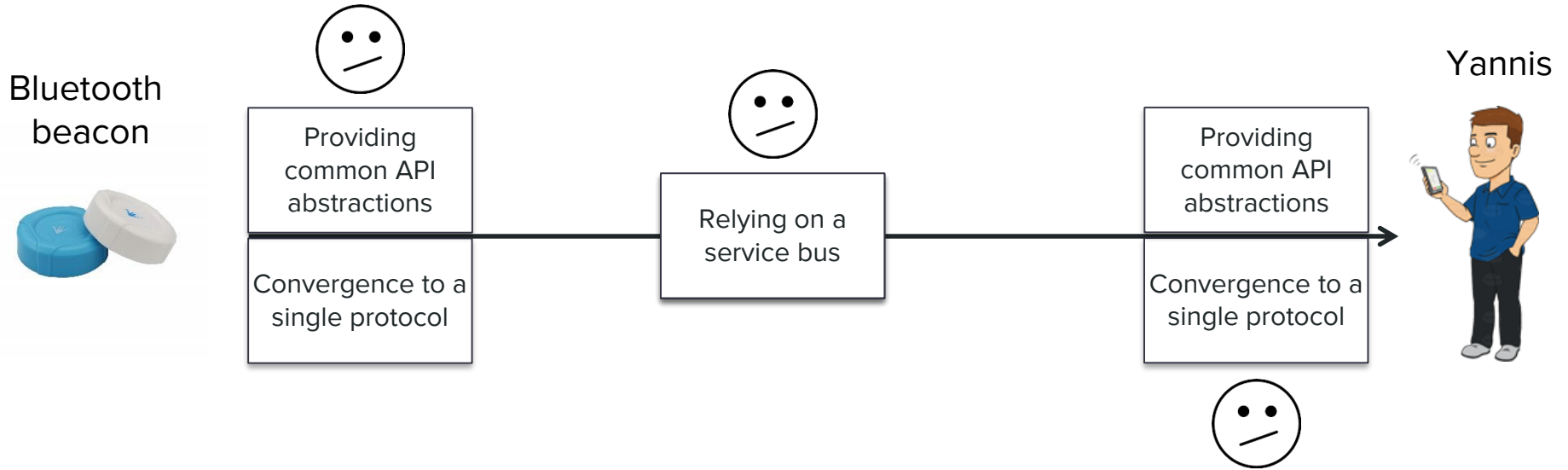
Pub/sub



WebSockets

Streaming

Heterogeneous interconnections in the IoT



❑ How to enable interconnections in the mobile IoT ?

Our proposed solution

Bluetooth
beacon



Protocol X

systematic solution to
interoperability

systematic solution
to deployment

Protocol Y



e.g. CoAP server

- push-based
- resource

e.g. MQTT subscriber

- pub/sub
- topic

functional semantics

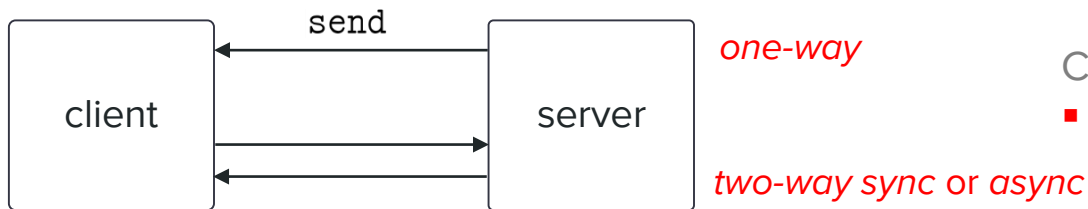
Automated synthesis of interoperability artifacts (mediators):

- enables functional middleware-layer interoperability

Automated placement and deployment at the Edge:

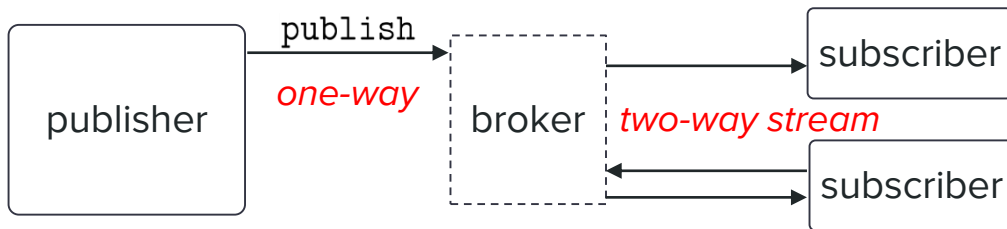
- enables the deployment of interoperability artifacts at the Edge

