cloud.iO Introduction

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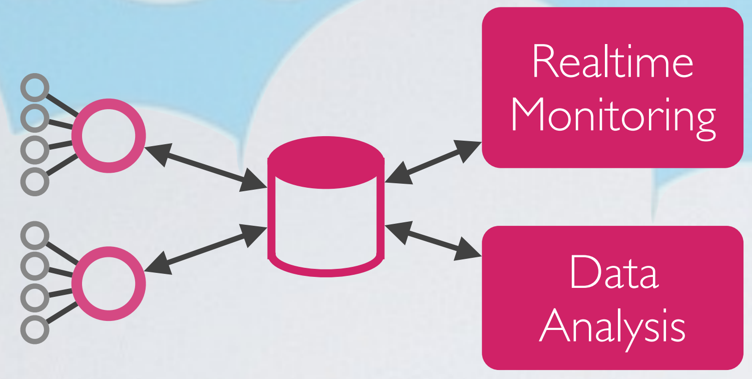
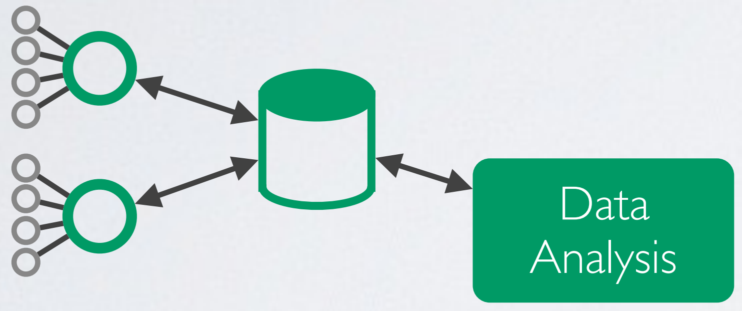
cloud.iO

Why cloud.iO?

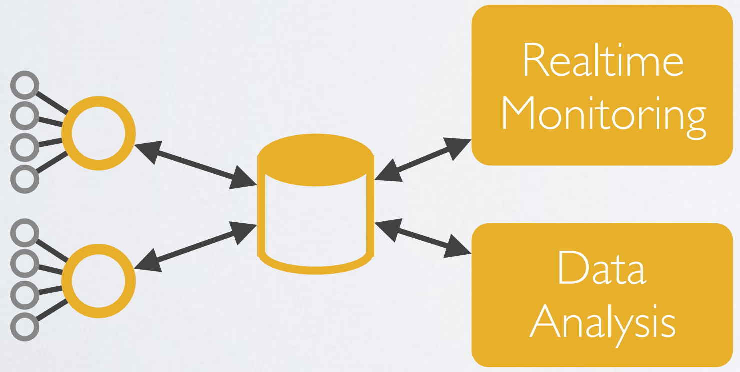
Motivation for **cloud.iO**



My Solution

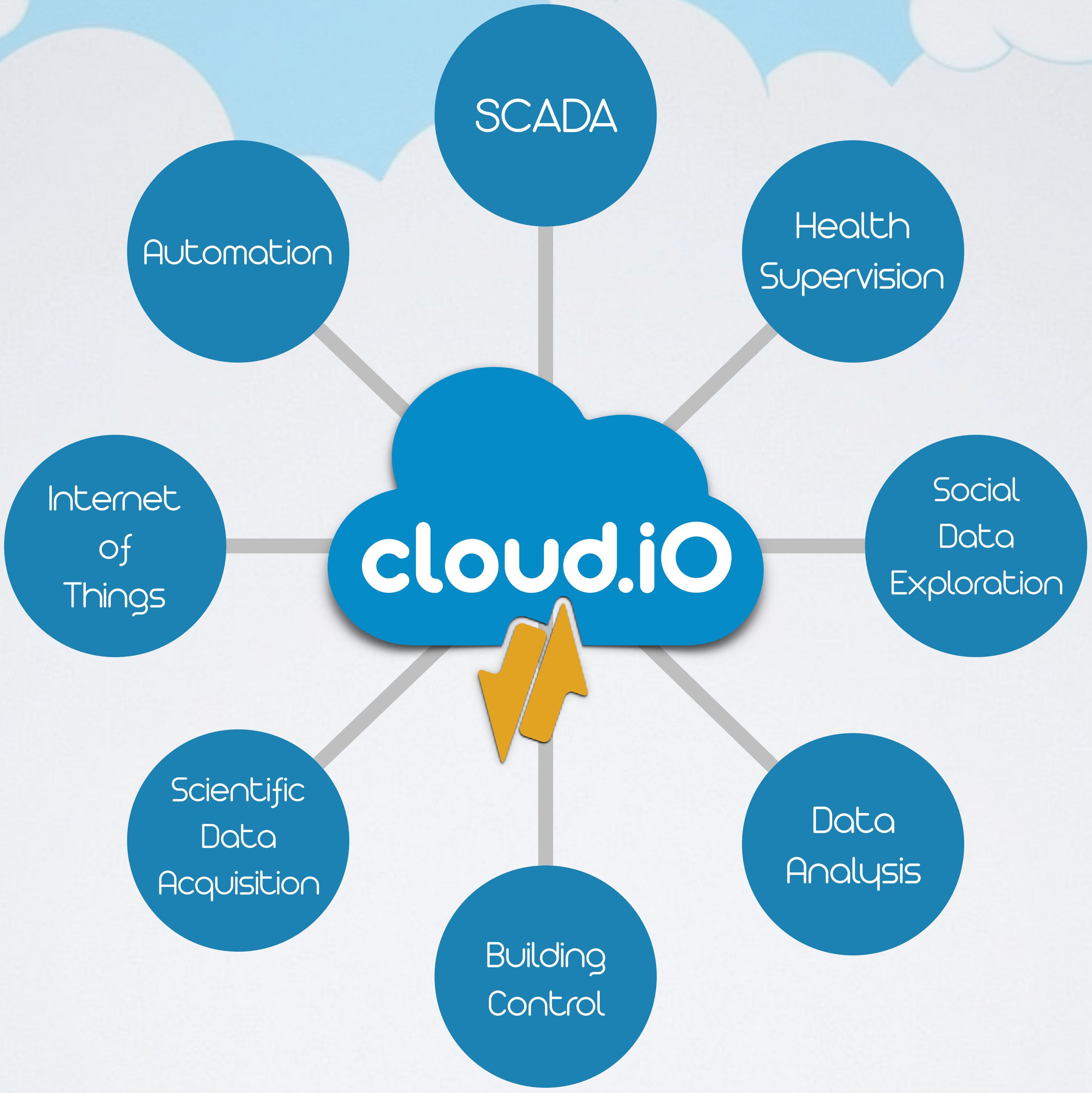


Colleague A Solution



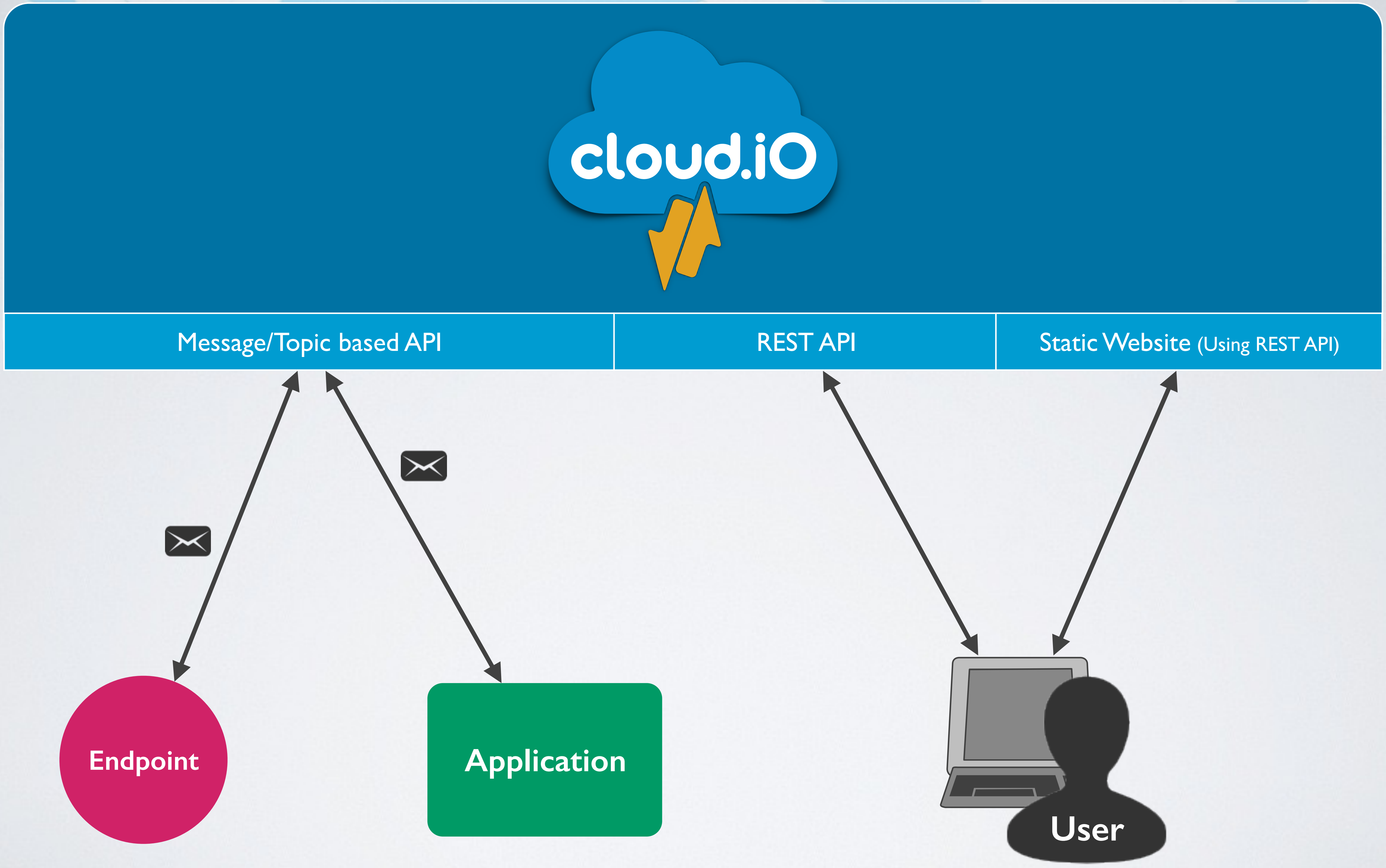
Colleague B Solution

- **Our problems:**
  - Each time a new solution for similar problems is developed.
  - There is not that much budget to create a stable/flexible solution.
  - Data analyst has to work each time with different systems.
  - Data of different projects are not simple to compare and may have to be converted first.
  - Scientists can not easily share their data with others.
  - Control often is not possible, as the data passes by a database.
  - Monitoring is mostly very inefficient (Database Polling for example)

