Quality of Observation within Sensor Web systems: from theory to practice

Qualité des Observations pour les systèmes Sensor Webs : de la théorie à la pratique

Antoine Auger

April 20, 2018

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M. Ernesto EXPOSITO	Co-Directeur de thèse	Univ. Pau & Pays Adour

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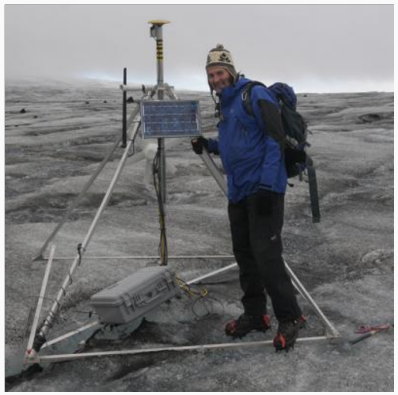
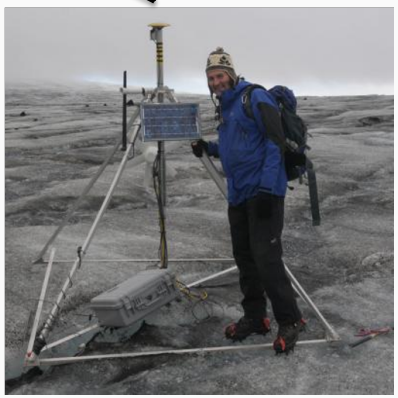


Context and Problem Statement

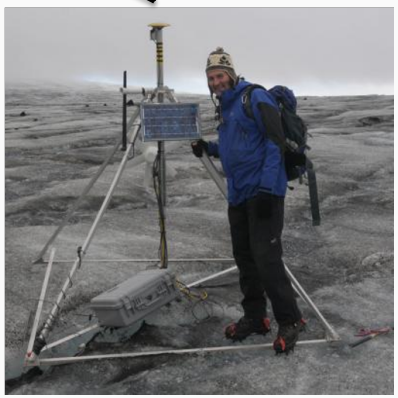
Integration



Context and Problem Statement

Integration

Integration: How to bridge the gap between sensor capabilities and consumer needs while reducing the complexity of end applications?



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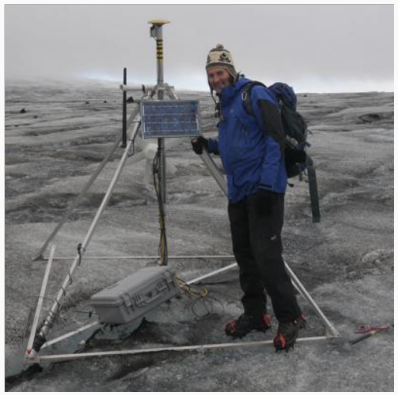
Integration | Quality of Observation (QoO)



Context and Problem Statement

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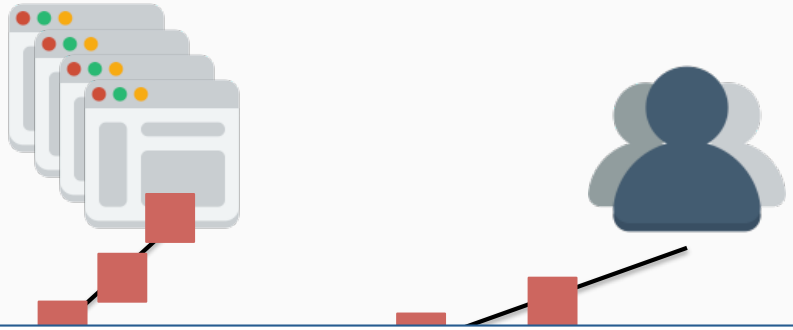
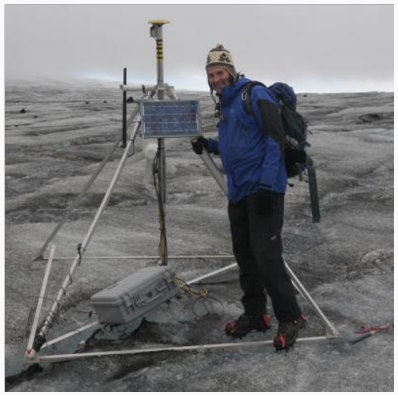
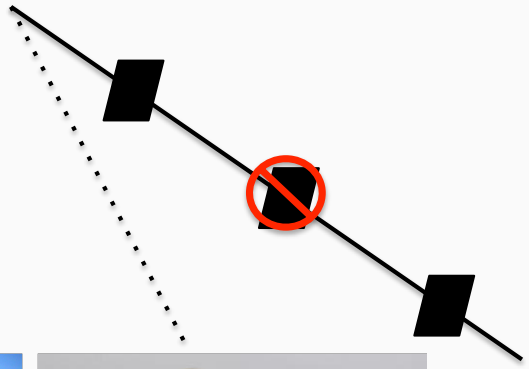


Quality of Observation (QoO): How to provide fit-for-use observations in a consumer-specific fashion?



Context and Problem Statement

Integration | Quality of Observation (QoO) | System Adaptation



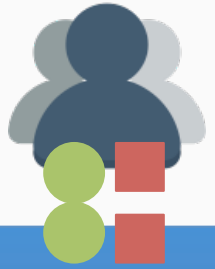
Context and Problem Statement

Integration | Quality of Observation (QoO) | System Adaptation

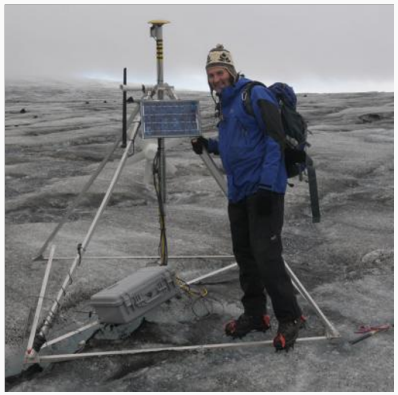
System adaptation: How to take into account context changeability over time?

Context and Problem Statement

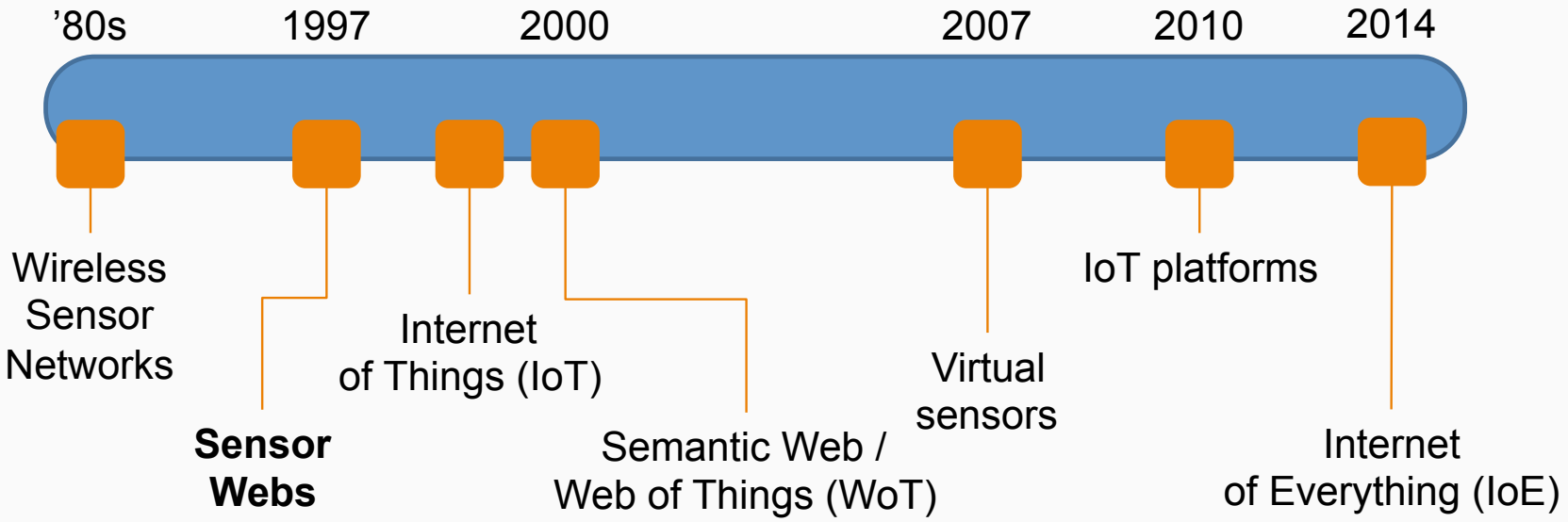
Integration | Quality of Observation (QoO) | System Adaptation

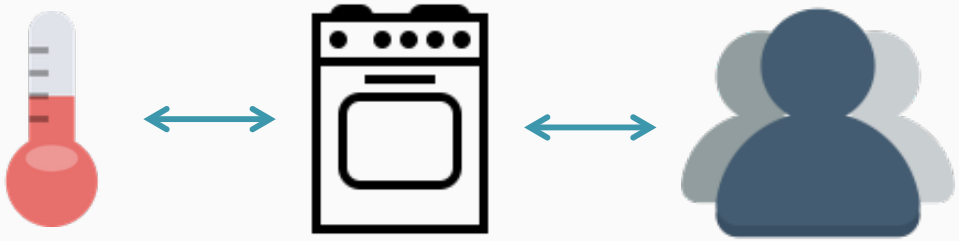


Sensor middlewares a.k.a **Sensor Webs**



New paradigms continue to emerge:





50+ billion Things will be connected by **2020**

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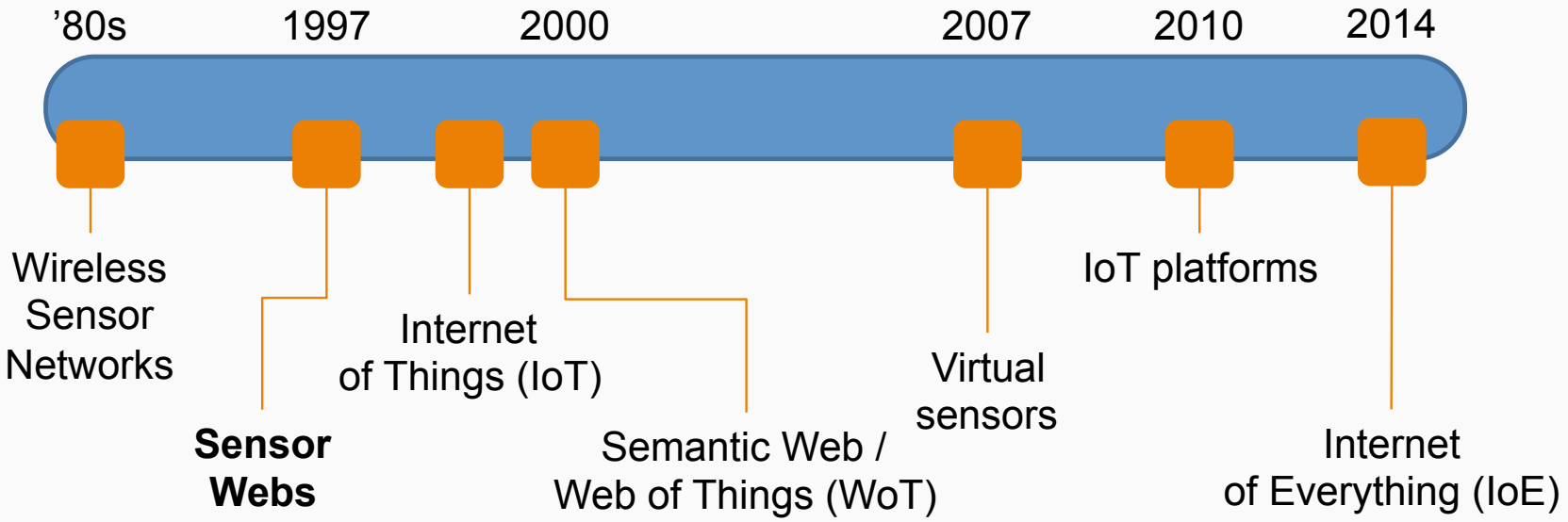

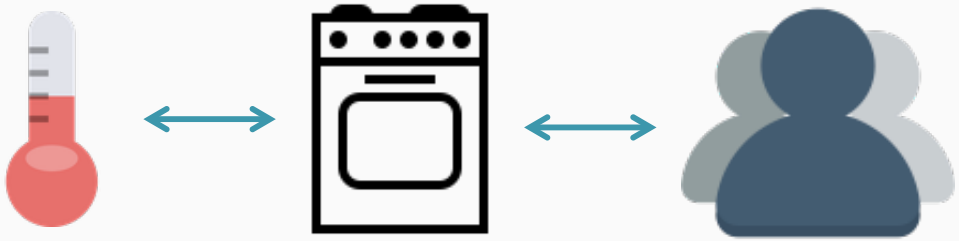

50+ billion Things will be connected by **2020**

⇒ Sensors Webs have evolved as well to cope with new issues

What was a Sensor Web?

NASA JPL (1999)

Developmental collections of sensor pods that could be scattered over land or water areas or other regions of interest to gather data on spatial and temporal patterns of relatively slowly changing physical, chemical, or biological phenomena in those regions.

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What is a modern Sensor Web?

Our definition

A Sensor Web is a system that bridges the gap between any kind of sensors (physical or virtual) and higher-level applications.

$\Rightarrow$ Integration, QoO and system adaptation are still **valid issues**!

30 Sensor Webs selected and reviewed (2013-2017)

		Bouillet et al.	*Pathan et al.*	*Teixera et al.*	OpenIoT	CityPulse
Int.	Heterogeneous consumers	-	-	-	✓	✓
	Semantic integration	✓	∽	✓	✓	✓
	Scalable integration	-	-	-	✓	✓
QoO	QoO-based SLAs	∽	-	-	✓	✓
	Custom-based QoO mech.	-	-	-	-	-
Adapt.	Adaptation control loop(s)	-	✓	-	-	✓
	Auto QoO-based adapt.	-	-	∽	✓	∽

✓: supported, ∽: partially supported, -: not mentioned

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We envision a new generation of Sensor Webs:

QoO-aware **A**daptive **S**ensor **W**eb **S**ystems (QASWS)

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QoO-aware **A**daptive **S**ensor **W**eb **S**ystems (QASWS)

. . . that aim to cope with:

- **Integration**
- **Quality of Observation**
- System **Adaptation**

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QoO-aware **A**daptive **S**ensor **W**eb **S**ystems (QASWS)

. . . that aim to cope with:

- **Integration**
- **Quality of Observation**
- System **Adaptation**

. . . through the proposal of two contributions:

1. A generic framework for QASWS $\Rightarrow$ **theory**
2. A functional QASWS prototype $\Rightarrow$ **practice**

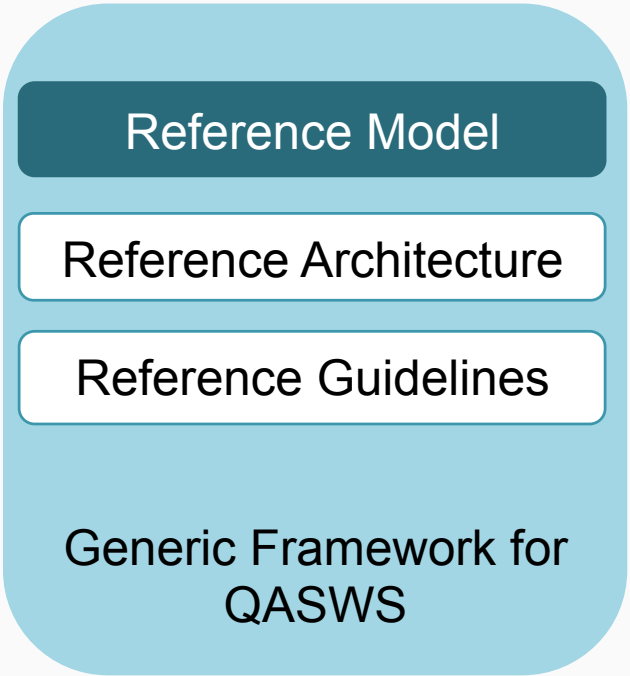
First contribution - A generic framework for QASWS