Models for core interaction paradigms



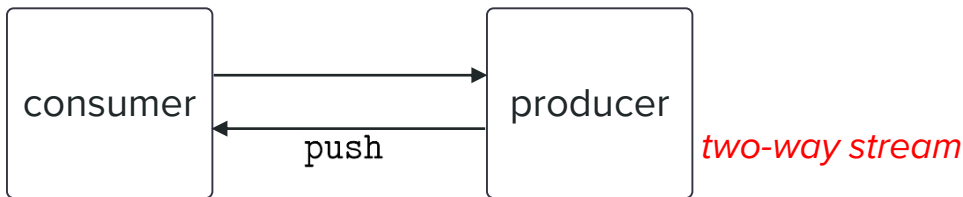
Client-Service (CS)

- Tight Time & Space Coupling



Publish-Subscribe (PS)

- Time & Space Decoupling

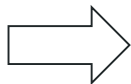
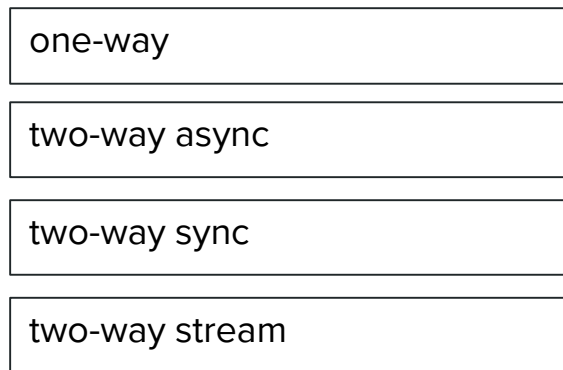


Data Streaming (DS)

- Tight Time & Space Coupling

Data eXchange (DeX) connector model

- Our generic connector defines 4 basic interaction types:



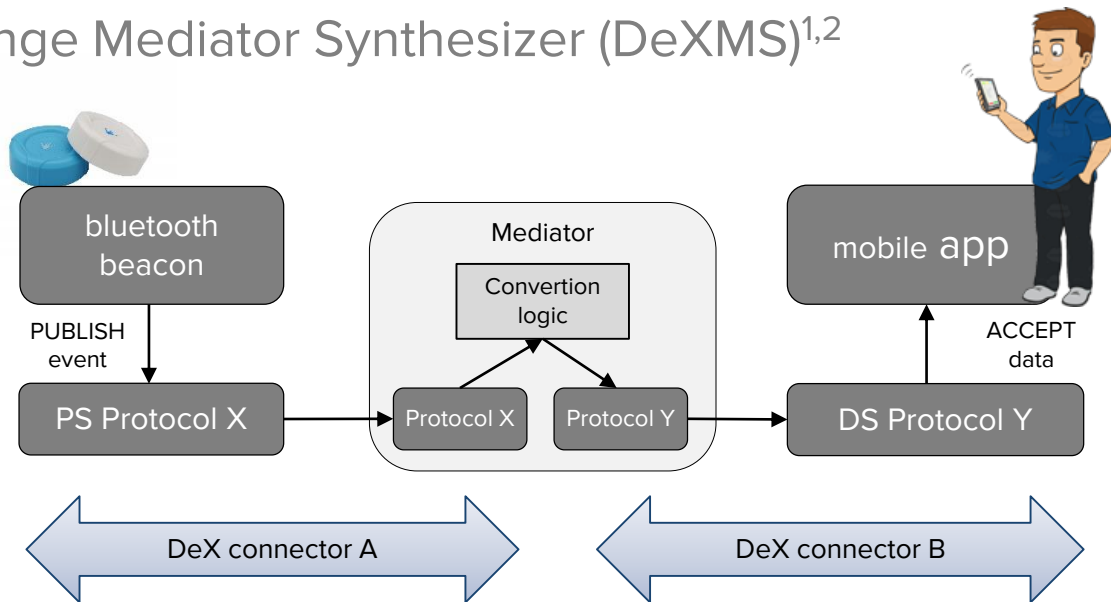
each interaction is represented as combination of **post** and **get** primitives

post and **get** primitives abstract CS, PS, DS and TS primitives

We rely on the DeX abstraction to introduce our middleware protocol interoperability solution