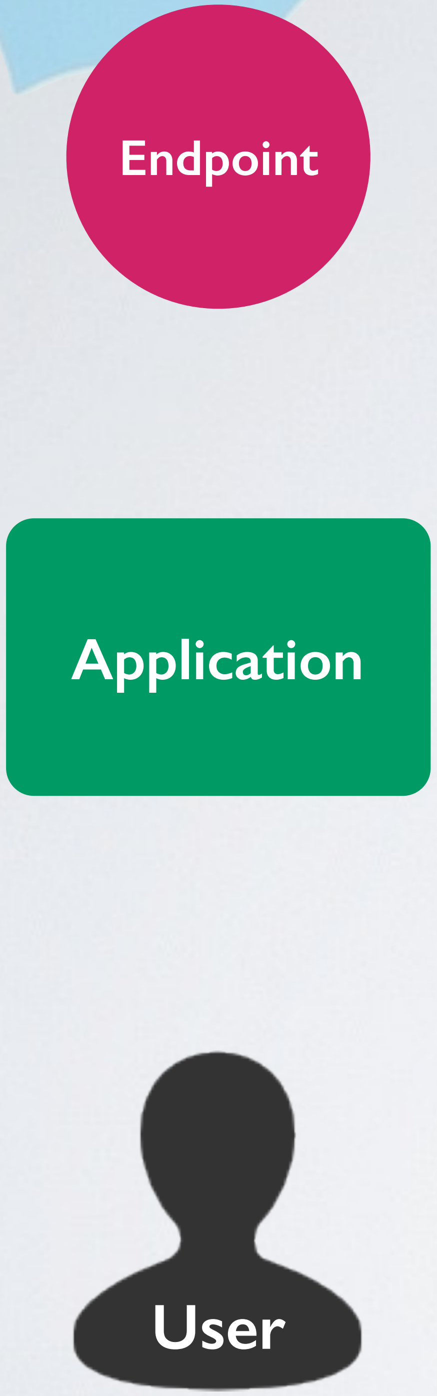

SCADA
Automation
Health Supervision
Internet of Things
cloud.iO
Social Data Exploration
Scientific Data Acquisition
Data Analysis
Building Control

cloud.iO Concepts

Overview


cloud.iO
Message/Topic based API
REST API
Static Website (Using REST API)
Endpoint
Application
User

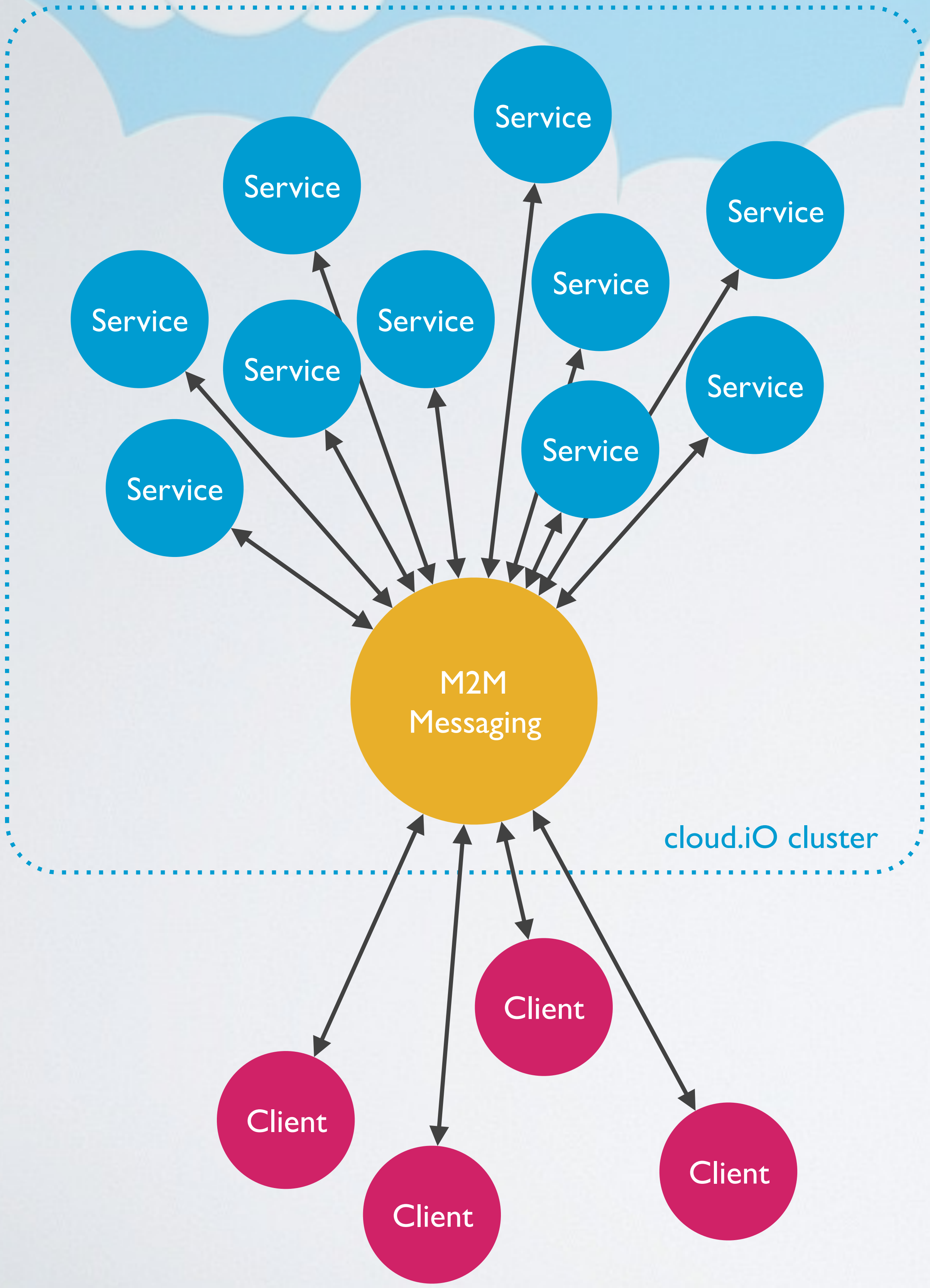
Actors



- **Endpoint**
  - Publishes it's complete data model.
  - Sends messages when some data of the model changes.
  - Some data can be modified from the outside (control, parameters).
- **Application**
  - Has access to a subset of all „Endpoints" data models.
  - Can search for actual data using schemes (interfaces, data-classes).
  - Can get actual and historical data for „Endpoints".
  - Can control set points and parameters of „Endpoints".
- **User**
  - Owns one or more „Endpoints".
  - Can give access to Endpoint or part of them to other users.
  - Can give access to Endpoint or part of them to applications.
  - Can write his own applications.
  - We actually do not distinguish between different kind of users (Simple users, developers, …)

cloud.iO Components

Message based Microservice Architecture

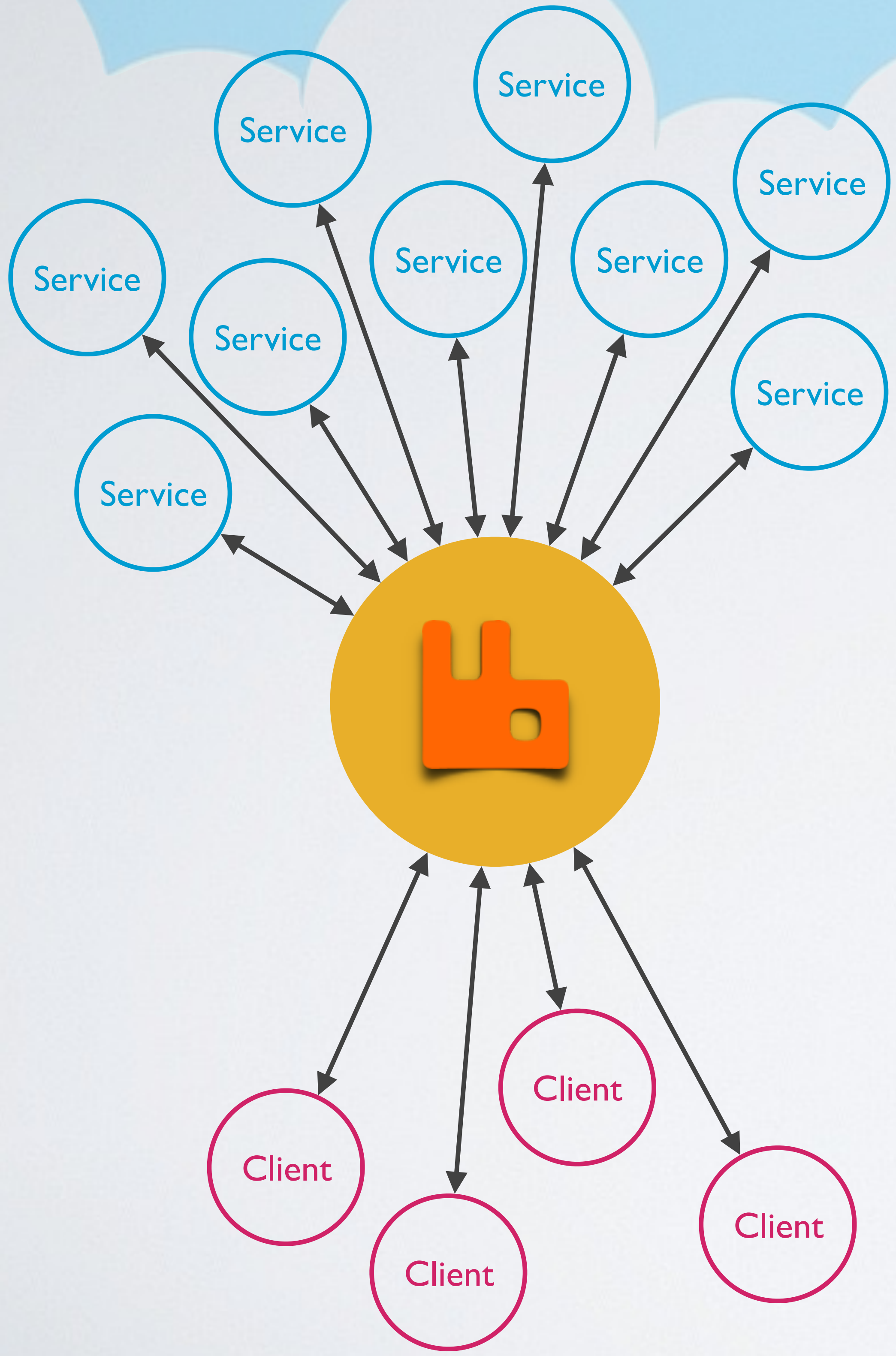


- **Simplicity**
  - A complex system can be composed by a lot of simple services.
  - Most services are stateless.
- **Scalability**
  - Services can be spread over multiple nodes.
  - Services under high load can be dynamically deployed to additional cluster nodes.
- **Extensibility**
  - System can be extended by new services or services can be modified without any downtime of the system.

Microservice Platform – **Spring.io**

- Lightweight framework to build Java Enterprise applications.
- Inversion of Control.
- Dependency injection (Decoupling components).
- A ton of libraries to facilitate the developers work.
- Excellent AMQP support.
- Excellent MongoDB support.
- Open source.

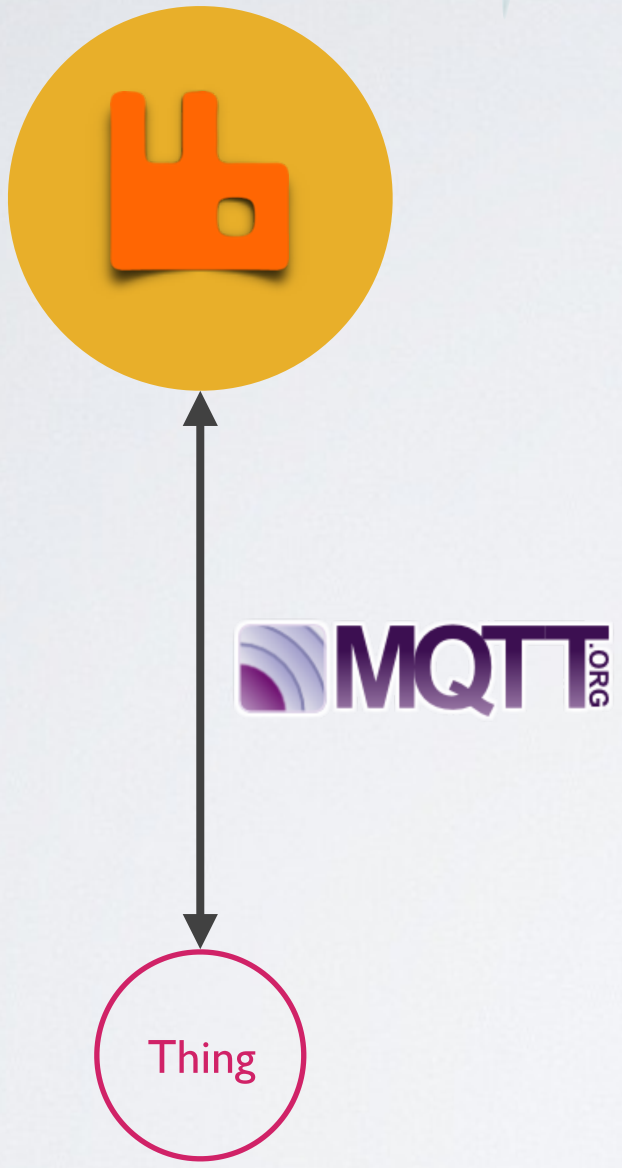
Message Broker - **RabbitMQ**



- Very powerful **AMQP** & **MQTT** (among others) message broker.
- Stable and broadly used in production (Instagram as an example).
- Flexible message routing.
- Scalable (high availability cluster).
- Open source.
- User authentication and access rights possible using multiple backends.

