



ICSOC 2016

Revisiting SoA for the IoT

A Middleware Perspective

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Inria Paris

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and many other colleagues*

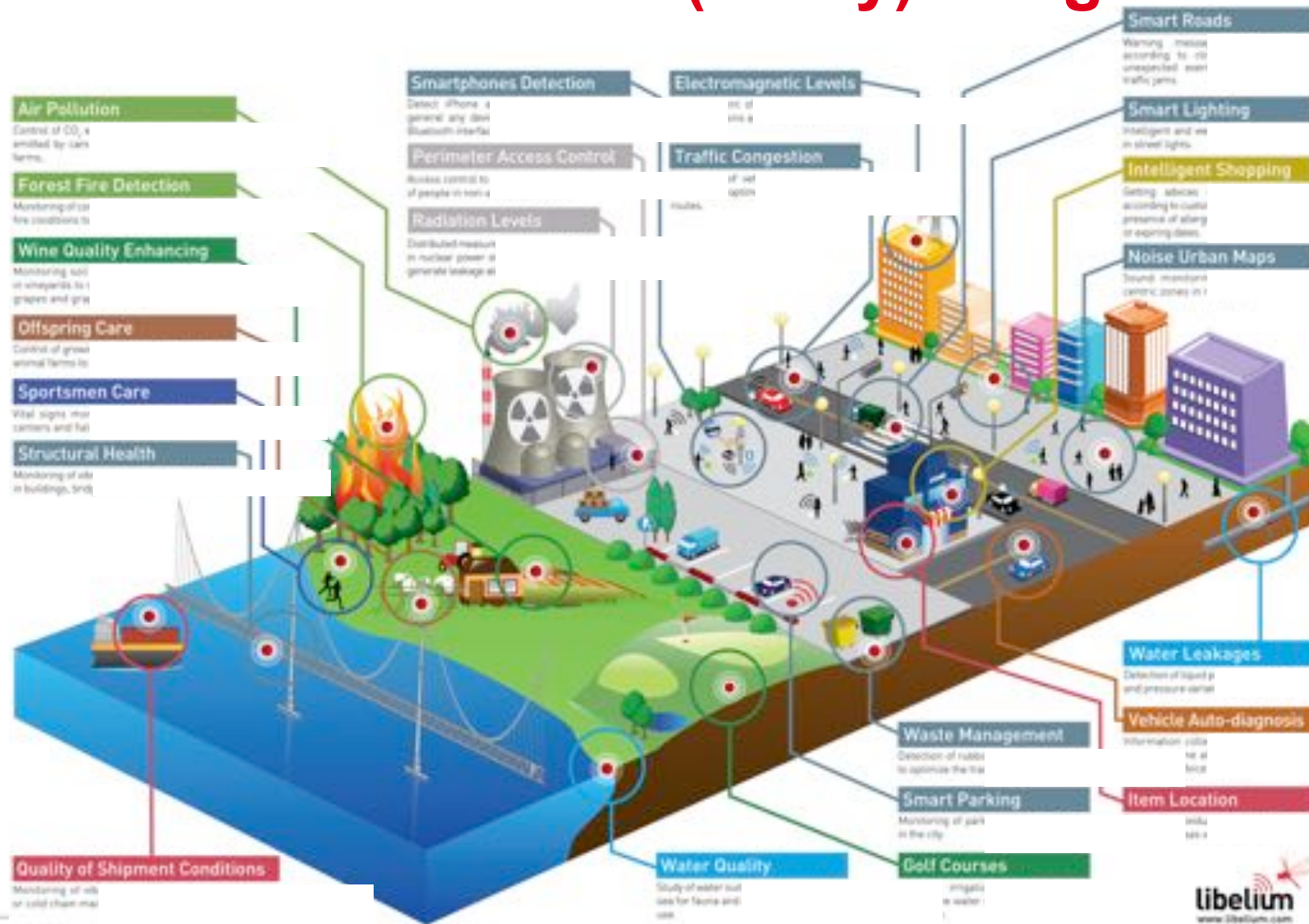
Agenda

1. The IoT: An Introduction
2. A Service-Oriented IoT: Why & How
3. SoA for the IoT: Some Middleware Insight
4. Conclusion: What's Next

1

But what is the Internet of Things?

The Internet of (Every)Things



When the Virtual absorbs the Physical World



Matrix trailer

Not yet there... hopefully 😊

When the Virtual & Physical Worlds Connect



Why bother? It's already there!

But the Physical World is Complex



123RF Consuelo Barreto + Inria edition

And so is the IoT!

The Pollution Monitoring use Case



https://www.youtube.com/watch?v=Yw_Er8fMmMw

Fixed Sensing

High cost
but accurate



Mobile Crowdsensing

Low cost &
high redundancy
but low accuracy &
high diversity



Inria

Social Sensing

Qualitative add-on
but highly subjective

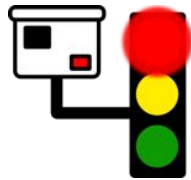
Challenges



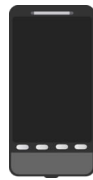
- Ultra-large scale
 - # Things
 - # Data
- Deep heterogeneity
 - Technical
 - Functional
 - Social
- Physical knowledge
 - Time-dependency
- High dynamics
- Privacy & security

What if...

**Everything connects and contributes
to urban knowledge**



Fixed Sensors



Mobile Sensors



Citizens



Social
Networks



Urban middleware with hybrid sensing/actuation



Middleware tames high heterogeneity, scale & dynamics



And QoS @ large – cf Elisa's keynote on security & privacy

Learning from an Urban Scale Experiment



Inria / photo C. Morel

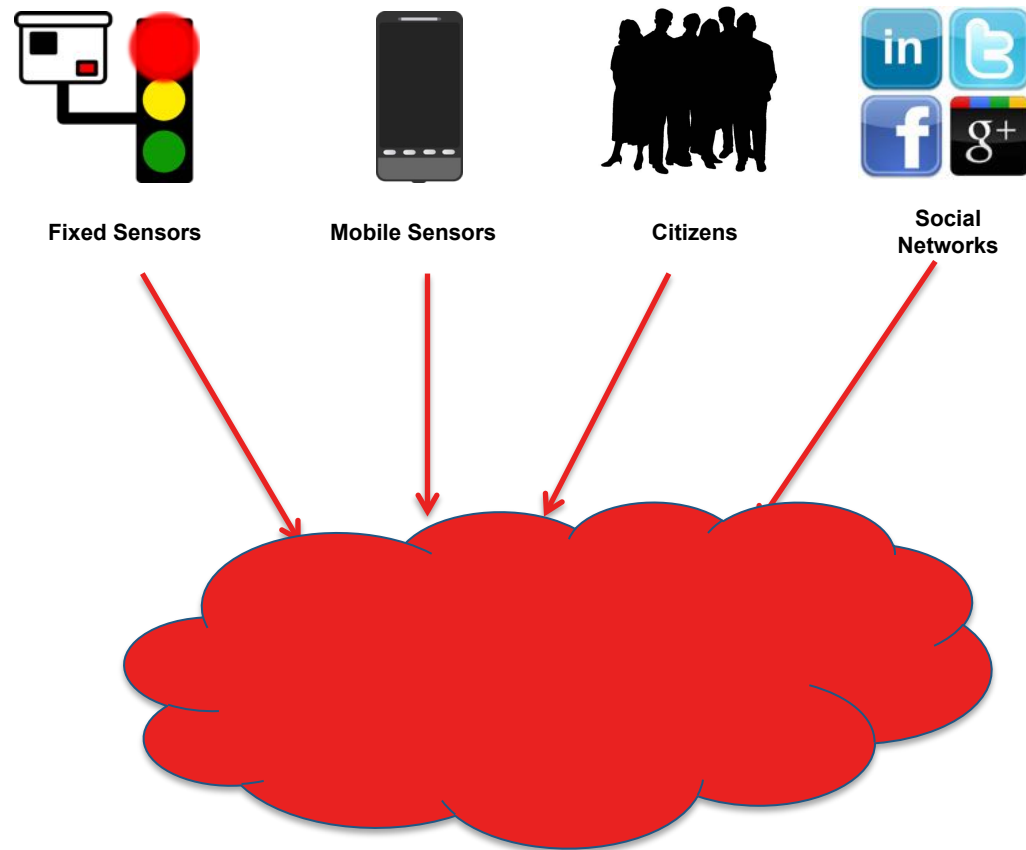
Ambiciti App informing about individual and collective exposure to urban pollution