Our middleware protocol interoperability solution (1/2)

➤ Data eXchange Mediator Synthesizer (DeXMS)^{1,2}



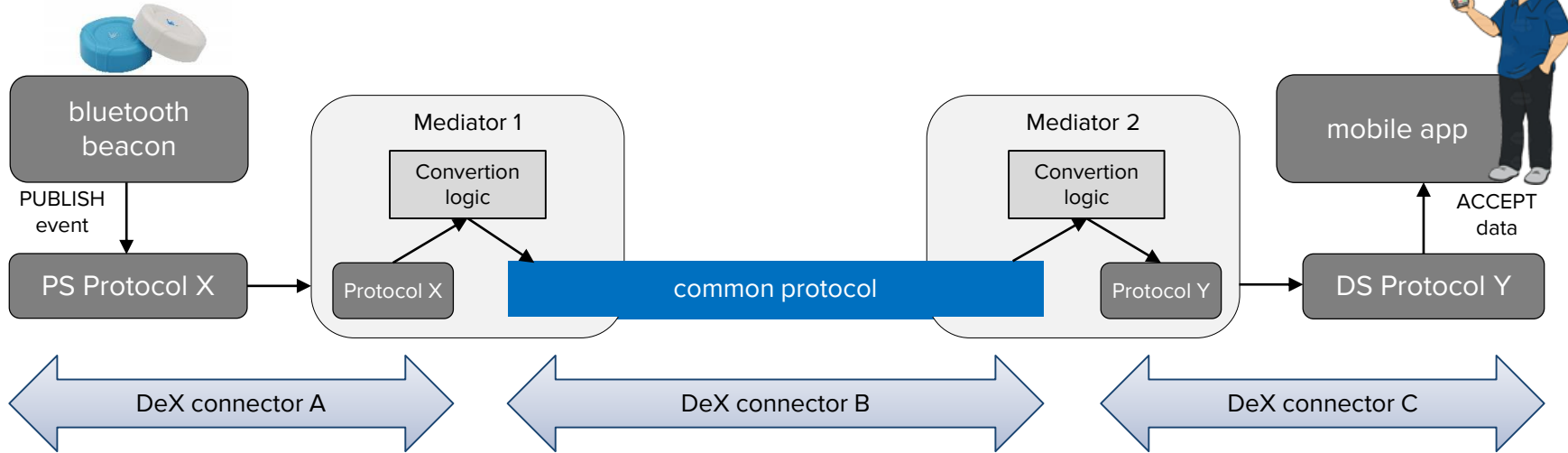
- ❑ Mediator architecture: relies on DeX for automated Mediator synthesis
- ❑ Primitives & data conversion between the Things' protocols
- ❑ **Direct mediation**