Generic framework for QASWS ▶ Overview

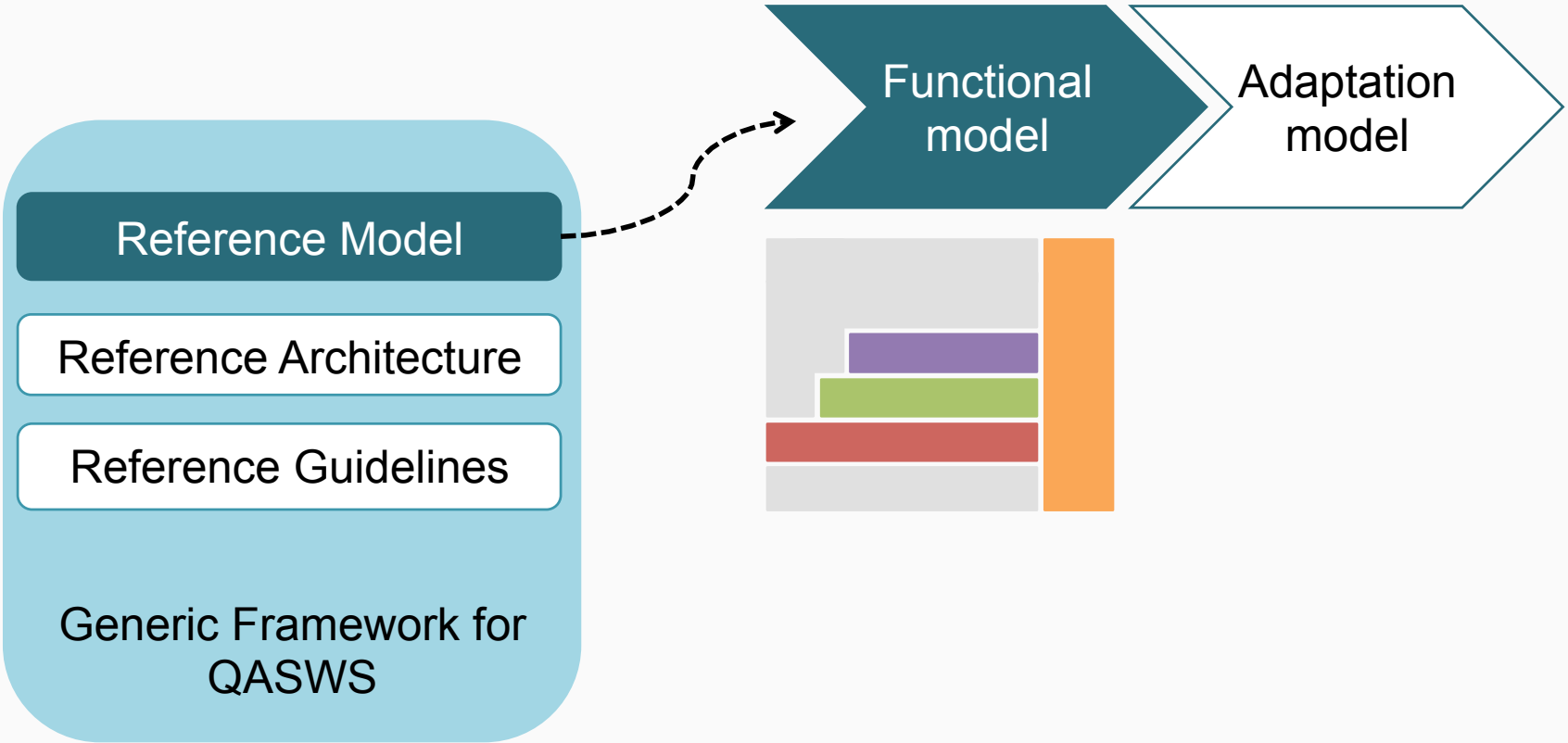
Framework for researchers and developers who may want to conceive their own QASWS:

- Based on the **ISO/IEC/IEEE 42010 standard** (terminology)
- Comput. and Platform Independent Models (CIM / PIM)
- Generic, should be **instantiated** to a specific use case

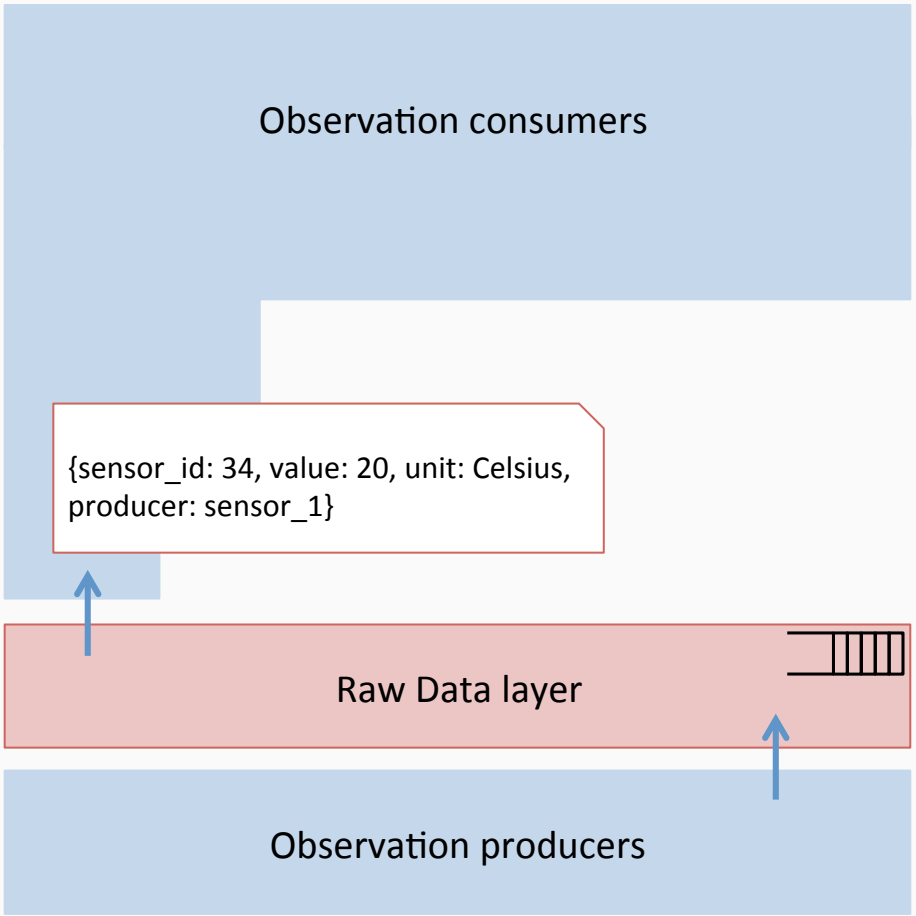
Generic framework for QASWS ▶ Overview



Generic framework for QASWS ▶ Overview



Generic framework for QASWS ▶ Reference Model

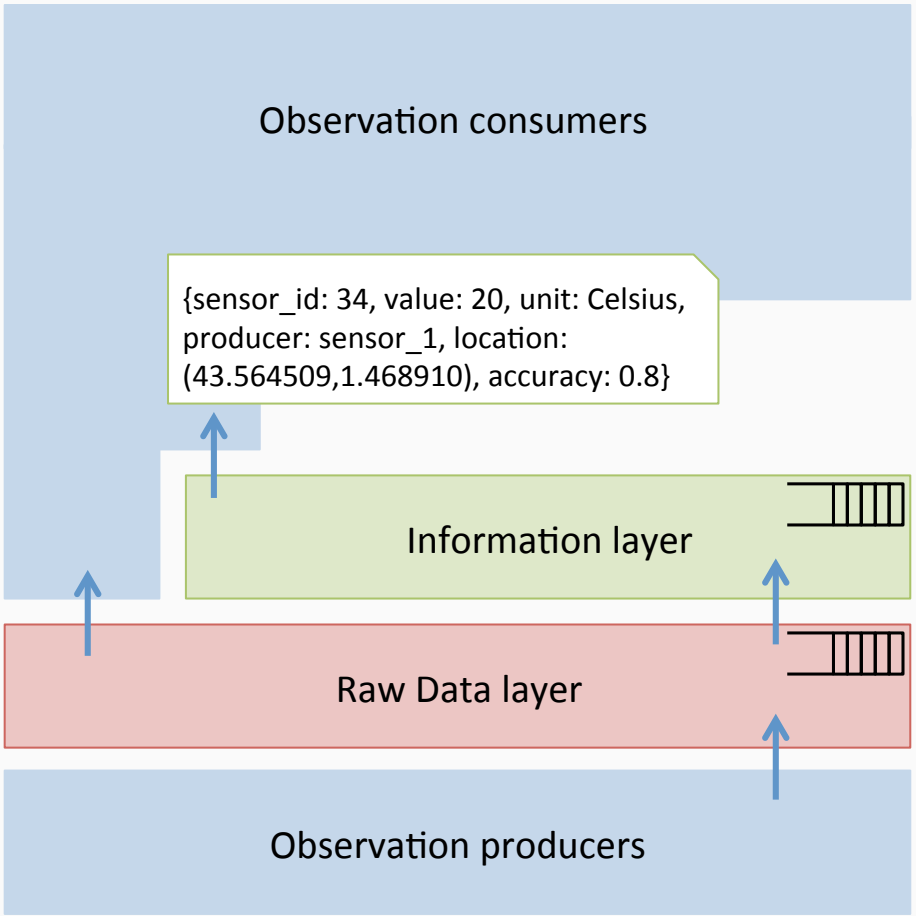


$f_{\text{digit}}(\text{Sensor outputs})$

$= \text{Raw Data}$

Antoine Auger et al. "A Generic Framework for Quality-based Autonomic Adaptation within Sensor-based Systems". In: *ICSOC 2016 - ASOCA workshop*. Banff, CA, 2017, pp. 21–32.

Generic framework for QASWS ▶ Reference Model



$f_{\text{charac}}(\text{Raw Data}, \text{Context})$
$=$ Information

$f_{\text{digit}}(\text{Sensor outputs})$

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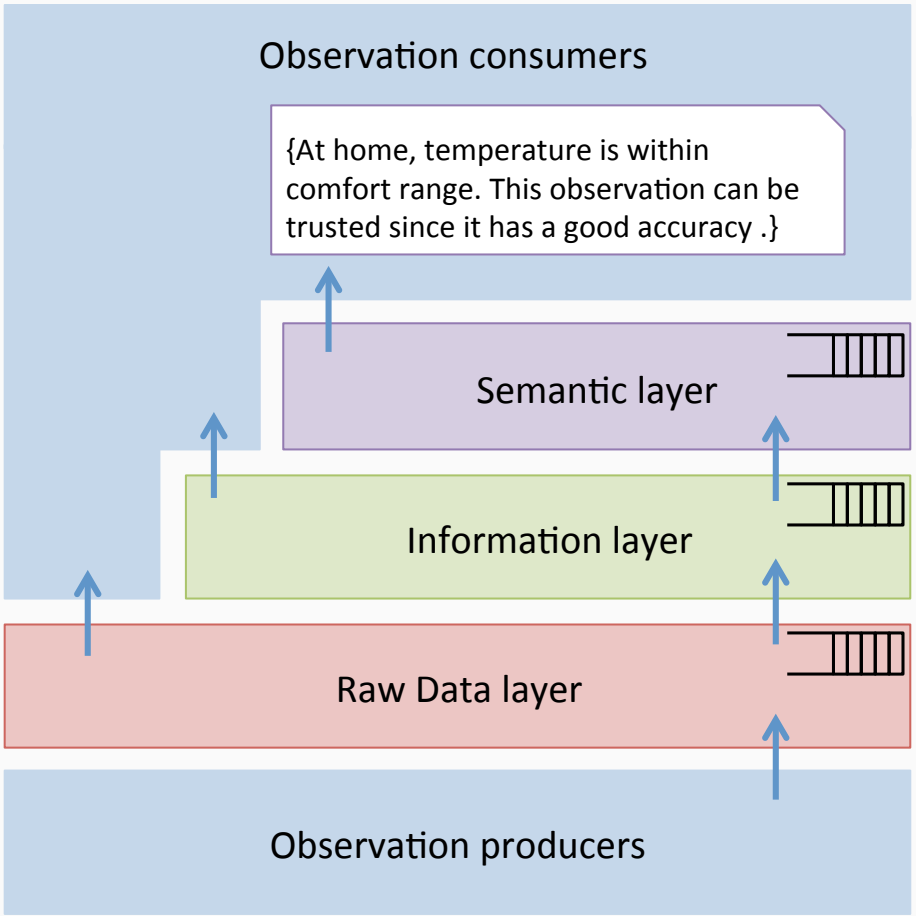

$f_{\text{sem}}(\text{Information}, \text{OntoModel})$
$=$ Knowledge

$f_{\text{charac}}(\text{Raw Data}, \text{Context})$
$=$ Information

$f_{\text{digit}}(\text{Sensor outputs})$

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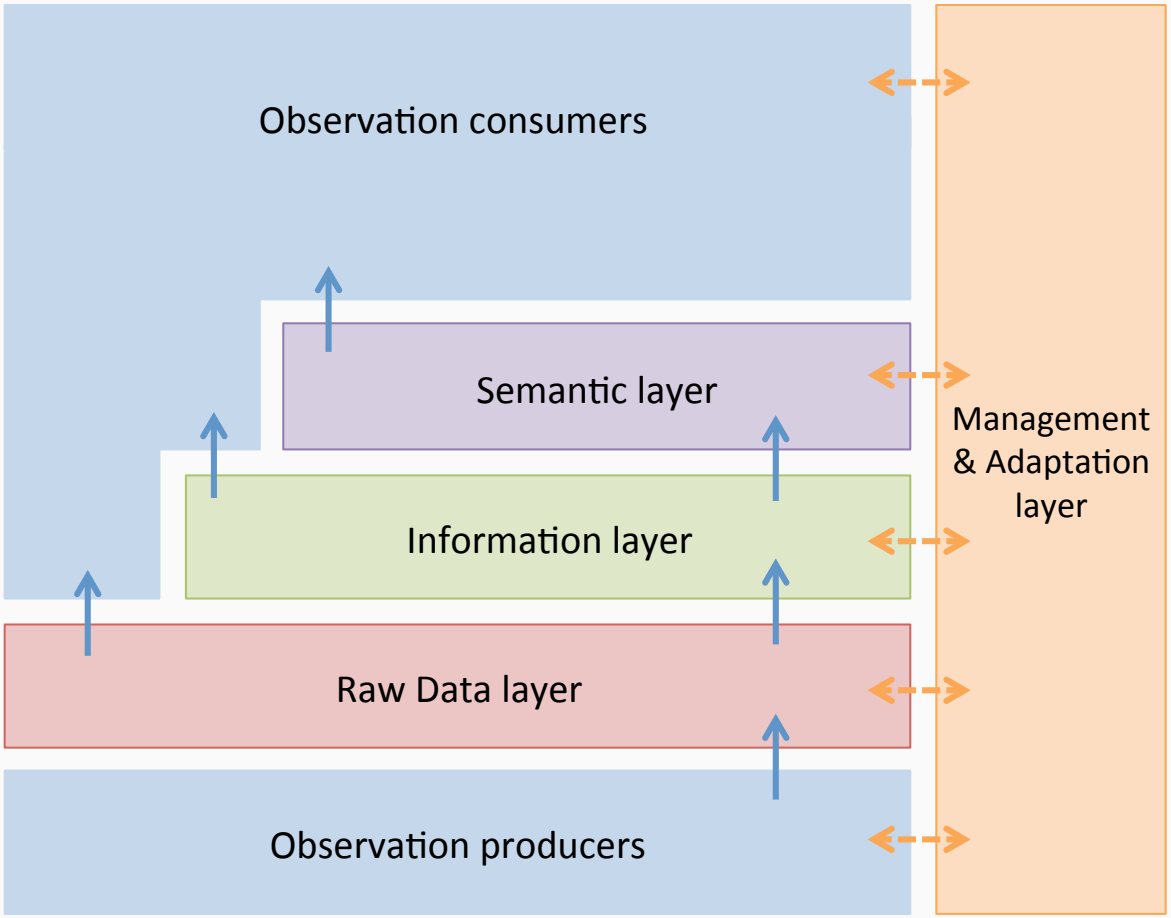