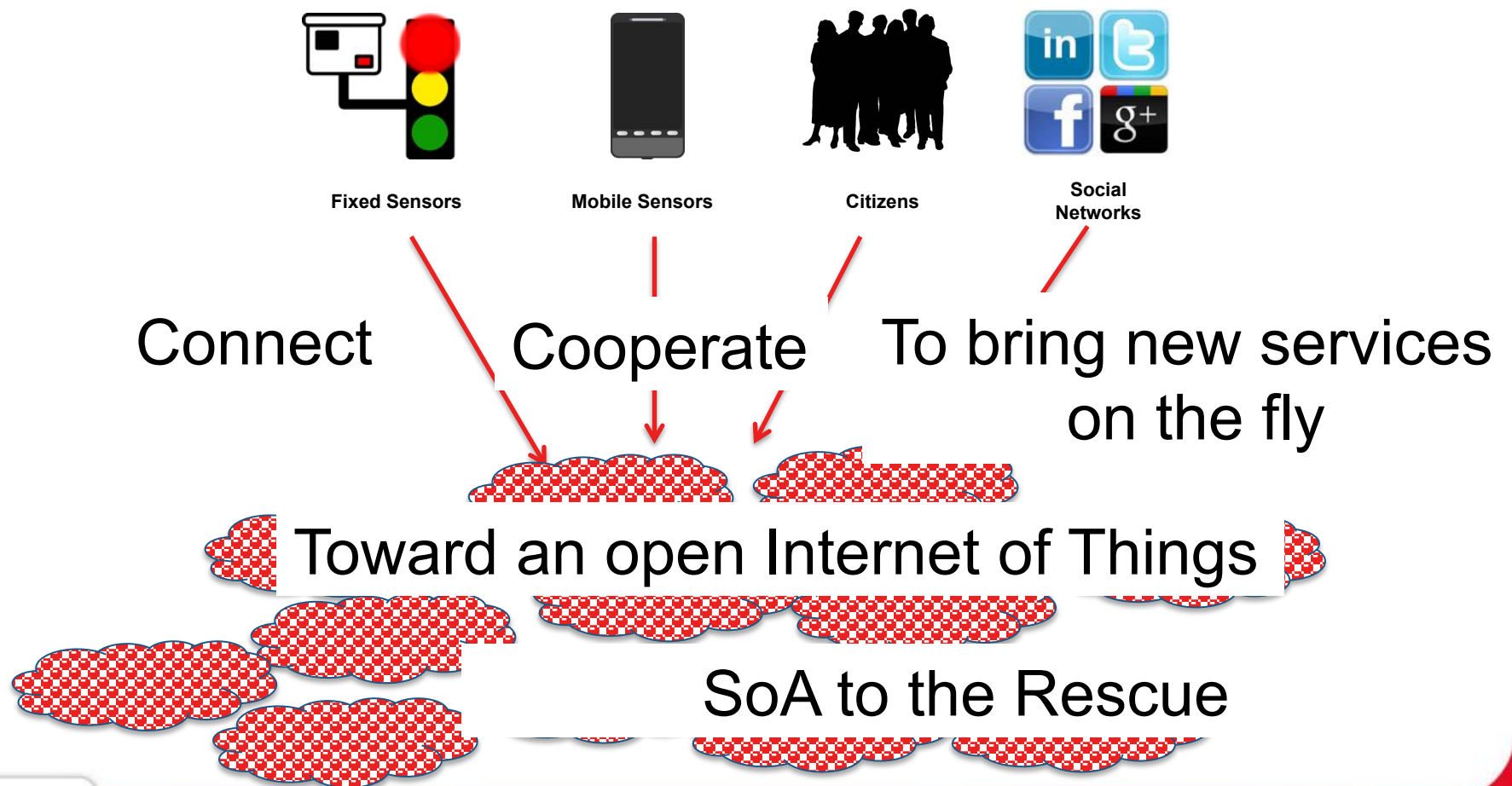
Noise pollution monitoring in Paris since summer 2015

Scale, Heterogeneity, Physical, Dynamics, Privacy, ...

The 2 Ends of the Spectrum



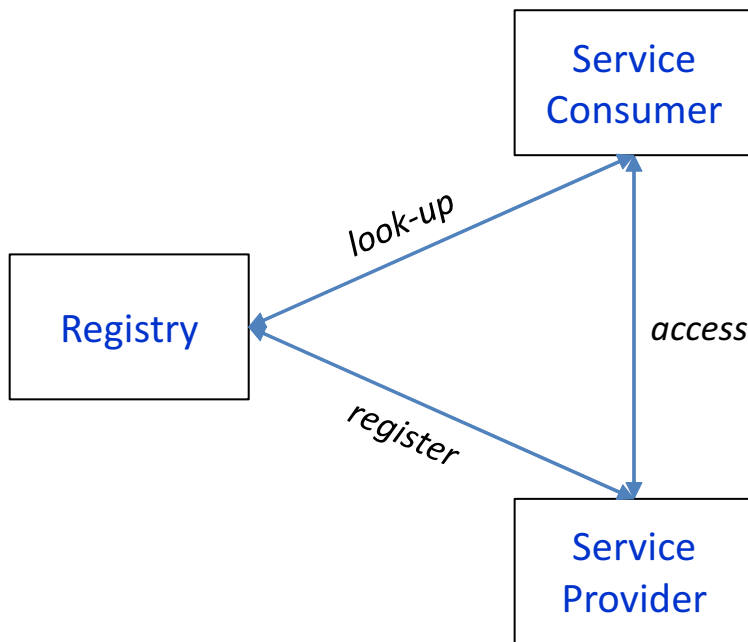
The 2 Ends of the Spectrum



2

Toward a Service-oriented IoT?

Service-oriented Architecture Meets the IoT



Service Abstraction
Discovery, Composition
& Access

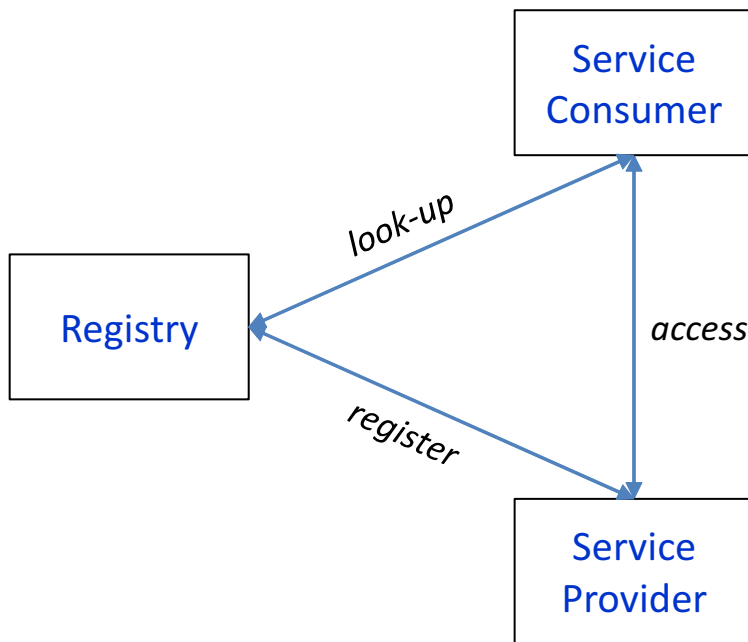
BUT

Ultra-large scale
Continuous data streams
Multi-paradigm interactions

A Rich State of the Art

- Ultra-large scale
 - Cloud of Things, In-network processing
 - Continuous processing, Map-reduce
- Heterogeneity
 - SoA, WoT, Virtualization
 - Ontology, Semantic WoT
- Physical knowledge
 - Sensor data streams
- Dynamics
 - Dynamic discovery
- Privacy & security