¹G. Bouloukakis et al., FGCS, 2019

²G. Bouloukakis et al., ICSOC, 2016

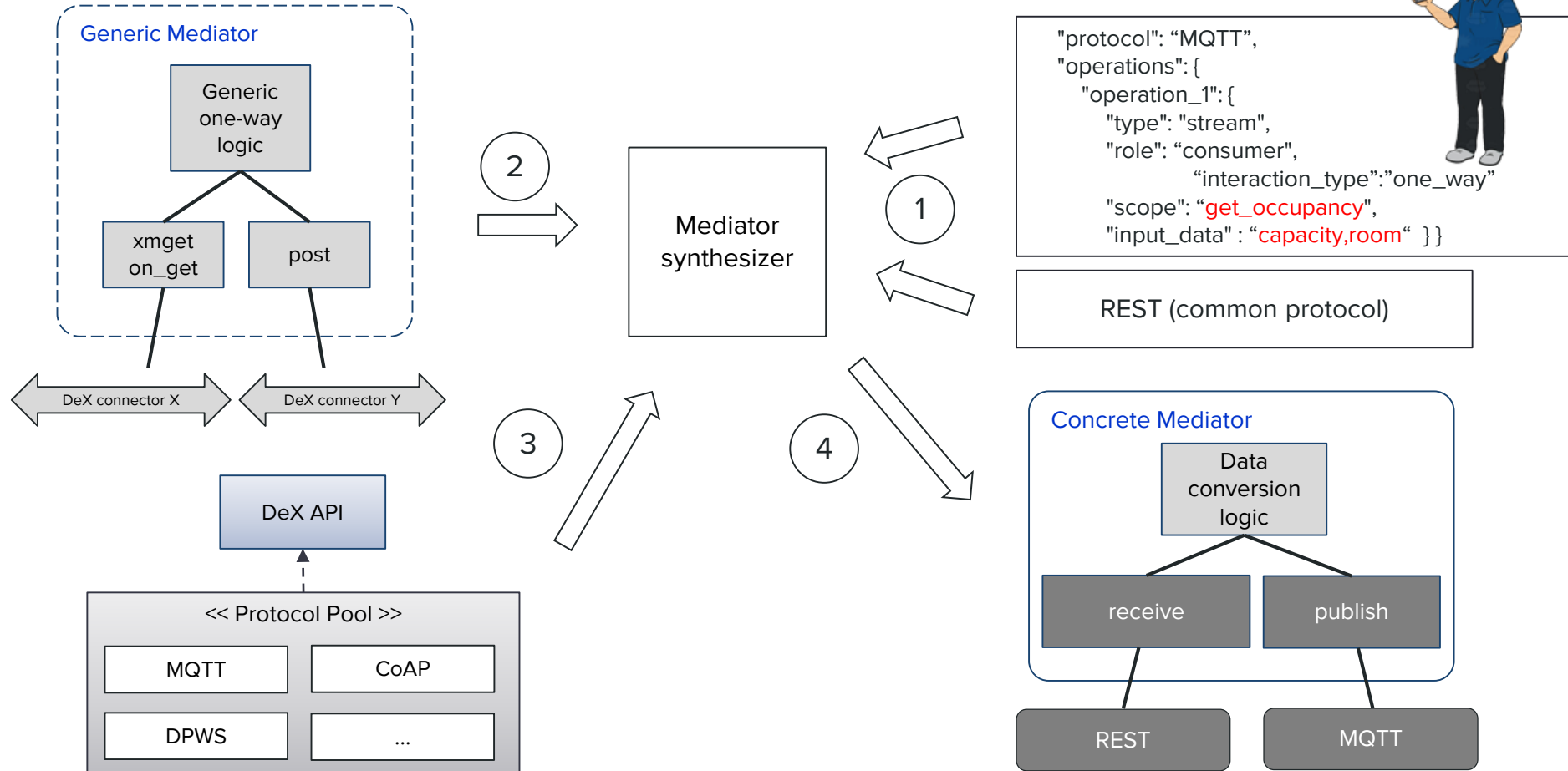
Our middleware protocol interoperability solution (2/2)

➤ Indirect mediation



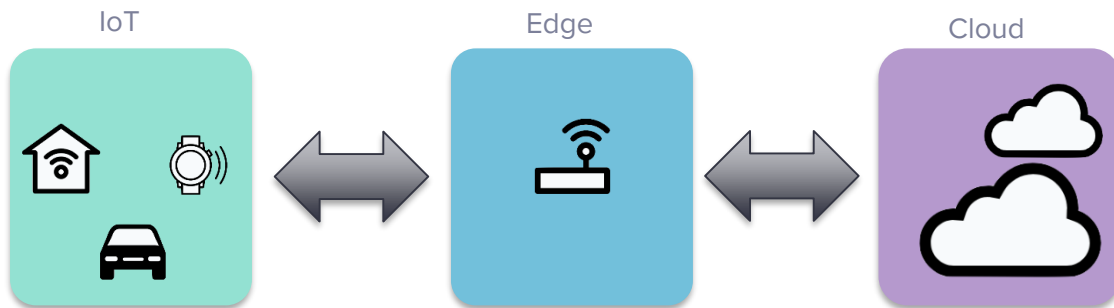
- ❑ Primitives & data conversion between the common protocol and the Things' protocols
- ❑ A universal way to describe the Things' I/O required

