A Message Broker Architecture for Adaptive Date Exchange in the IoT

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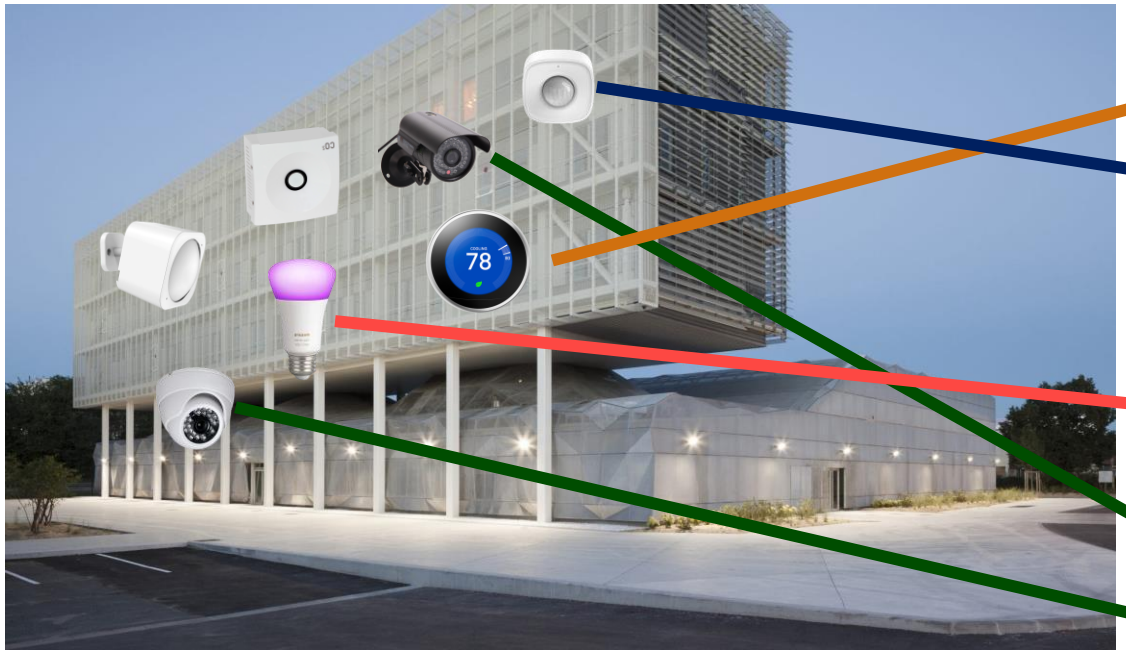
Motivating Scenario

Smart Spaces' IoT Applications

Télécom SudParis - Évry campus

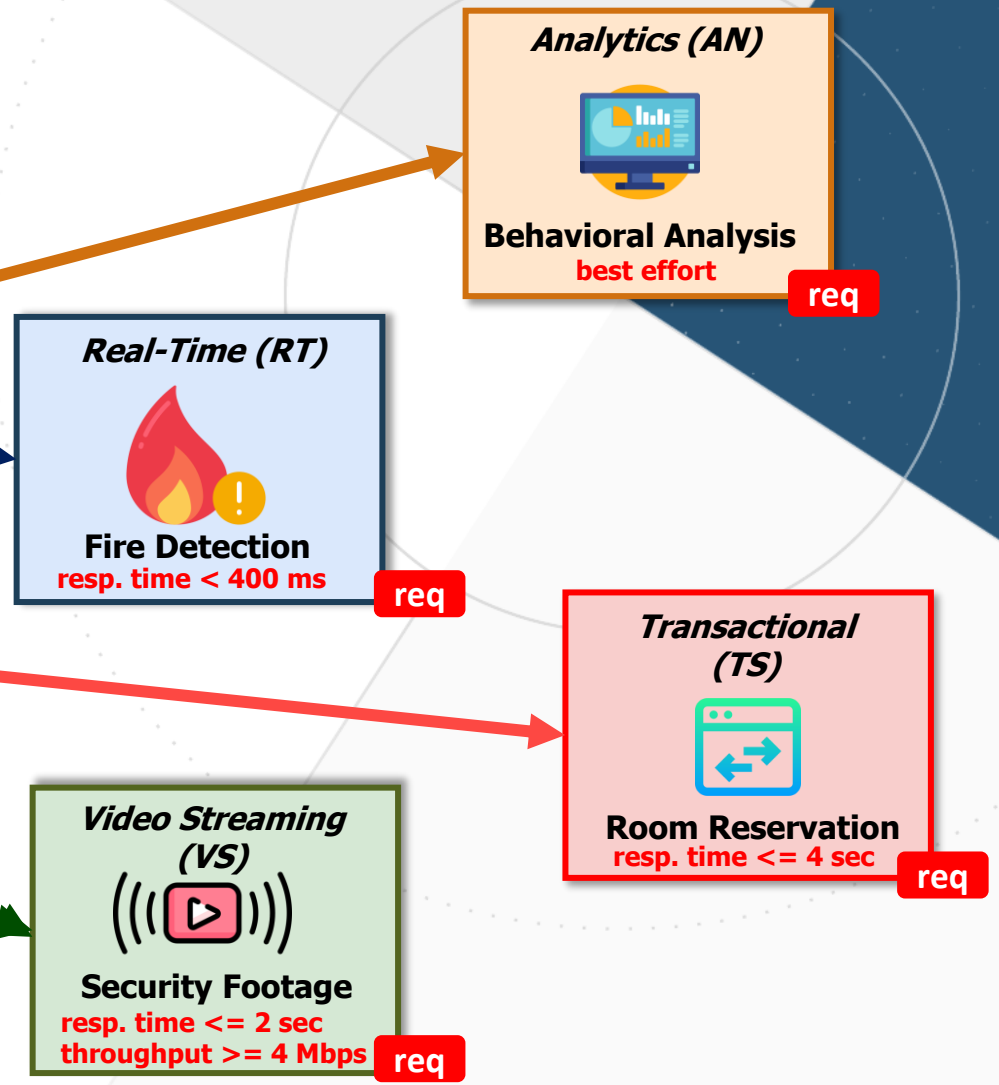


Building occupants:

- Approximately 6,000 occupants / day

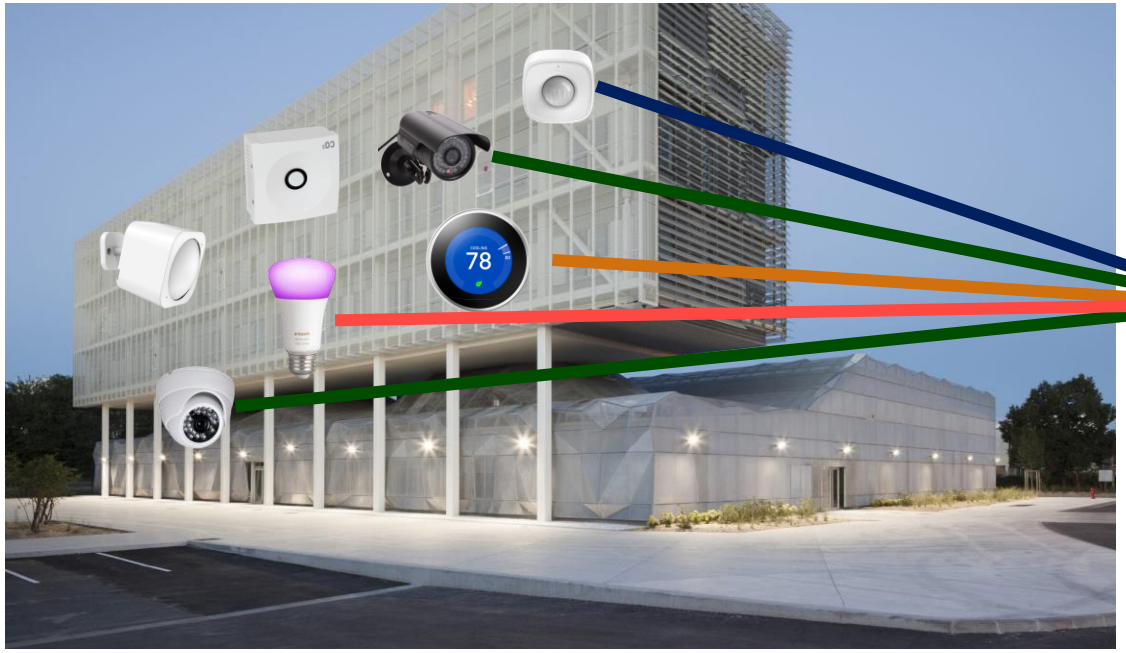
Shared rooms:

- 10 lecture halls, 220 conference & medium-size rooms
- 4 cafes and 3 restaurants



Motivating Scenario

Pub/sub-based IoT Data Exchange



I need to configure the message broker to satisfy the QoS requirements of applications

Message Broker

Analytics (AN)

Behavioral Analysis

best effort

req

Real-Time (RT)

Fire Detection

resp. time < 400 ms

req

Transactional (TS)

Room Reservation

resp. time <= 4 sec

req

Video Streaming (VS)

Security Footage

resp. time <= 2 sec

throughput >= 4 Mbps

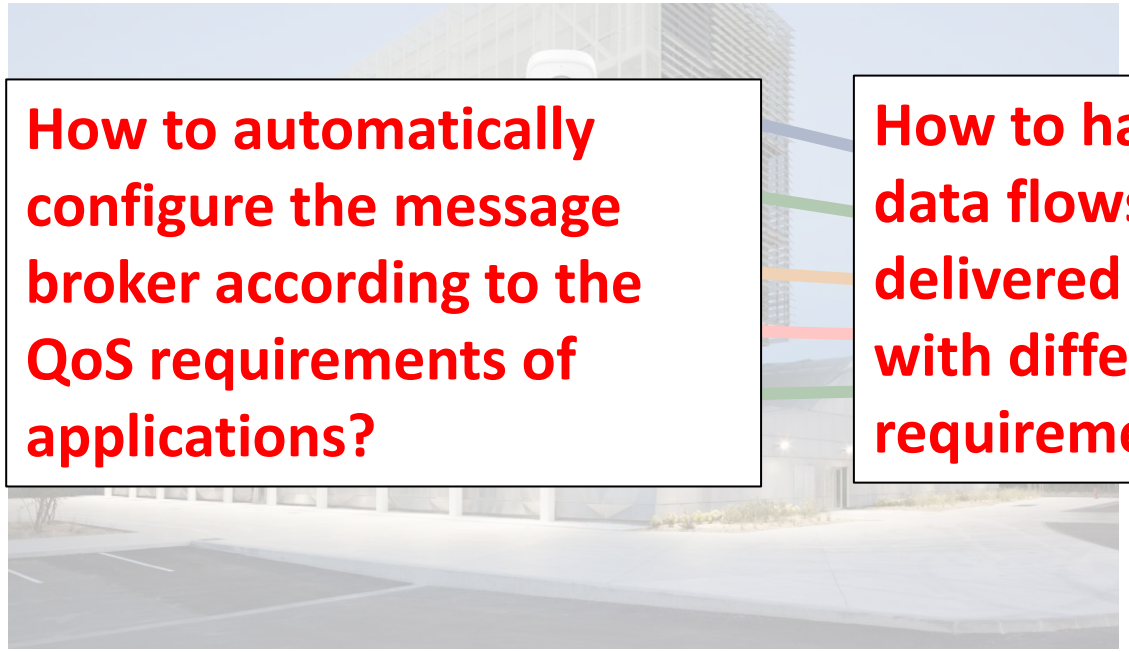
req

Existing message broker configuration options include:

- Support for different delivery guarantees levels
- Creation of priority queues for topics
- Rate limiting and capacity configuration
- …

Motivating Scenario

Pub/sub-based IoT Data Exchange



I need to configure the message broker to satisfy the QoS requirements of applications

How to automatically configure the message broker according to the QoS requirements of applications?

How to handle identical data flows that must be delivered to applications with different QoS requirements?

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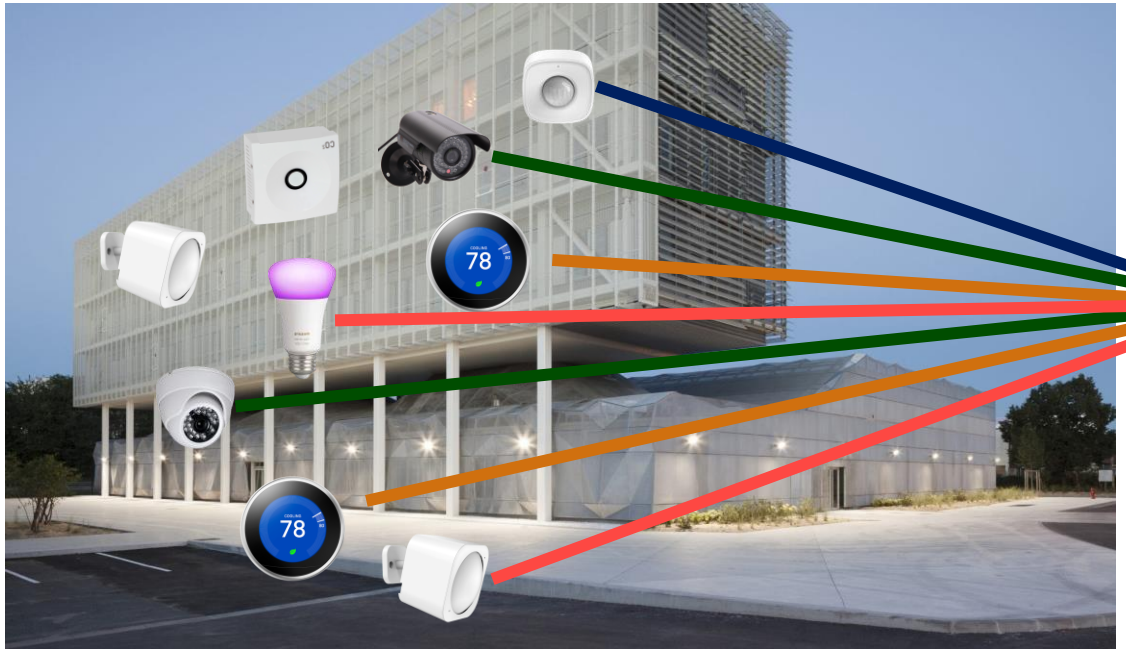
Motivating Scenario