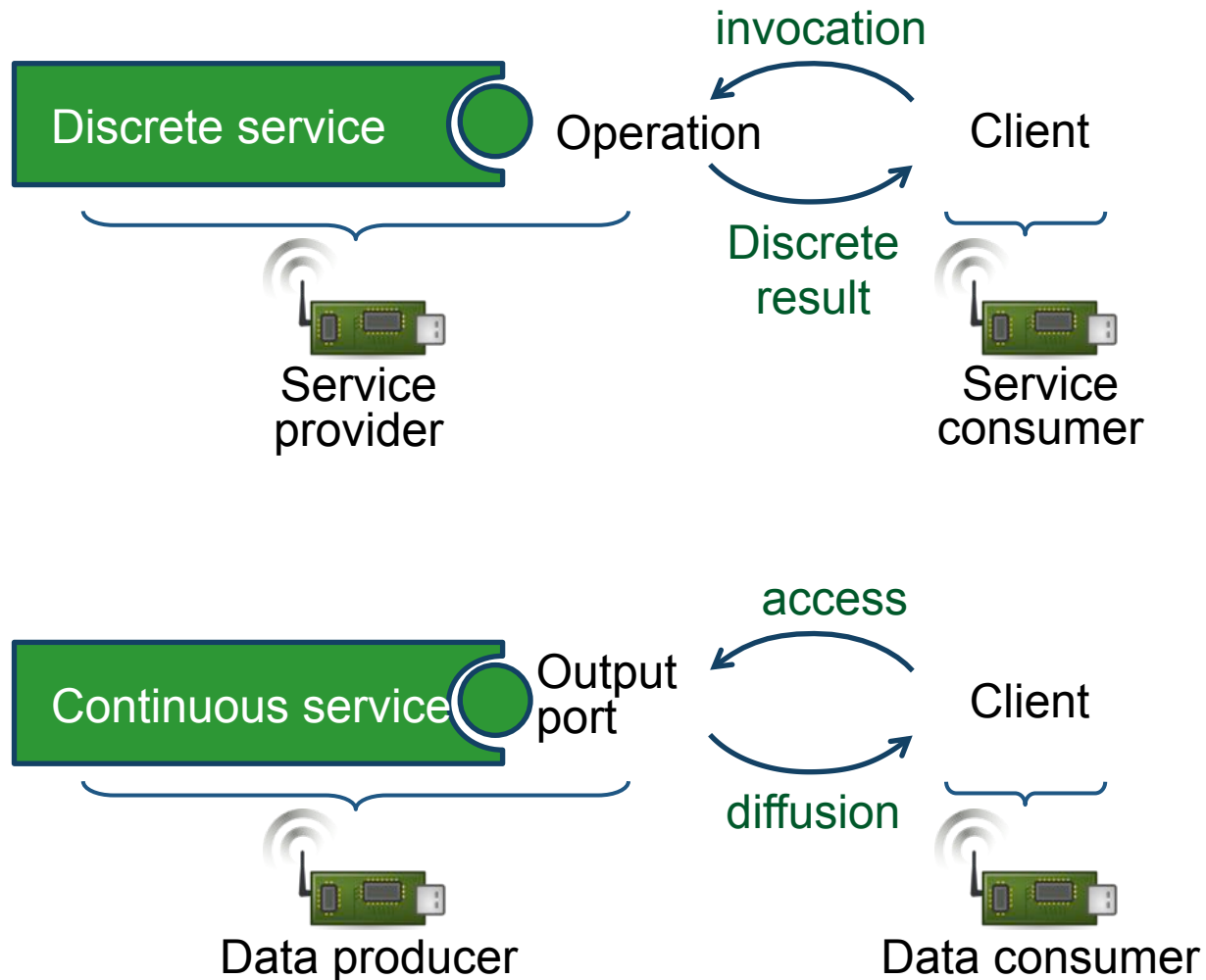
A Thing-based SoA



Service abstraction for Things

- Connect with the physical world
- Semantic knowledge
- Functional & non-functional
- Discrete & continuous

A Thing-based SoA

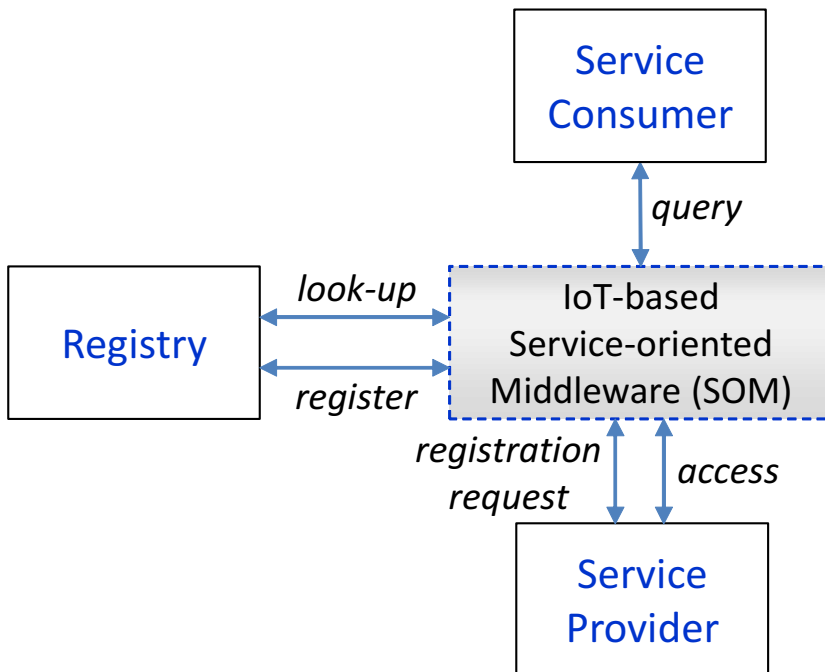


A Thing-based SoA

Things Abstraction

Thing discovery

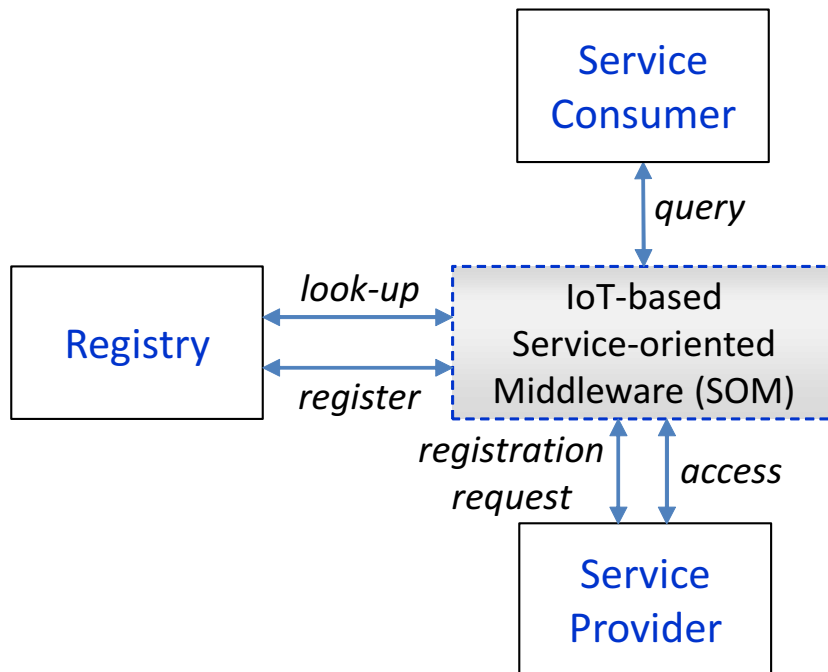
- Query for real-world phenomena
- Mobile and fixed things
- Diversity of the connected things
- Redundancy