Automated Mediator synthesis

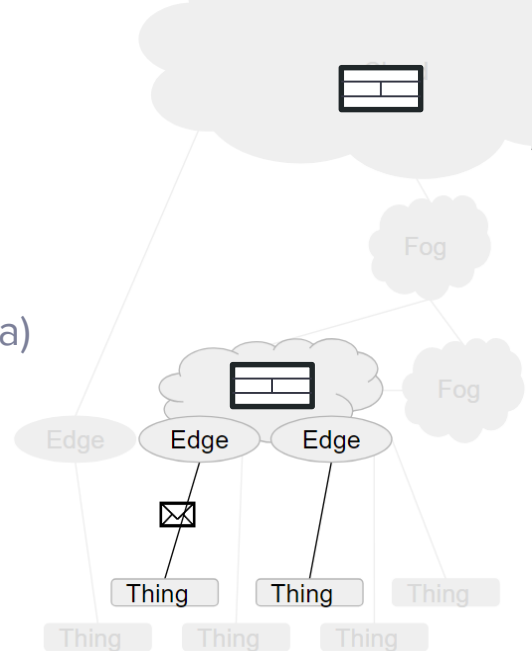


The *Where* and *How* Problem

- *Where* to place mediators: Cloud, Edge, and Fog Computing
- Obvious solution: The Edge and Fog
 - Things push data to the Cloud to be analyzed (e.g., 4k camera)
 - Use artifacts at the Edge/Fog to filter these data
 - Timeliness, data privacy, etc



- Work in progress:
 - Systematic solution to automate the deployment of mediators at the Edge
 - Utilize mediators for data filter for forwarding on Cloud



Mediators at the Edge



Docker

- Delivers software in packages called containers.
- DeXMS provides mediators as Dockerfiles.
- A Dockerfile produces a Docker image.

Ansible

- Automation tool to perform installation, maintenance, or monitoring operations.
- Used to automate the installation of the smart space infrastructure as well the DeXMS service.

DeXMS

Ansible

- Triggers the DeXMS service to generate the required Mediator containers.
- Can be used to monitor networks and services.

Kubernetes

- Container-orchestration system for automated deployment, scaling, and management.
- Supports the automated deployment of mediators.



The *How* Problem

- *How* to place mediators?
 - Related Problem: Operator Placement
 - Compute a “cost space”¹ to represent *Things* and *Physical Nodes*
 - E.g., a smart building with heterogeneous Things
 - Place mediators in an optimized manner

Criteria: distance, energy, bandwidth, latency, availability, etc

Optimization techniques^{2,3}: constraint programming solvers, heuristics, linear programming, genetic programming, etc.