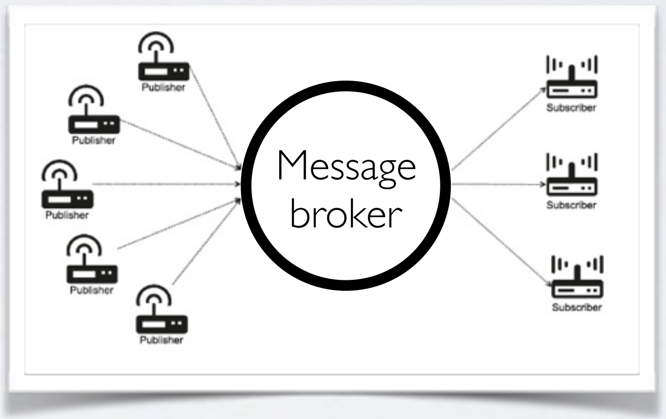
http://www.rabbitmq.com

Endpoint connectivity – MQTT



Message **Q**ueue **T**elemetry **T**ransport

- Simple message based protocol.
- Builds on top of TCP (SSL).
- Publish-Subscribe architecture.



- Binary protocol with minimal overhead.
- Designed for low bandwidth and unreliable networks.
- Data agnostic.
- Open source.

http://mqtt.org

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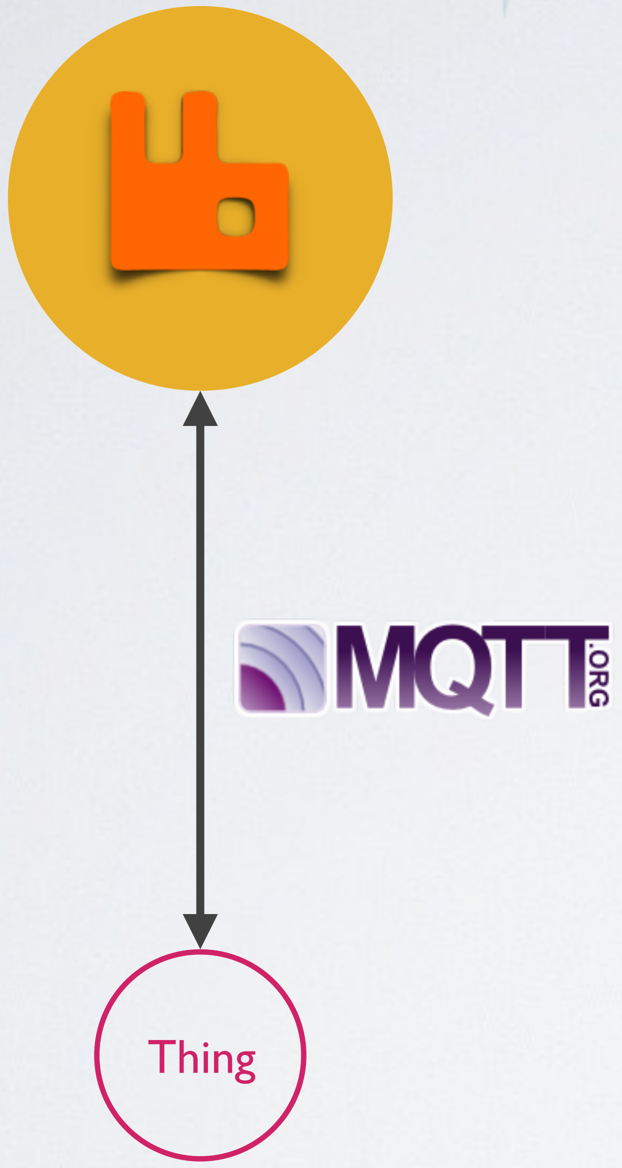
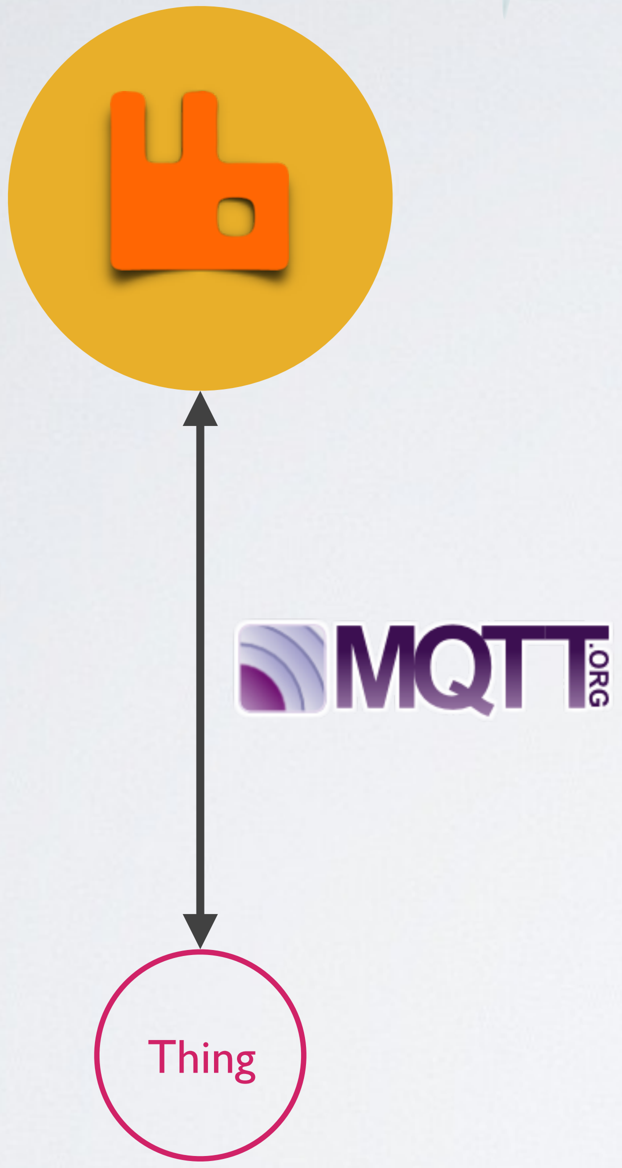
Endpoint connectivity – **MQTT** (2)



- **Use Cases**
  - Push instead of poll.
  - Bandwidth is a premium.
  - Possible to interact with enterprise applications.
  - Reliable delivery of messages over unreliable networks.
  - Constrained devices.
  - Low latency.

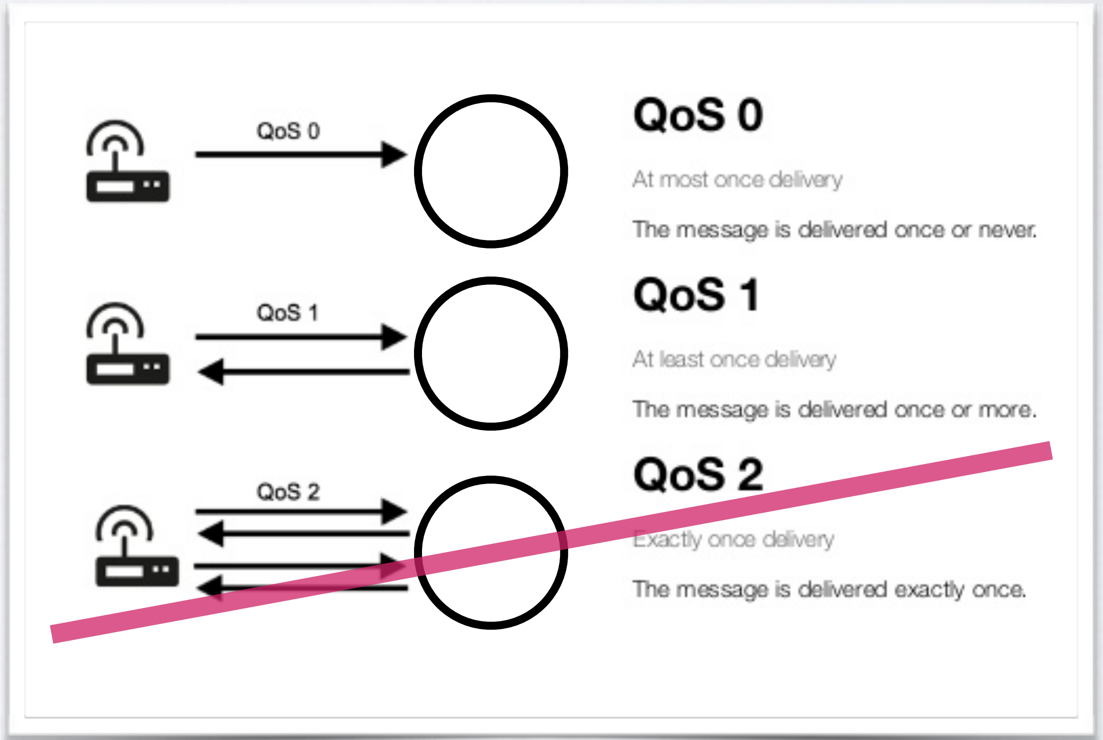
- **Features**
  - Topic Wildcards.
  - 3 Quality of service levels:
  - Retained messages.
  - Last will and testament.
  - Persistent sessions.

Endpoint connectivity - **MQTT** (3)



- **Security**
  - Username | Password authentication.
  - x509 certificate based authentication using TLS.
  - Payload encryption using TLS.

- **Quality of Service**

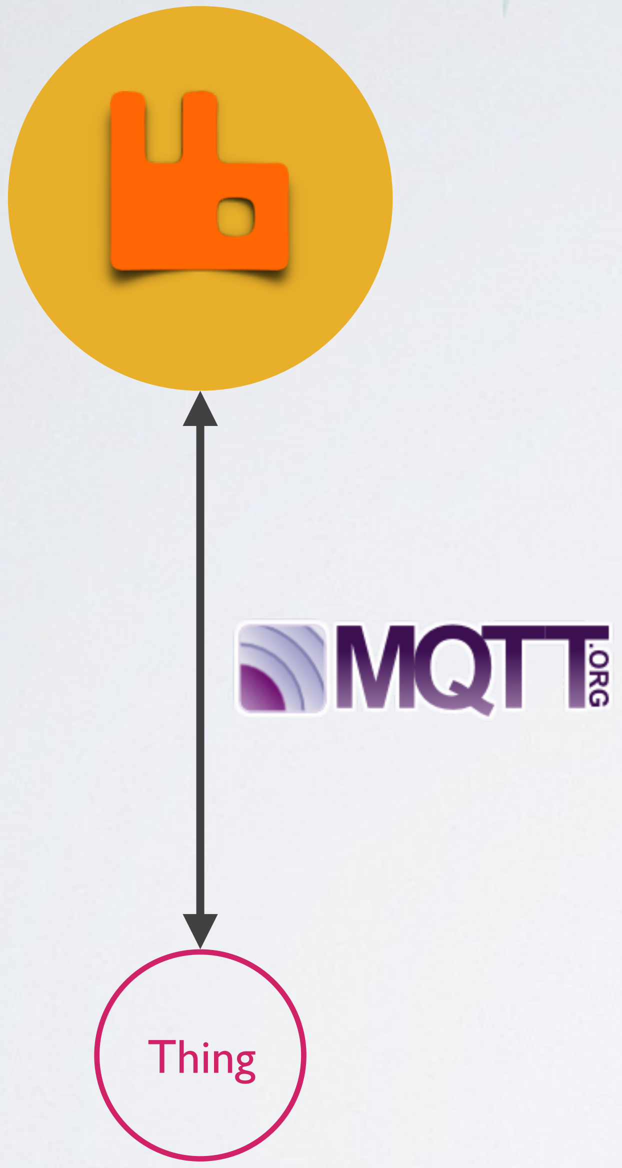


QoS 0
At most once delivery
The message is delivered once or never.