A Thing-based SoA

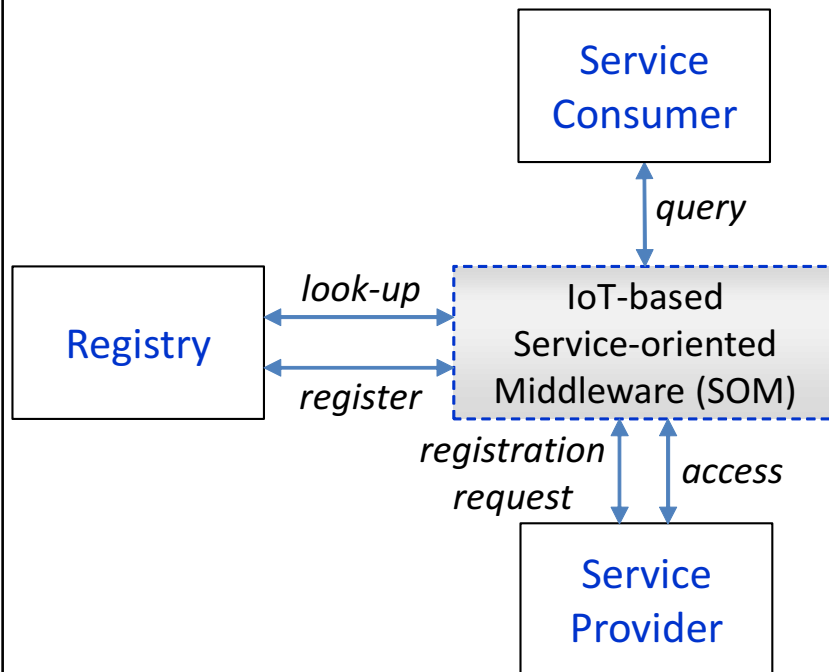
Things **Abstraction,** **Discovery** **Thing** composition

- Complexity of the physical world
- Diversity of the connected things
- Sense & actuate continuous real-world phenomena



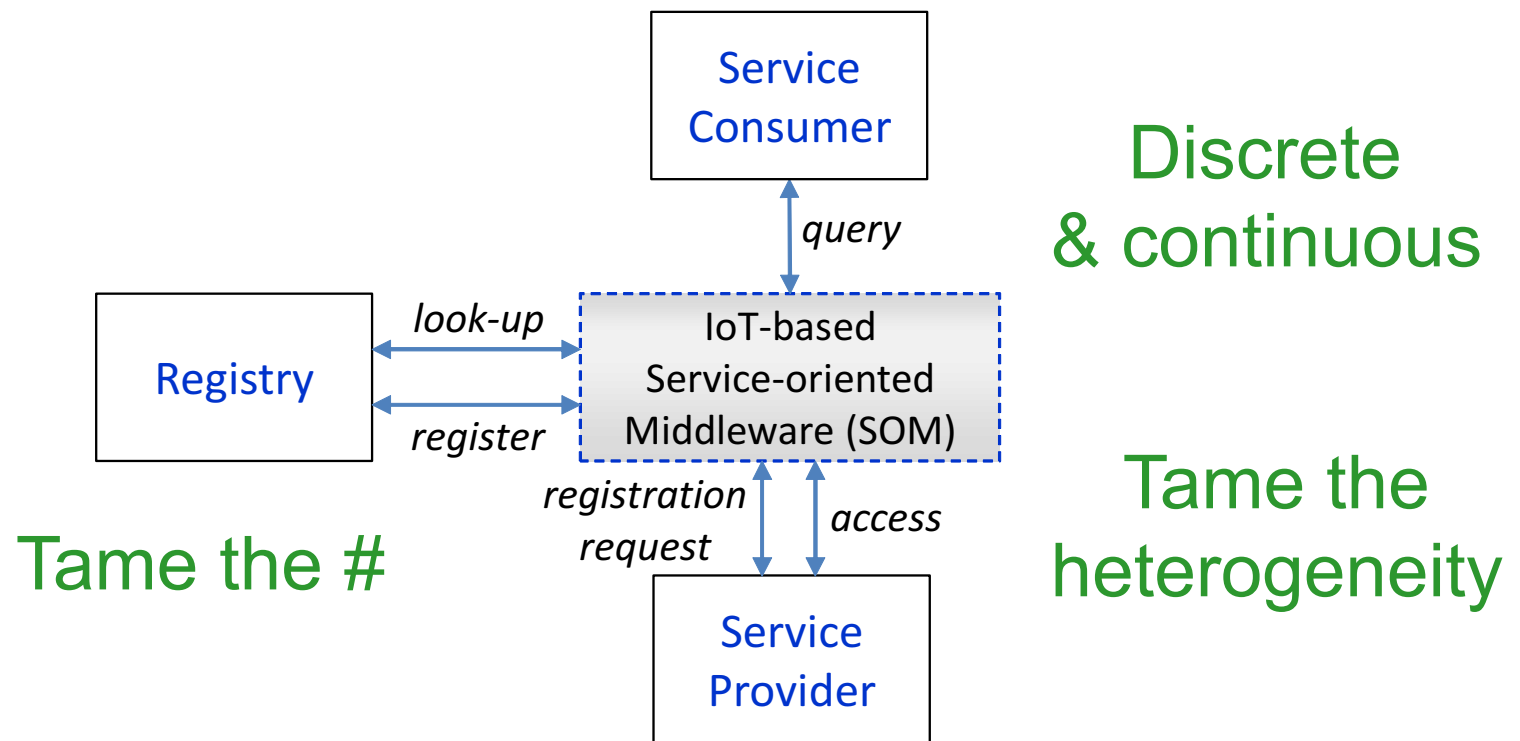
A Thing-based SoA

Things Abstraction, Discovery, Composition Thing access



- Resource-constraints
- Proxy/gateway
- Thing node
- Diversity of access protocols for the tiny to the wealthy things