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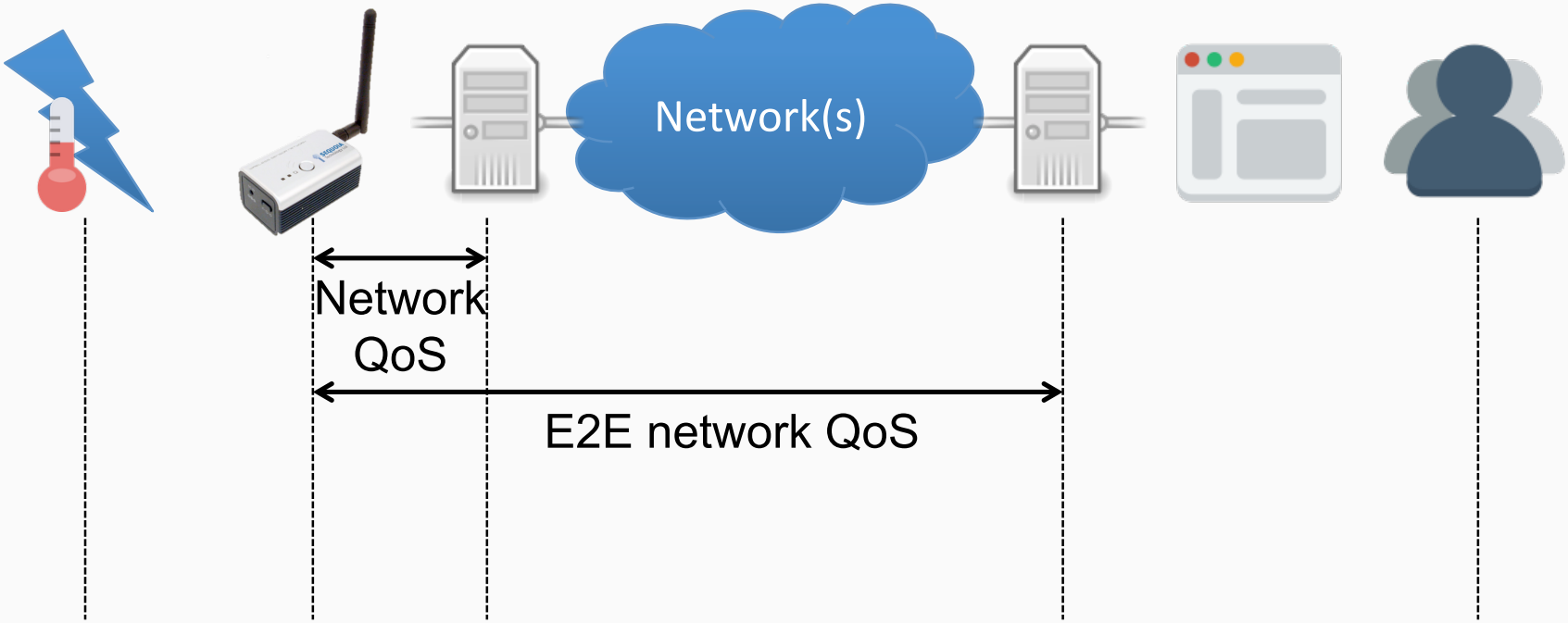
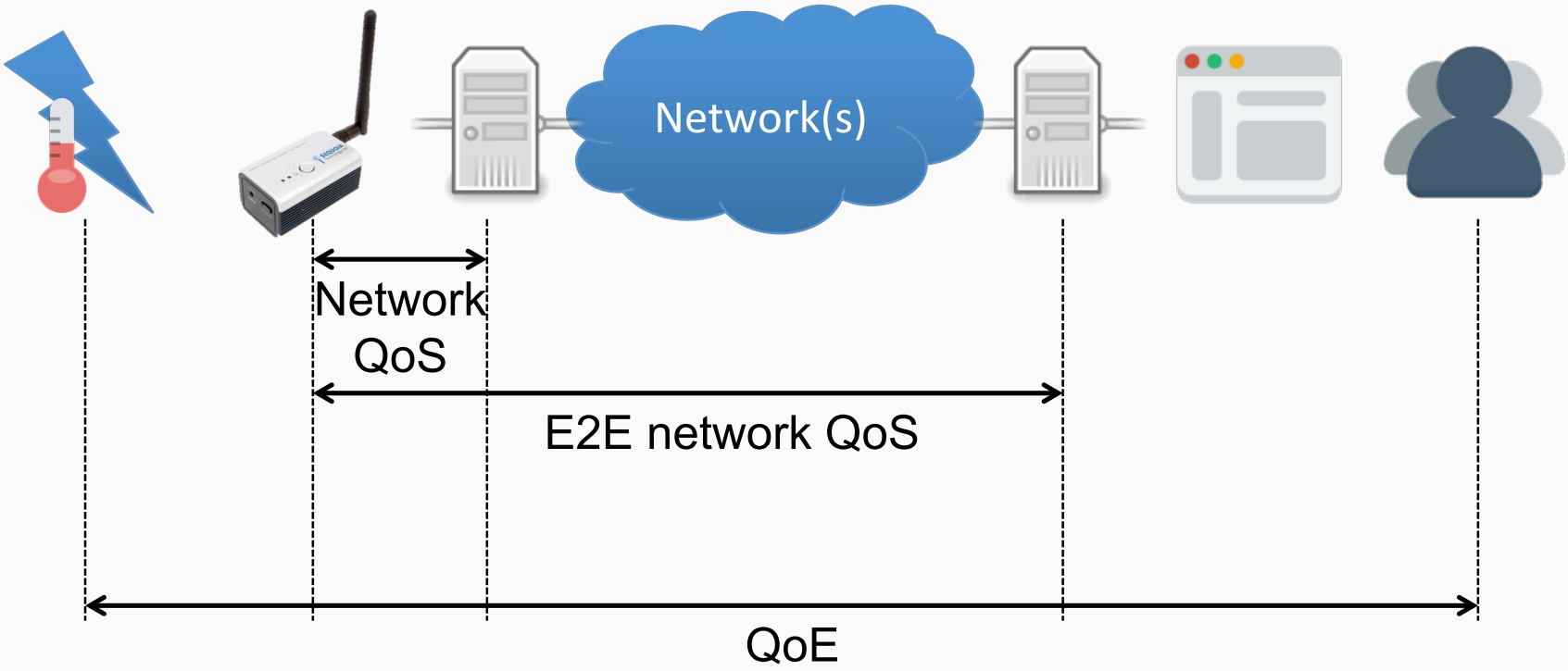
Observations should be of **"good quality"** for each consumer



Quality of Service (QoS)

$\Rightarrow$ *capacity, delay, jitter, packet loss, . . .*

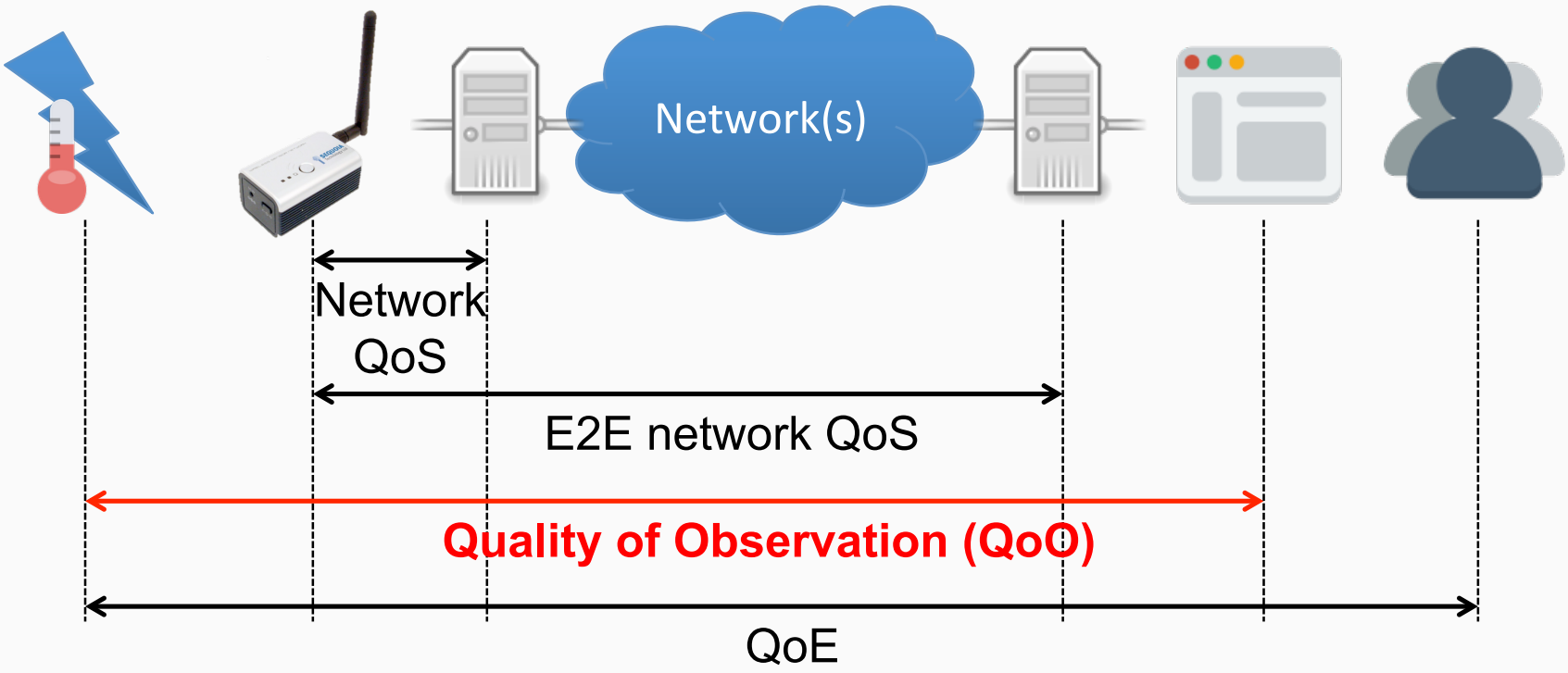
Observations should be of **"good quality"** for each consumer



Quality of Experience (QoE)

⇒ *R-factor, Mean Opinion Score (MOS), . . .*

Observations should be of **"good quality"** for each consumer



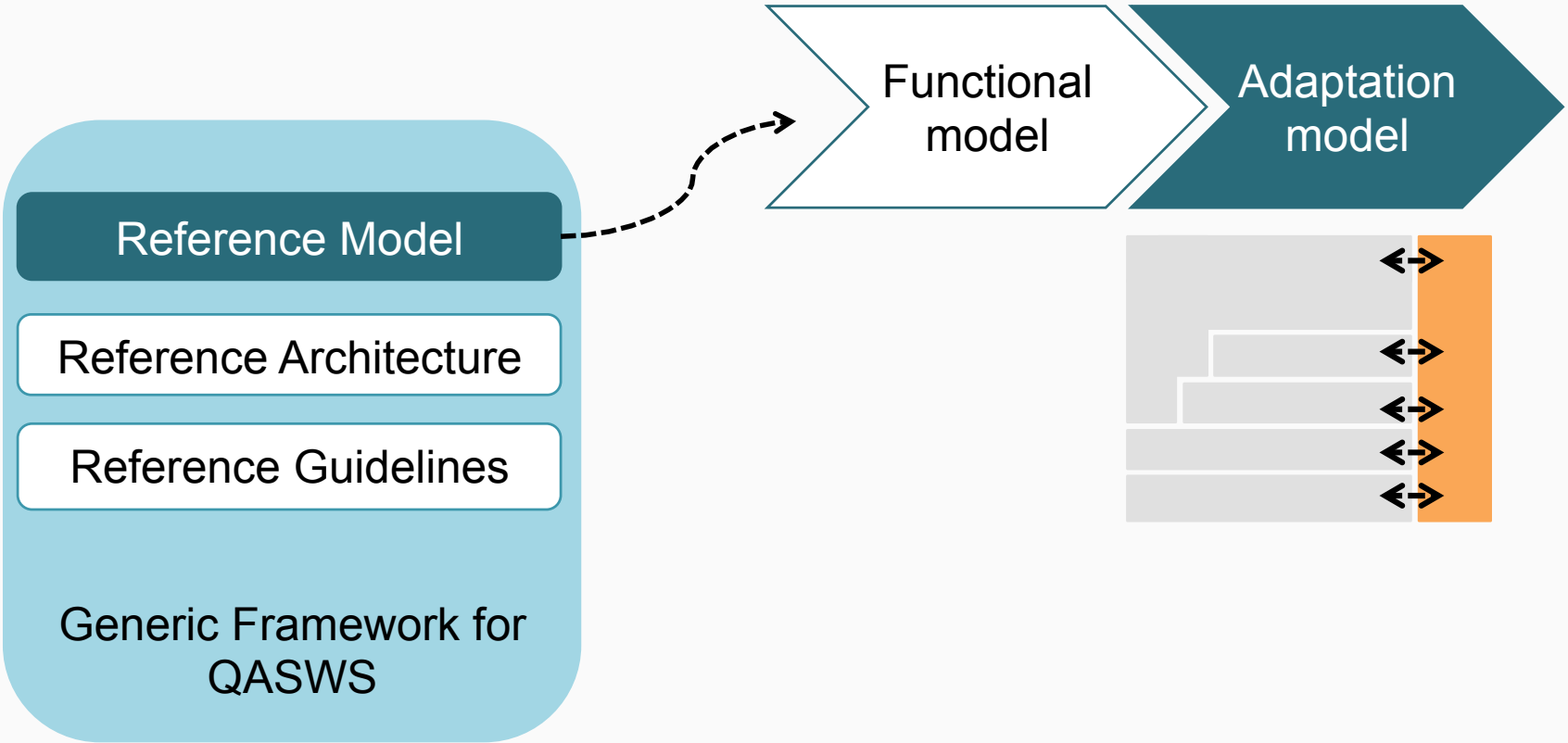
⇒ QoO is the **new QoE** for observation consumers

Quality of Observation (QoO) a.k.a Quality of Information

QoO is the collective effect of observation attributes that determine the degree by which the observation is (or perceived to be) fit-to-use for a purpose. [Bis+09]

E.g. of QoO attributes: *frequency*, *accuracy*, *freshness*, *provenance*, *reputation*, . . .

Generic framework for QASWS ▶ Reference Model



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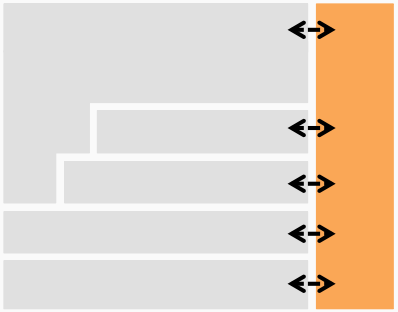
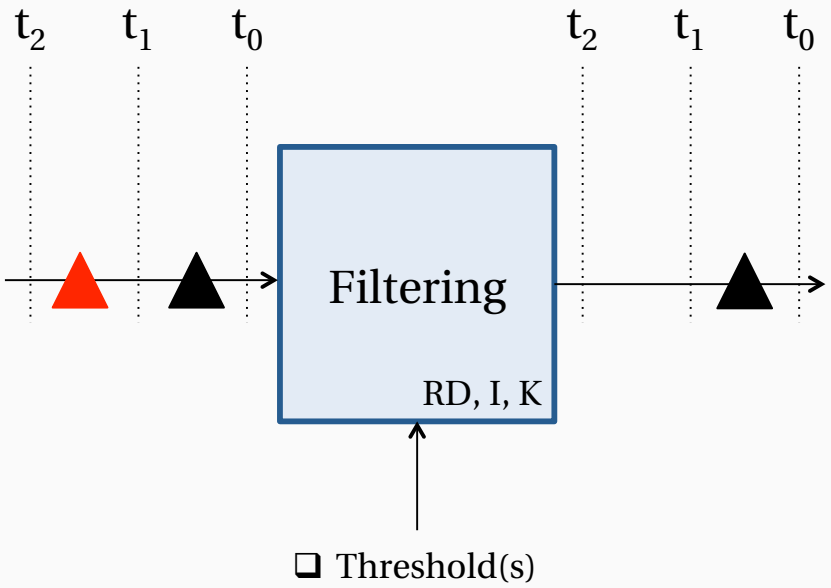
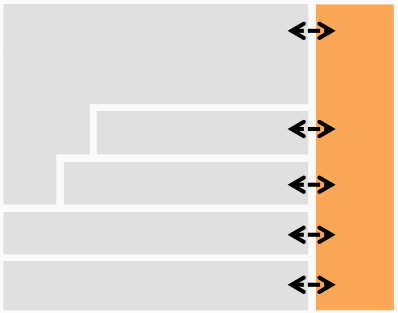
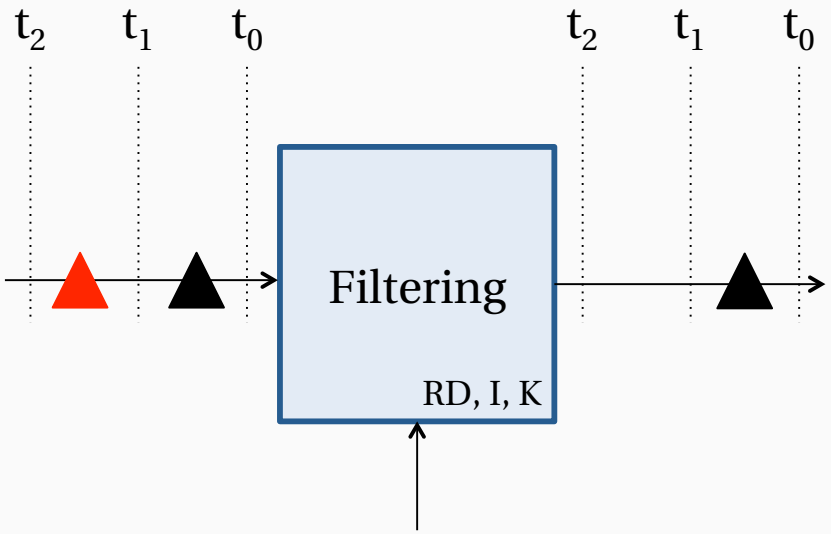




- Threshold(s)

Generic framework for QASWS ▶ Reference Model





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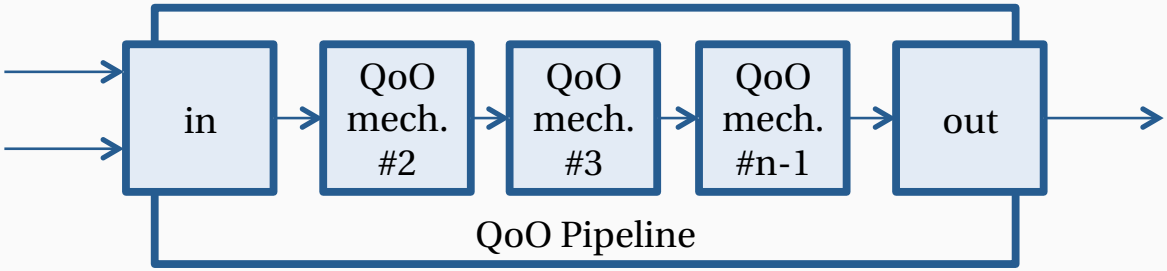