QoS 1
At least once delivery
The message is delivered once or more.

~~**QoS 2**~~
~~Exactly once delivery~~
~~The message is delivered exactly once.~~

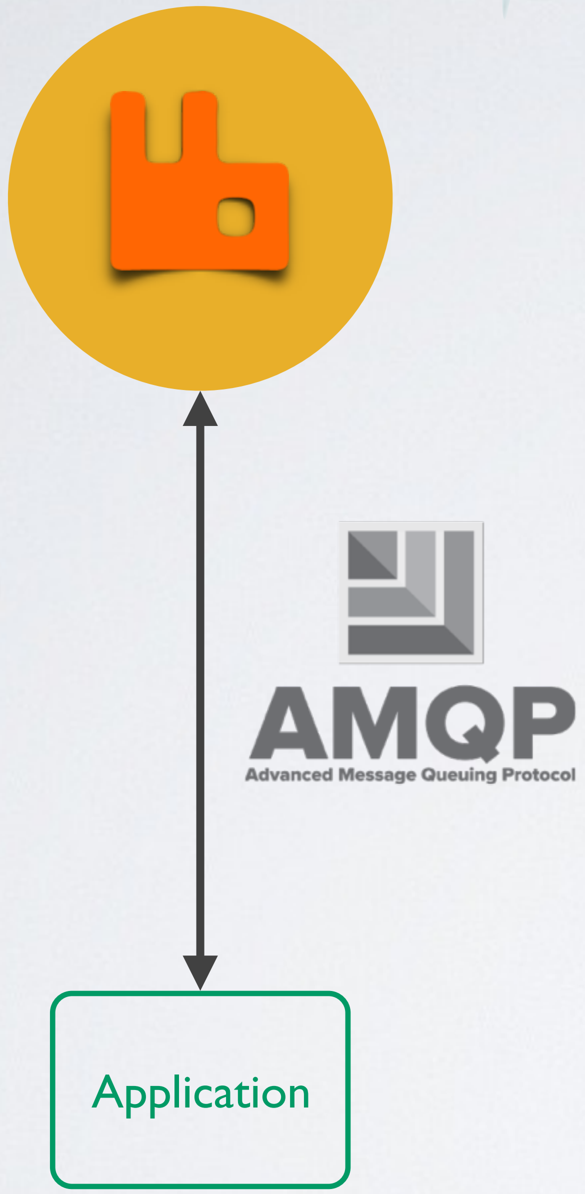
Endpoint connectivity - MQTT (4)



- **Last will and testament**
  - Clients can specify a Last will and testament.
  - Broker publishes the LWT message on behalf of the client on „death".
  - Useful for reporting problems.
  - Real push on device „death".
  - Mostly used for reporting the connection status of a publisher.

- **Client libraries**
  - paho project
    - C, C++, Go, Java, Javascript, Lua, Python
  - Other languages
    - ActionScript, Clojure, Dart, Delphi, Erlang, Node.js, LotusScript,.NET, Objective-C, Perl, PHP, REXX ,Ruby ,Tcl
  - Devices
    - Arduino, mbed, Nonode, Netduino

Application connectivity - **AMQP**

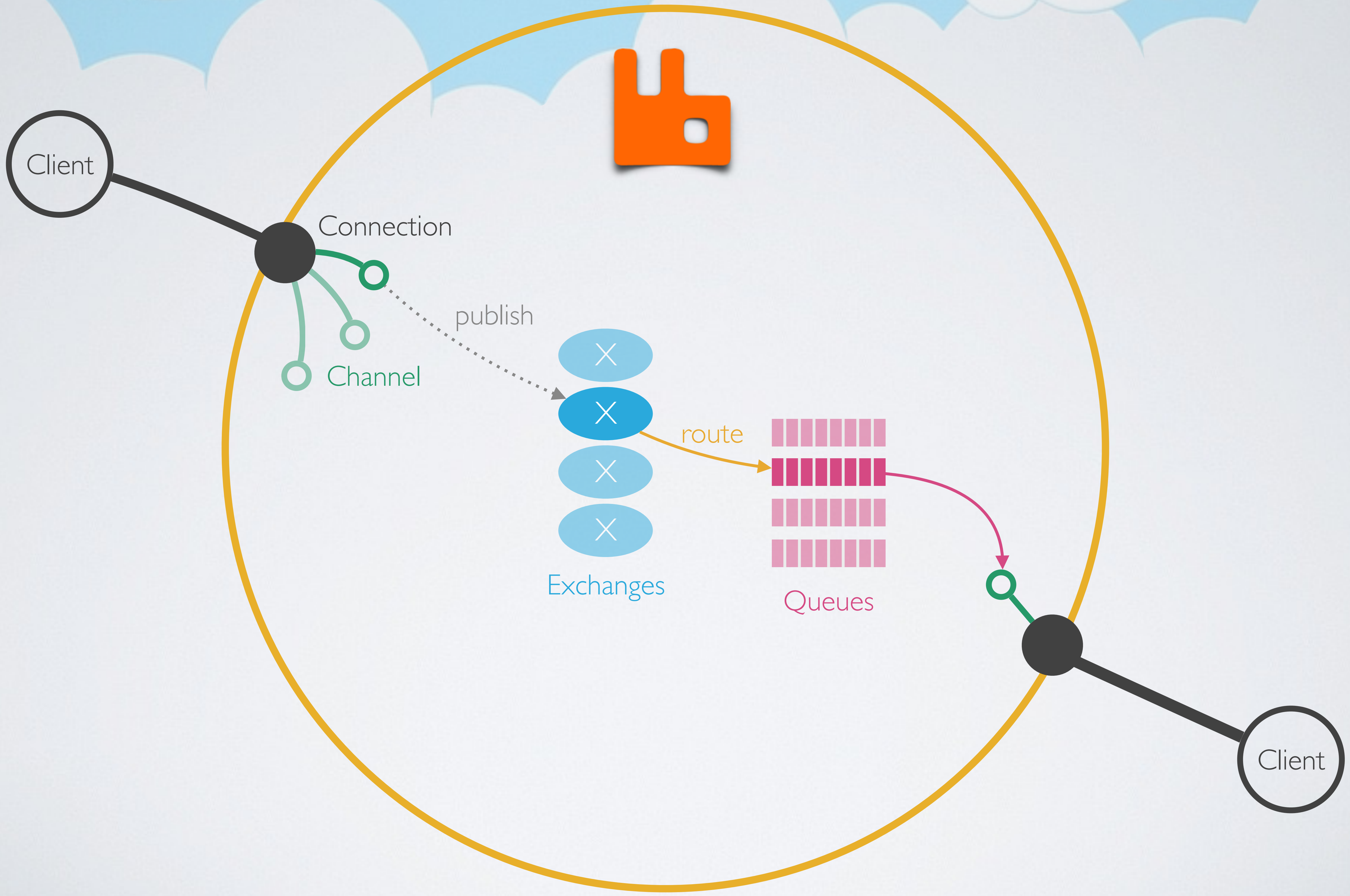


Advanced **M**essaging **Q**ueue **P**rotocol

- Open standard for passing business messages between different applications / processes.
- Can be used to scale the system (multi-process, multi-host).
- Very flexible message routing and queuing.
- Queuing of messages can be used to avoid the need for buffer DB's for load peaks.
- Mixing of different programming languages possible in order to be able to use an adapted language for a given job.
- **RabbitMQ** uses AMQP at its core.

http://www.amqp.org

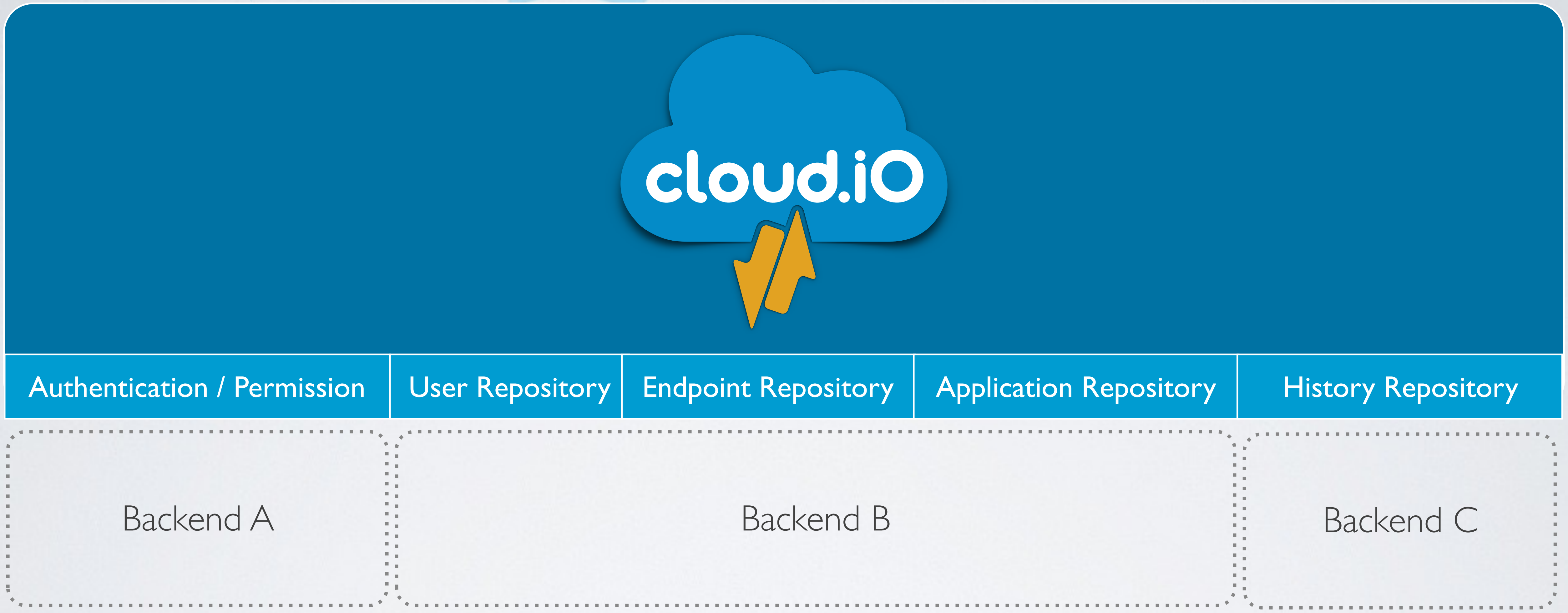
Application connectivity - **AMQP** (2)