A Thing-based SoA

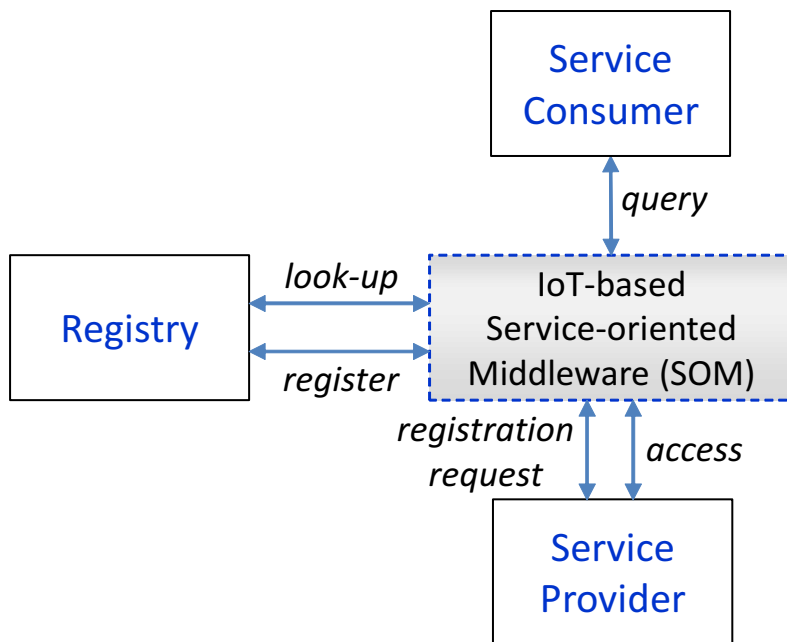


3

Middleware for a Service-oriented IoT

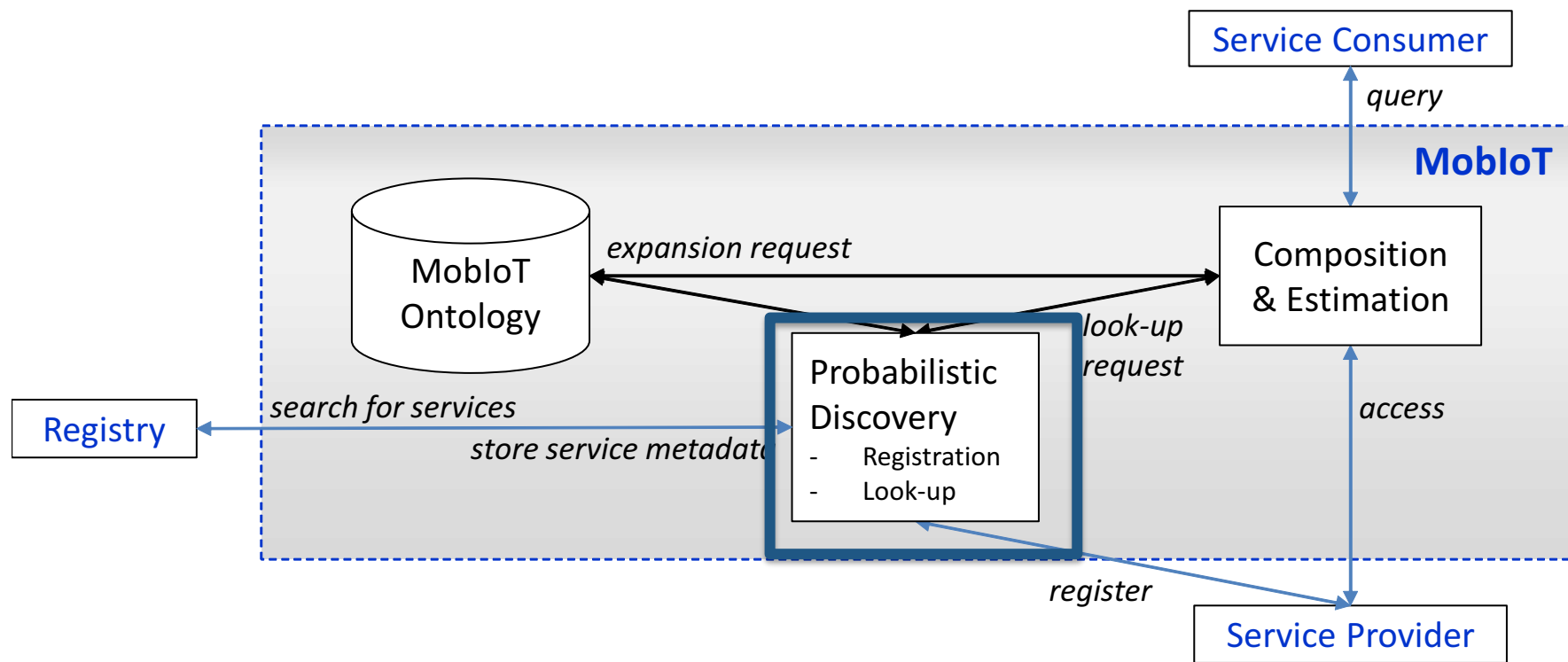
Middleware Solutions for a Thing-based SOA

Sensing the Physical World



- **Discovery** in the ultra-large scale IoT
- **Composition** in the Dynamic **resource-constrained** IoT
- **Access** in the **Heterogeneous** IoT

Service Discovery in the Ultra-large Scale IoT



Probabilistic discovery for the mobile IoT

Probabilistic Discovery for the Mobile IoT

Enough
coverage

More likely to
not register



Jardin des Tuileries

Design Rationale

- Do not register redundant Things to reduce number
- Leverage user mobility knowledge

Probabilistic Discovery: How



Jardin des Tuileries

Centralized Approach

- Compute decision on Registry as search problem
- Using global displacement knowledge
- But computation time increases linearly

Probabilistic Discovery: How



Jardin des Tuileries

Distributed Approach

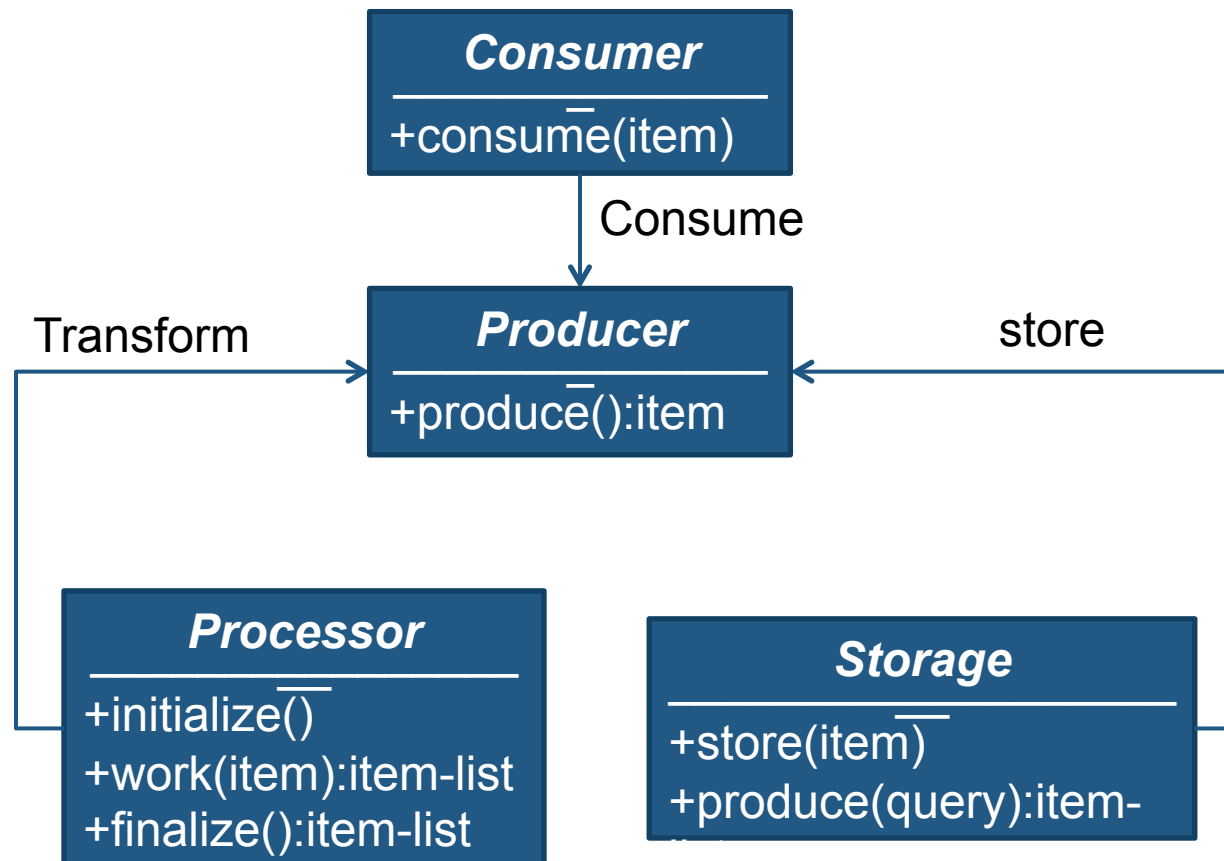
- Compute decision on Thing
- Estimate displacements of registered Things using mobility models (e.g., TLW)