Supporting Dynamic IoT Environments



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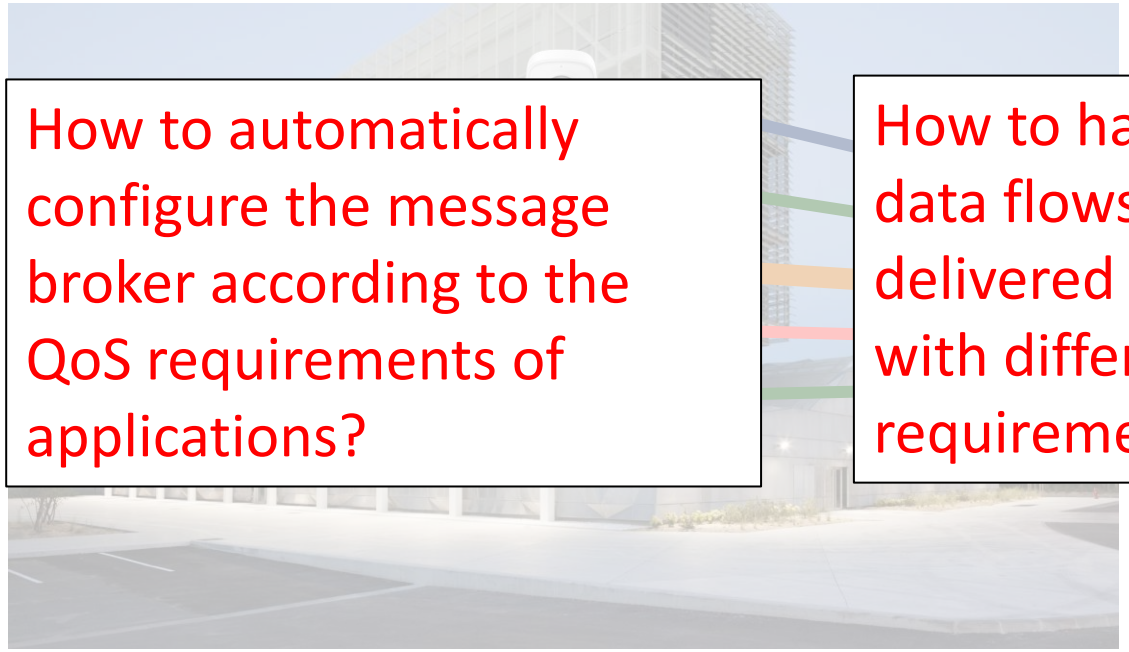
Dynamic changes that might happen in smart environments include:

- Subscriber churn
- Addition/removal of IoT devices/applications
- Changing QoS requirements
- …

Motivating Scenario

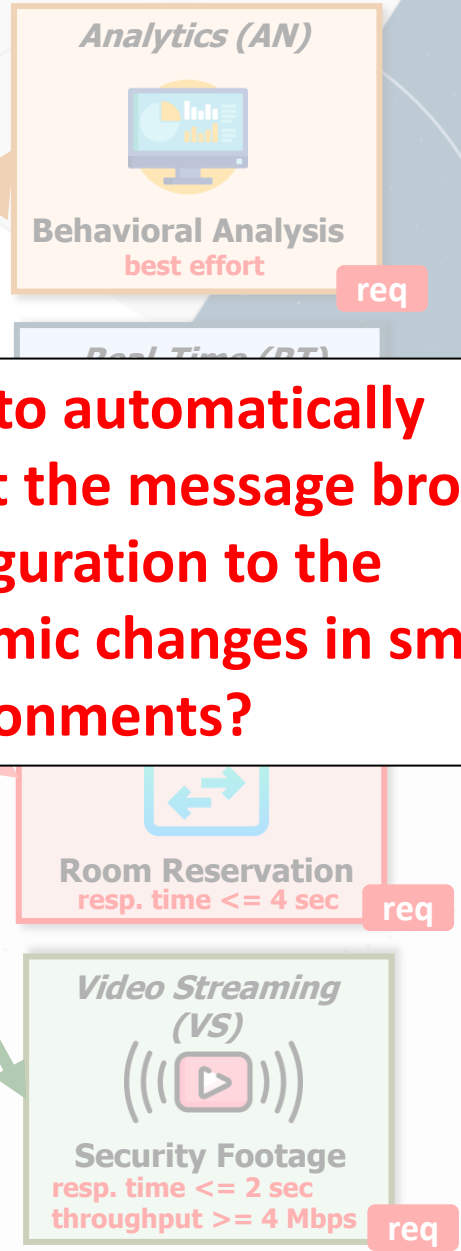
Supporting Dynamic IoT Environments



How to automatically configure the message broker according to the QoS requirements of applications?

How to handle identical data flows that must be delivered to applications with different QoS requirements?

How to automatically adapt the message broker configuration to the dynamic changes in smart environments?