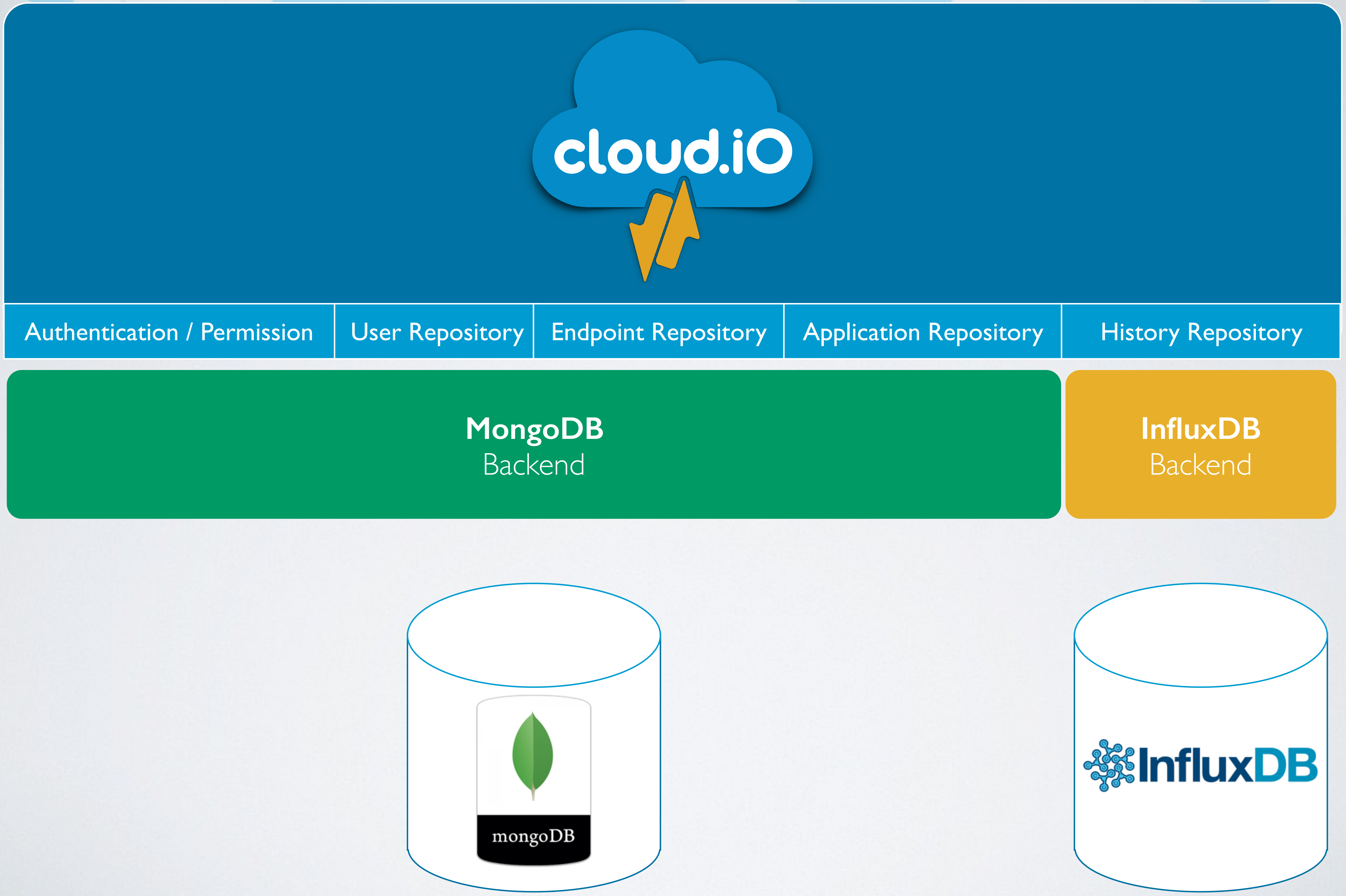
Topic Syntax – **AMQP** vs. **MQTT**

`toto.lala.doe`	`toto/lala/doe`
`toto.*.doe`	`toto/+/doe`
`toto.#`	`toto/#`

Data Backends

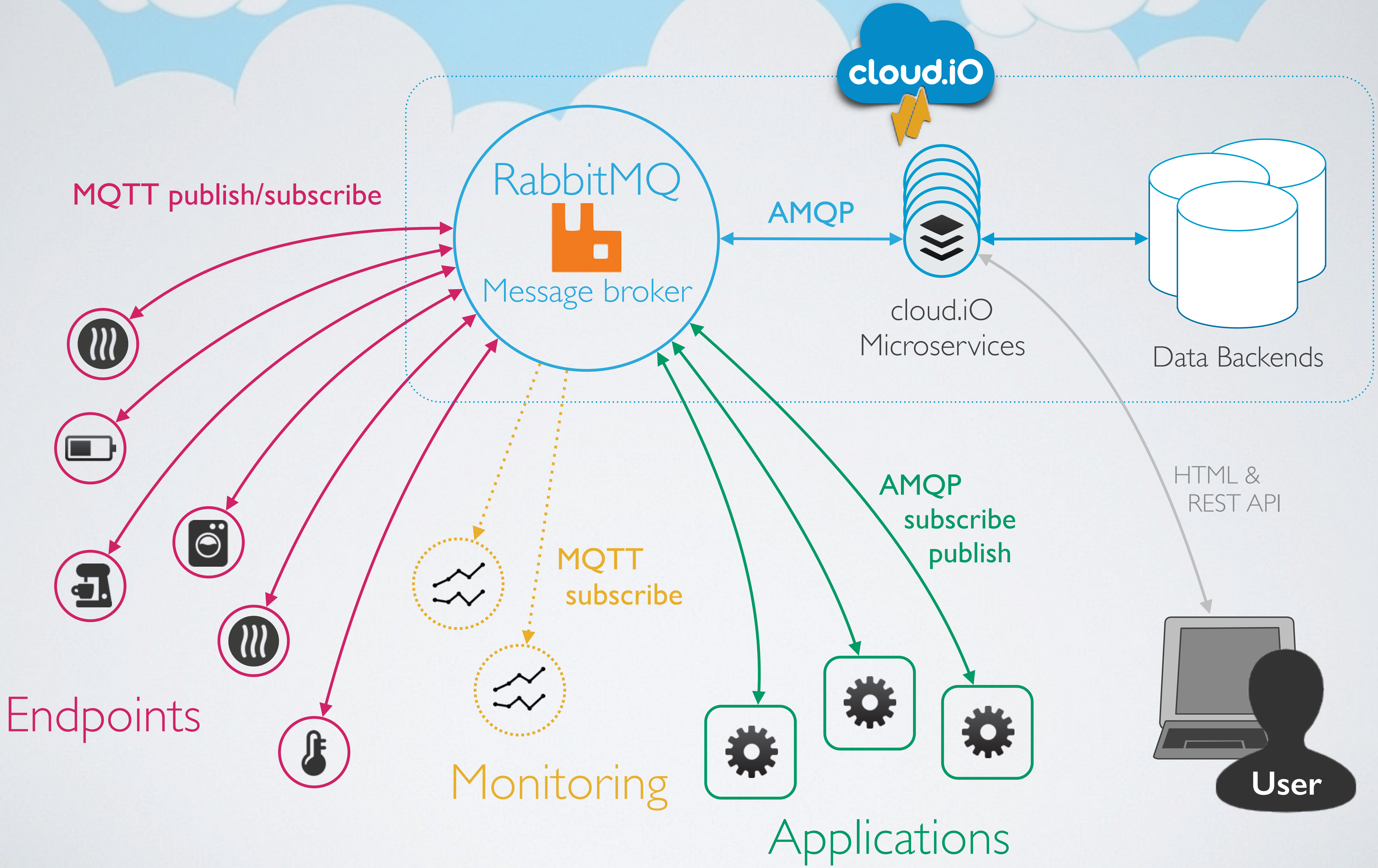


Data Backends (2)

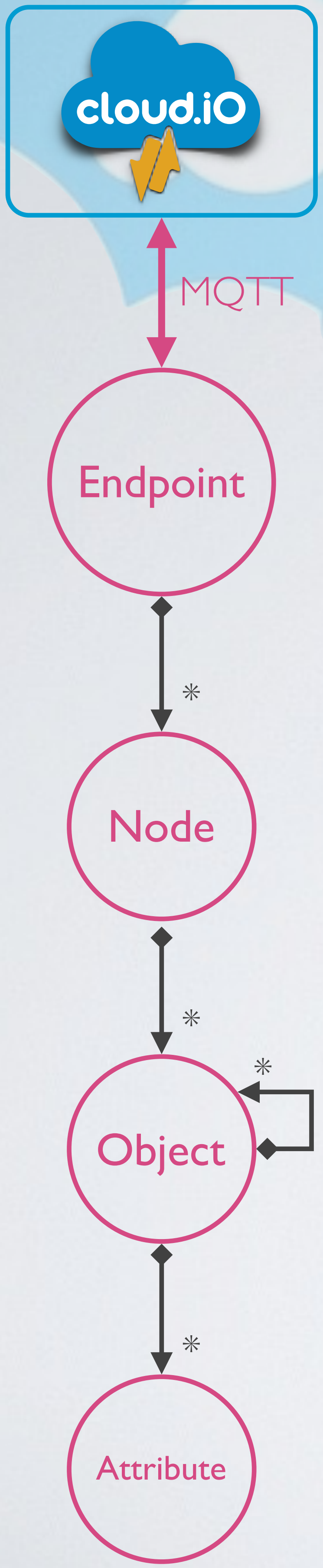


cloud.iO Architecture

Overview


cloud.iO
RabbitMQ
Message broker
AMQP
cloud.iO
Microservices
Data Backends
MQTT publish/subscribe
Endpoints
MQTT
subscribe
Monitoring
AMQP
subscribe
publish
Applications
HTML &
REST API
User

Endpoint structure



D640cdd70-1bdb-11e4-8c21-0800200c9a66

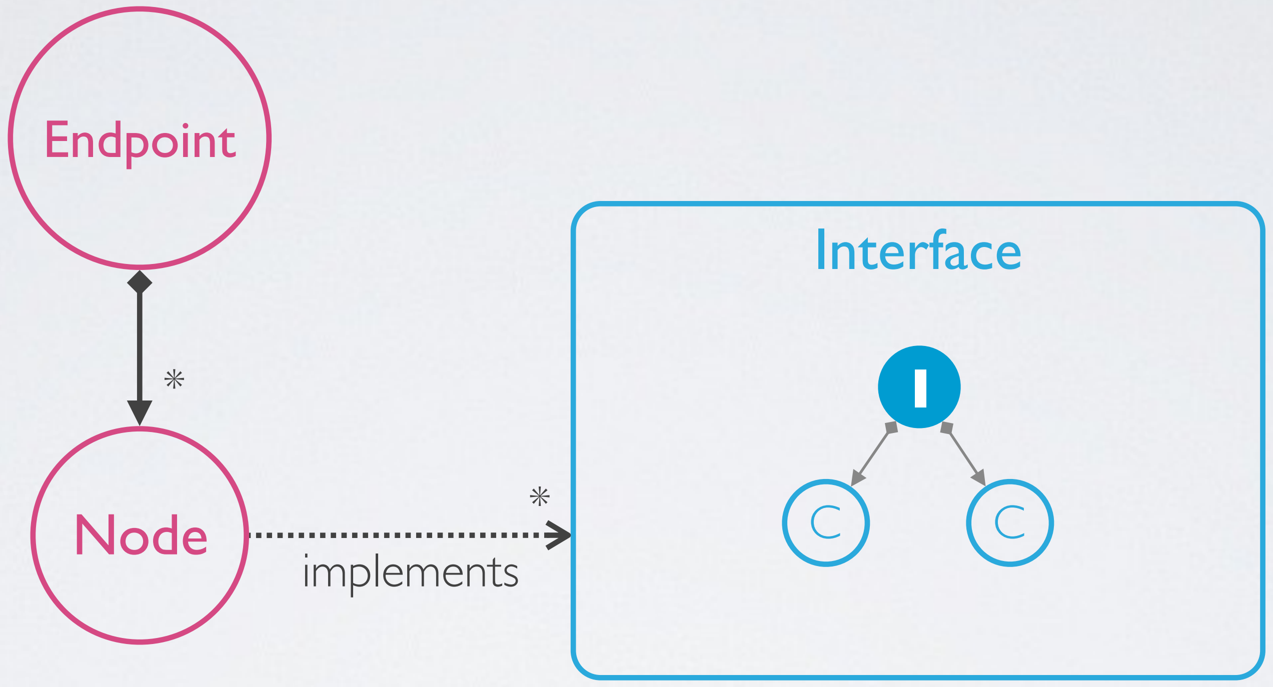
D640cdd70-1bdb-11e4-8c21-0800200c9a66**/nodes/Heat-Pump**

