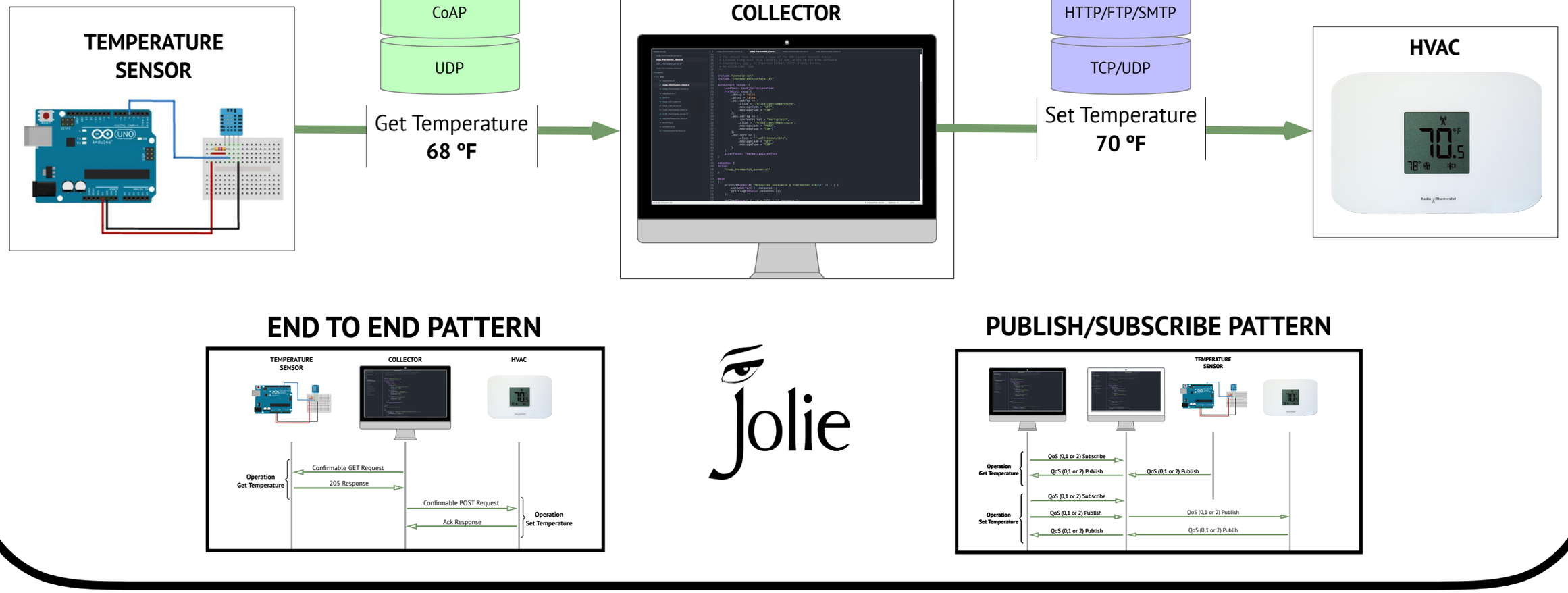
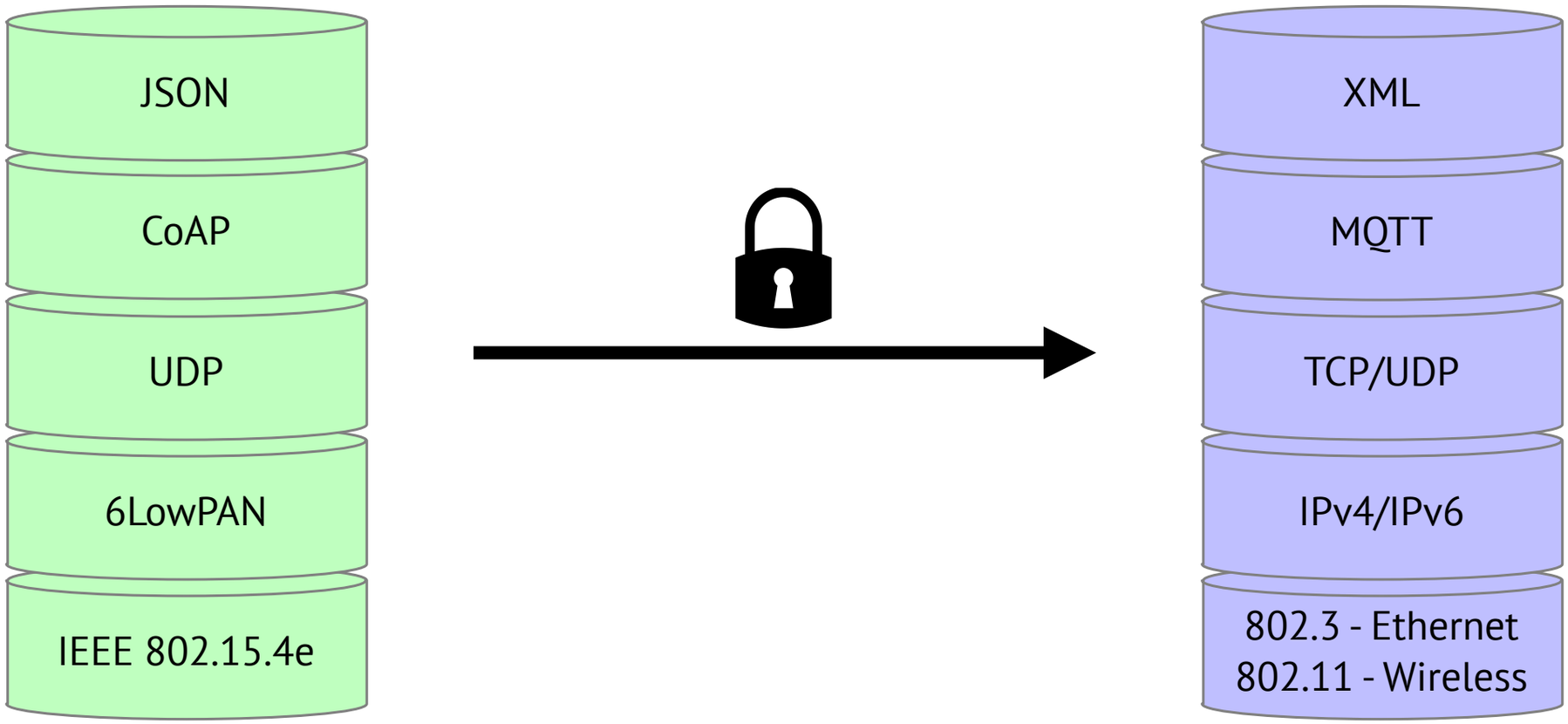