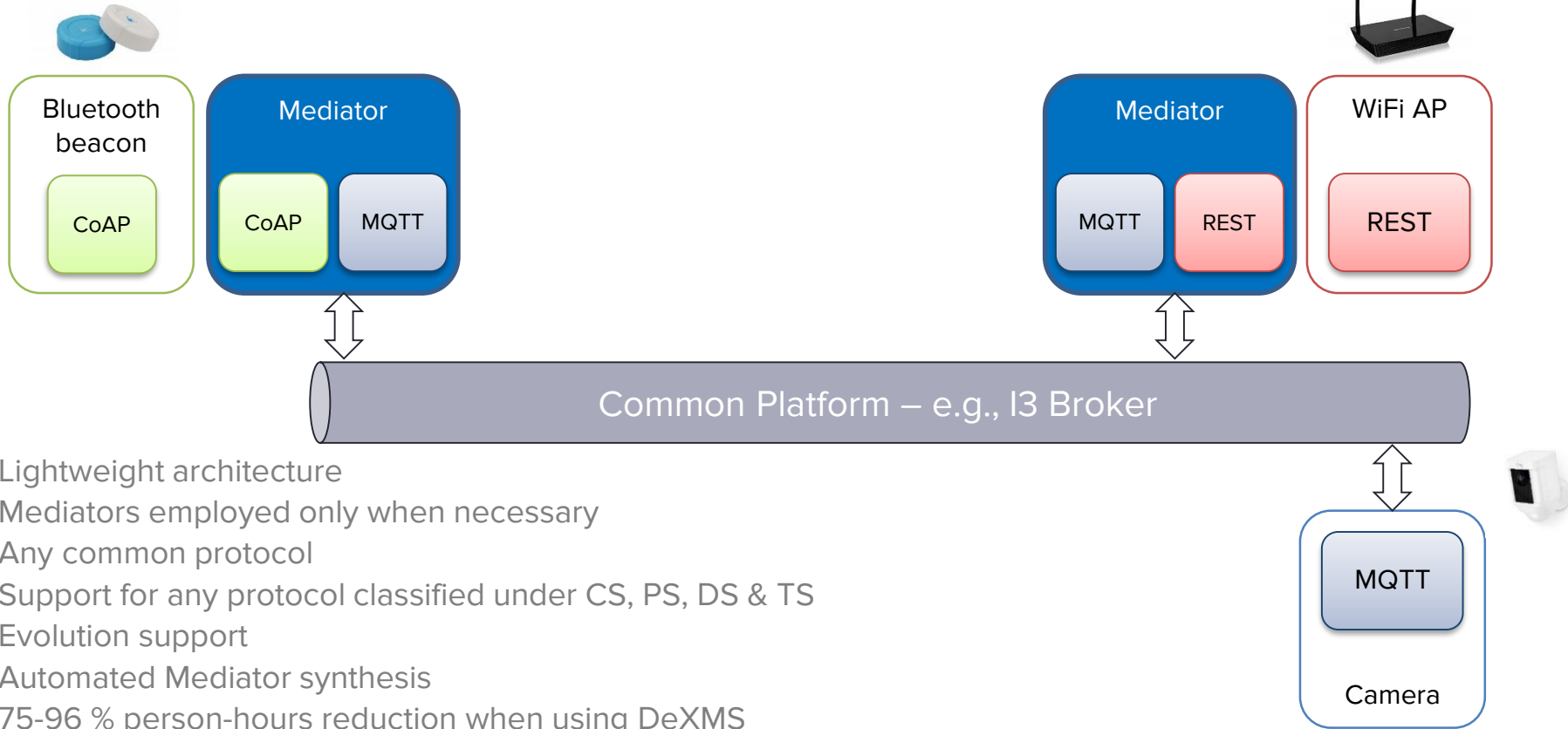


¹P. Pietzuch et al., ICDE, 2006

²V. Issarny et al., ICDCS, 2019

³A. Chio et al., ARM, 2019

DeXMS novelty




- Lightweight architecture
- Mediators employed only when necessary
- Any common protocol
- Support for any protocol classified under CS, PS, DS & TS
- Evolution support
- Automated Mediator synthesis
- 75-96 % person-hours reduction when using DeXMS
- Work in progress: enabling application-layer data exchange¹

¹R. Yus et al., Buildsys, 2019

LA Smart Parking use case (1/4)

- ❑ Heterogeneous services/devices providing parking information:
 - Several middleware protocols employed – REST, Websockets, etc
 - Different data models and schemas created by different stakeholders
 - Different data formats used -- JSON, XML, etc

 Data

[LADOT Parking Meter Zones](#)
City of Los Angeles Hub | lahub_admin

Parking meters are divided into zones for maintenance and management of the meters. LADOT manages approximately...

Type: Feature Layer
Last Updated: Feb 20, 2020

Rows: 71
Tags: NavigateLA, Los Angeles, LA, ...

 Data

[LADOT Parking Enforcement Districts](#)
City of Los Angeles Hub | lahub_admin

LADOT parking enforcement districts are the regions of the city that were established for efficient management of...

Type: Feature Layer
Last Updated: Feb 20, 2020

Rows: 5
Tags: NavigateLA, Los Angeles, LA, ...