D640cdd70-1bdb-11e4-8c21-0800200c9a66/nodes/Heat-Pump/**objects/Status**

…1e4-8c21-0800200c9a66/nodes/Heat-Pump/objects/Status/**attributes/Active**

Node interfaces

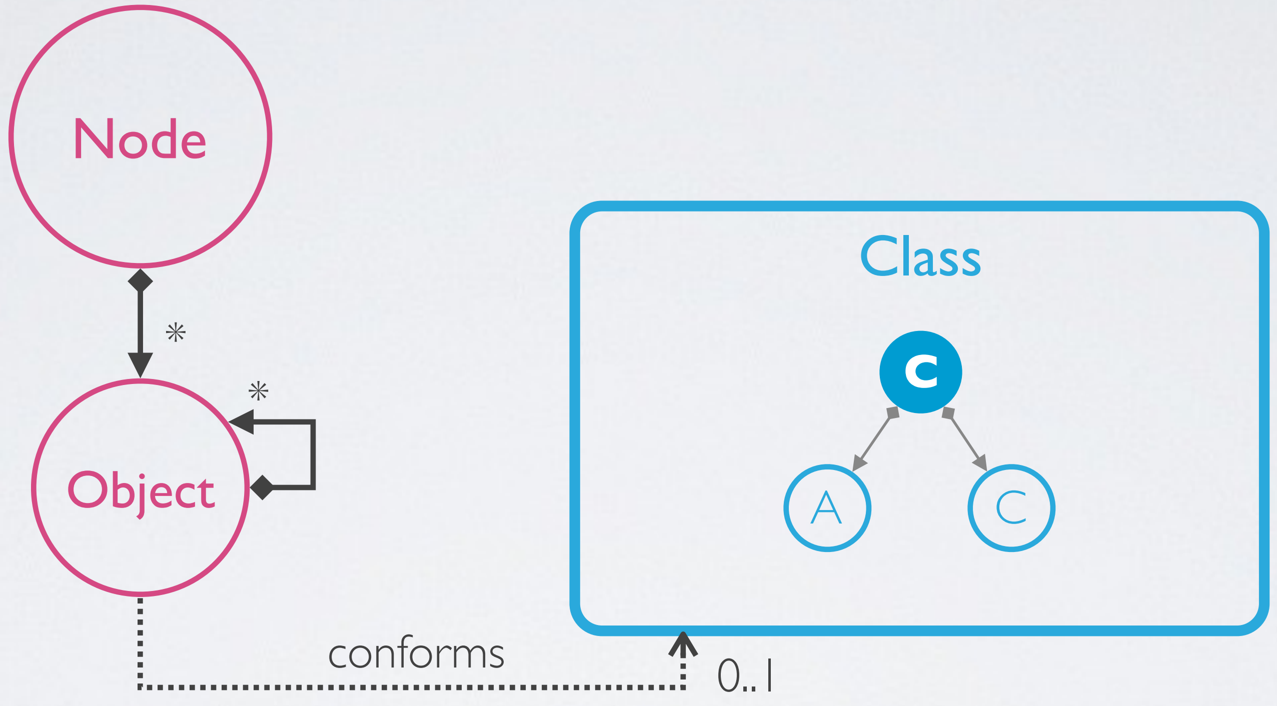
- Node structure is theoretically completely free, classification can be done using **interface** definitions:



- An **interface** defines which **object classes** a given node has to offer among others.
- A node can implement any number of **interfaces**.
- The actual structure of a node is fix and can not be changed once the node has been added to the Endpoint.

Object classes

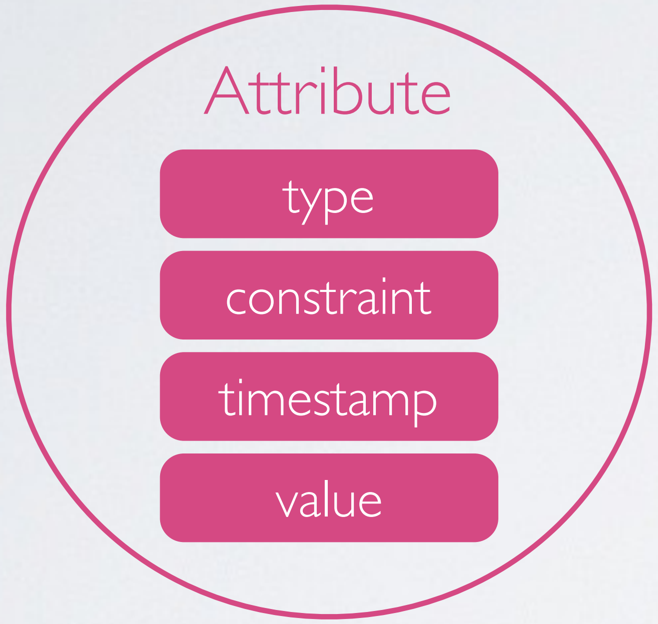
- In order to enable the reuse of object definitions, **classes** for common object structures can be defined:



- A **class** defines the exact structure of child **object classes** and **attributes** a given object has to be composed of.
- An object can only conform to no or exactly one **class**.
- Classes can contain other classes, this enables hierarchical structures.

Attributes

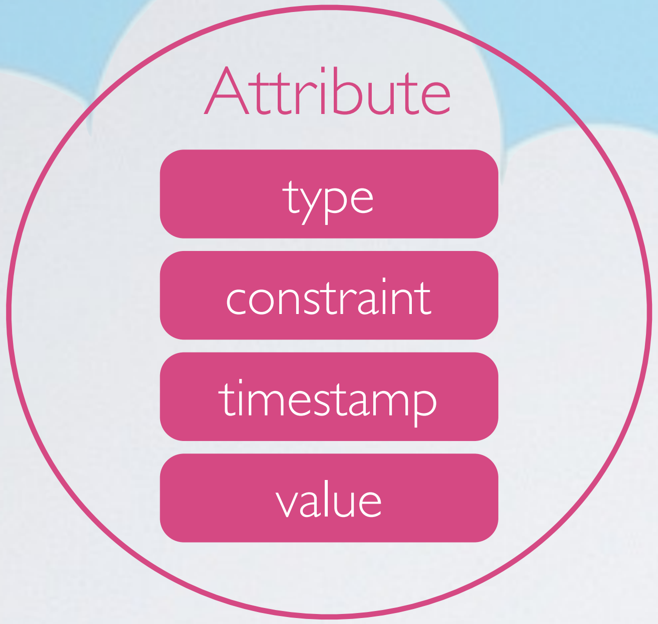
- Attributes are the very atomic elements objects are made of.
- Attributes always have four fields:



```
{
  „type“: „Number“,
  „constraint“: „Measure“,
  „timestamp“: 45878945.457,
  „value“: 19.2
}
```

- The constraint defines the actual kind of an attribute:
  - **Static**: Static value, never changes, read-only. For example manufacturer, model, serial number…
  - **Status**: Read-only value representing a state or a calculated value.
  - **Measure**: Read-only value representing an actual measure made by the device.
  - **Parameter**: Parameter that can be written to, changes the configuration of the device.
  - **SetPoint**: An output or a set point of a local regulation. Temperature threshold for example.

Attributes (2)



```
{
  „type“: „Number“,
  „constraint“: „Measure“,
  „timestamp“: 45878945.457,
  „value“: 19.2
}
```

- The timestamp is in seconds since epoch
  - In order to support sub-second resolution of time, the timestamp can be optionally of floating point type.
- The value has to be of a given type:
  - Basic Types: **`Bool`, `Integer`, `Number`, `String`**
  - Complex Types: **`Bool[]`, `Integer[]`, `Number[]`, `String[]`**

Topic / Content relation

Topic:
@UPDATE/D640cdd70-1bdb-11e4-8c21-0800200c9a

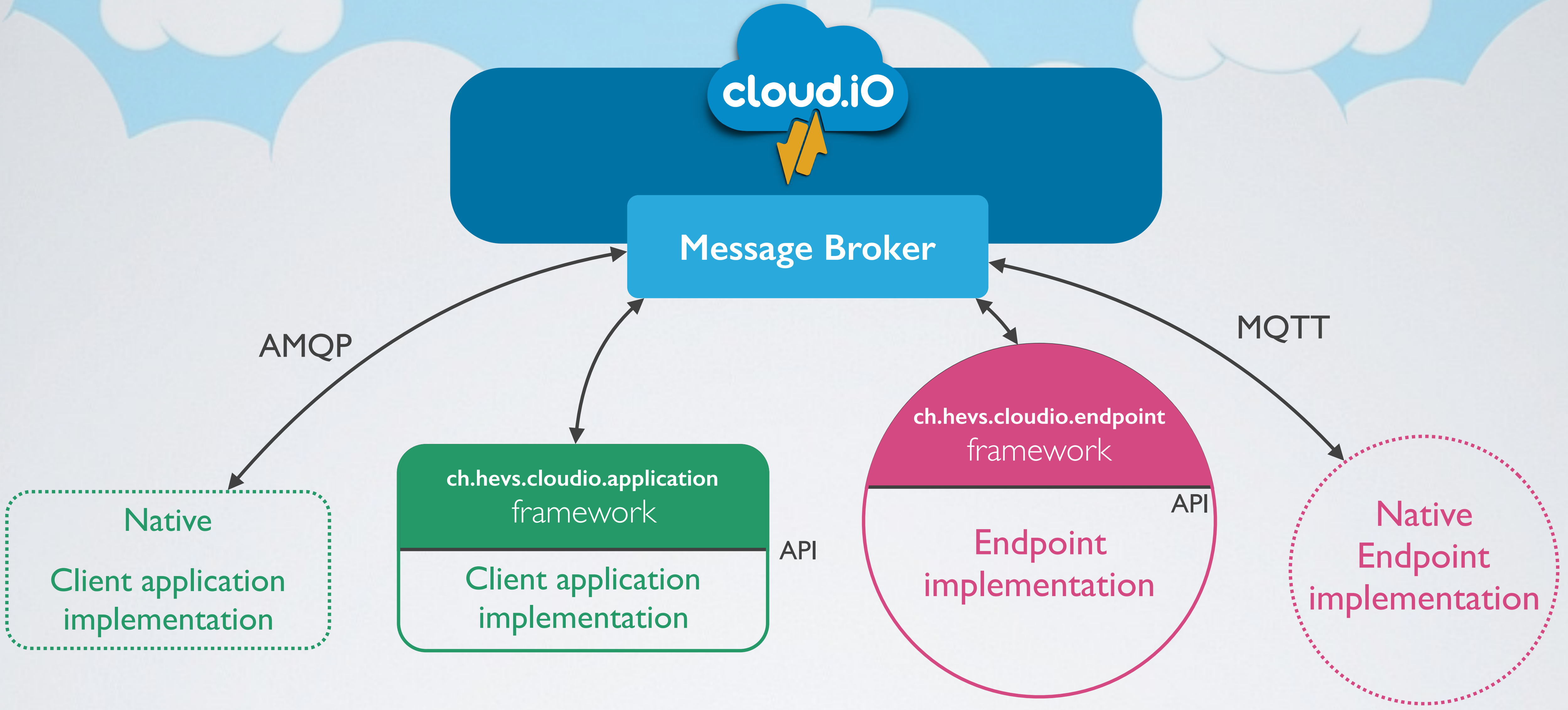
```
{
  „uuid“: „640cdd70-1bdb-11e4-8c21-0800200c9a66“,
  „nodes“: {
    „Meteo“: {
      „implements“: [„MeteoStation“],
      „objects“: {
        „temperatures“: {
          „conforms“: null,
          „objects“: {
            „inside“: {
              „conforms“: „TemperatureMeasure“,
              „attributes“: {
                „unit“: {
                  „constraint“: „Static“,
                  „timestamp“: null,
                  „value“: „K“
                },
                „temperature“: {
                  „type“: „Number“,
                  „constraint“: „Measure“,
                  „timestamp“: 45878945.457,
                  „value“: 19.2
                }
              }
            }
          }
        }
      }
    }
  }
}
```

Topic:
@UPDATE/D640cdd70-1bdb-11e4-8c21-0800200c9a/nodes/Meteo/objects/temperatures/objects/inside/attributes/temperature

```
{
  „TYPE“: „Number“,
  „constraint“: „Measure“,
  „timestamp“: 45878945.457,
  „value“: 19.2
}
```

- It is possible to send just a subset of a device data model
- The topic reflects the path to the content in the complete device data model.