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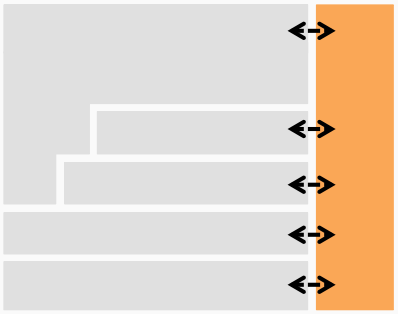
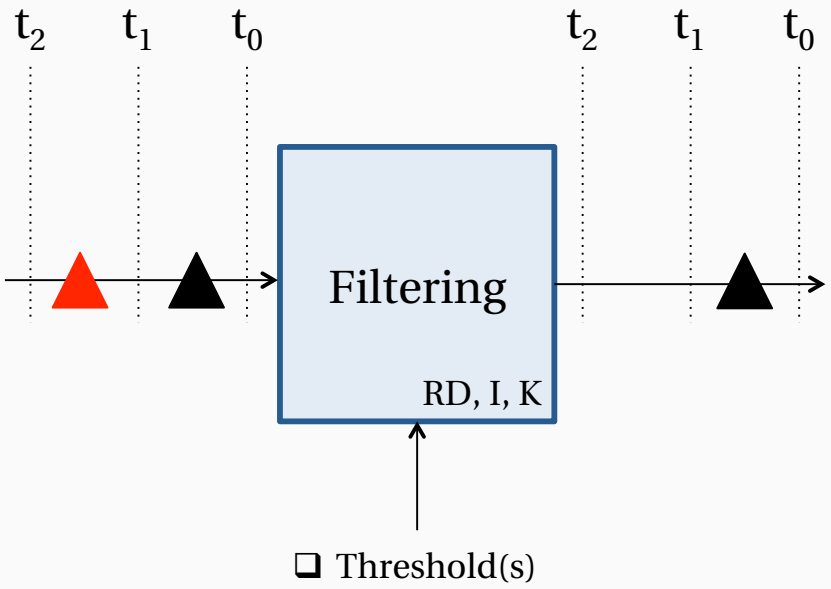
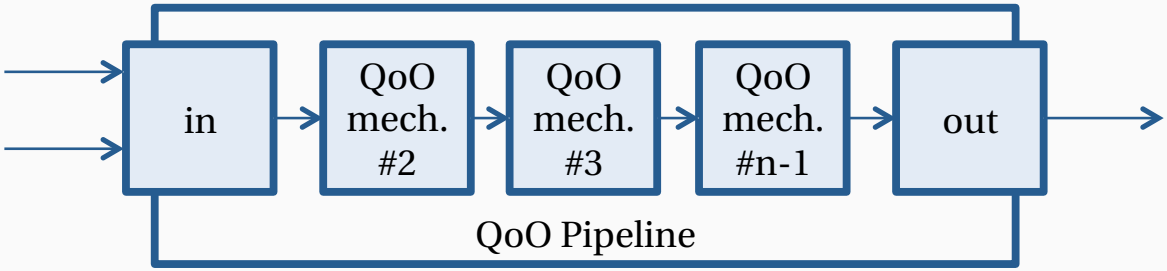


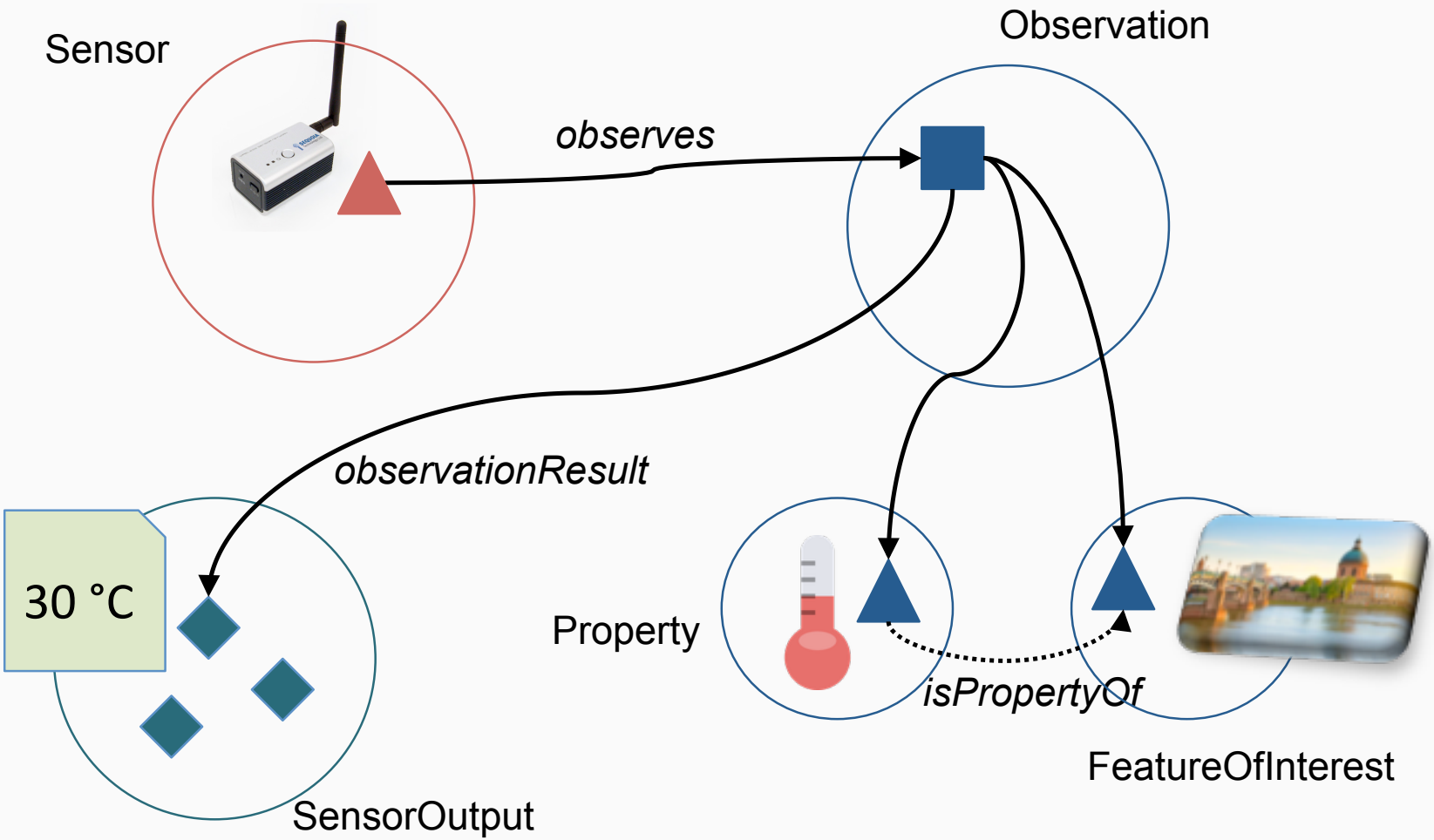




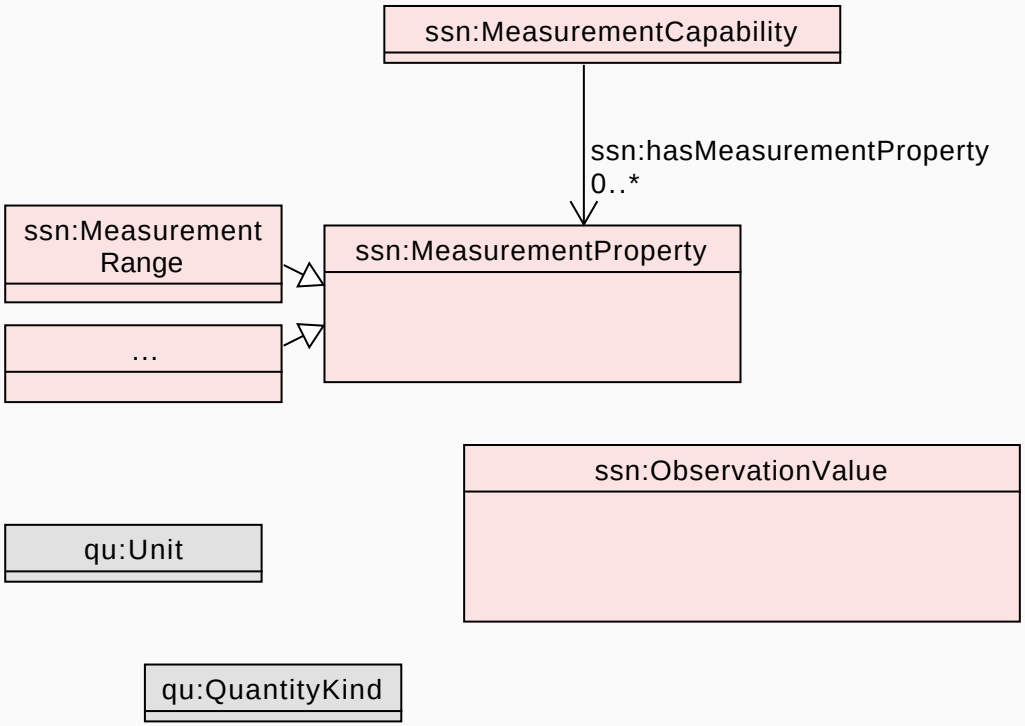
How to **make the link** between observations, QoO, mechanisms and pipelines?

Ontology

A formal explicit description of concepts, properties and restrictions in a domain of discourse.



Based on the W3C SSN standard, we propose the **QoOnto ontology** to describe obs., QoO, mechanisms and pipelines:



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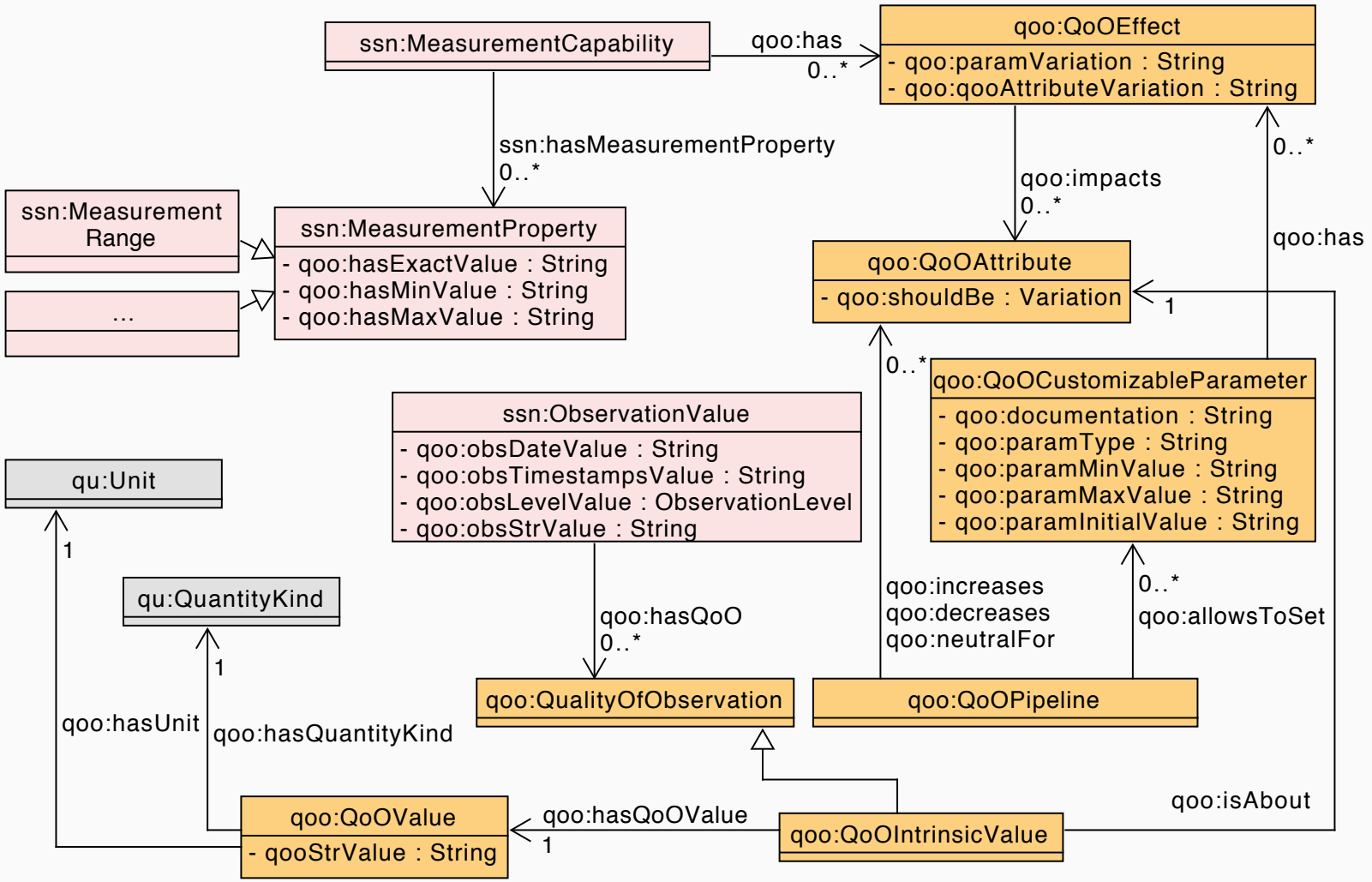
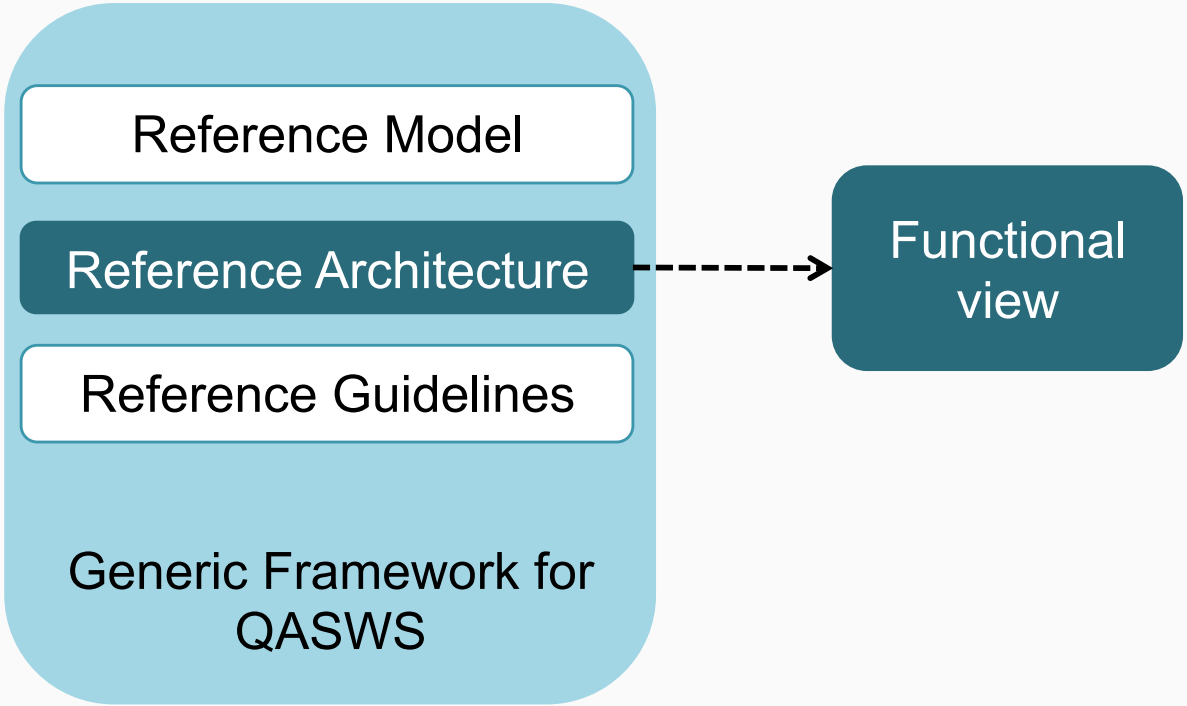
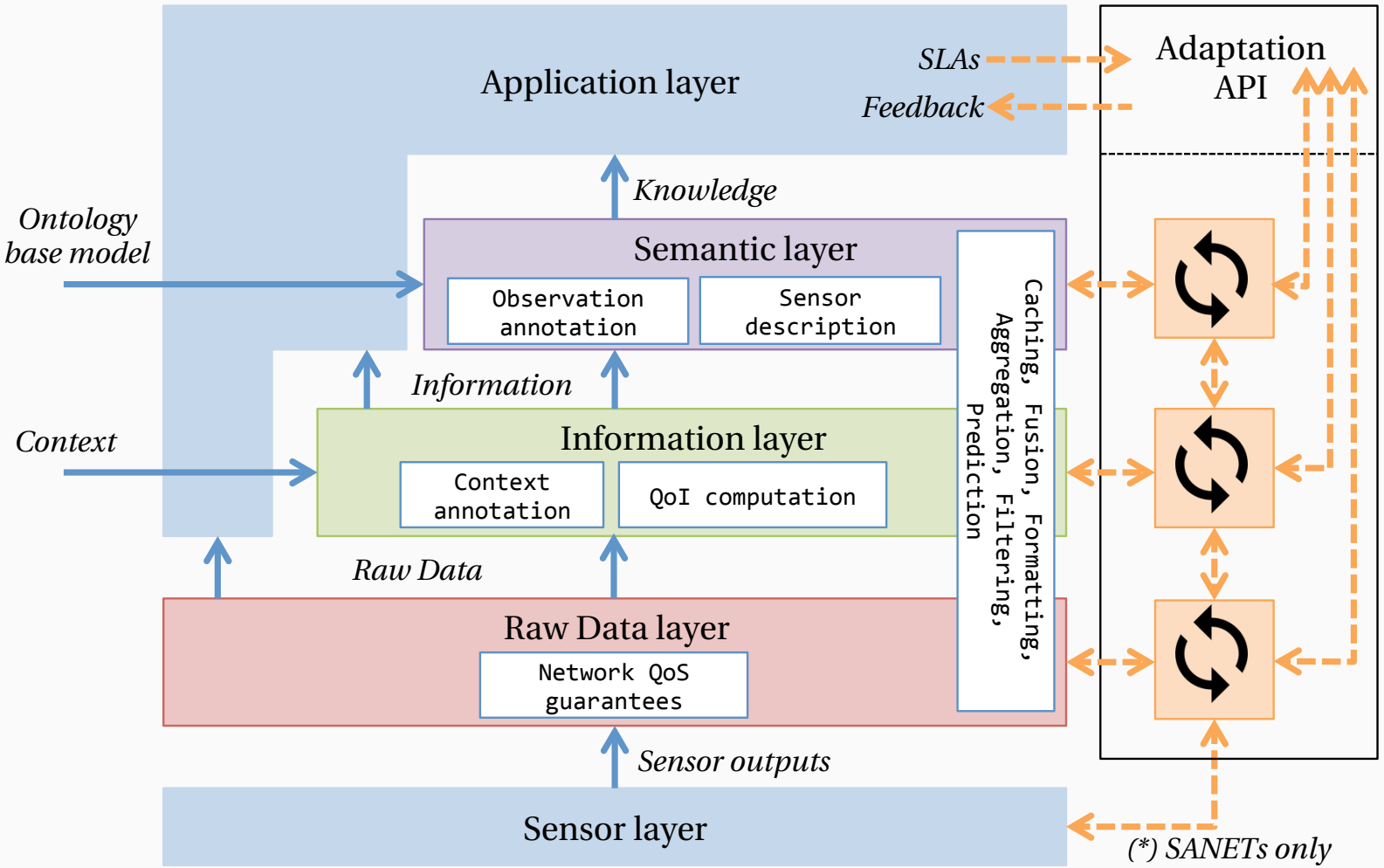