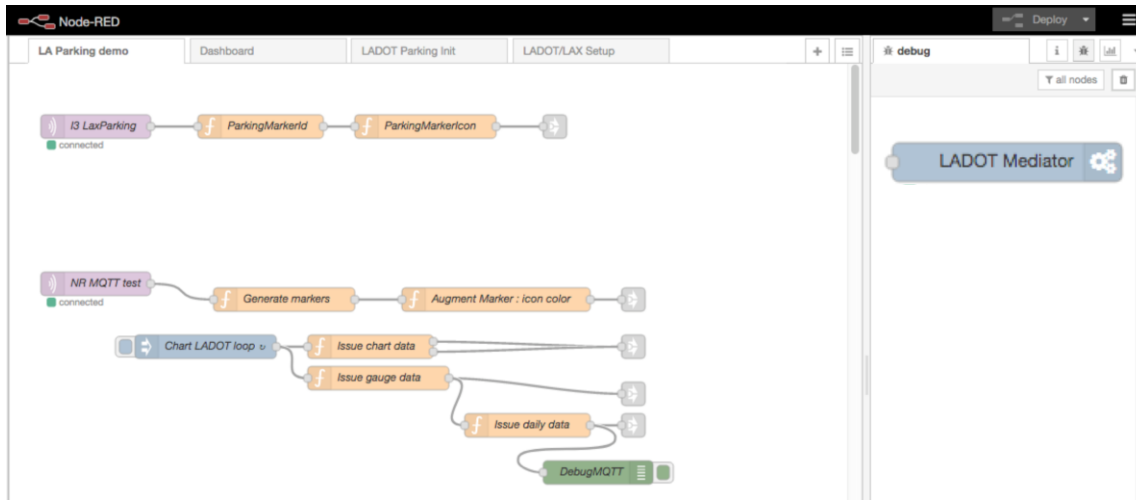
LA Smart Parking use case (2/4)

- ❑ We leverage the I3 platform to build the LA smart parking application
- ❑ We assign different I3 subscribers to different regions of LA
- ❑ This enables extensible app development
 - relying on single protocol, data format and data representation
- ❑ Data from heterogeneous services/devices?



LA Smart Parking use case (3/4)

- ❑ We rely on Node-RED to build and demonstrate our application

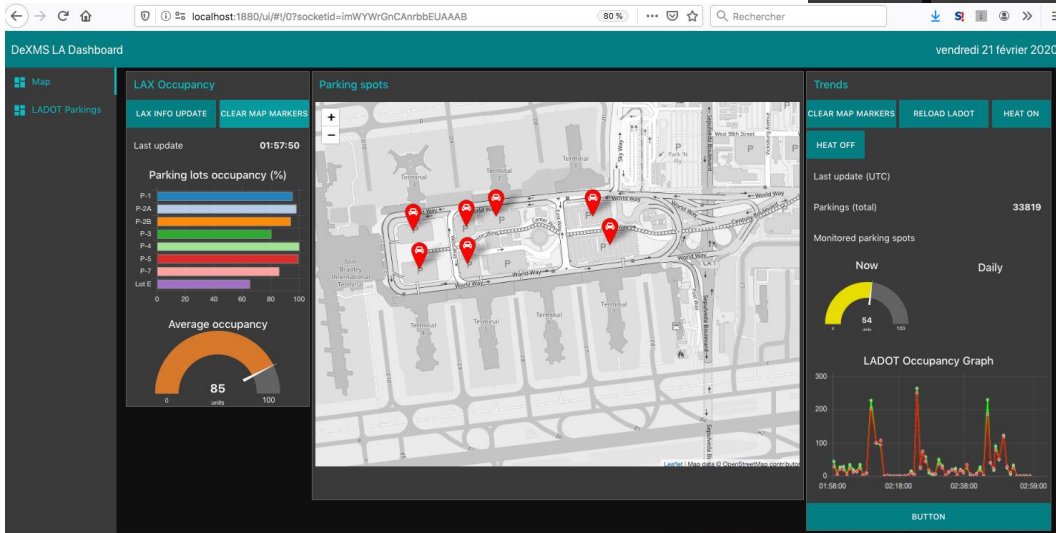
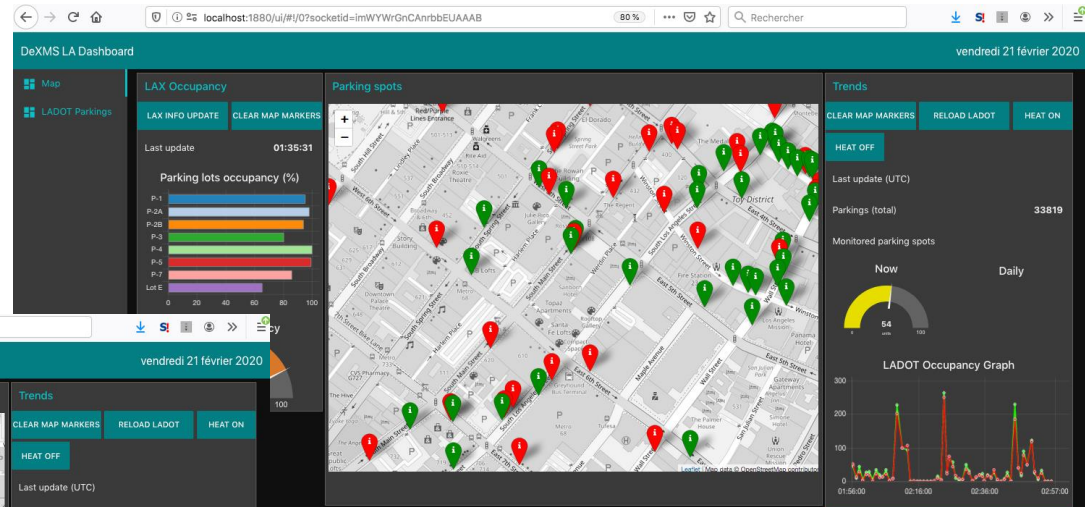