Endpoint & Application frameworks



- The messaging API between the actors in IoT cloud can be completely hidden by the application frameworks, however the messaging API is defined too in order to allow „native“ endpoints and applications.
- The application or endpoint developer does not necessary need to have any knowledge of the messaging system behind the scenes,.
- The messaging system can be changed at any time without the need to rewrite the application and endpoint software if the frameworks are used.

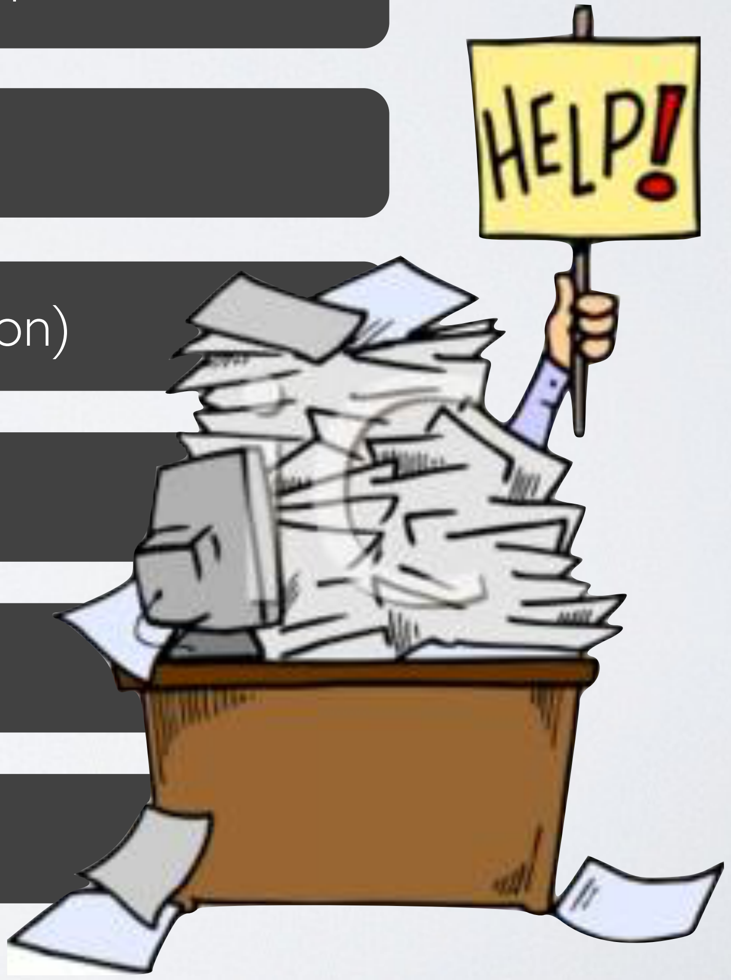
cloud.iO Status & Roadmap

Open source

https://github.com/cloudio-project

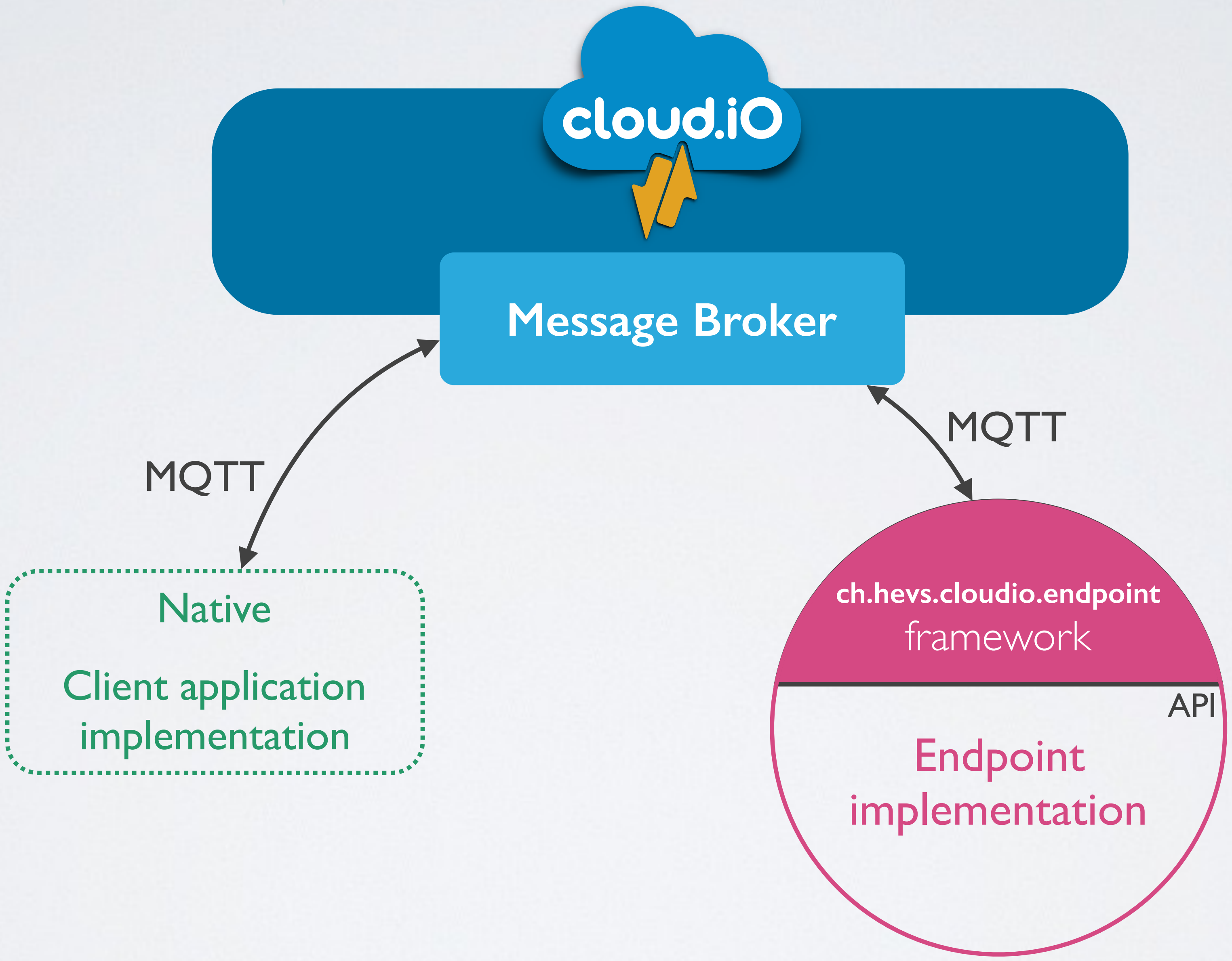
Status & Roadmap

- ✓ Security/Privacy related modifications to RabbitMQ
- ✓ Proof of concept Cloud implementation
- ✓ Endpoint API (Java)
- ✕ Cloud implementation including default data backends
- ✕ Formal topic and message specification
- ✕ Application & Monitoring API (Java)
- ✕ API in other Languages (C, C++, Python)
- ✕ Management REST API
- ✕ Common data classes library (Java)
- ✕ Public documentation and examples



cloud.iO Example

Example


cloud.iO
Message Broker
MQTT
MQTT
Native
Client application implementation
ch.hevs.cloudio.endpoint
framework
API
Endpoint implementation

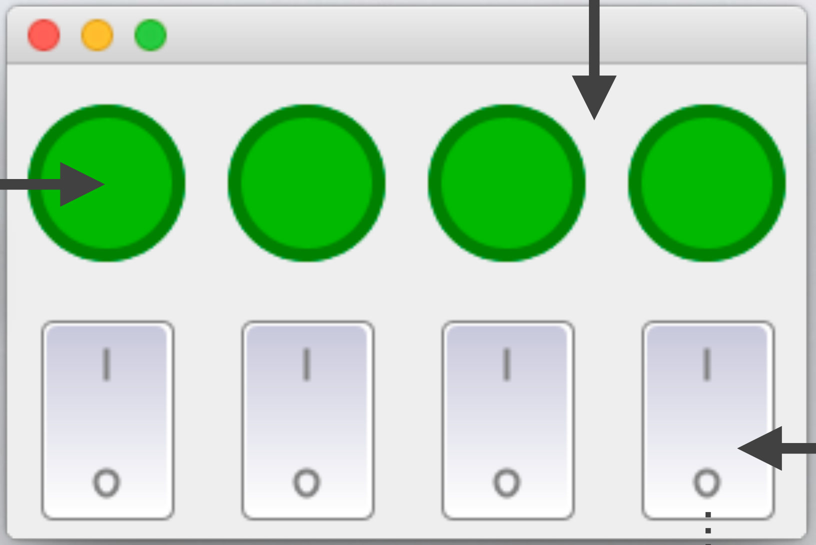
Given Application

JIoBoxFrame

```
public JIoBoxFrame(final int ioCount)
public JLed getLed(int index)
public JSwitch getSwitch(int index)
```

JLed

```
public void setState(boolean state)
```



JSwitch

```
public void setListener(JSwitchListener listener)
```

JSwitchListener

```
public interface JSwitchListener {
    void stateChanged(JSwitch jswitch);
}
```

Endpoint API Library

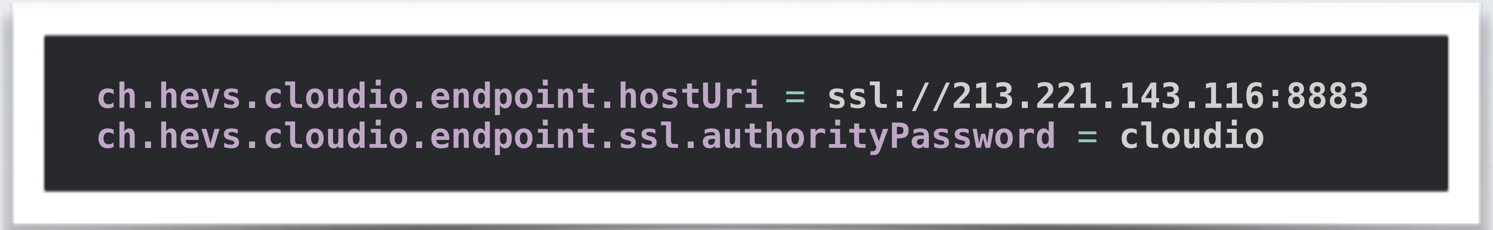
- One single artifact (Jar file)
- Very few dependencies
  - Paho
  - Jackson-core
  - Log4j

gradle

```
dependencies {
    compile 'ch.hevs.cloudio:cloudio-endpoint-java:0.1-SNAPSHOT'
}
```

Settings

- Loads configuration from Java Properties file
  - ~/.config/cloud.io/{Endpoint UUID}.properties
  - /etc/cloud.io/{Endpoint UUID}.properties
  - cloud.io/{Endpoint UUID}.properties inside the application bundle