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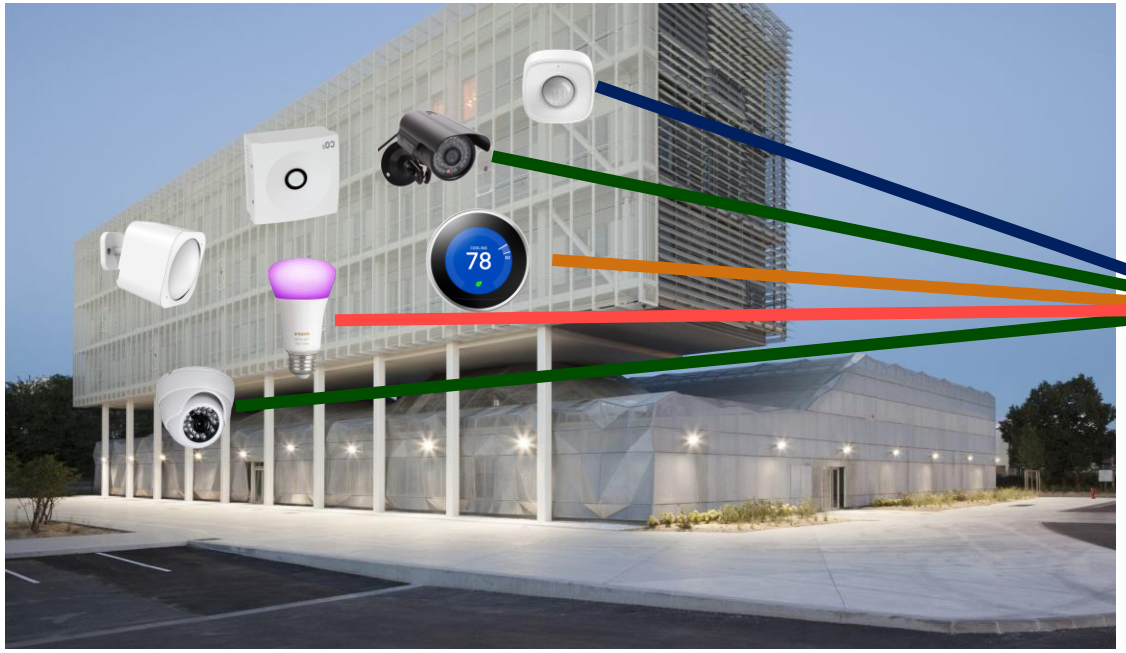
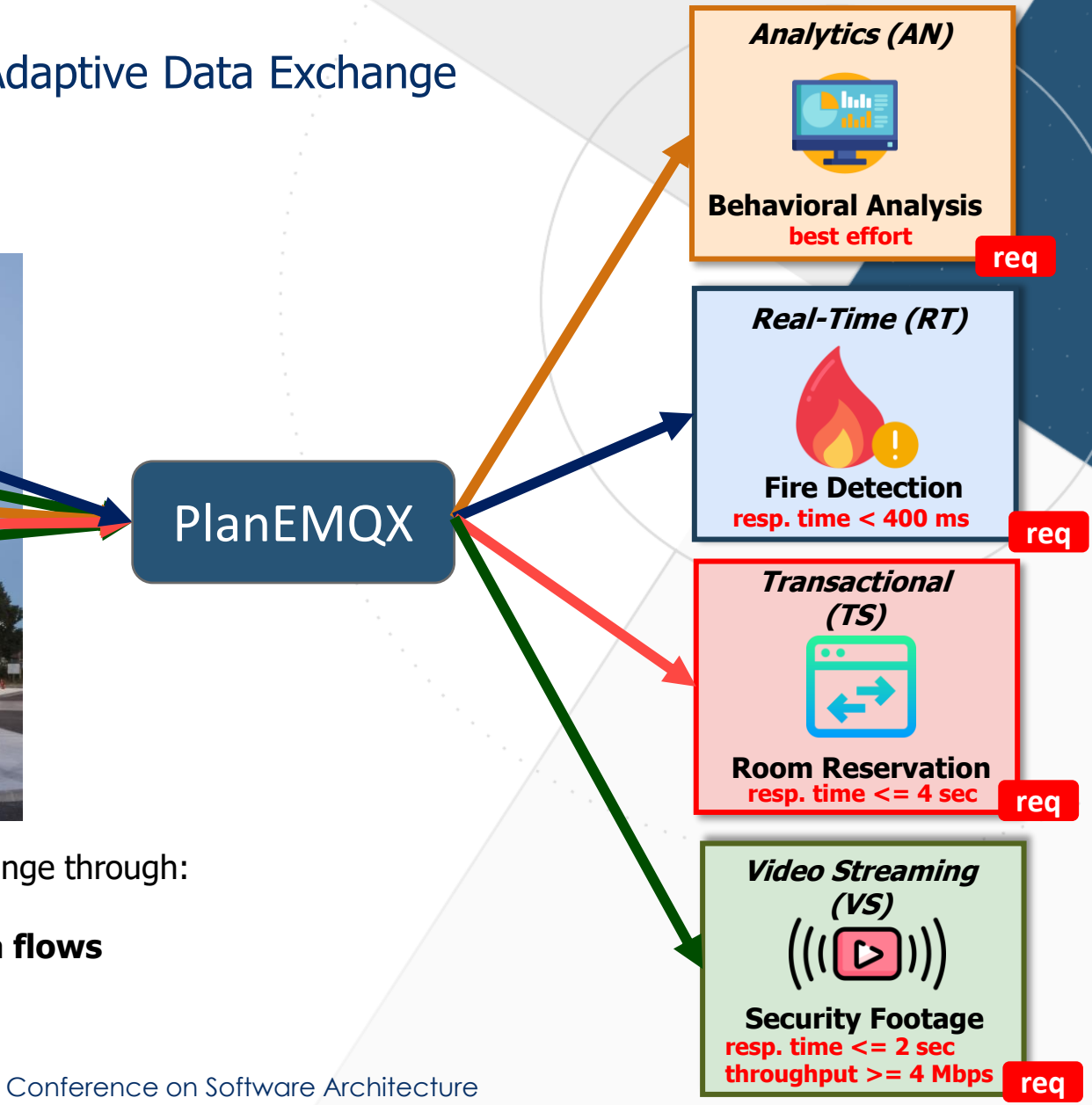
- …

PlanEMQX

A Message Broker Architecture for Adaptive Data Exchange



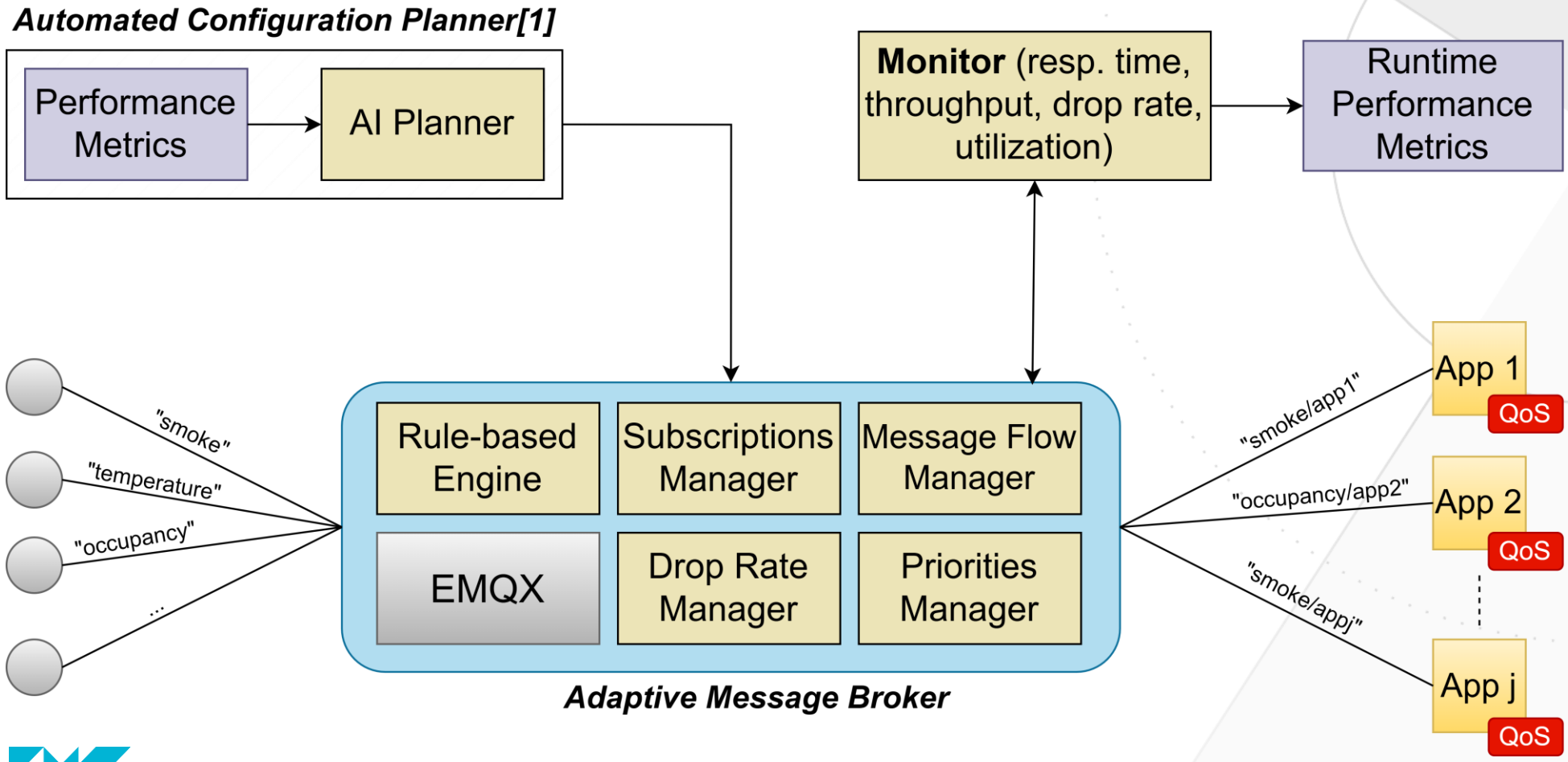


Message broker architecture for efficient and adaptive data exchange through:

1. An **automated configuration planning** component
2. Runtime components for **controlling per-subscription data flows**

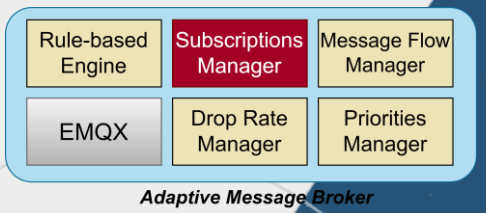
Adaptive Message Broker Architecture

High-Level Overview



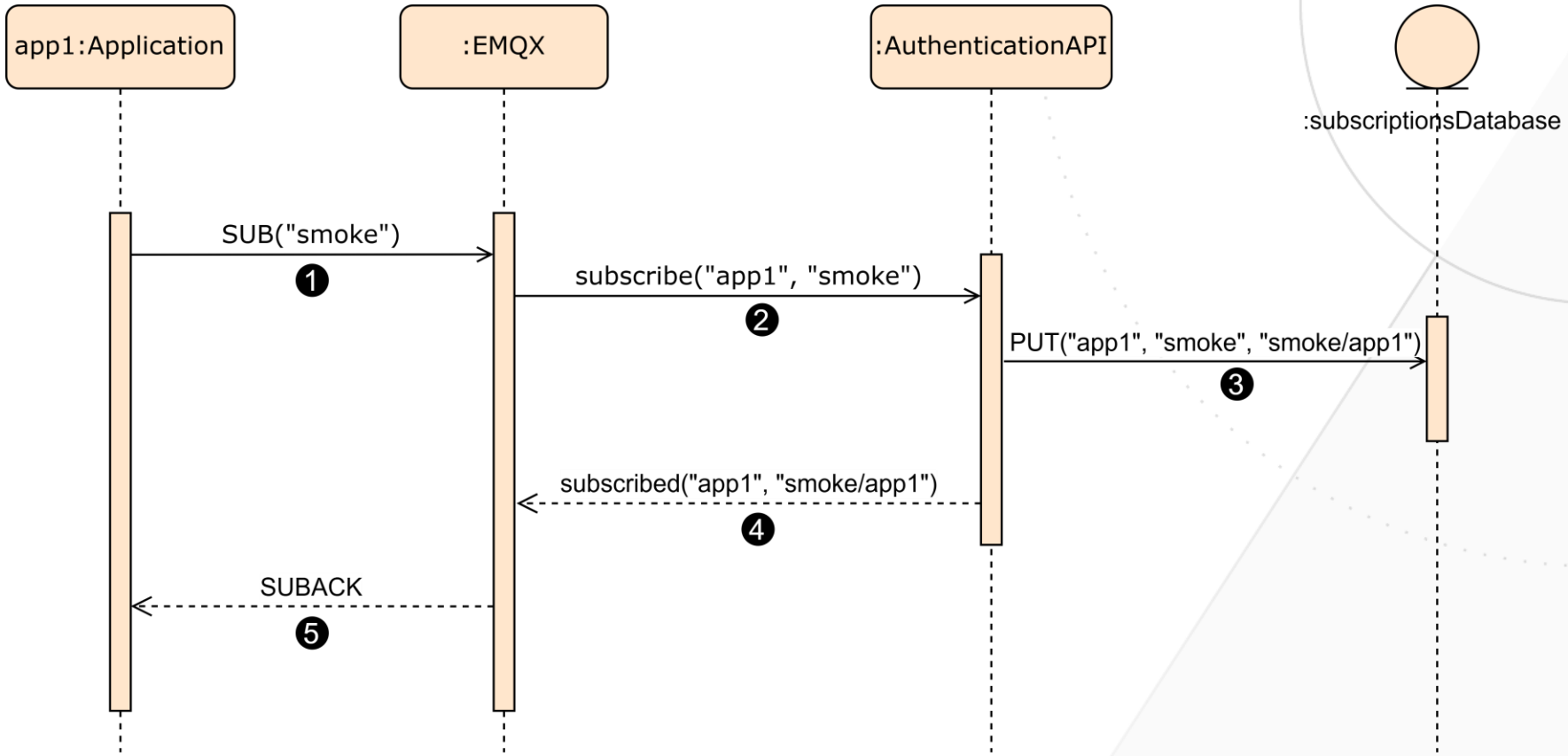
[1] H. Hajj Hassan et al. SEAMS 2023.