Reference Model
Reference Architecture
Reference Guidelines
Generic Framework for QASWS
Functional view

Generic framework for QASWS ▶ Reference Architecture



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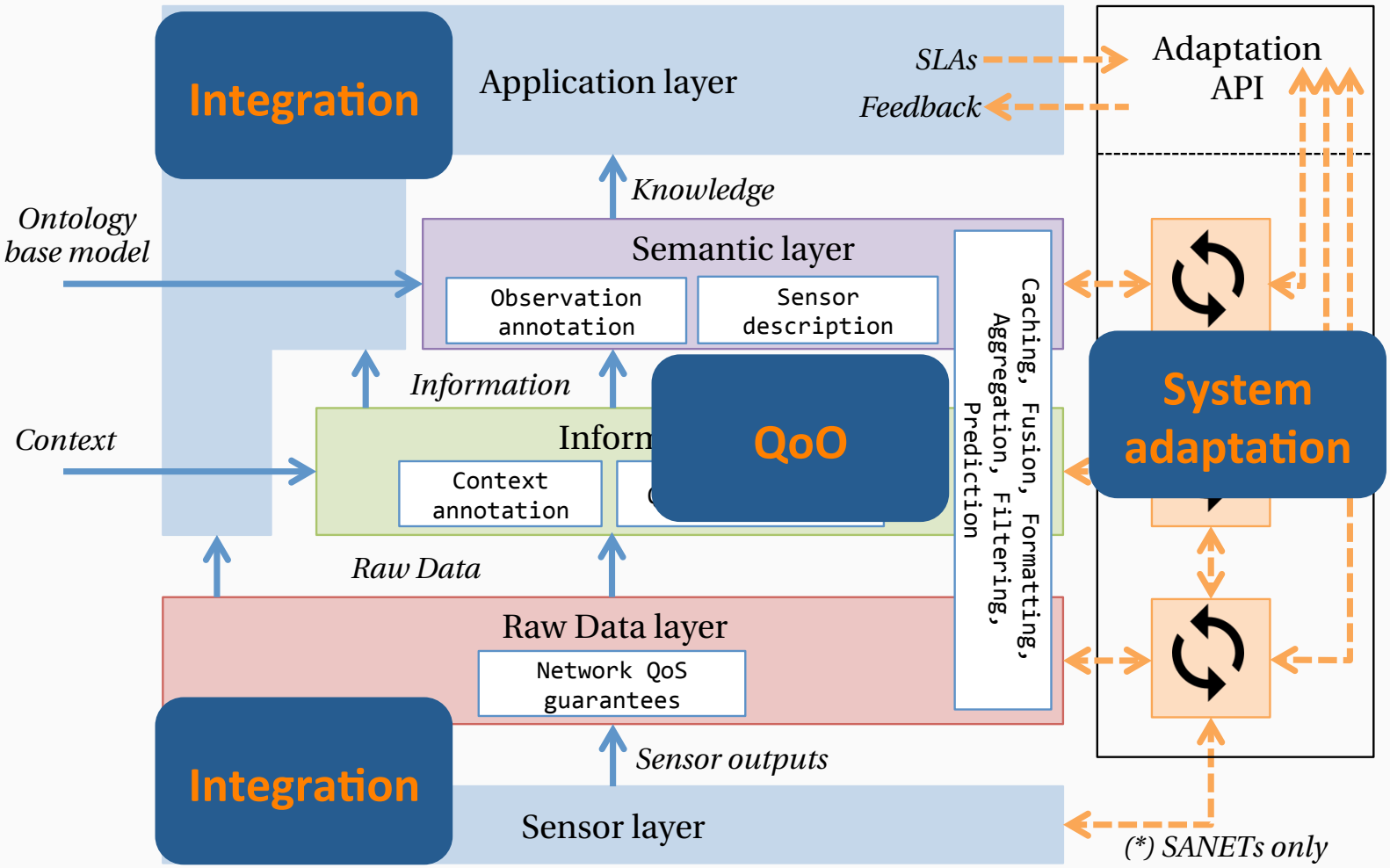
Generic framework for QASWS ▶ Reference Architecture



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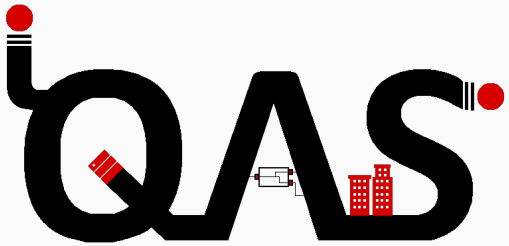
Second contribution - A functional QASWS prototype: the iQAS platform

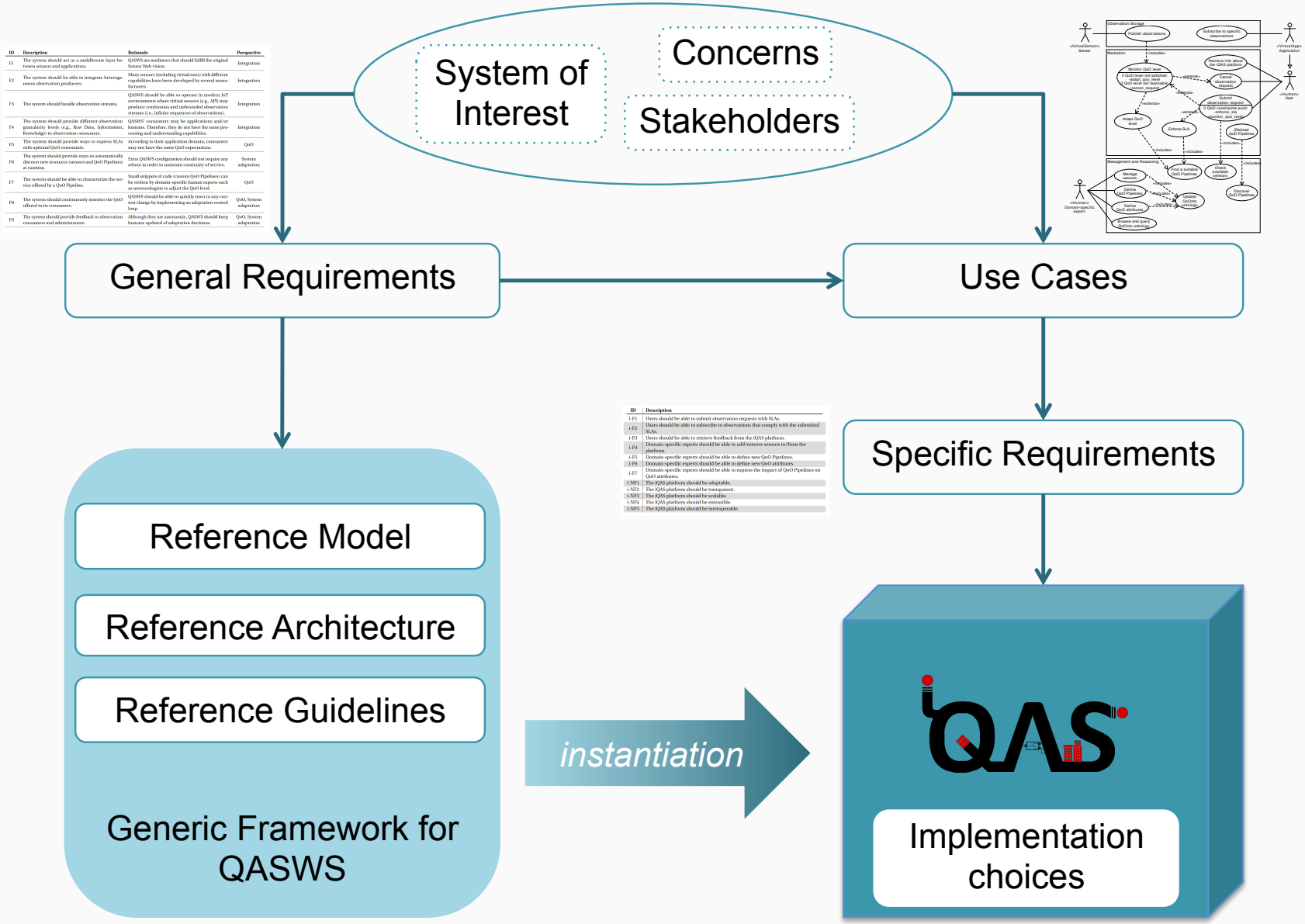


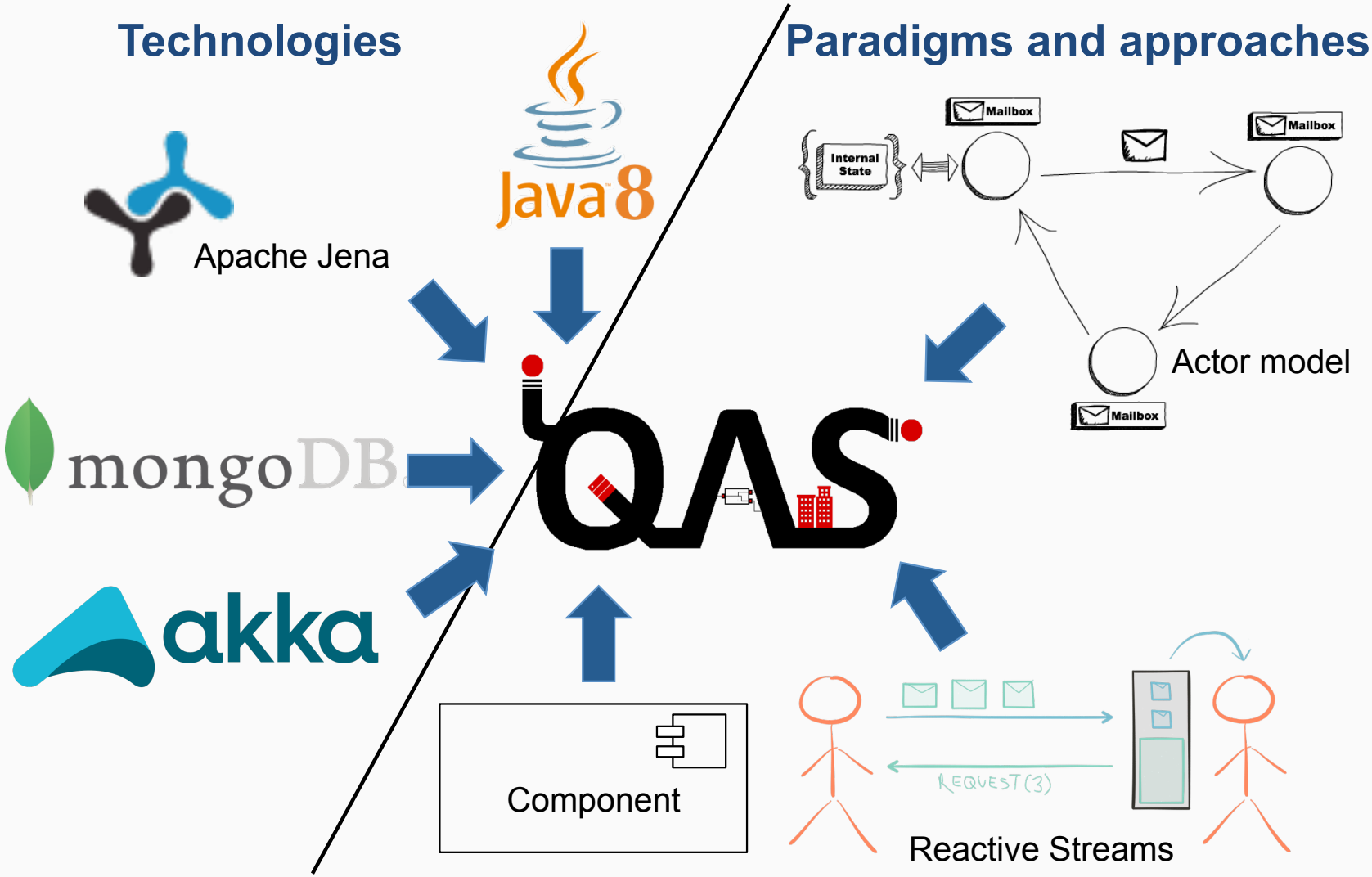
integration platform for **Q**oO **A**ssessment as a **S**ervice (iQAS)

Why develop a new platform, again?