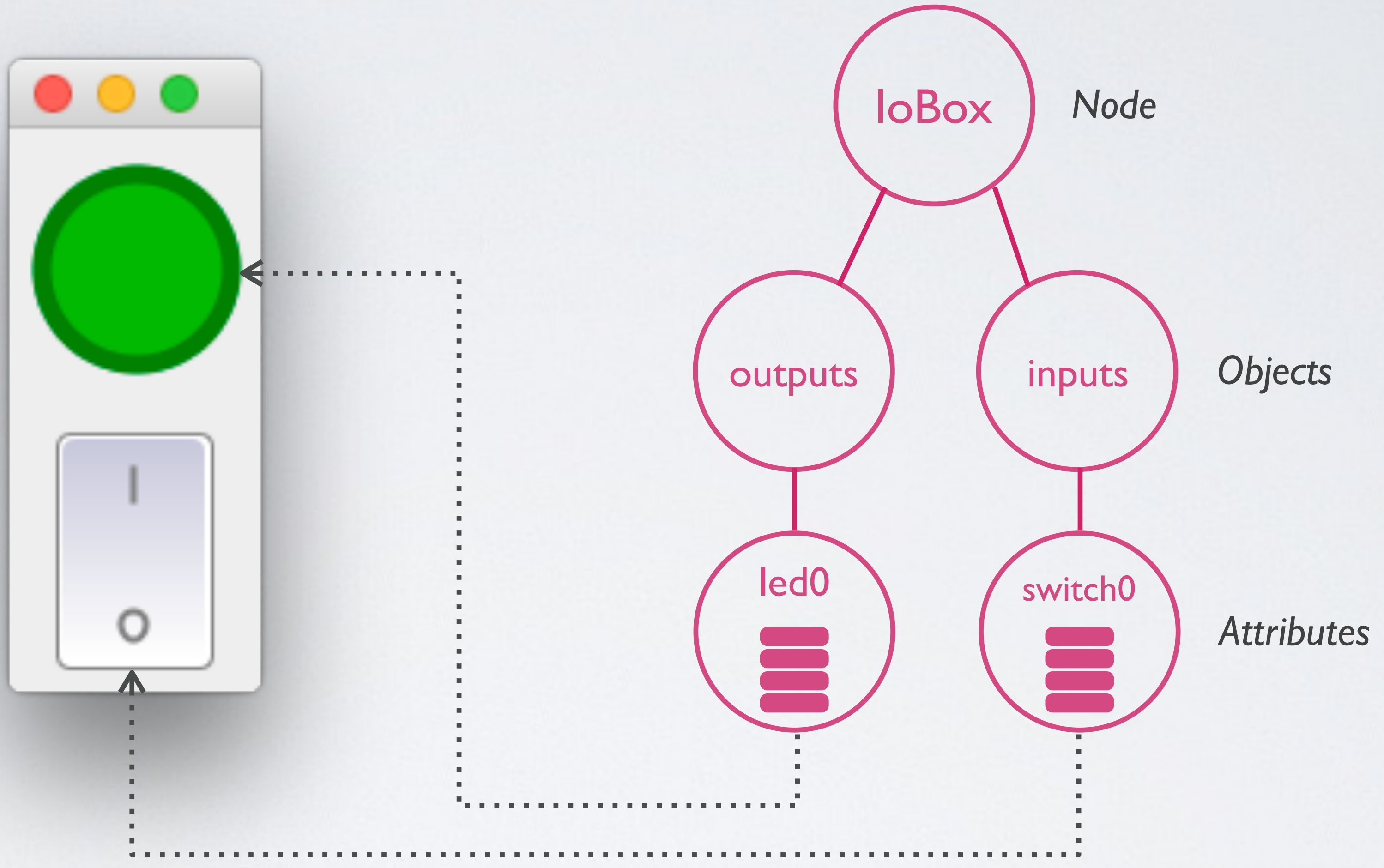


```
ch.hevs.cloudio.endpoint.hostUri = ssl://213.221.143.116:8883
ch.hevs.cloudio.endpoint.ssl.authorityPassword = cloudio
```

- Endpoint certificate is searched here:
  - ~/.config/cloud.io/{Endpoint UUID}.p12
  - /etc/cloud.io/{Endpoint UUID}.p12
  - cloud.io/{Endpoint UUID}.p12 inside the application bundle

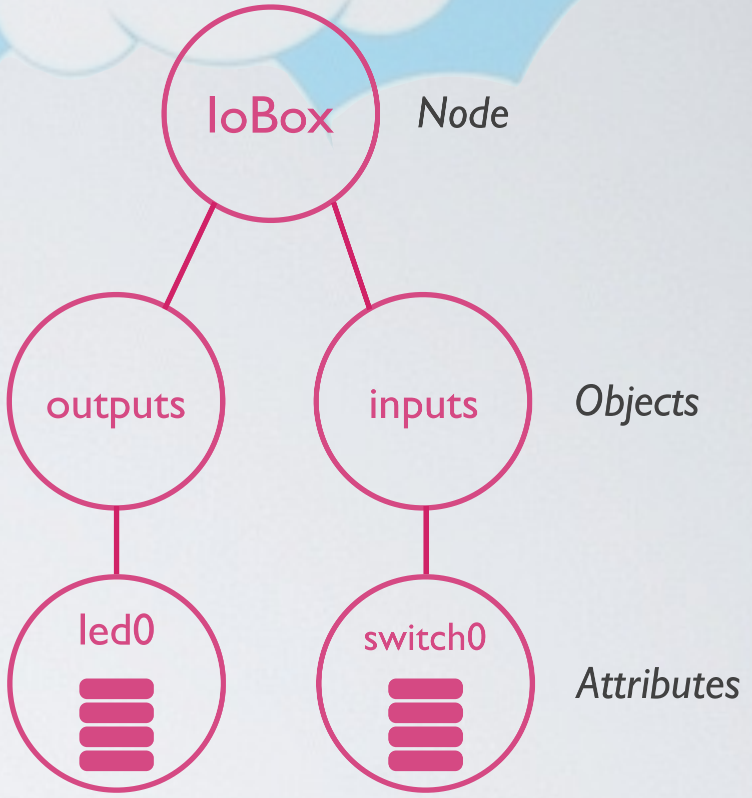
- Certificate authority certificate is searched here:
  - ~/.config/cloud.io/authority.jks
  - /etc/cloud.io/authority.jks
  - cloud.io/authority.jks inside the application bundle

Data Model


IoBox
Node
outputs
inputs
Objects
led0
switch0
Attributes

Data Model (2)

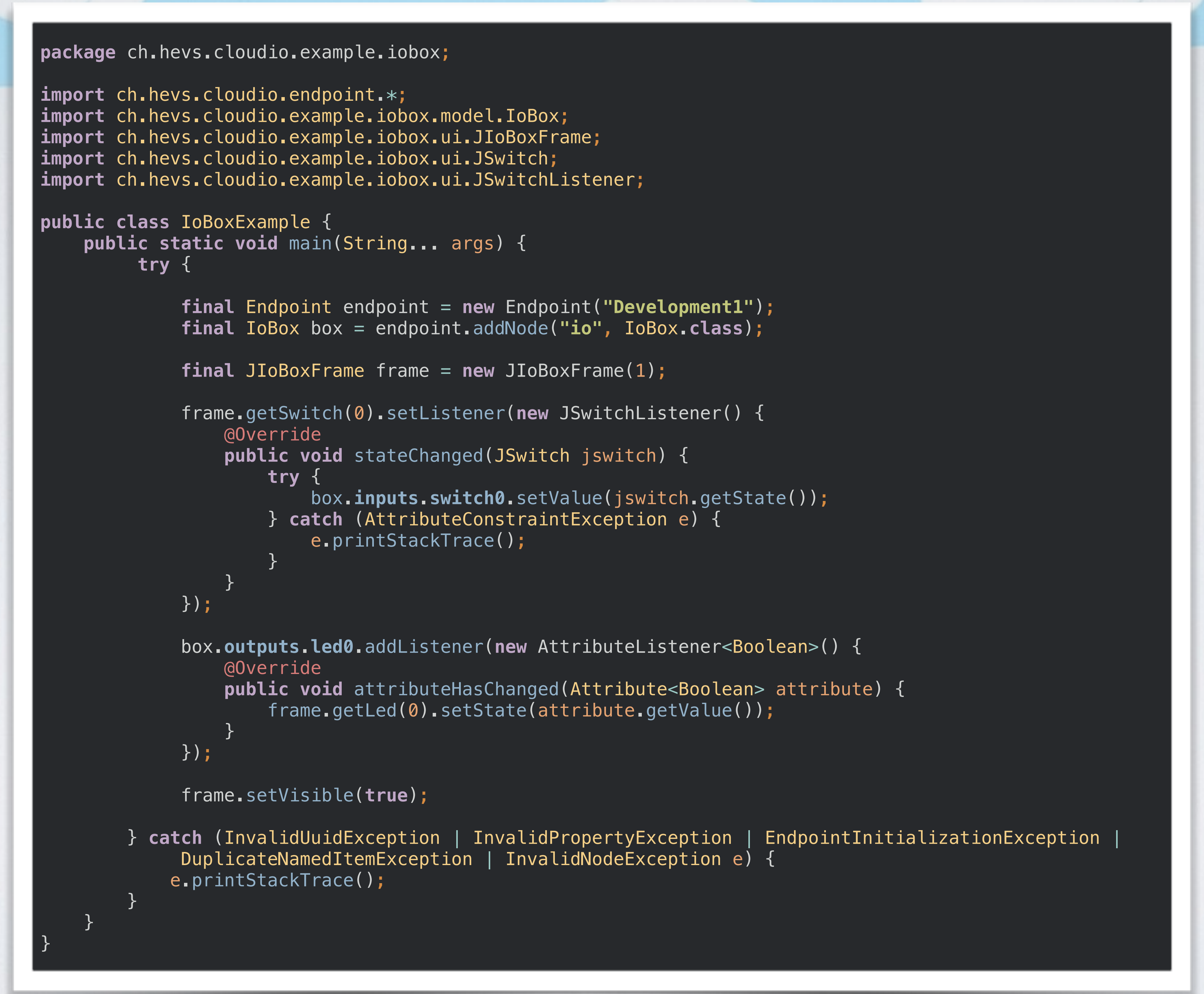
```java
package ch.hevs.cloudio.example.iobox.model;

import ch.hevs.cloudio.endpoint.Node;

public class IoBox extends Node {
    public Inputs inputs;
    public Outputs outputs;
}
```



```java
package ch.hevs.cloudio.example.iobox.model;

import ch.hevs.cloudio.endpoint.Attribute;
import ch.hevs.cloudio.endpoint.SetPoint;
import ch.hevs.cloudio.endpoint.Object;

public class Outputs extends Object {
    @SetPoint
    public Attribute<Boolean> led0;
}
```

```java
package ch.hevs.cloudio.example.iobox.model;

import ch.hevs.cloudio.endpoint.Attribute;
import ch.hevs.cloudio.endpoint.Measure;
import ch.hevs.cloudio.endpoint.Object;

public class Inputs extends Object {
    @Measure
    public Attribute<Boolean> switch0;
}
```

Application



```java
package ch.hevs.cloudio.example.iobox;

import ch.hevs.cloudio.endpoint.*;
import ch.hevs.cloudio.example.iobox.model.IoBox;
import ch.hevs.cloudio.example.iobox.ui.JIoBoxFrame;
import ch.hevs.cloudio.example.iobox.ui.JSwitch;
import ch.hevs.cloudio.example.iobox.ui.JSwitchListener;

public class IoBoxExample {
    public static void main(String... args) {
         try {

             final Endpoint endpoint = new Endpoint("Development1");
             final IoBox box = endpoint.addNode("io", IoBox.class);

             final JIoBoxFrame frame = new JIoBoxFrame(1);

             frame.getSwitch(0).setListener(new JSwitchListener() {
                 @Override
                 public void stateChanged(JSwitch jswitch) {
                     try {
                         box.inputs.switch0.setValue(jswitch.getState());
                     } catch (AttributeConstraintException e) {
                         e.printStackTrace();
                     }
                 }
             });

             box.outputs.led0.addListener(new AttributeListener<Boolean>() {
                 @Override
                 public void attributeHasChanged(Attribute<Boolean> attribute) {
                     frame.getLed(0).setState(attribute.getValue());
                 }
             });

             frame.setVisible(true);

        } catch (InvalidUuidException | InvalidPropertyException | EndpointInitializationException |
            DuplicateNamedItemException | InvalidNodeException e) {
           e.printStackTrace();
        }
    }
}
```

🤔

Questions?