Service Discovery in the Ultra-large Scale IoT

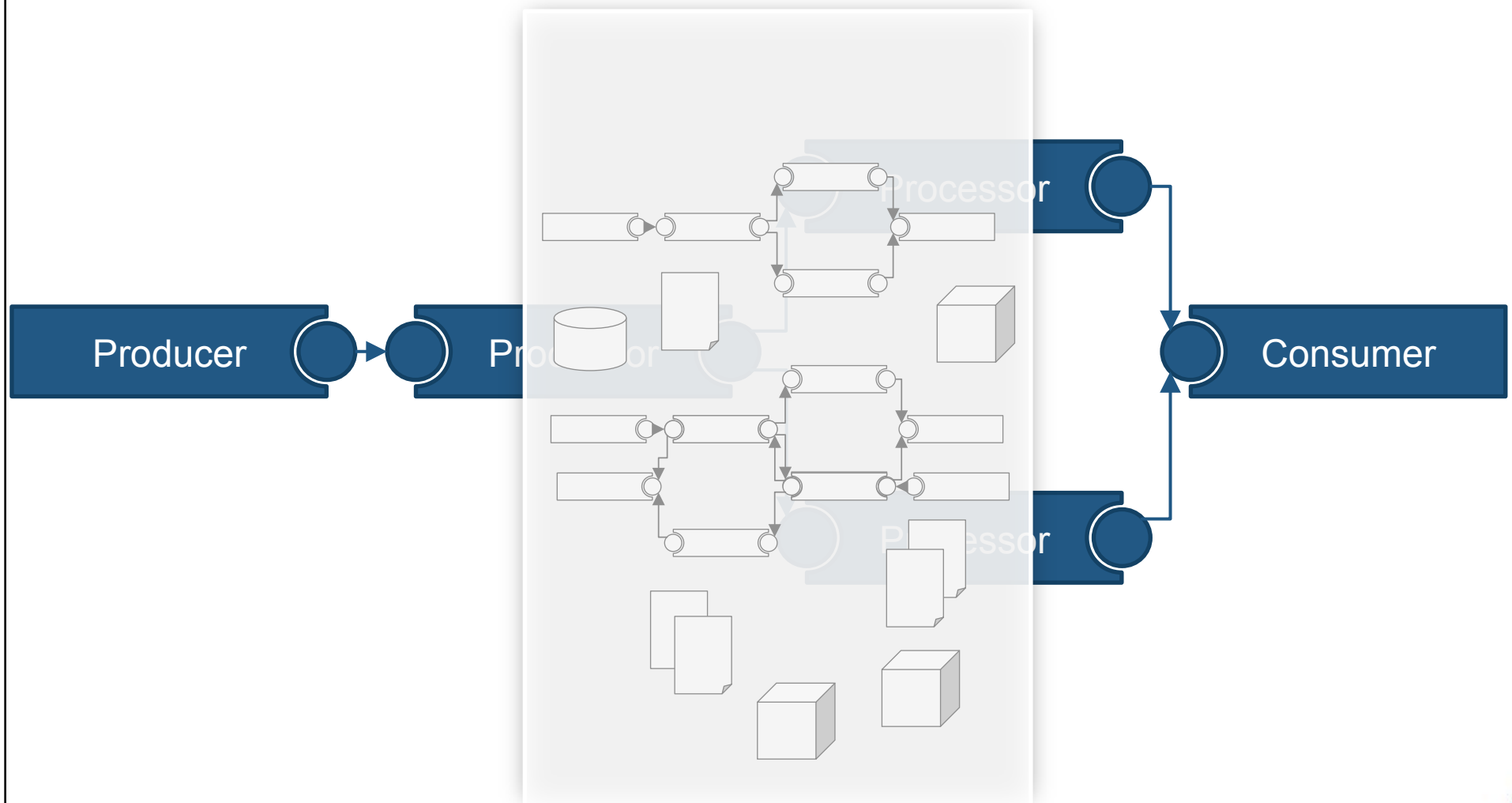


Composing the discovered things

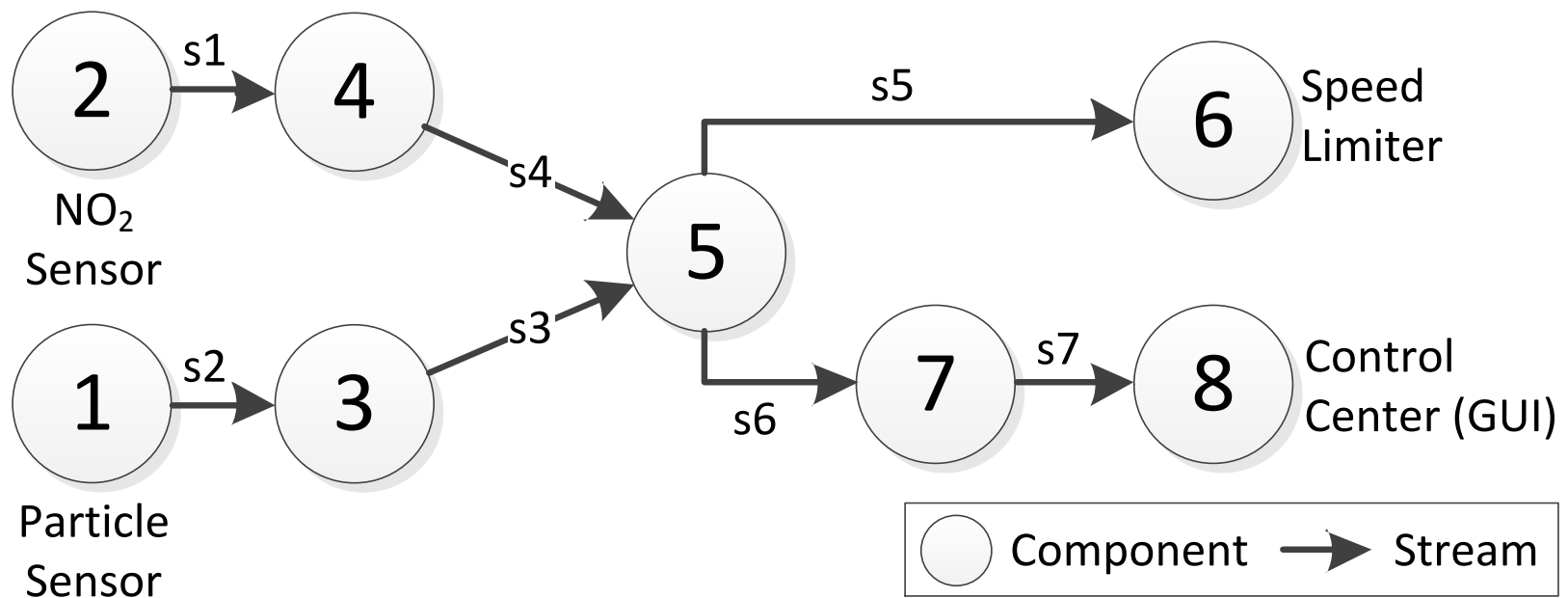
Service Composition in the Resource-constrained IoT