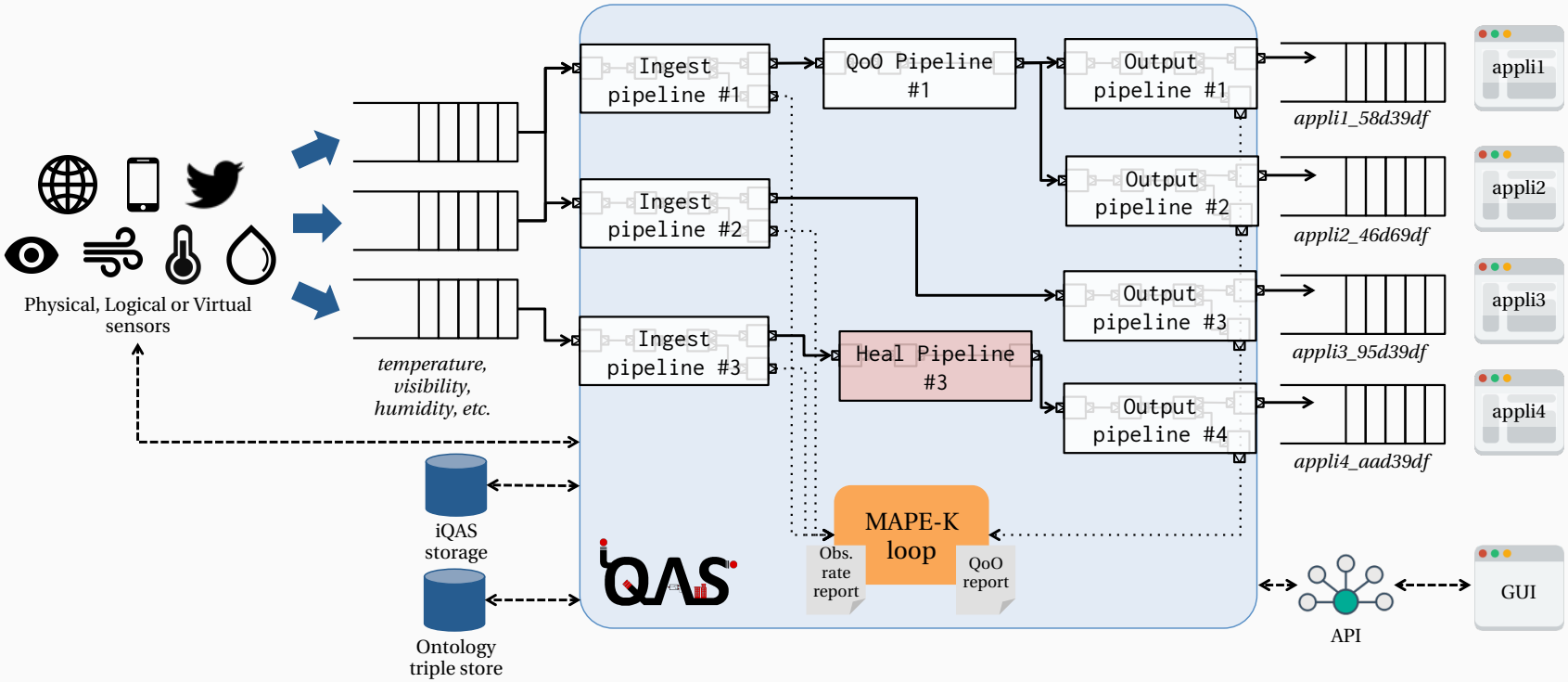
- Instantiate and validate our generic framework
- Understand the impact of implementation choices on QoO
- Teaching objective

The iQAS platform ▶ Instantiation process



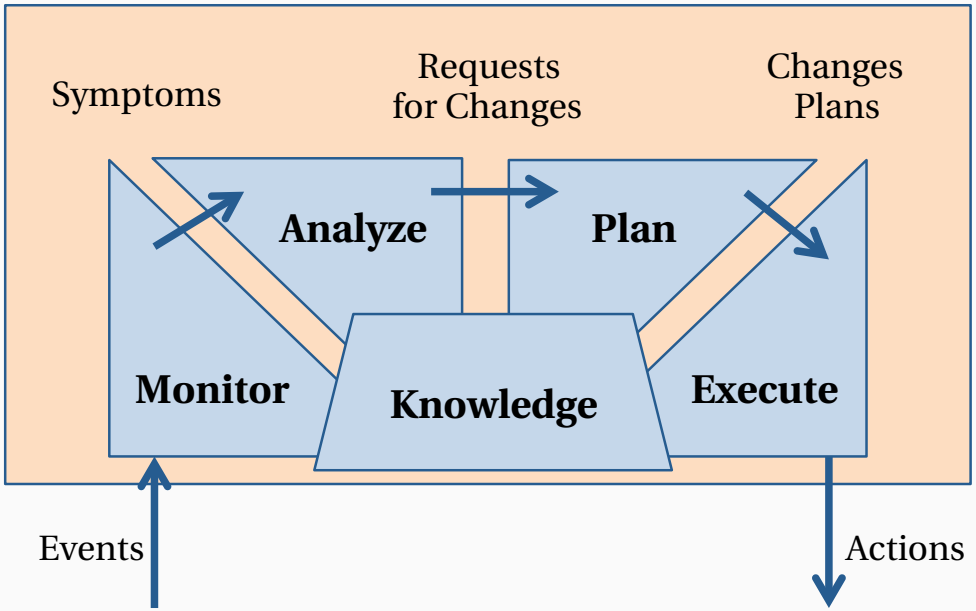

Technologies
Paradigms and approaches
Java 8
Apache Jena
mongoDB
akka
iQAS
Component
Mailbox
Internal State
Mailbox
Actor model
Mailbox
REQUEST(3)
Reactive Streams

The iQAS platform ▶ High-level architecture

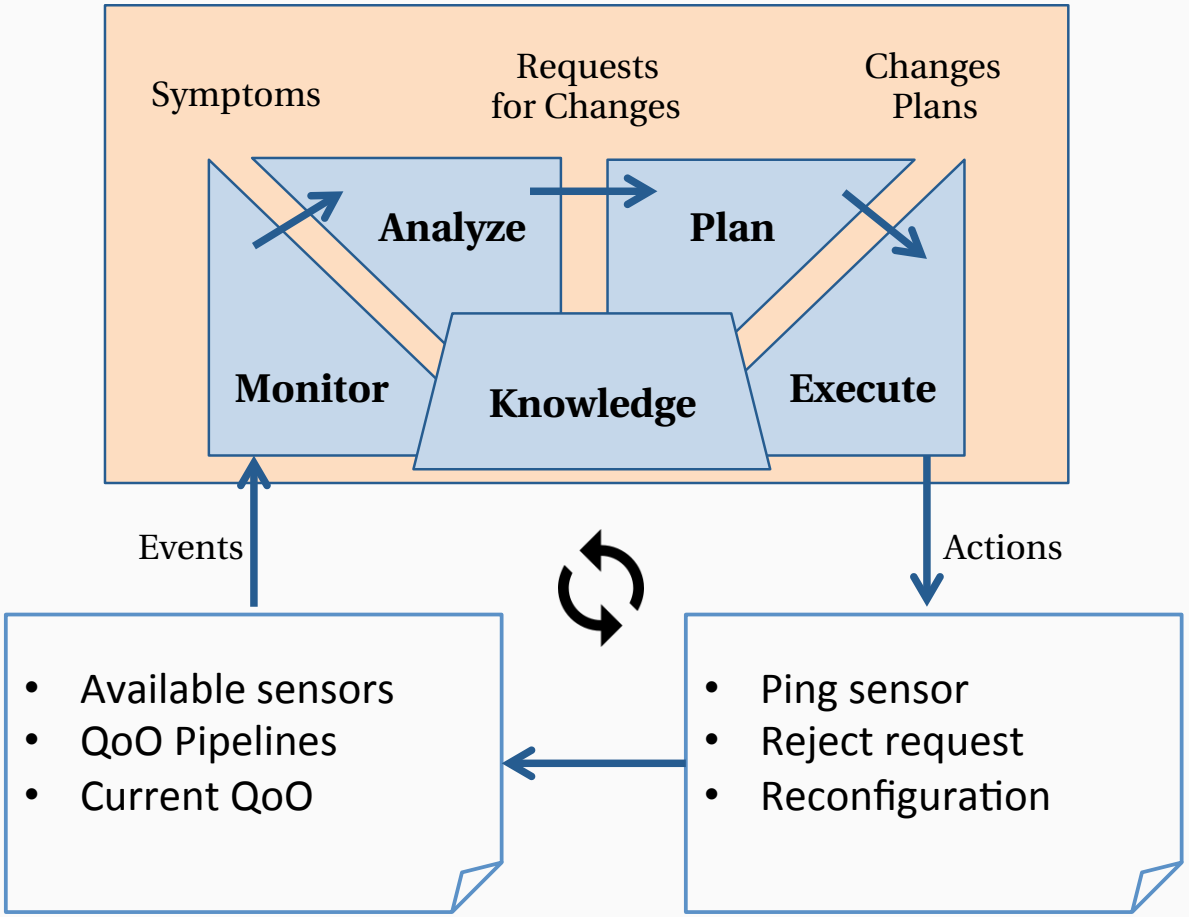


Antoine Auger et al. "iQAS: an Integration Platform for QoI Assessment as a Service for Smart Cities". In: *IEEE WF-IoT 2016*. Reston, VA, USA, 2017, pp. 88–93.

Autonomic Computing with **MAPE-K loop** for enabling dynamic adaptation

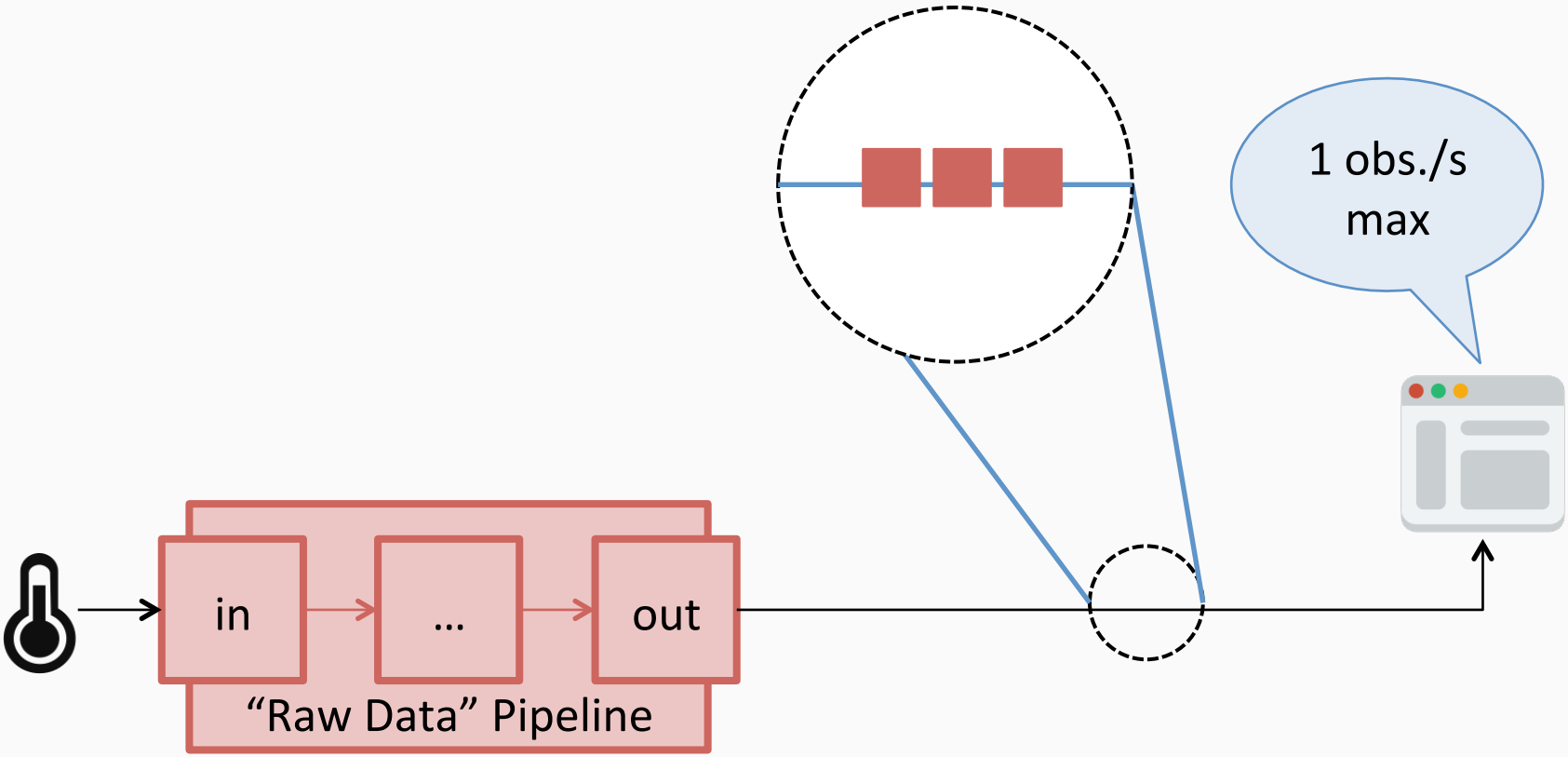


Autonomic Computing with **MAPE-K loop** for enabling dynamic adaptation



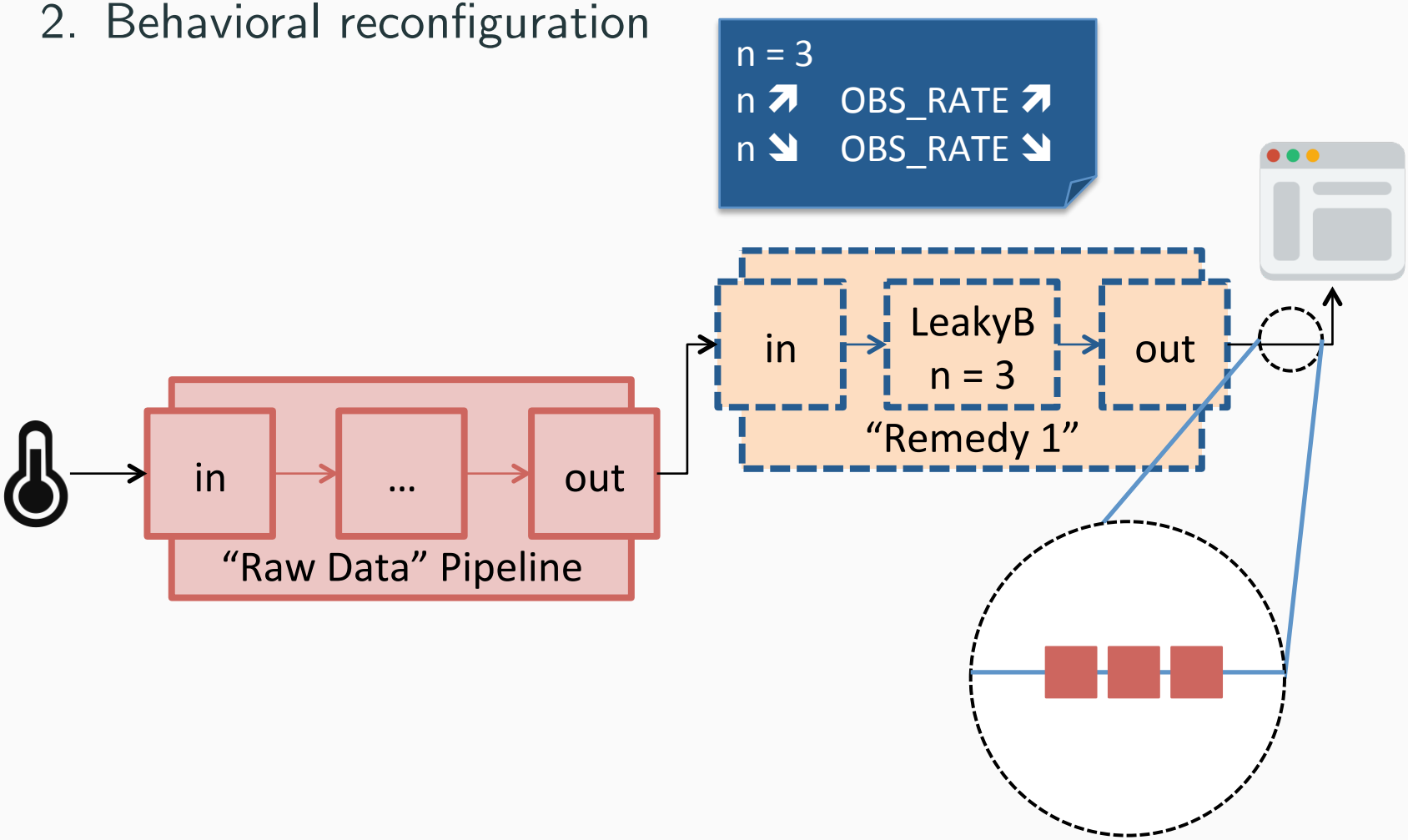
2 kinds of reconfiguration:

1. Structural reconfiguration
2. Behavioral reconfiguration



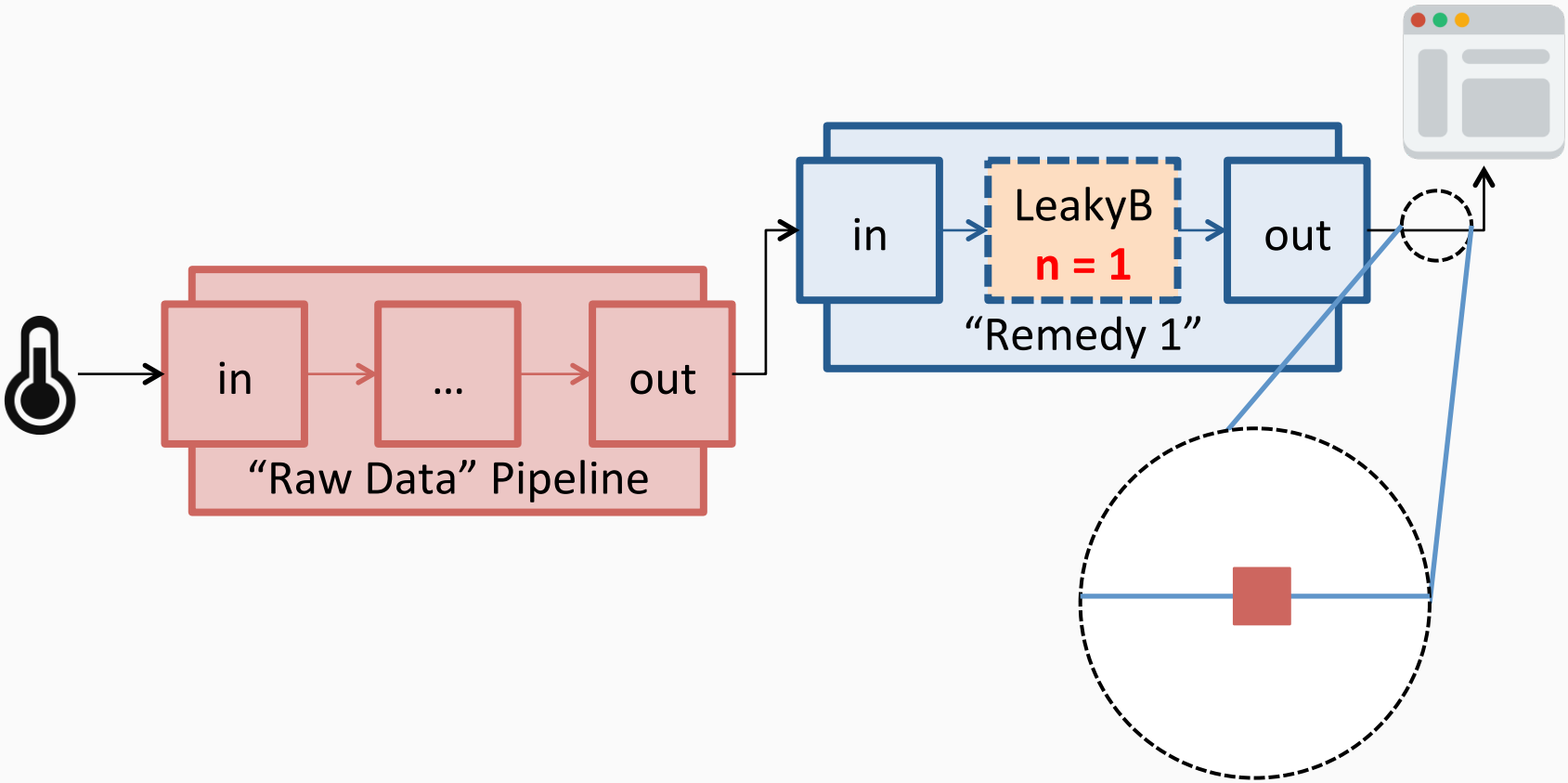
2 kinds of reconfiguration:

1. **Structural reconfiguration**
2. Behavioral reconfiguration



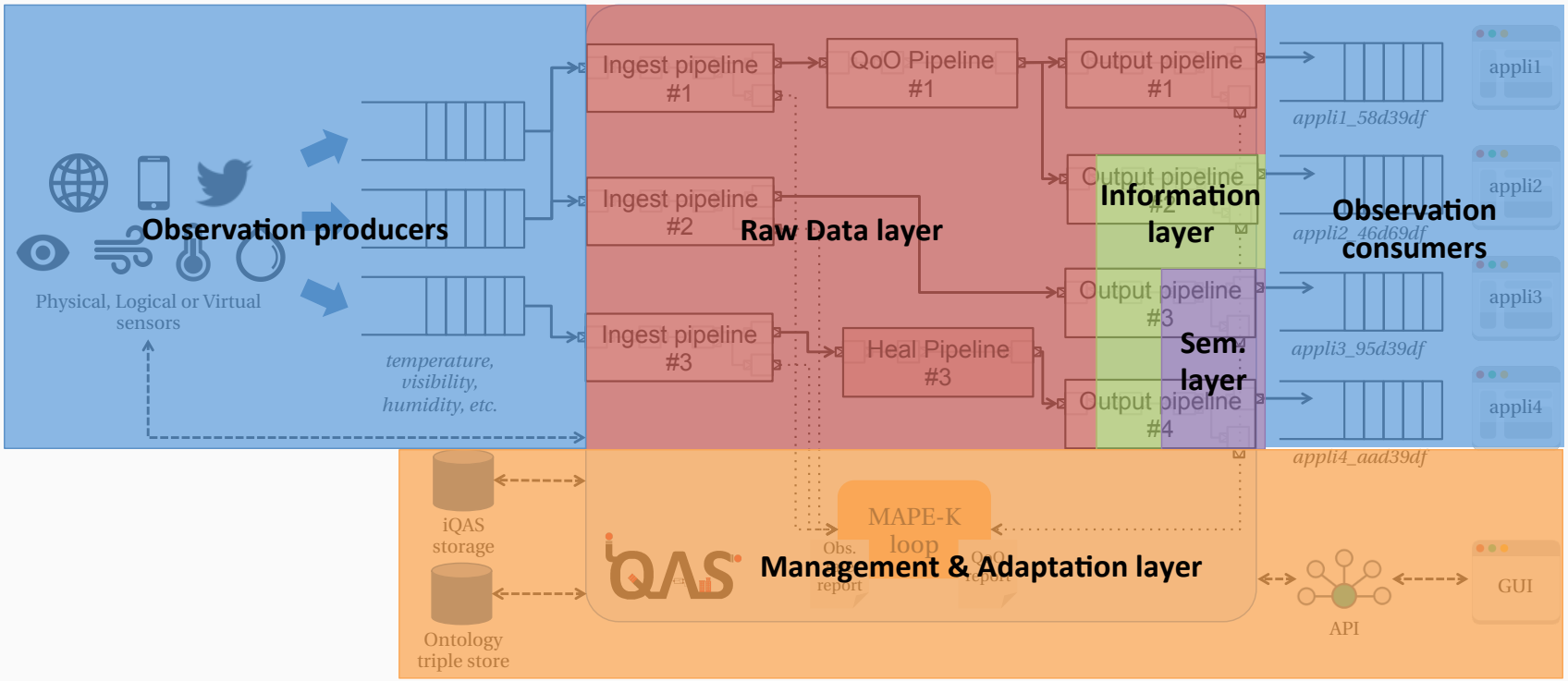
2 kinds of reconfiguration:

1. Structural reconfiguration
2. **Behavioral reconfiguration**



Once developed, we evaluated and validated the iQAS platform from **several perspectives**.

The iQAS platform ▶ Evaluation (design)



The iQAS platform ▶ Evaluation (requirements)

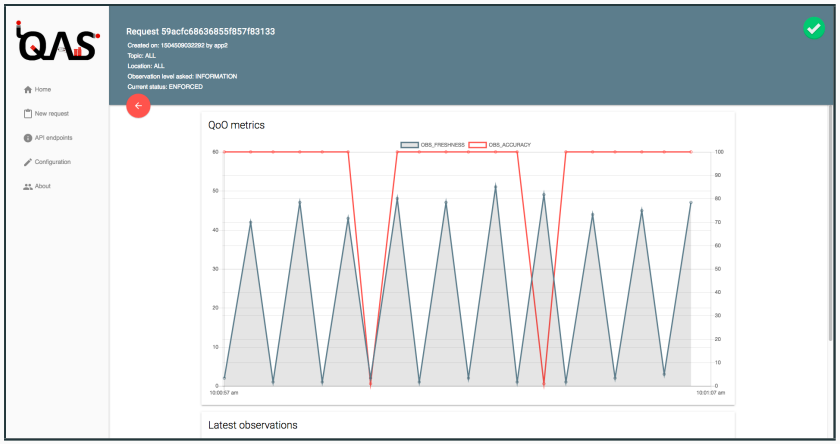
iQAS Use Cases	QASWS General Requirements	
	Functional	Non-Functional
Publish observations	F1, F7	NF1, NF4
Subscribe to specific observations	F2, F4	NF1, NF6
Monitor QoO level	F6	-
Adapt QoO level	F3	NF3
Enforce SLA	F3	NF4, NF5
Retrieve info about the iQAS platform	F8	-
Cancel observation request	F2	NF1
Submit observation request	F2	NF1
Reload QoO Pipelines	-	NF3
Manage sensors	-	NF7
Define QoO Pipelines	-	NF2
Define QoO attributes	-	NF9
Browse and query QoOnto ontology	-	NF9
Update QoOnto ontology	-	NF9
Find a suitable QoO Pipeline	F5	NF3
Discover available sensors	F1	NF7
Discover QoO Pipelines	-	NF8

⇒ iQAS fulfills all the requirements of our generic framework

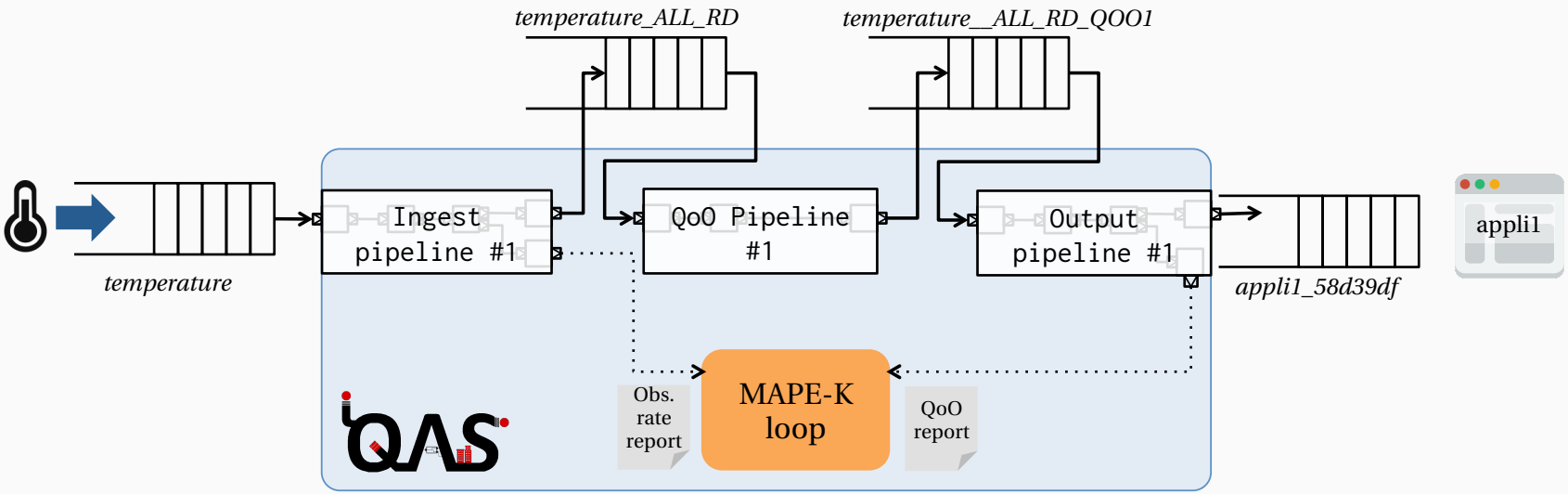
⇒ iQAS addresses the 3 research problems (integration, QoO, adaptation)

We evaluated iQAS performances by defining **Key Primary Indicators (KPIs)**:

- iQAS latency (overhead)
- iQAS throughput
- iQAS response time



Due to our implementation choices, iQAS performances depend on **Apache Kafka** configuration (parallelism, replication)



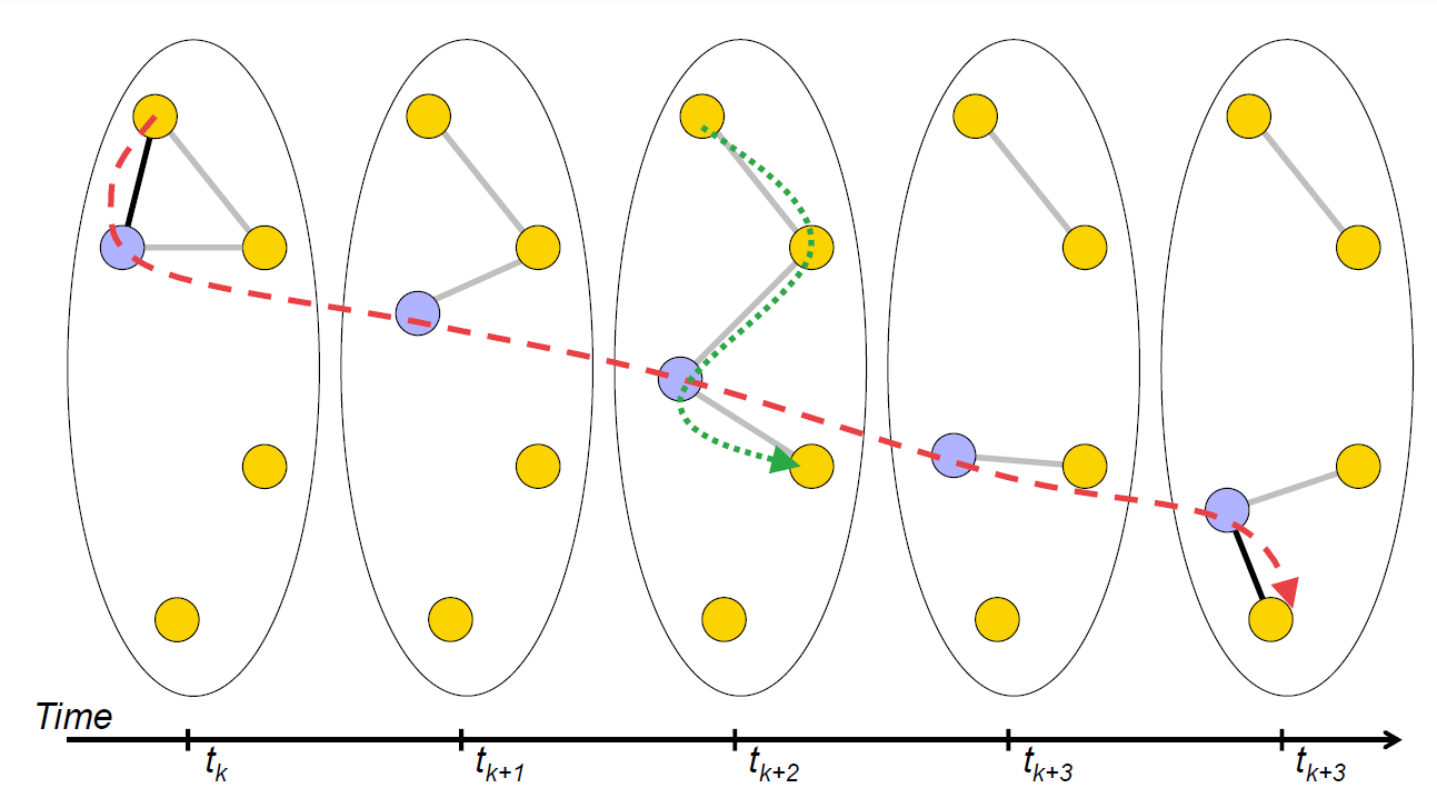
⇒ Tradeoffs between observation size, latency and throughput

Antoine Auger et al. "Sensor Observation Streams Within Cloud-based IoT Platforms: Challenges and Directions". In: *20th ICIN Conference Innovations in Clouds, Internet and Networks*. Paris, FR, 2017, pp. 177–184.

A deployment scenario: QoO for challenging Internets

Opportunistic Network

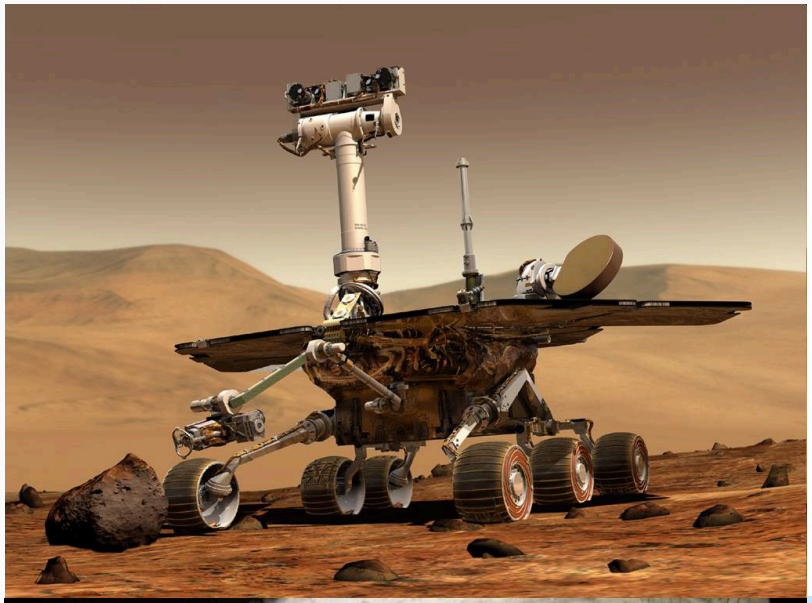
A network that may lack of instantaneous end-to-end paths. Human social characteristics may be used to perform bundle routing.