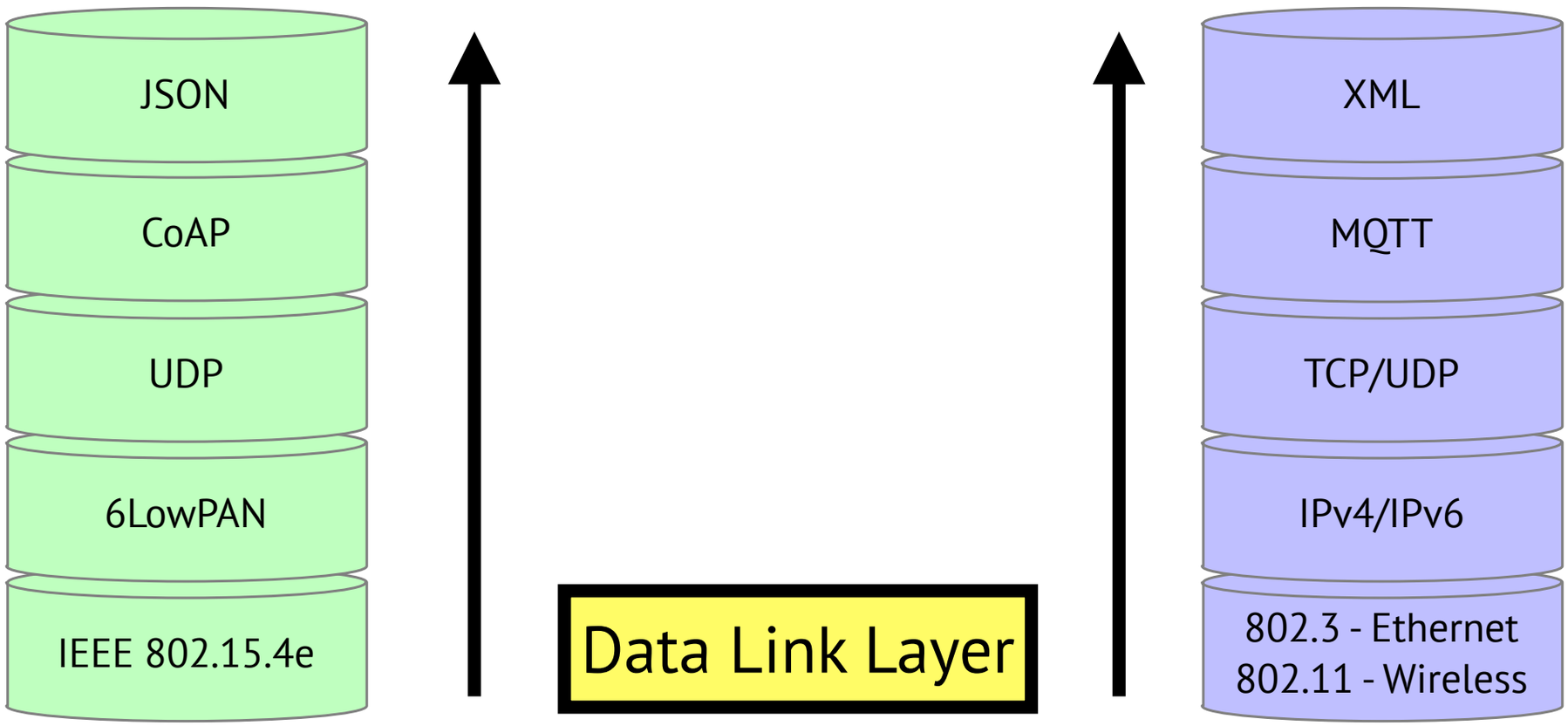
A Language-based Approach to Interoperability of IoT Platforms

The challenge



IoT platforms frequently take the shape of **vertical solutions** that rely on a single communication technology stack.

The challenge



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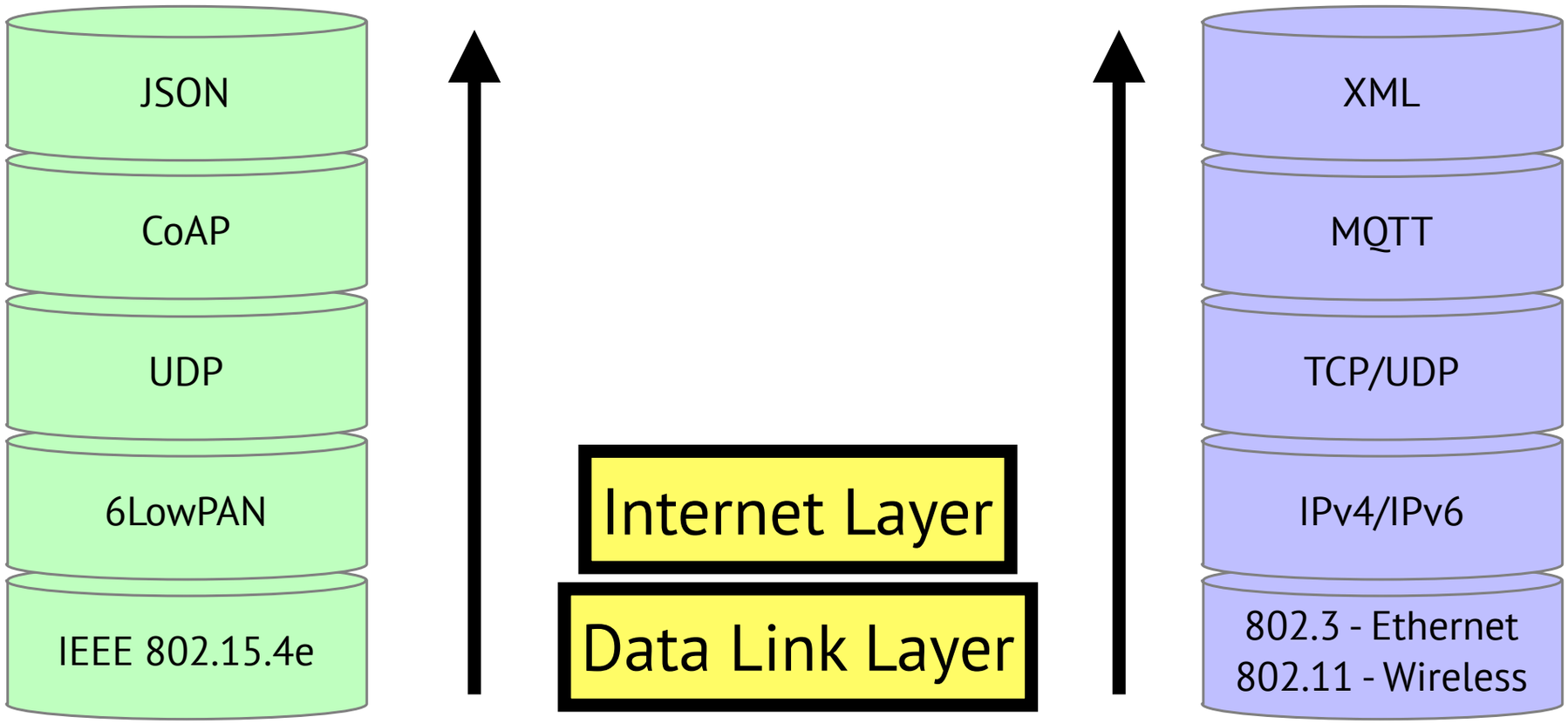