Subscription Manager

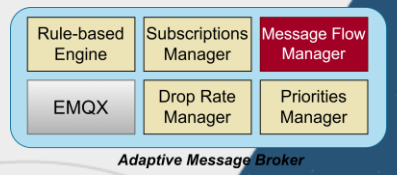


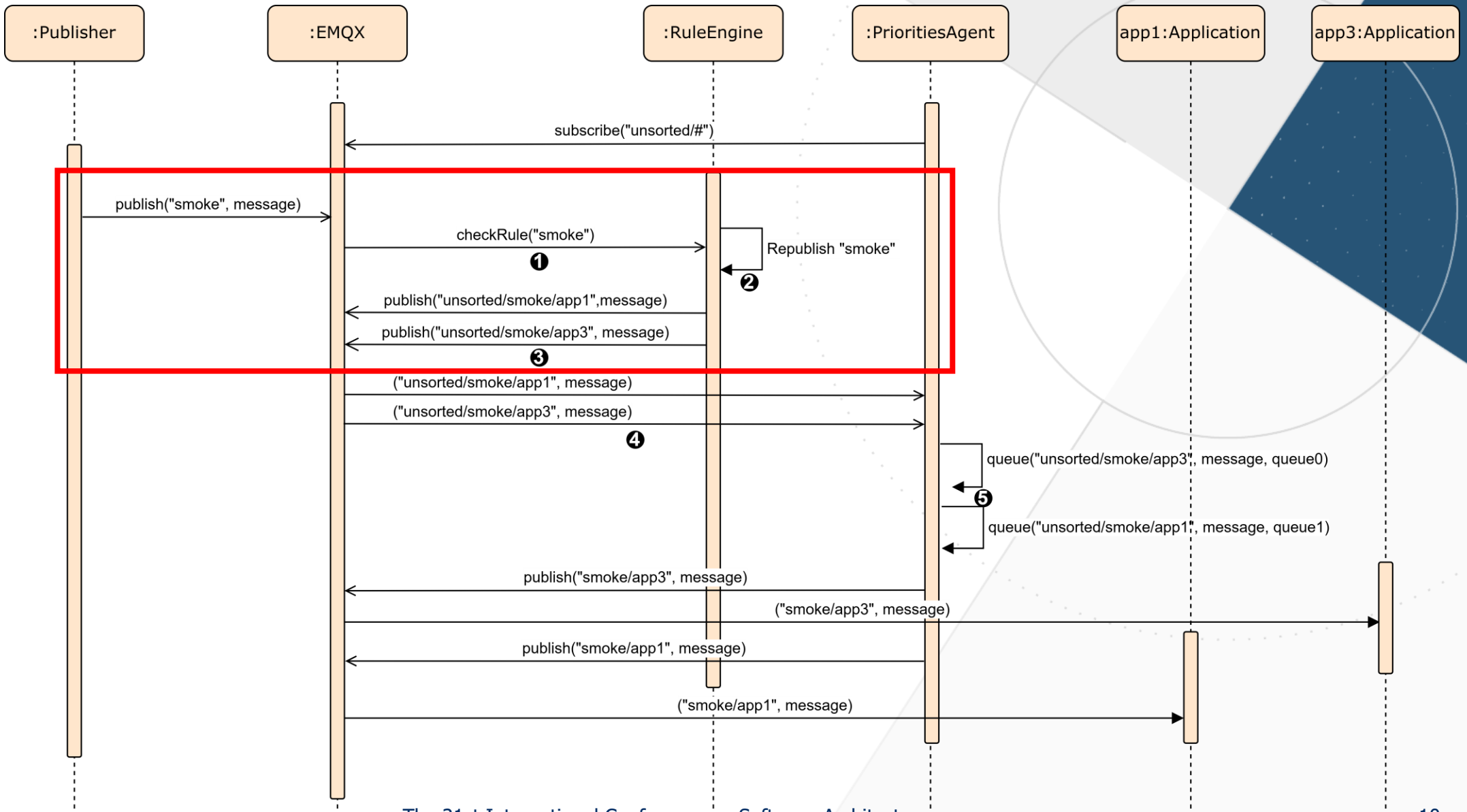
PlanEMQX refines the traditional pub/sub architecture by creating **one topic per subscription.**

*How to implement this mechanism so that publishers & subscribers are **agnostic** to the **back-end topics** used to handle data flows?*

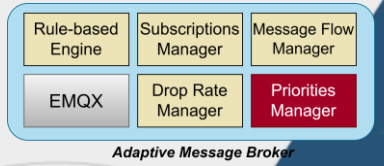


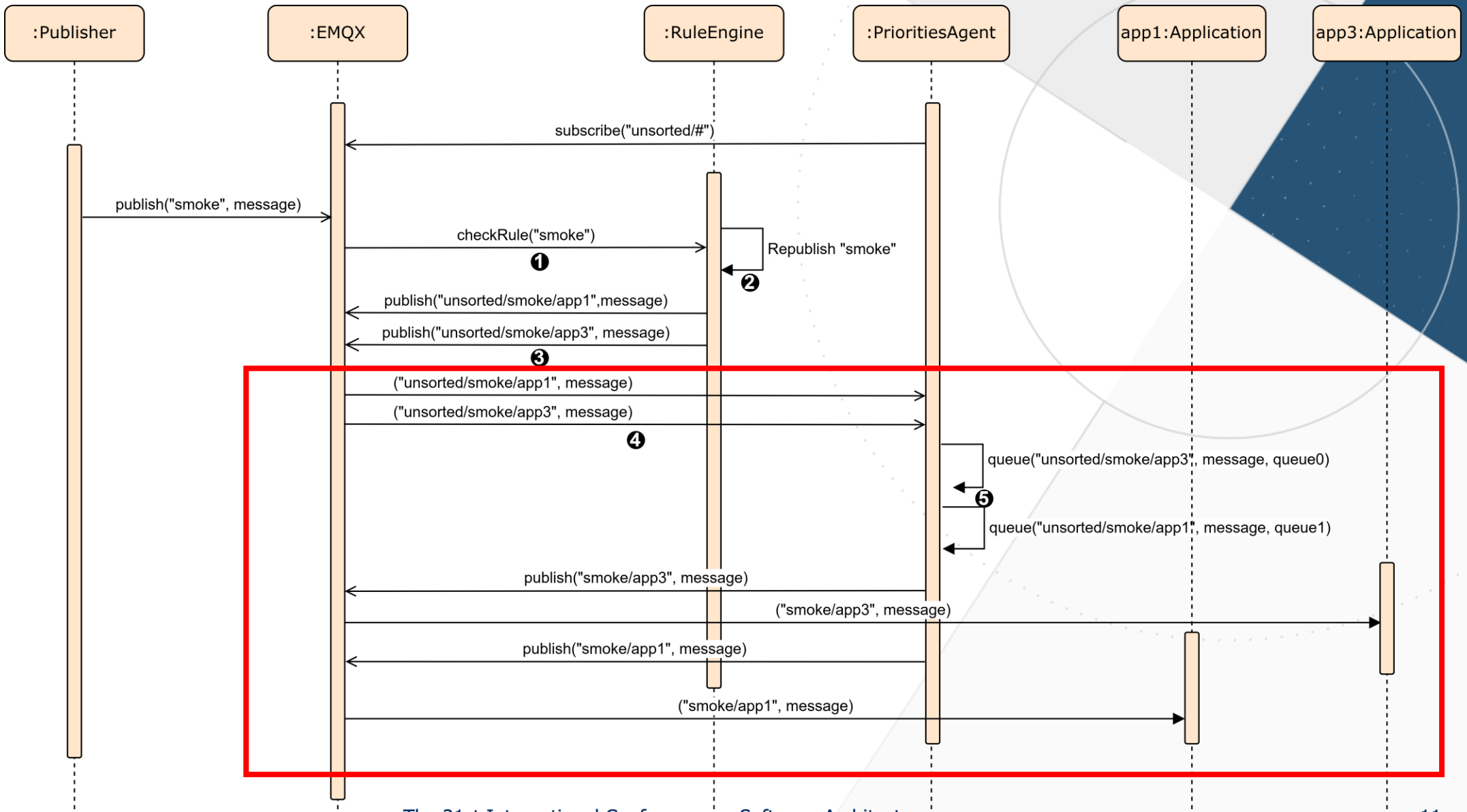
Message Flows Manager



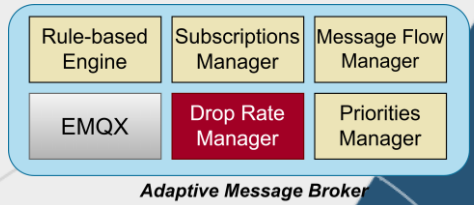


Priorities Manager





Drop Rate Manager



PlanEMQX leverages EMQX's *Rule Engine* to create rules for assigning drop rates to data flows based on applications' QoS requirements

Compare the SHA-256 of the ID of the message with the percentage to be dropped

```
SELECT qos, payload,
    sha256(id) < thresholdValue
AS republish
FROM smoke/app1
WHERE republish = true
AND payload != 'unsubscribe'
```

Experimental Results

The PlanEMQX Prototype Implementation

- PlanEMQX is implemented on top of the EMQX[1] message broker.
- The Java MQTT-Paho library[2] is used to implement publishers and subcribers (i.e., devices and applications)
- The Subscriptions Manager, Message Flows Manager, Priorities Manager, Drop Rate Manager, are implemented as Java processes.
- Containernet[4] is used to emulation the networking infrastructure.