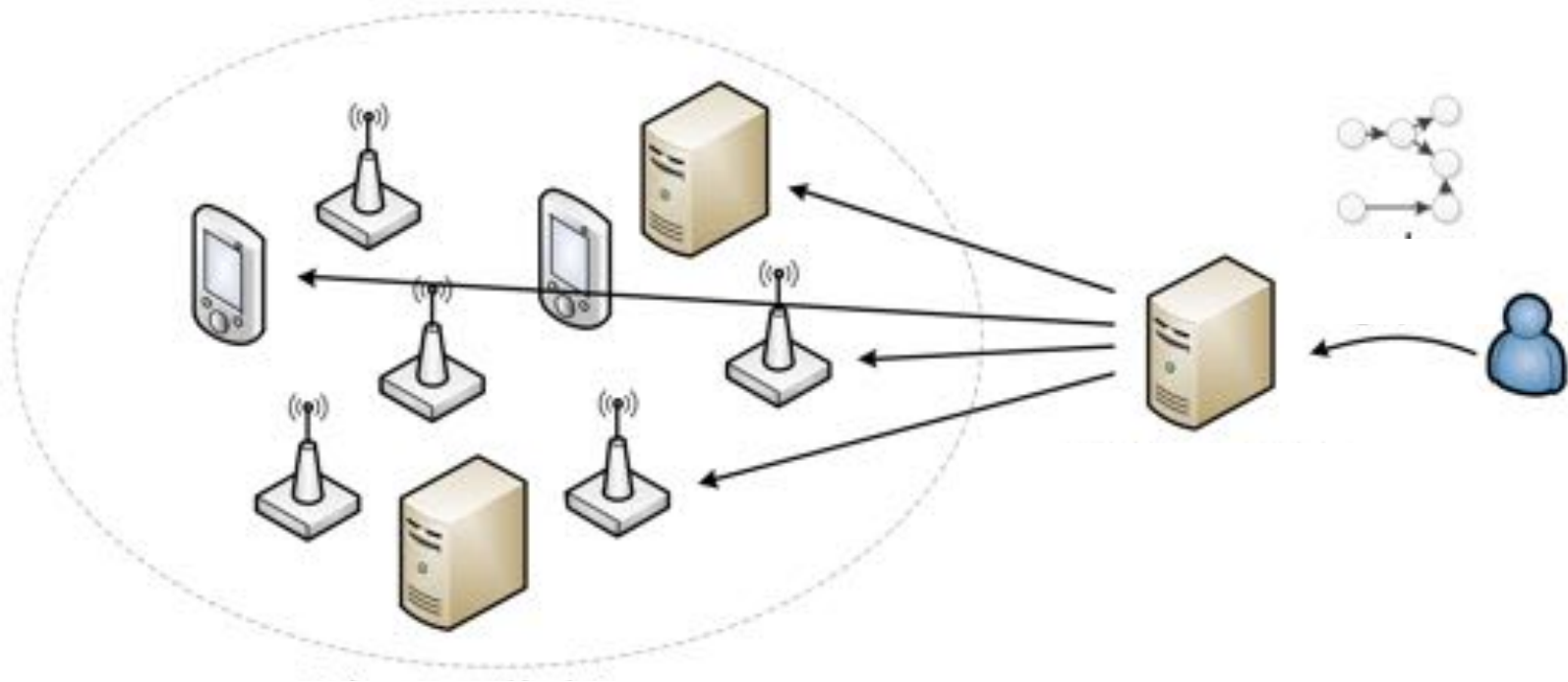
Logical Mashup Graph



Logical Mashup Graph Example



Deploying the Graph



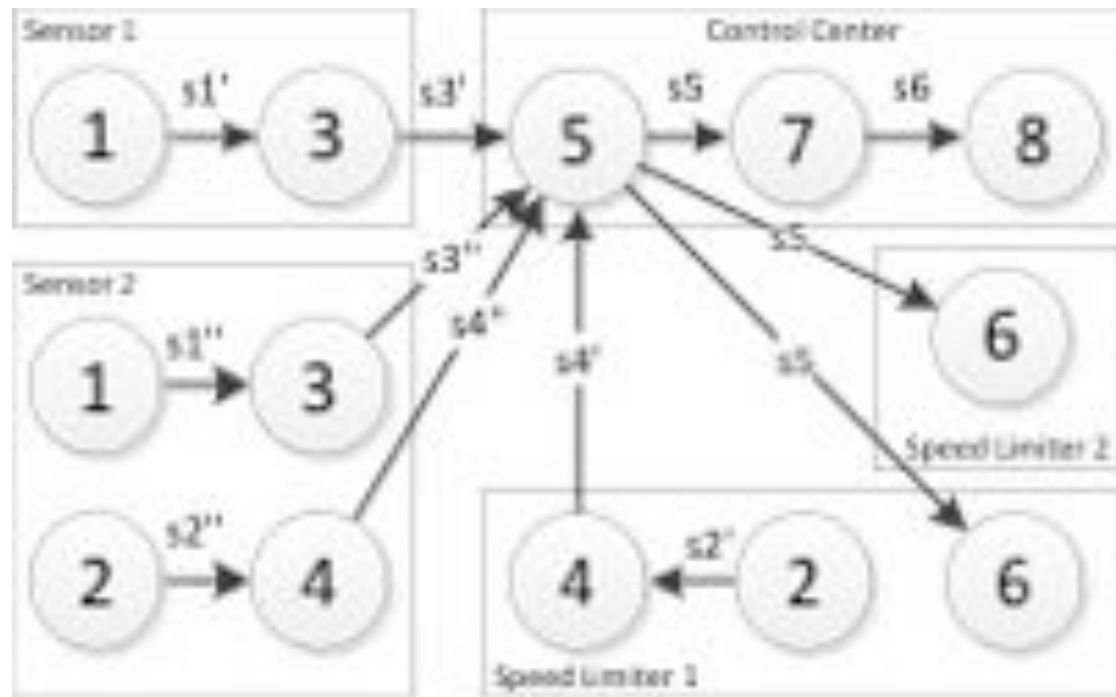
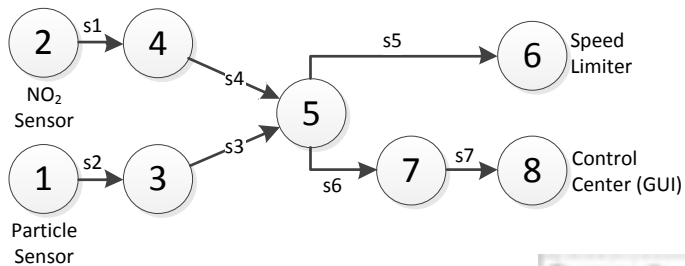
Energy, Resource-constraints, Load balancing,
Timeliness

Modeling Tasks and Things for Physical Mapping

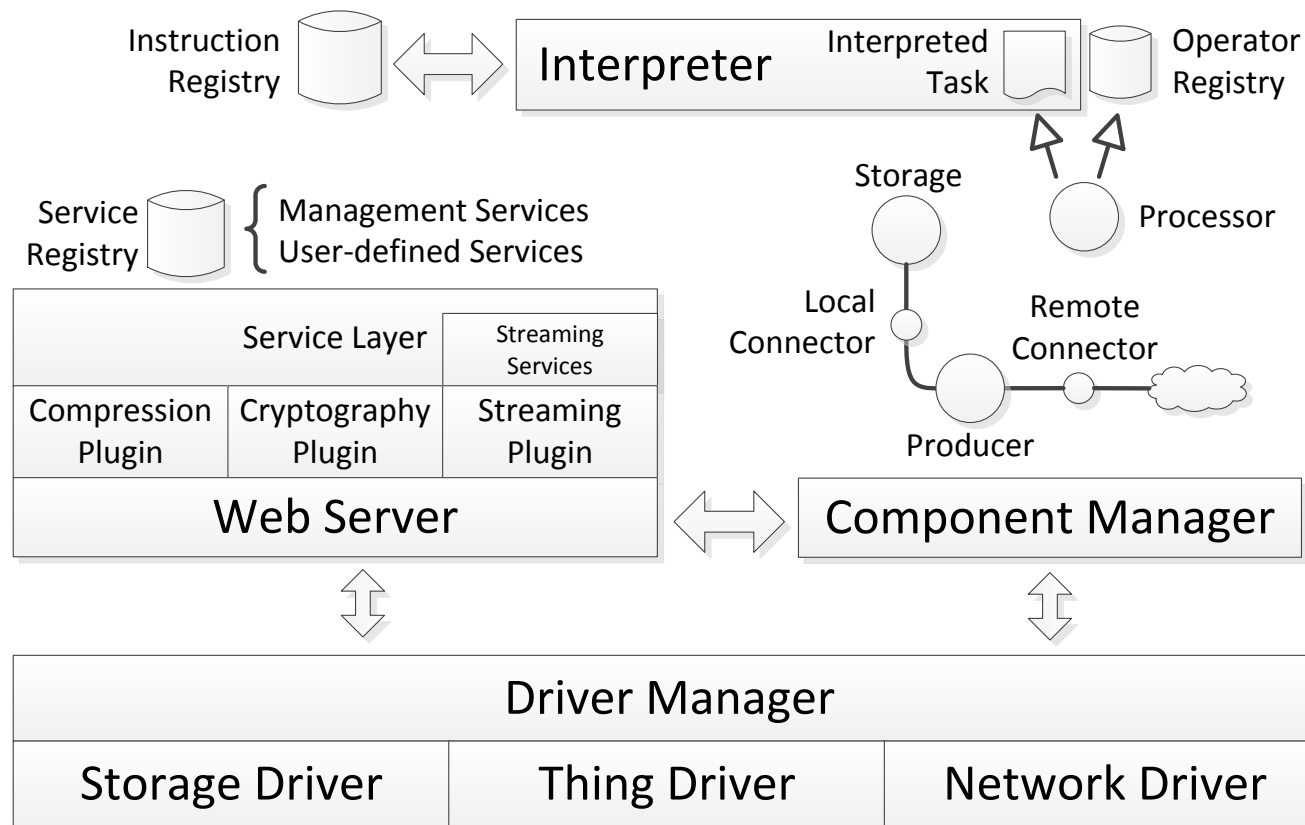


Solving the problem optimally & approximately

Physical Composition of the Resource-constrained Things Example



Dioptase Middleware for Things



Dioptase is one solution...