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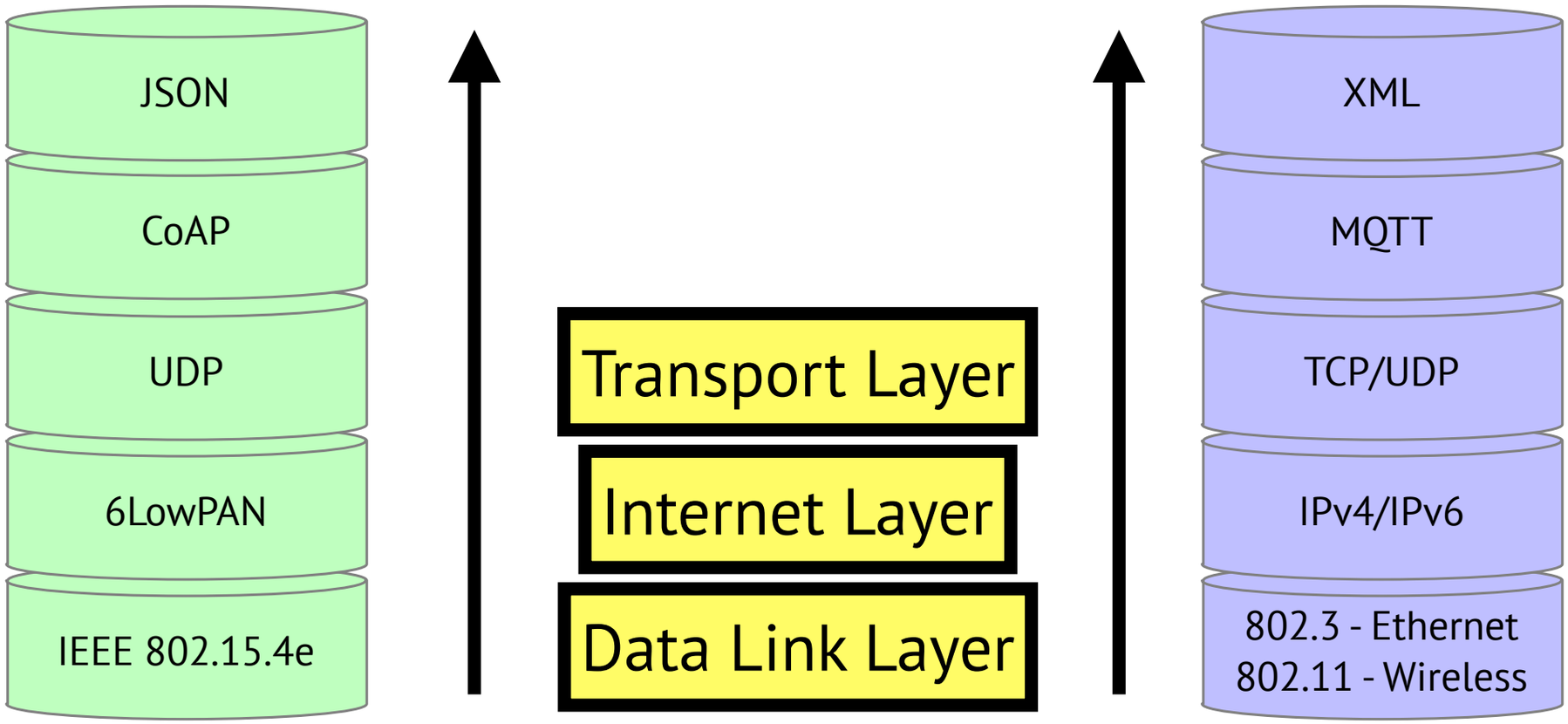

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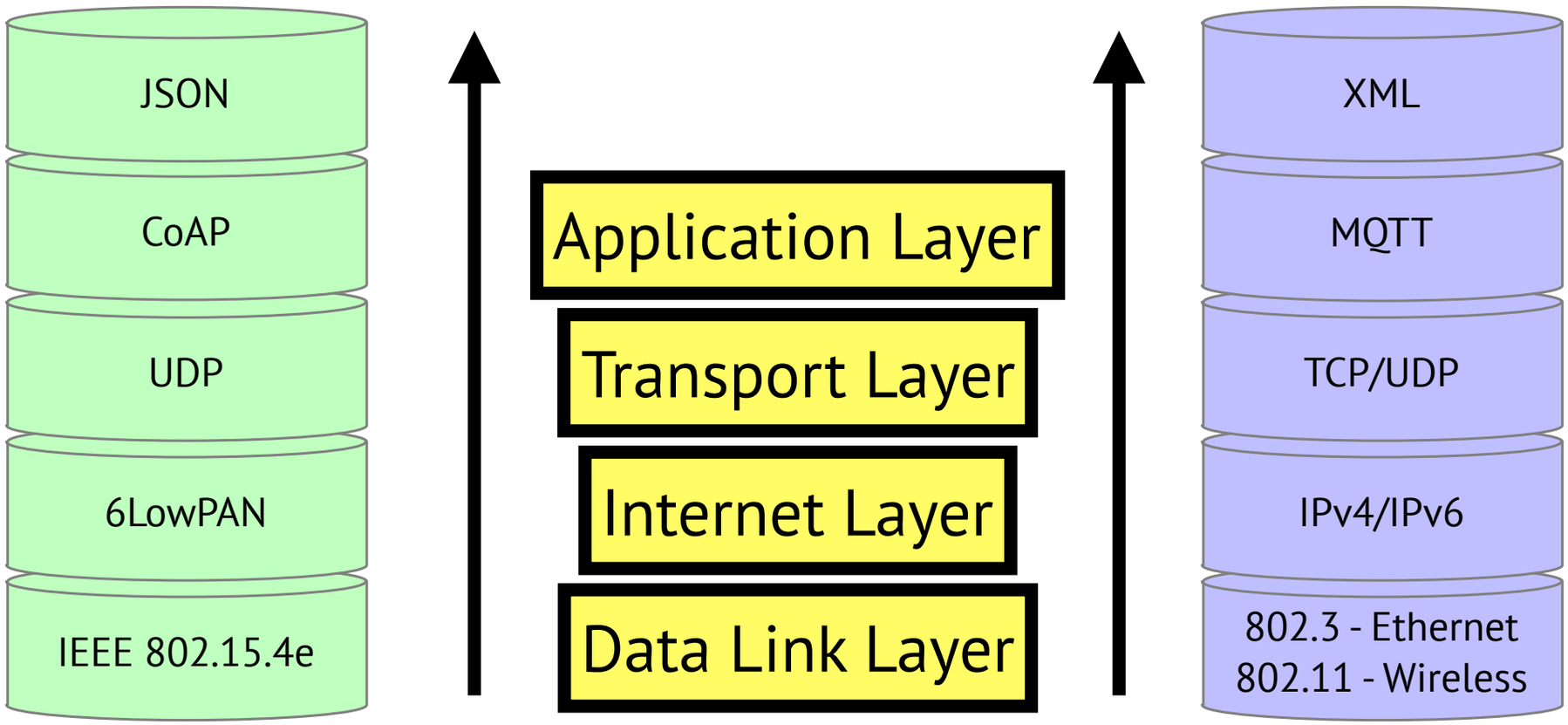
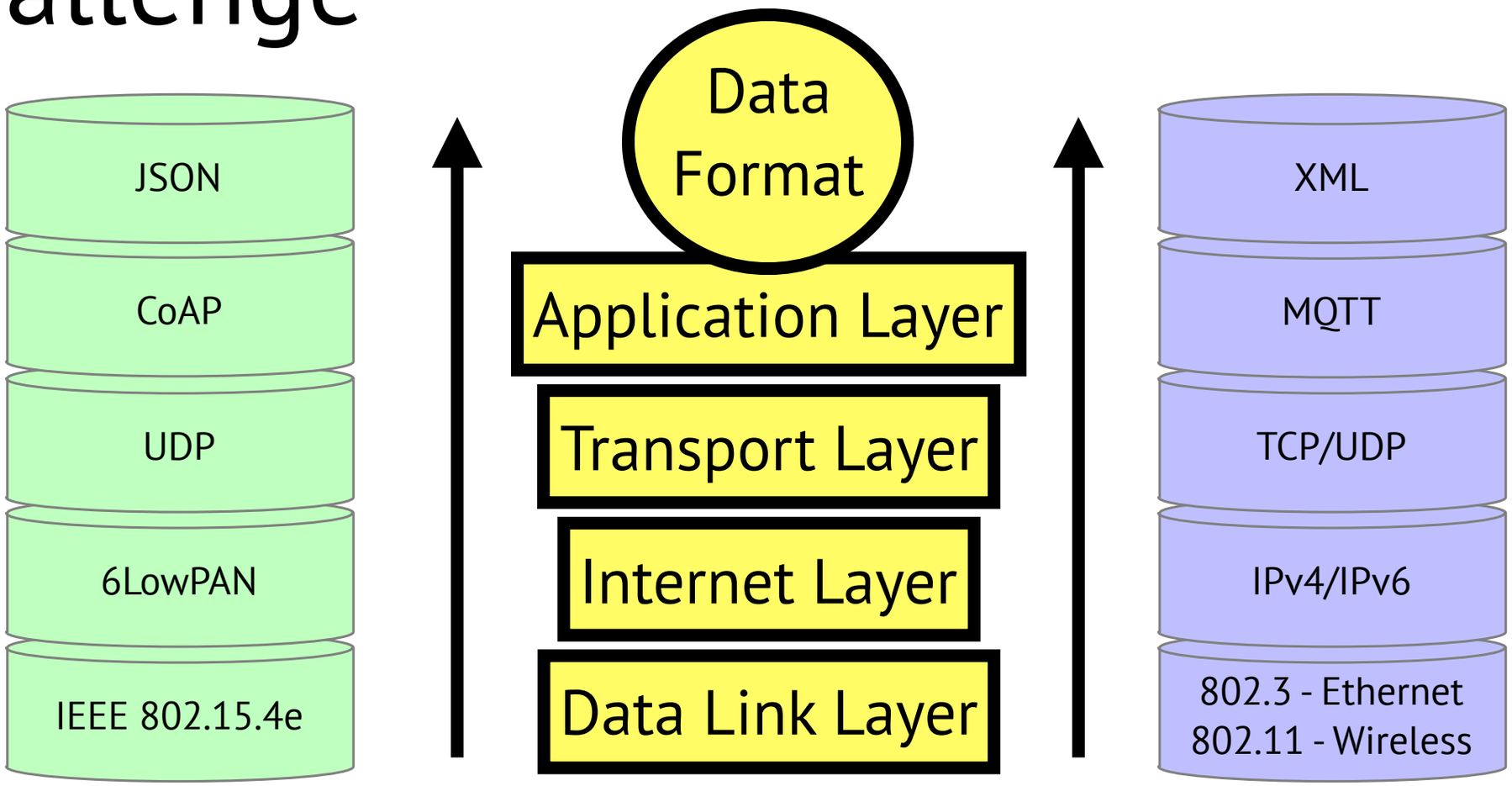