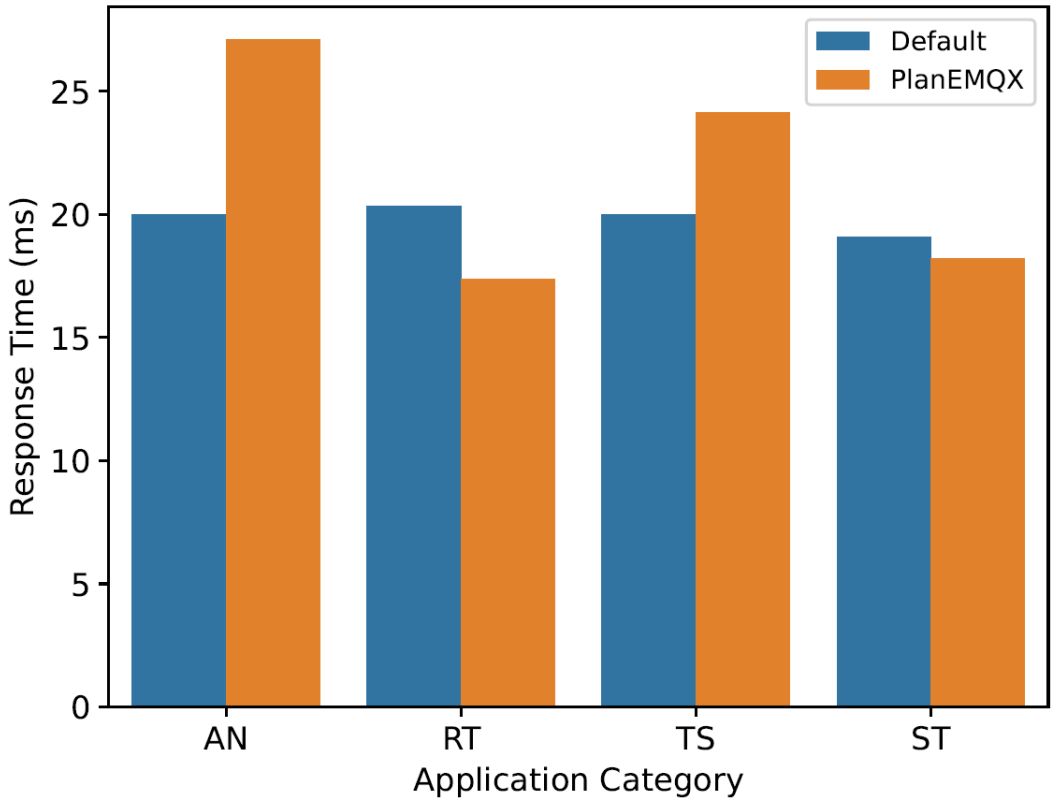
IoT system properties				
Category	*#topics*	*#subscriptions*	*Load (Mbps)*	*Available bandwidth (Mbps)*
AN	15	21	1.90	10
RT	18	21	2.33	
TS	11	18	2.05	
VS	16	20	1.61	
Total	30	80	7.9	10

IoT System Properties

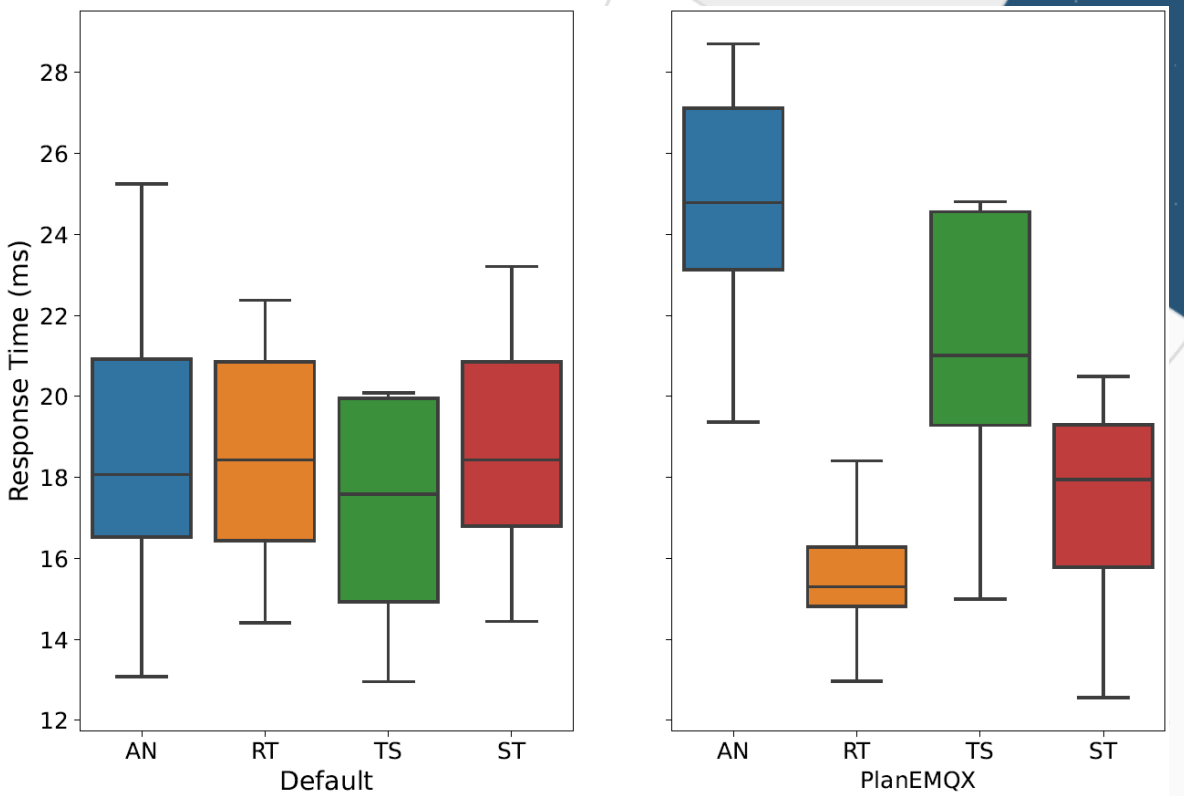
1 https://www.emqx.com/
2 https://eclipse.dev/paho
3 J. Hoffman. ECAI 2002.
4 https://containernet.github.io/