Service Access in the Heterogeneous IoT



Dioptase DPWS MQTT CoAP ...

Streaming Discrete Sync Async Pus/sub ...

Service Bus for the IoT

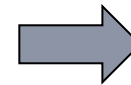
4 basic operations:

One-way sender operation
One-way receiver operation

Two-way asynchronous client operation
Two-way asynchronous server operation

Two-way synchronous client operation
Two-way synchronous server operation

Stream consumer operation
Stream producer operation

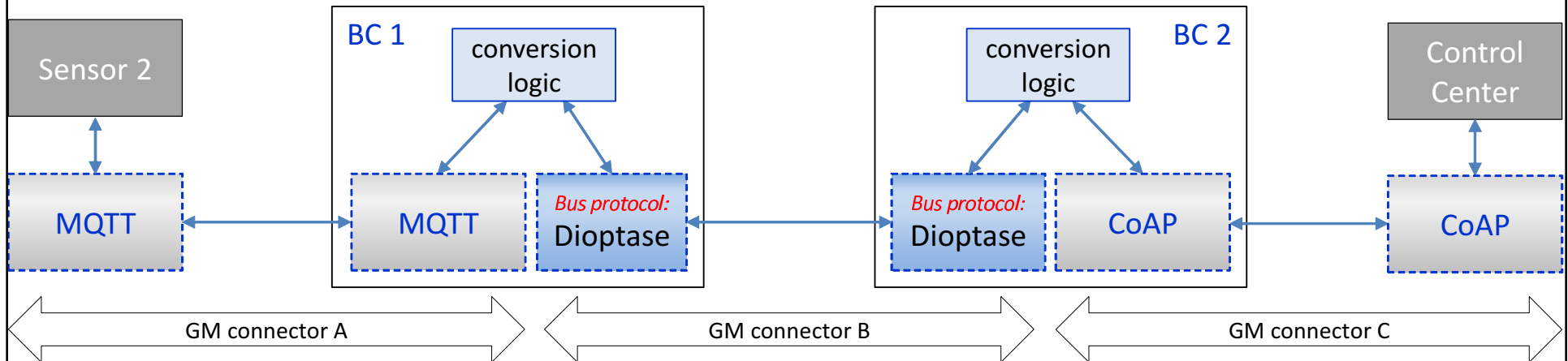


each operation
represented as
combination of *post*
and *get* primitives

post and *get* primitives
mapped to each
protocol:
SOAP, REST, CoAP,
MQTT, etc.

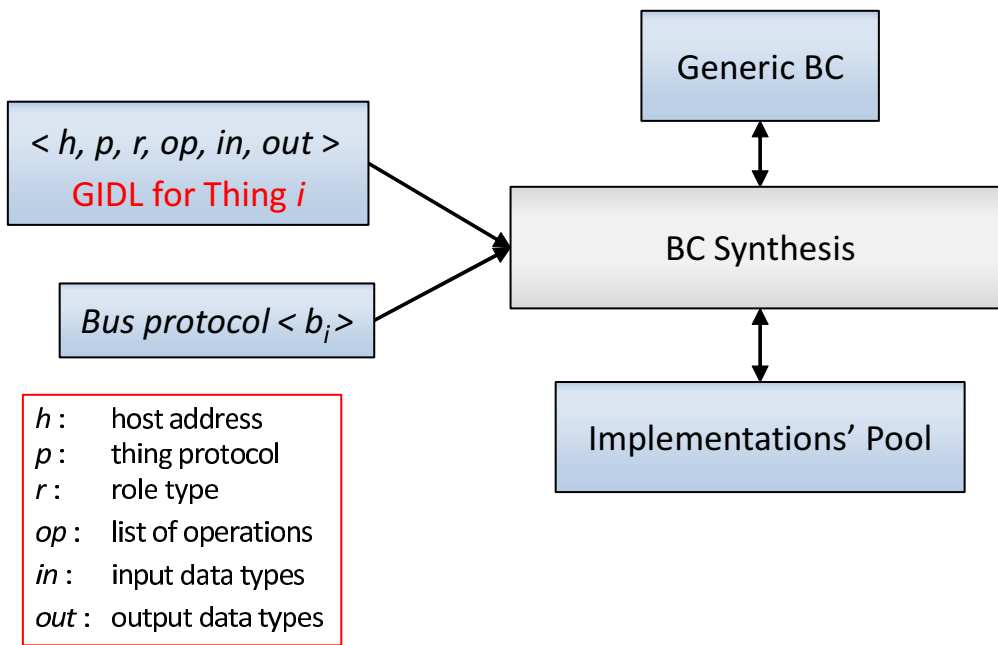
Reconciling multi-paradigm interactions

VSB: The eVolution Service Bus

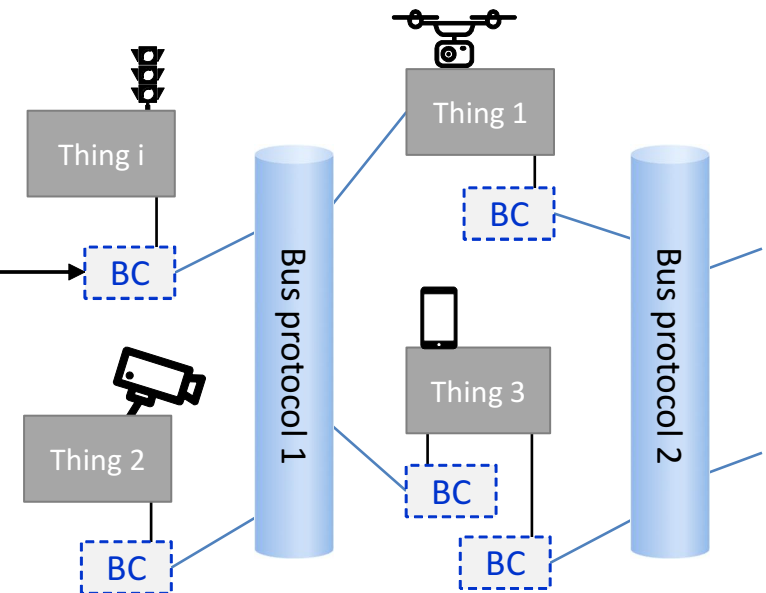


VSB Development & Run-time Environments

VSB at development time:



VSB at runtime:



Icons designed by Freepik and distributed by Flaticon

An Urban Middleware Leveraging the IoT?



4

What's next?

Contributions so far...

A perspective on SoA for the IoT

A flavor of SoA but...

Middleware solutions to tame the complex IoT

Scale, heterogeneity, ...

But the centralized approach remains the winner...

What's next...

Next generation Internet of Things

- Security & Privacy
- Reliability & Dependability
- Usability, Management, Interoperability
- Software architecture
- Information-centric networks
- Closed-loop operation
- Testing & Evaluation

Is it all about Big Data....?

<http://anrg.usc.edu/ngiot16/>

Thank you!

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