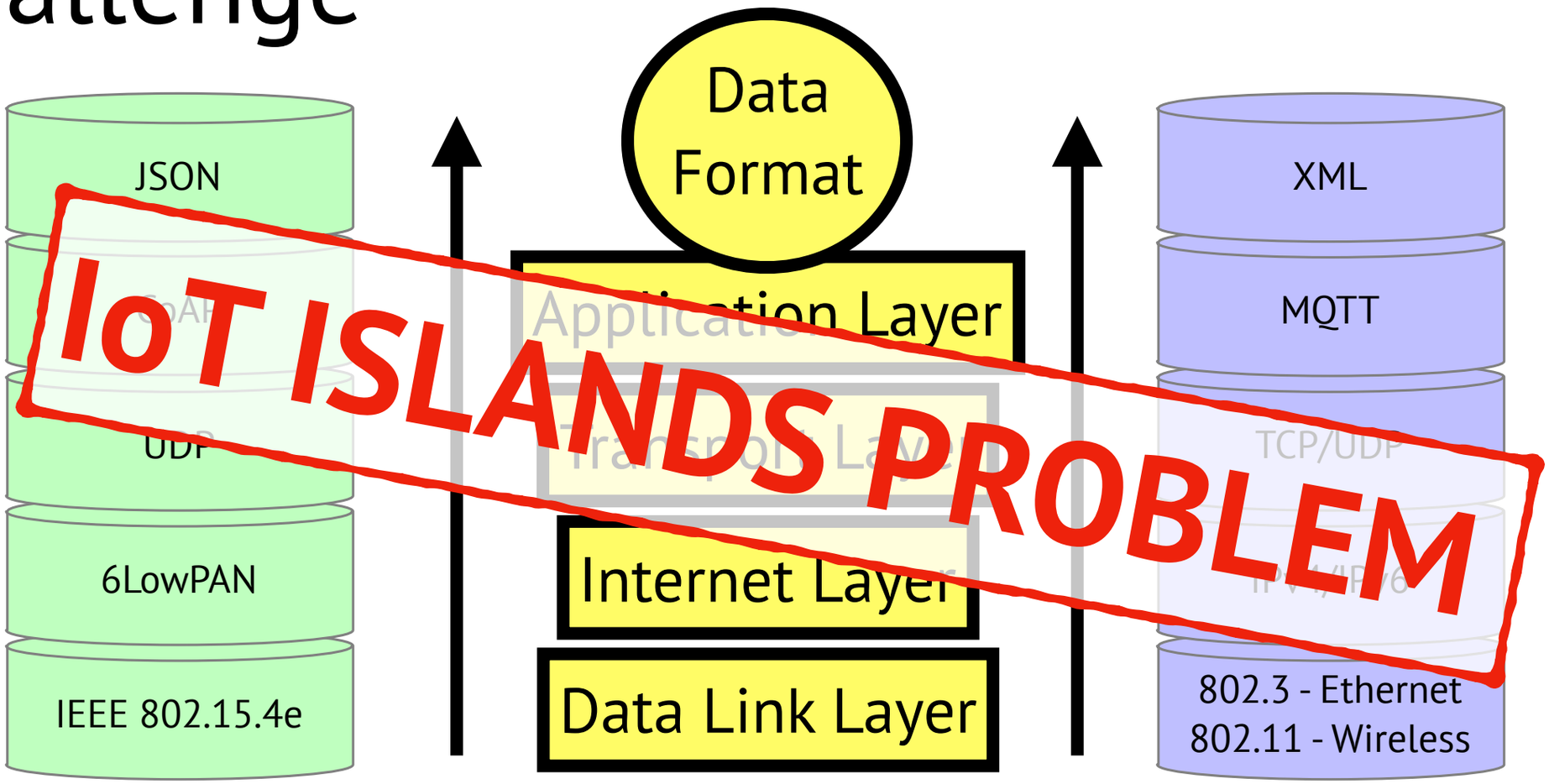
IoT platforms frequently take the shape of **vertical solutions** that rely on a single communication technology stack.

The challenge



IoT platforms frequently take the shape of **vertical solutions** that rely on a single communication technology stack.