Experimental Results

PlanEMQX Evaluation



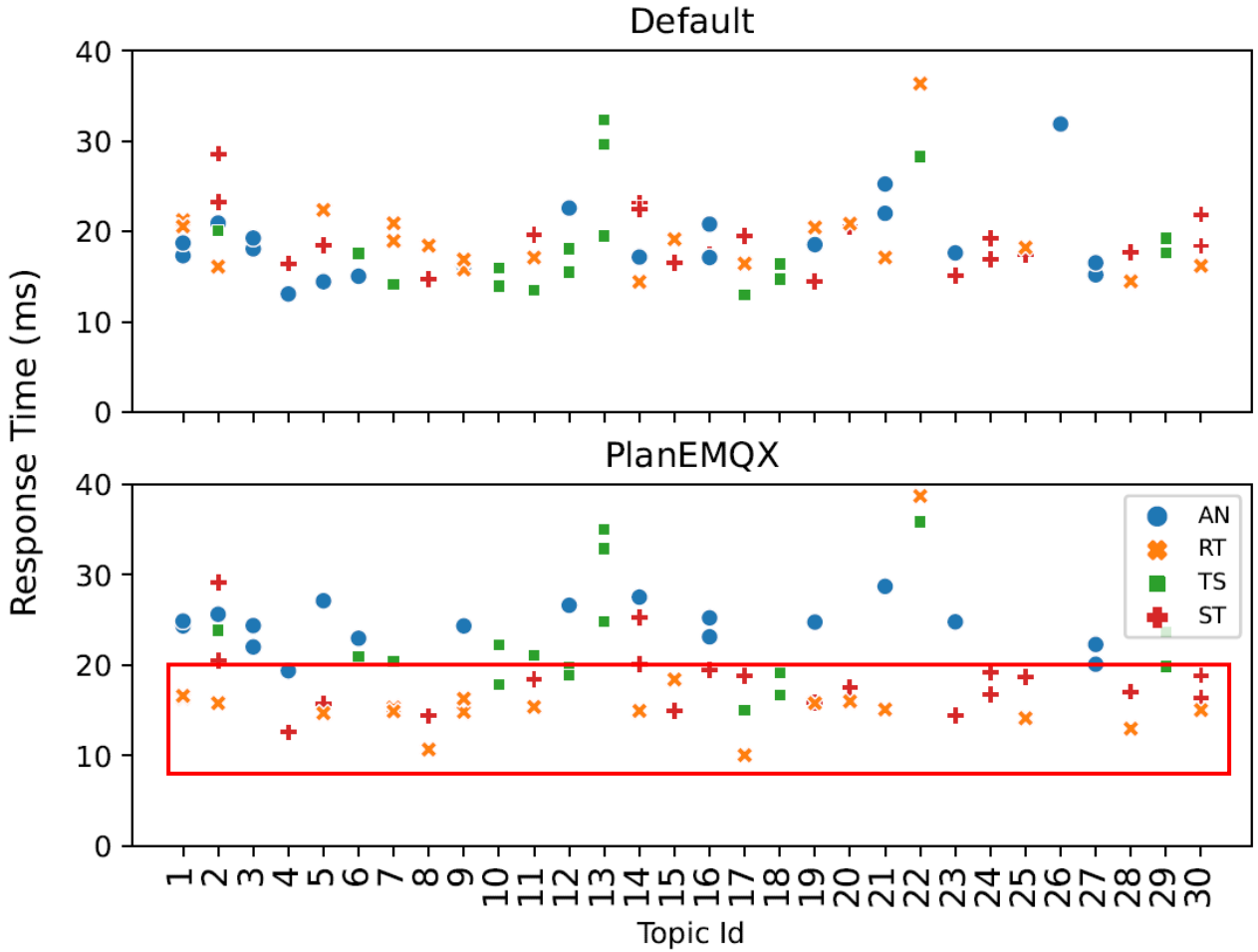
Average response time per app. category



Response times per app. Category box plot

Experimental Results

PlanEMQX Evaluation

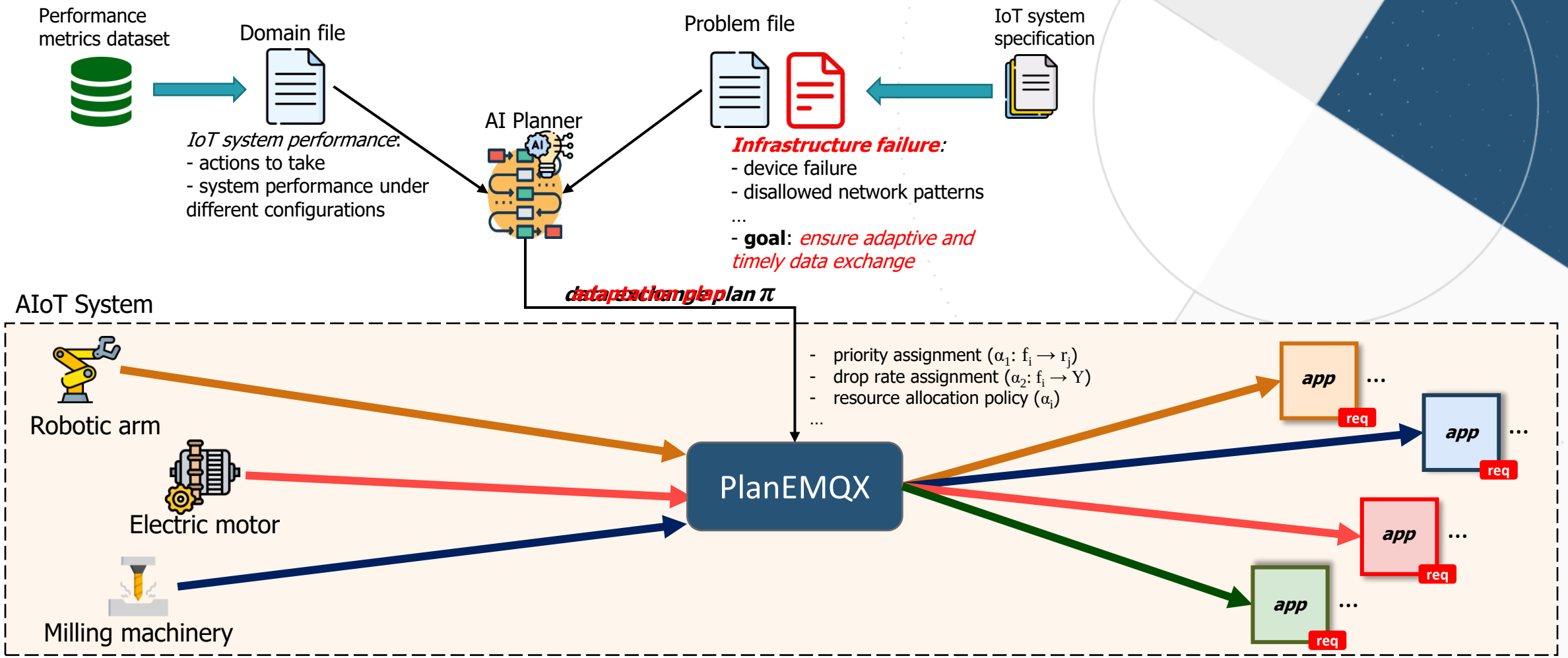


Response time per subscription

For the same topic, PlanEMQX achieves to deliver messages according to the subscribers' QoS requirements

PANDORA (https://pandora-heu.eu)

Using PlanEMQx in the Horizon EU PANDORA[1] Project



Key Takeaways and Future Directions

- We propose a novel message broker architecture for adaptive data exchange in IoT environments.
- **An automated configuration planner is** used to configure and adapt IoT data exchange in dynamic situations.
- The PlanEMQX code is publicly available on: https://github.com/satrai-lab/planemqx

Future Work:

- How to effectively predict the changes in the IoT system *before* they happen?
- How to adapt the system in response to *unseen changes*?

Thank you!

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