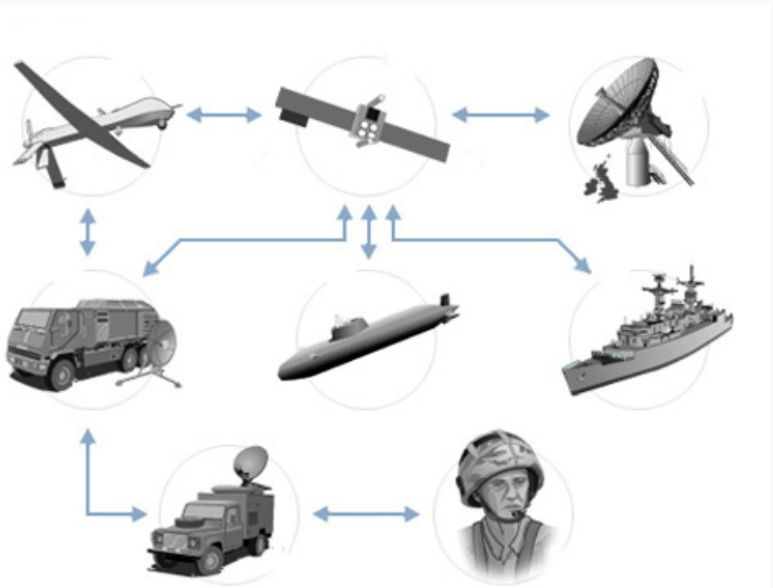


Deployment scenario ▶ Opportunistic Networks (OppNets)

Architecture can **fail**!

⇒ OppNets and DTNs as an alternative for challenging Internets





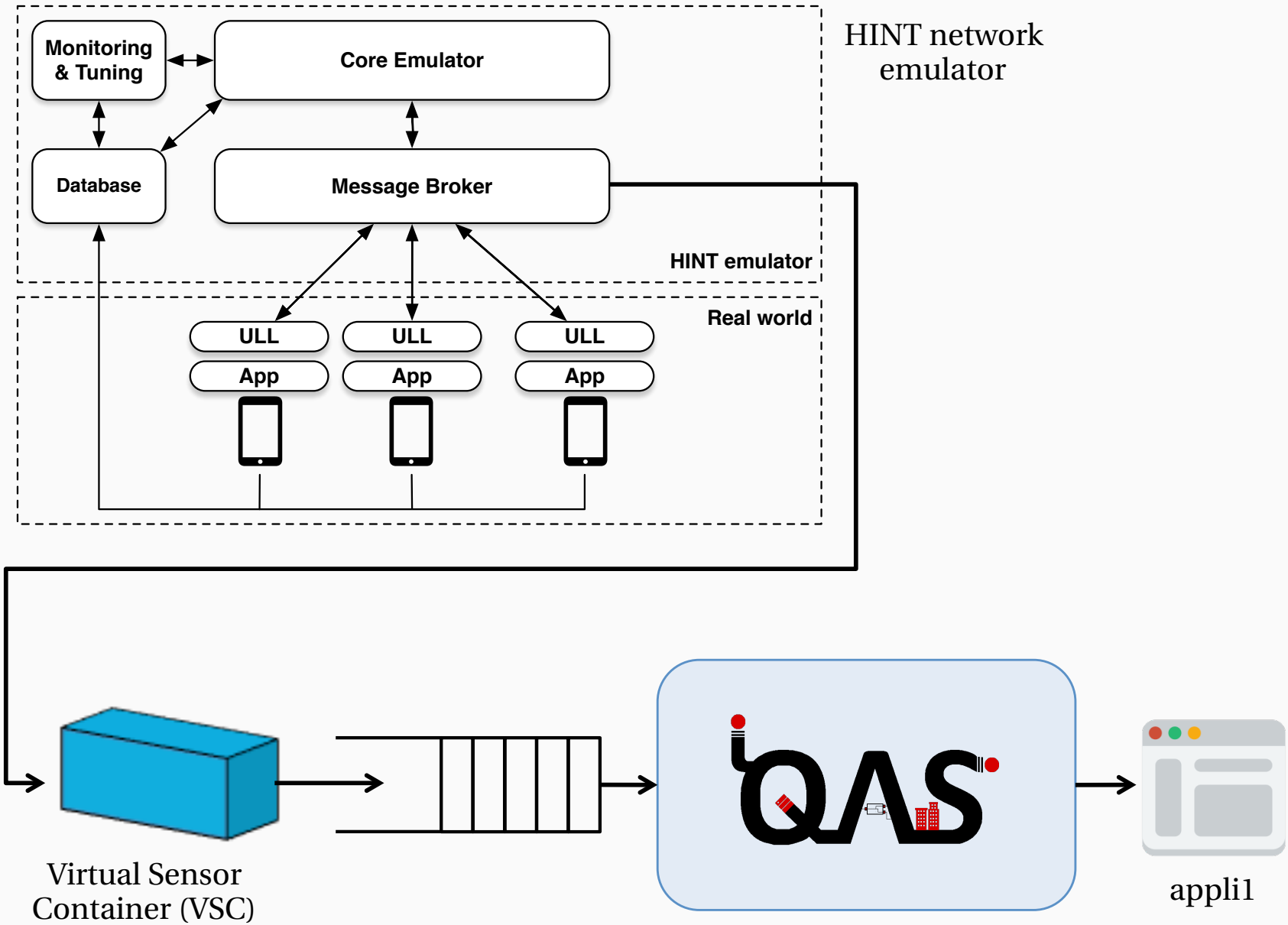
Deployment scenario ▶ Hypothesis and tools

We chose to:

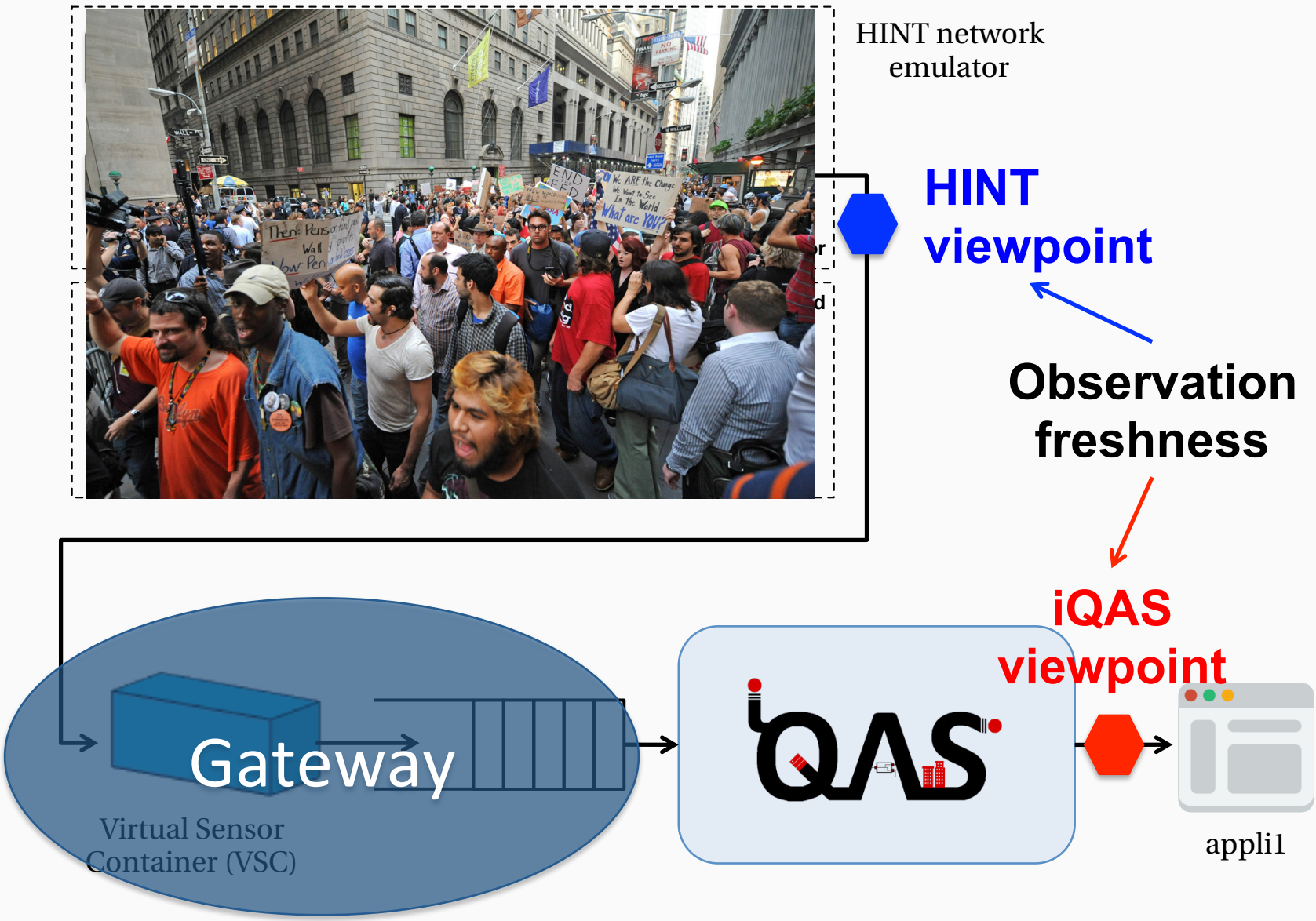
- ✓ Reuse the **HINT emulator** from the DGAME project
- ✓ Retrieve all observations
- ✓ Compute **freshness** for each observation

Gwilherm Baudic et al. "HINT: From Network Characterization to Opportunistic Applications". In: *ACM CHANTS '16*. New York City, NY, USA, 2016, pp. 13–18.

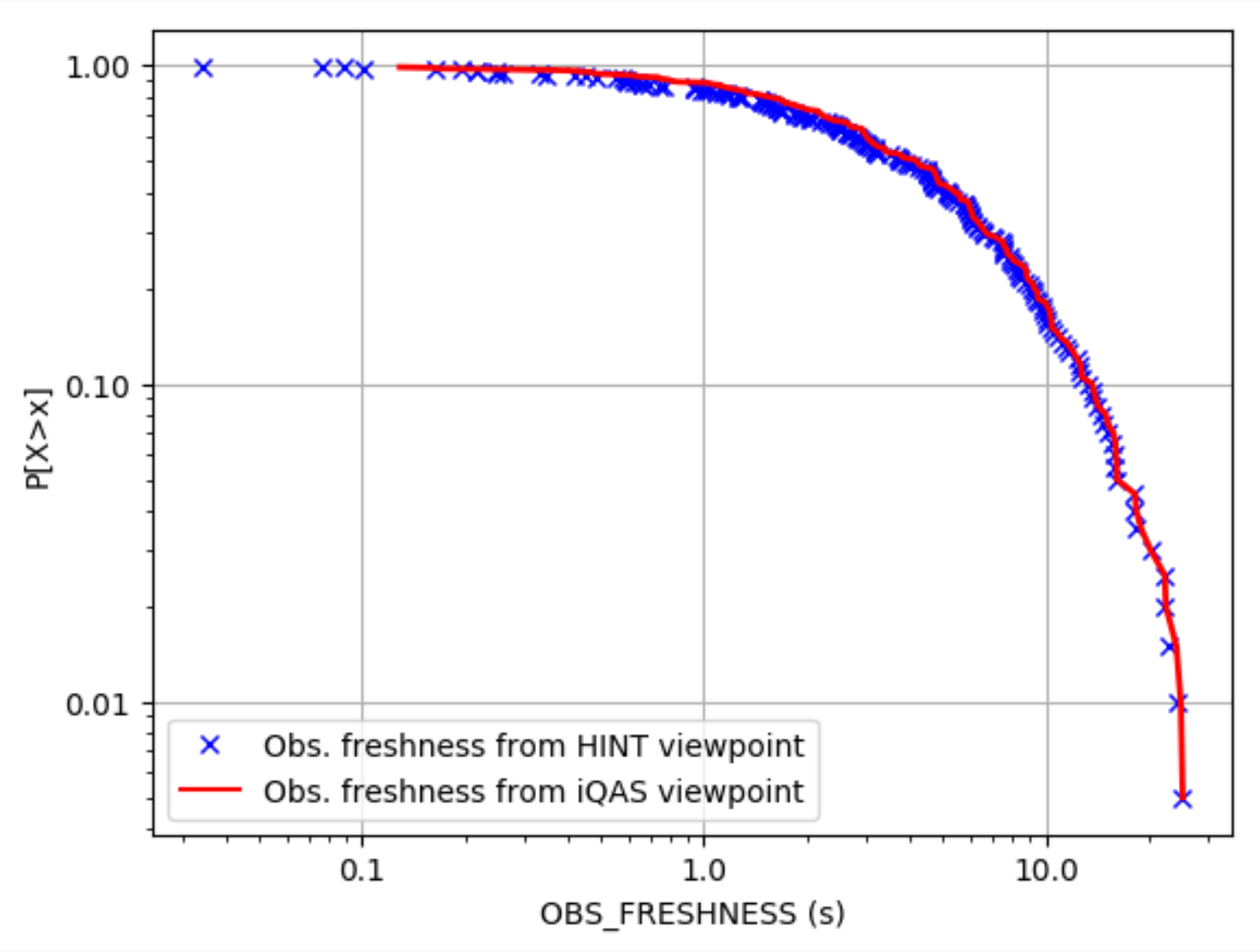
Deployment scenario ▶ Experimental setup

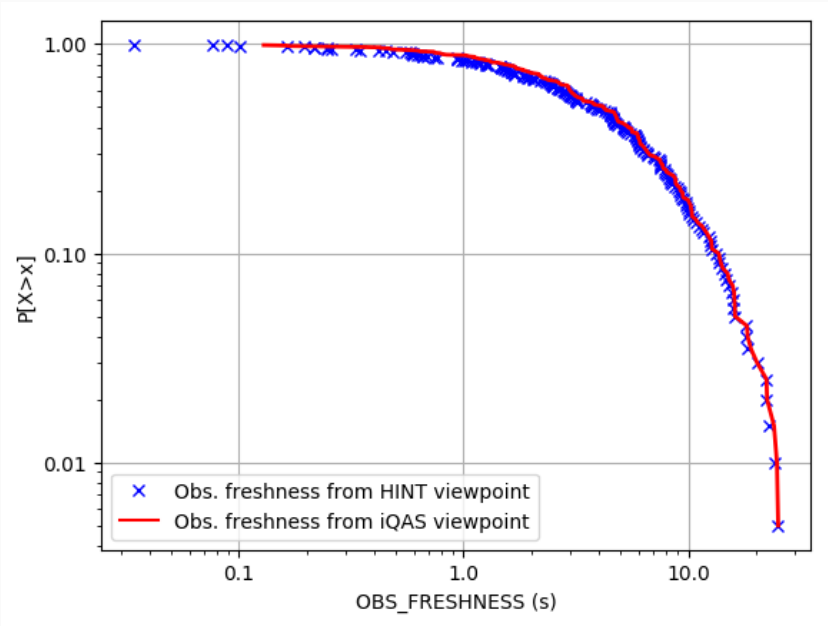


Deployment scenario ▶ Experimental setup



Complementary Cumulative Distribution Function (CCDF):





- iQAS processing time is negligible compared to recollection time
- Subject to a small overhead, iQAS may greatly improve QoO (and QoE)
- Some QoO constraints may be partially **translated** into network QoS constraints

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Antoine Auger et al. "Towards the Internet of Everything: Deployment Scenarios for a QoO-aware Integration Platform". In: *IEEE WF-IoT 2018*. Singapore, Singapore, 2018, pp. 504–509.

Conclusions and Perspectives

Conclusions

- The **Sensor Web** field is in constant evolution
- Numerous paradigms have brought new research challenges and uses

✓ Integration, QoO and adaptation are still valid issues

✓ We proposed 2 contributions regarding the design and development of QoO-aware Adaptive Sensor Web Systems (**QASWS**)

⇒ QoO may be impacted by software and its configuration

⇒ QoO is often the **missing link** between network QoS and QoE

Perspectives

What **directions** for QoO and future Sensor Webs?

- QoO Pipelines as Virtualized Network Functions (NFV)
- Reduce backbone traffic (Edge Computing)
- Improve sensor trust (Blockchain)
- Learn new adaptation strategies (Machine Learning)

Publications

- Antoine Auger et al. “Towards the Internet of Everything: Deployment Scenarios for a QoO-aware Integration Platform”. In: *IEEE WF-IoT 2018*. Singapore, Singapore, 2018, pp. 504–509
- Antoine Auger et al. “Survey on Quality of Observation within Sensor Web Systems”. In: *IET Wireless Sensor Systems* 7 (6 2017), 163–177(14)
- Antoine Auger et al. “Sensor Observation Streams Within Cloud-based IoT Platforms: Challenges and Directions”. In: *20th ICIN Conference Innovations in Clouds, Internet and Networks*. Paris, FR, 2017, pp. 177–184
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- Antoine Auger et al. “A Generic Framework for Quality-based Autonomic Adaptation within Sensor-based Systems”. In: *ICSOC 2016 - ASOCA workshop*. Banff, CA, 2017, pp. 21–32
- Antoine Auger et al. “Using the HINT Network Emulator to Develop Opportunistic Applications: Demo”. In: *ACM CHANTS '16*. New York City, NY, USA, 2016, pp. 35–36
- Gwilherm Baudic et al. “HINT: From Network Characterization to Opportunistic Applications”. In: *ACM CHANTS '16*. New York City, NY, USA, 2016, pp. 13–18

Thank you for your attention.

Question time!

References i

[Bis+09] C. Bisdikian et al. “A Letter Soup for the Quality of Information in Sensor Networks”. In: *IEEE International Conference on Pervasive Computing and Communications, 2009. PerCom 2009*. Mar. 2009, pp. 1–6.