The challenge

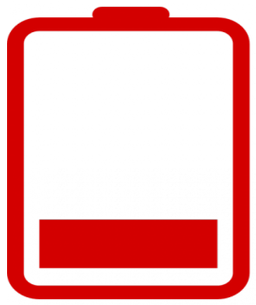


IoT platforms frequently take the shape of **vertical solutions** that rely on a single communication technology stack.

Possible solutions

To facilitate the development of IoT applications

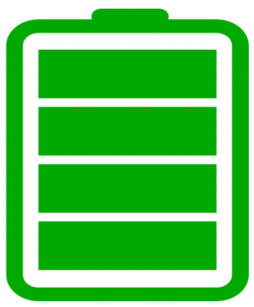
- **Low Level Abstractions**



  A. Middlewares

  B. Smart Gateways (Meshlium, etc.)

- **<u>High Level Abstractions</u> (our approach)**



  C. Integration Frameworks (Eclipse IoT)

  D. APIs (WoT from W3C)

Possible solutions

To facilitate the development of IoT applications

- **Low Level Abstractions**
  - A. Middlewares
  - B. Smart Gateways (Meshlium, etc.)
- **<u>High Level Abstractions</u> (our approach)**
  - C. Integration Frameworks (Eclipse IoT)
  - D. APIs (WoT from W3C)

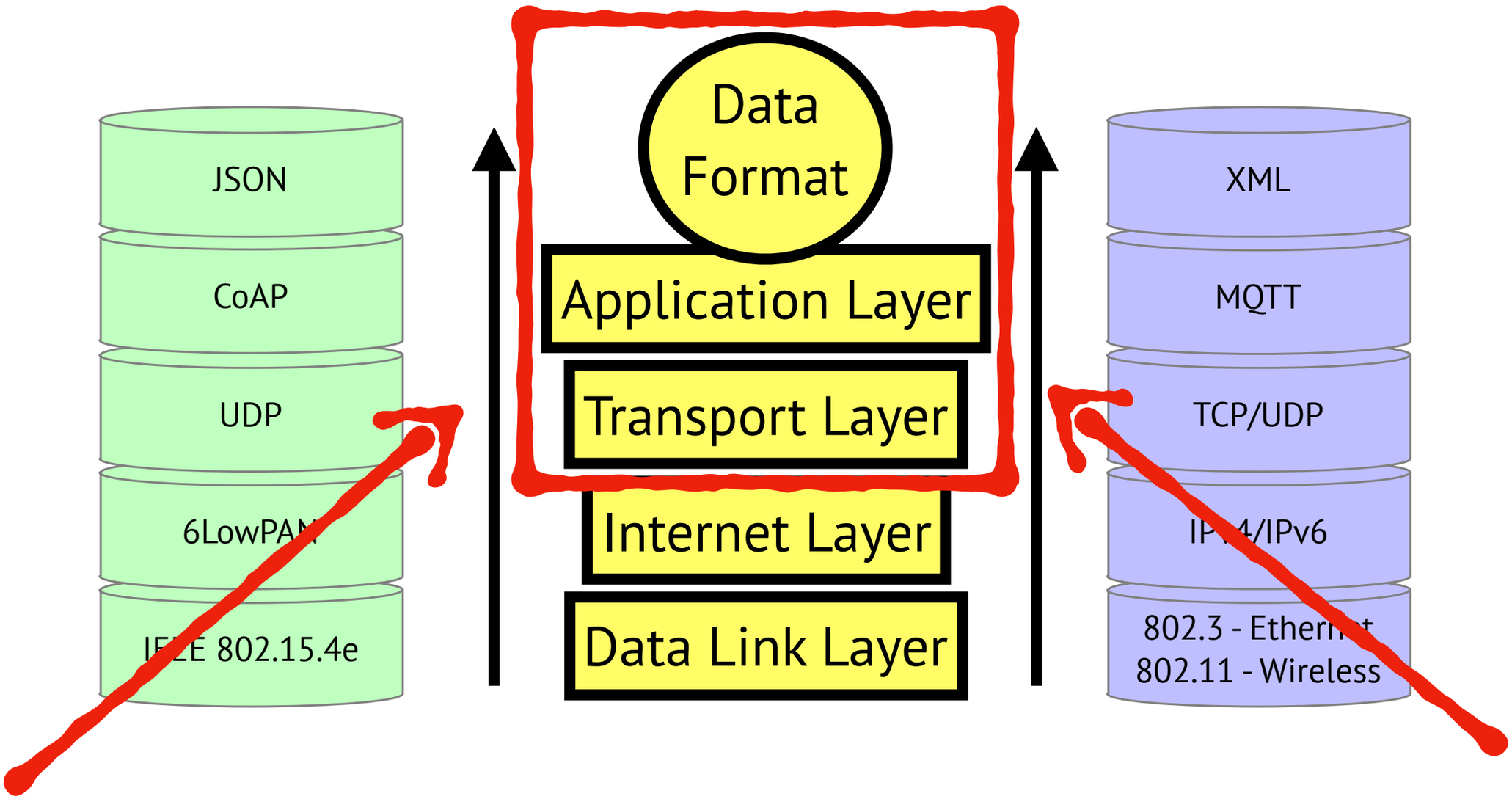
NOT A DEDICATED LANGUAGE!

The proposed solution

In order **to achieve a better integration** we propose a programming language:

- Programmers can easily **change the transport and application protocols** (even **at runtime**!)
- The language can automatically **marshal and un-marshal** data formats as required (e.g. HTTP/JSON to CoAP/JSON)
- The complexity of **guaranteeing interoperability** among protocols is managed by the programming language

The challenge



We **focus on integration** at the transport and application layer.

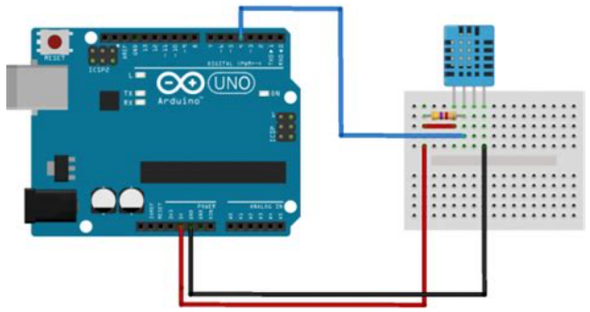
An Example of Interoperability

Suppose **we want to replace the technology** used:

- **Static replacement** — because of the deployment of new, heterogeneous devices in a pre-existing system.
- **Dynamic replacement** — to support a changing topology of disparate mobile devices.