- We use the DeXMS service and the Node-RED palette to generate mediators for heterogeneous services/devices

A screenshot of the Node-RED DeX-IDL configuration form. The form is titled "DeX-IDL Files" and "Create DeX-IDL". It contains fields for "Name" (LADOT), "Thing Type" (SERVICE), "Protocol" (REST), "Host Address" (https://data.lacity.org), and "Port Number". Below these fields is a "Generate new DeX-IDL" button. The form also displays the configuration for "Operation 1", which is a "CONSUMER" role with the operation name "LADOT_Parking_Meter_Occ". The "Operation Scope" is "Name: LADOT_Parking_Meter_Occ", "Verb: GET", and "Uri: resource/e7h6-4a3e.json". The "Input Data" section shows "Context: BODY" and "Media type: JSON". The "Simple Input Data 1" section shows "Name: spaceid", "Minimum occurrence: ONE", "Maximum occurrence: ONE", and "Type: STRING". At the bottom, there are buttons for "Add Simple data" and "Add Complex data".

LA Smart Parking use case (4/4)

Node-RED apps plotting MQTT-compatible data



Software artifacts and adoption

➤ DeXMS:

- Mediator generator: <https://gitlab.inria.fr/dexms/service>
- Eclipse plugin for defining Things' DeXIDLs: <https://gitlab.inria.fr/dexms/dexidl>
- Web interface: <https://sed-webtests.paris.inria.fr/dexms-service-1.2.0-SNAPSHOT/>

➤ Demos:

- Mediator generation: <https://youtu.be/UgfM3810RS8> (ICSOC 2016)
- Web console installation: <https://youtu.be/IGjZ5u3QYOW> (ICWE 2018)
- Fire Detection scenario: <https://youtu.be/SJeiqJkBhls> (ICWE 2018)

- DeXMS is used as a core component in H2020 CHOReVOLUTION, UCI TIPPERS and Inria/UCI MINES and I3 projects.



Publications

- G. Bouloukakis, N. Georgantas, P. Ntumba, V. Issarny, "Automated Synthesis of Mediators for Middleware-layer Protocol Interoperability in the IoT", FGCS Journal, 2019.
- R. Yus, G. Bouloukakis, S. Mehrotra, N. Venkatasubramanian, "Abstracting Interactions with IoT Devices Towards a Semantic Vision of Smart Spaces", ACM Buildsys, November 2019, New York, USA
- V. Issarny, B. Billet, G. Bouloukakis, D. Florescu, C. Toma, "LATTICE: A Framework for Optimizing IoT System Configurations at the Edge", ICDCS 2019, July 2019, Dallas, Texas, USA
- A. Chio, G. Bouloukakis, C.H. Hsu, S. Mehrotra, N. Venkatasubramanian. "Adaptive Mediation for Data Exchange in IoT Systems", 18th ARM Workshop 2019, Davis, CA, USA

Questions?

<https://gbouloukakis.com>
boulouk@gmail.com