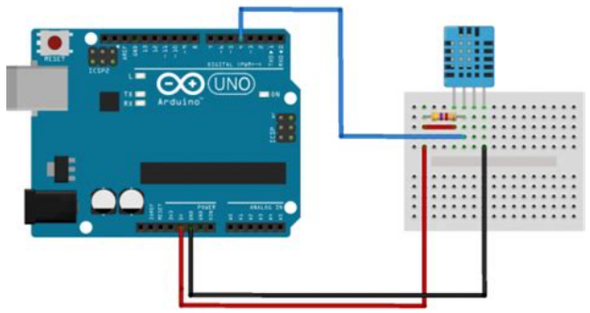
Another Example of Interoperability

COAP over UDP TEMPERATURE SENSOR



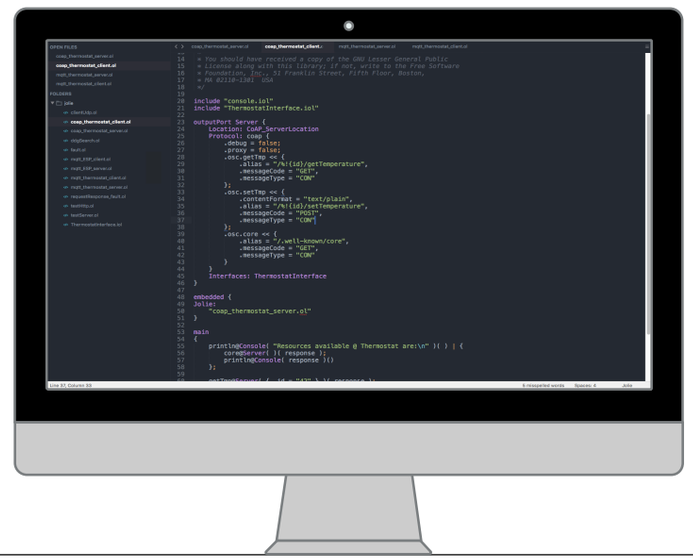
Send Temperature

HTTP over TCP TEMPERATURE SENSOR



Send Temperature

COLLECTOR



Another Example of Interoperability

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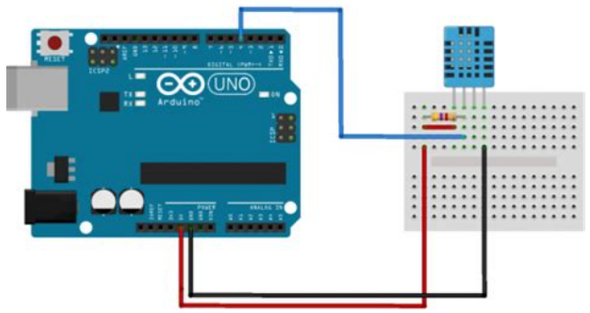
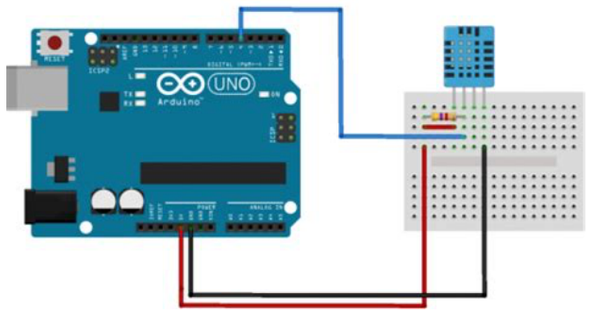


HTTP over TCP TEMPERATURE SENSOR



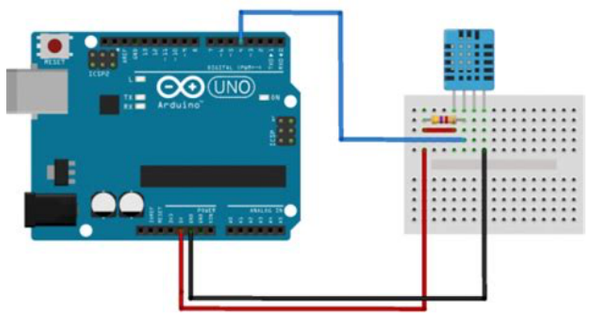
Send Tempera

Send Tempera

```
/*
* Unique behavior
*/
main {
  …
  receiveTemperature( data );
  …
}
```

Another Example of Interoperability

COAP over UDP TEMPERATURE SENSOR



Send Tempera

```
/*
* Unique behavior
*/
main {
  …
  receiveTemperature( data );
  …
}
```

HTTP over TCP

```
/*
* Deployment for HTTP/TCP
*/
inputPort HTTP_Collector {
  Location: “socket://collector.net:8000”
  Protocol: http
  OneWay: receiveTemperature( string )
}
```

Another Example of Interoperability

```
/*
* Deployment for CoAP/UDP
*/
inputPort CoAP_Collector {
  Location: “datagram://local.me:5683”
  Protocol: coap
  OneWay: receiveTemperature( string )
}
```

```
/*
* Deployment for HTTP/TCP
*/
inputPort HTTP_Collector {
  Location: “socket://collector.net:8000”
  Protocol: http
  OneWay: receiveTemperature( string )
}
```

```
/*
* Unique behavior
*/
main {
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  receiveTemperature( data );
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}
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Another Example of Interoperability

```
/*
* Deployment for CoAP/UDP
*/
inputPort CoAP Collector {
  Lo
  Pr
  On
}
```

```
/*
* De
*/
inpu
  Location: “socket://collector.net:8000”
  Protocol: http
  OneWay: receiveTemperature( string )
}
```

Use different communication modalities in a uniform way

```
/*
* Unique behavior
*/
main {
  …
  receiveTemperature( data );
  …
}
```

Another Example of Interoperability

```
/*
* Deployment for CoAP/UDP
*/
inputPort CoAP Collector {
  Lo                                    33”
  Pr
  On                                    ng )
}
```

```
/*
* De
*/
inpu
  Location: “socket://collector.net:8000”
  Protocol: http
  OneWay: receiveTemperature( string )
}
```

Use different communication modalities in a uniform way

```
/*
* Un
*/
main
  …
  rec
  …
}
```

Easily switch between them

The **JIoT** Project — Main Contribution

Integrating IoT related technologies **into the Jolie** *Service Oriented Programming Language*:

- The **Publish/Subscribe** communication pattern
- The **MQTT** Application Layer protocol
- The **UDP** Transport Layer protocol
- The **CoAP** Application Layer protocol

MQTT integration in Jolie

1. **Publish/Subscribe communication paradigm**

   Adding a generic publish/subscribe meta-channel that bridges **between end-to-end style** of communications **and publish/subscribe** interactions.
2. **Message Queue Telemetry Transport (MQTT)**

   Encoding/Decoding MQTT messages (Netty based)

CoAP and UDP integration in Jolie

1. **User Datagram Protocol (UDP)**
   - Adding Listener and Sender classes based on Netty
   - Extend the semantic to support un-reliable communications
2. **Constrained Application Protocol (CoAP)**

   Encoding/Decoding CoAP messages (nCoAP based)

JIoT Interpreter

Last Release of the interpreter can be found at:

http://cs.unibo.it/projects/jolie/jiot.html

- Requires JRE 1.8+
- Download jiot-1.0.3.jar
- Open a console and run:

```
java -jar jiot-1.0.3.jar
```

JIoT Sources

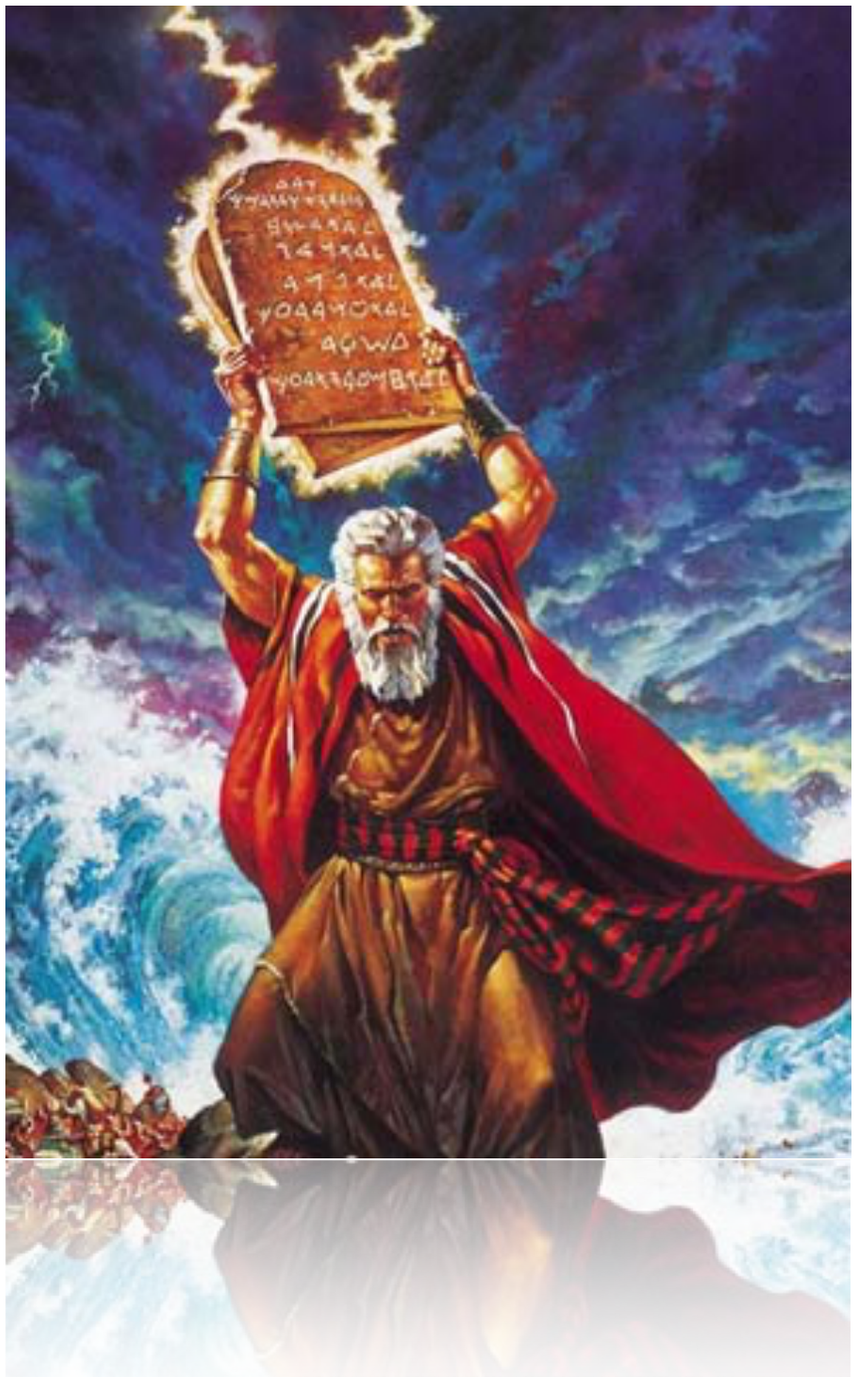
JIoT is an **open source** project developed as an extension to **Jolie**

The sources for the project can be found at:

https://github.com/stefanopiozingaro/jolie/tree/next

Recap – The Service Oriented Paradigm

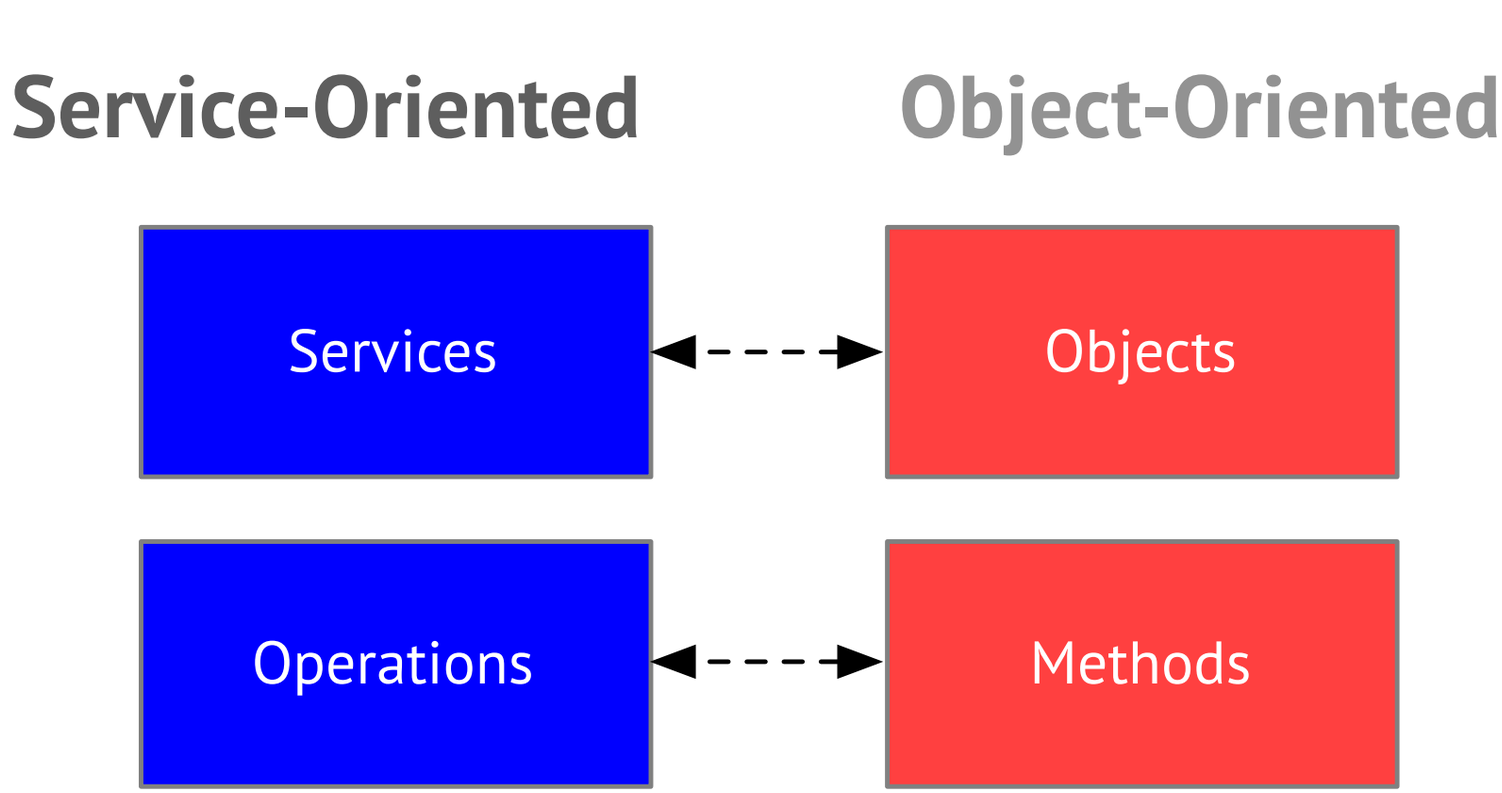
- **Everything is a service**
- A service is an application **that offers functionalities through operations**
- A **service can invoke another service** by calling one of its operations



Slide by Saverio Giallorenzo

Recap — What is Jolie?

A Service-Oriented Programming Language



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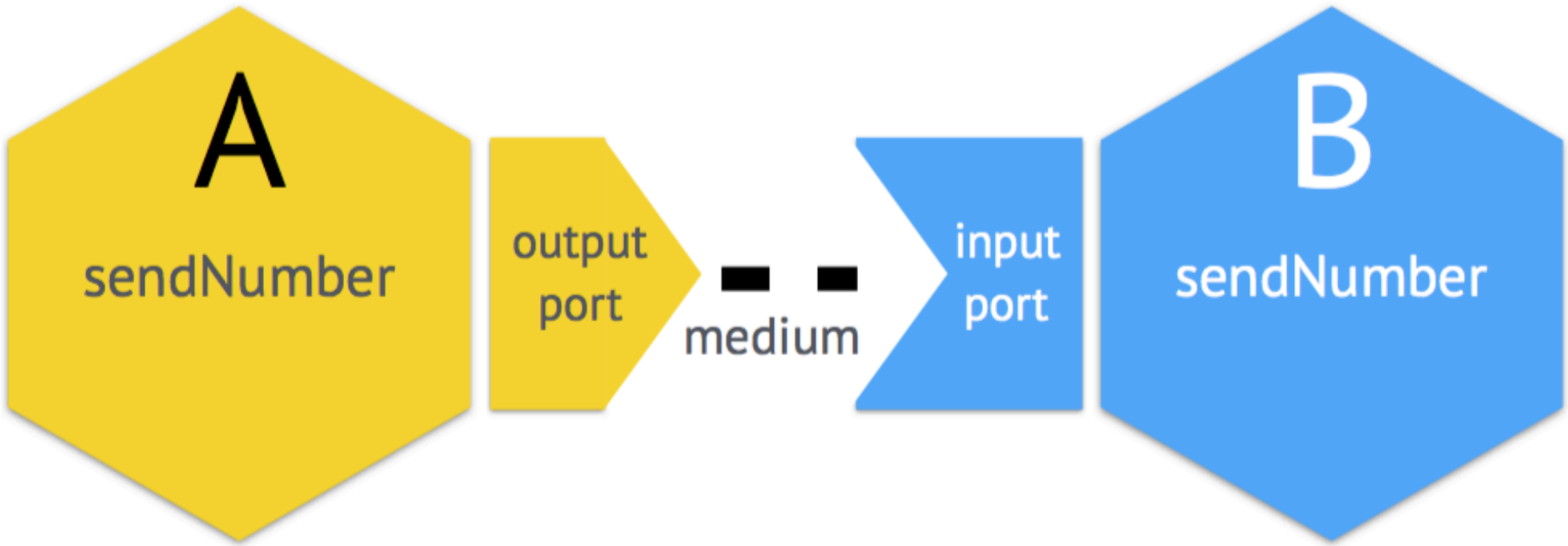
Deployments

Enabling Communications

Communication Ports in Deployments



Services communicate through **Ports**

Ports give access to an **Interface**

I**nterface** be a set of **Operations**

An **Output Port** is used to invoke interfaces exposed by other services

An **Input Port** is used to expose an interface

Slide by Saverio Giallorenzo

A closer look on ports - Protocols

- A protocol **defines the format** in which the data is sent (**encoded**) and received (**decoded**)
- In Jolie **protocols are described by names** and possibly some **parameters**:

```
json/rpc
```

```
sodep
```

```
https
```

```
soap
```

```
http { .debug = true }
```

Behaviours

Composing Interactions

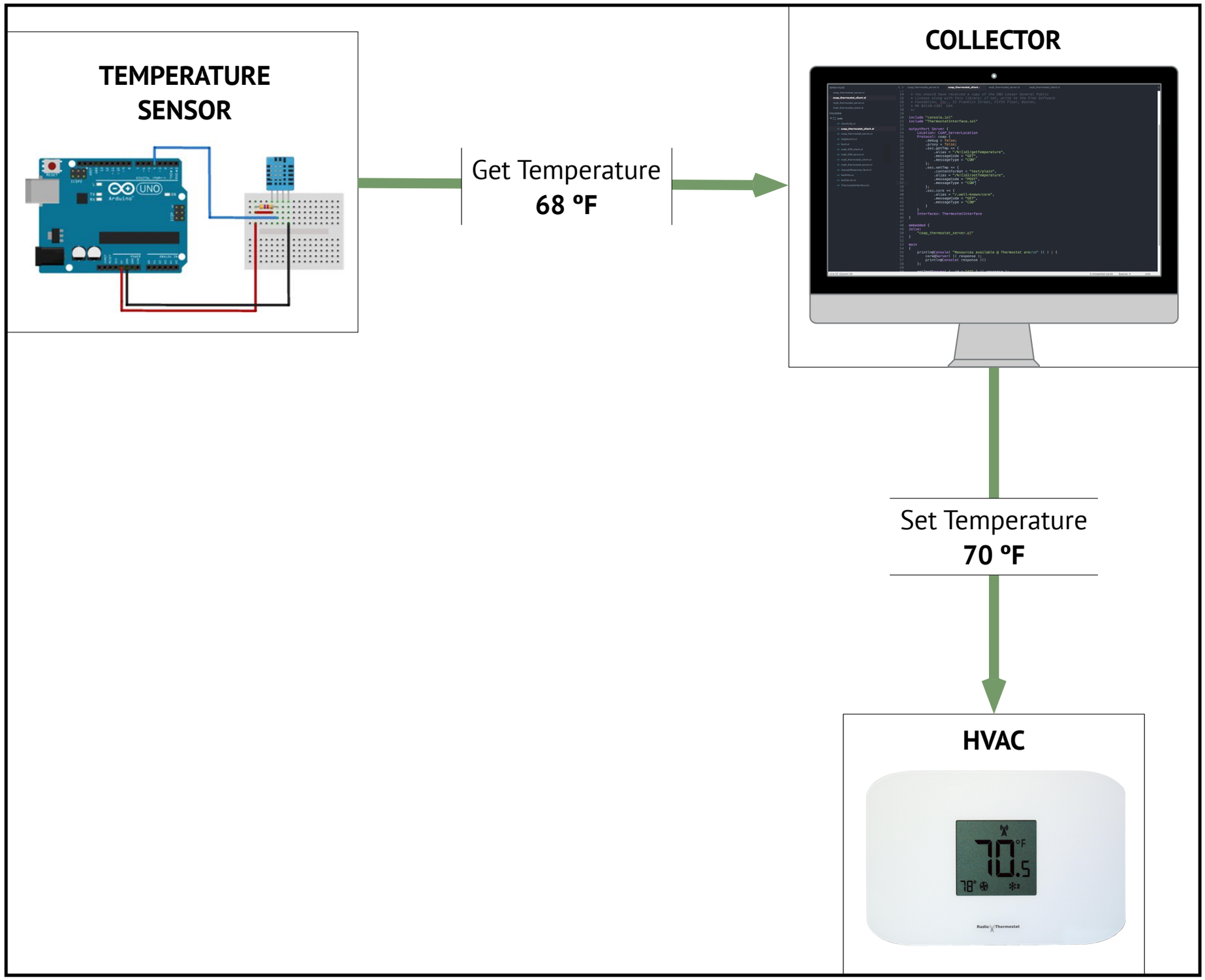
Interactions via Operations

Input Operations	`oneWay( req )`
	`reqRes( req )( res ){`
	`  // code block`
	`}`

Output Operations	`oneWay@Port( req )` `reqRes@Port( req )( res )`

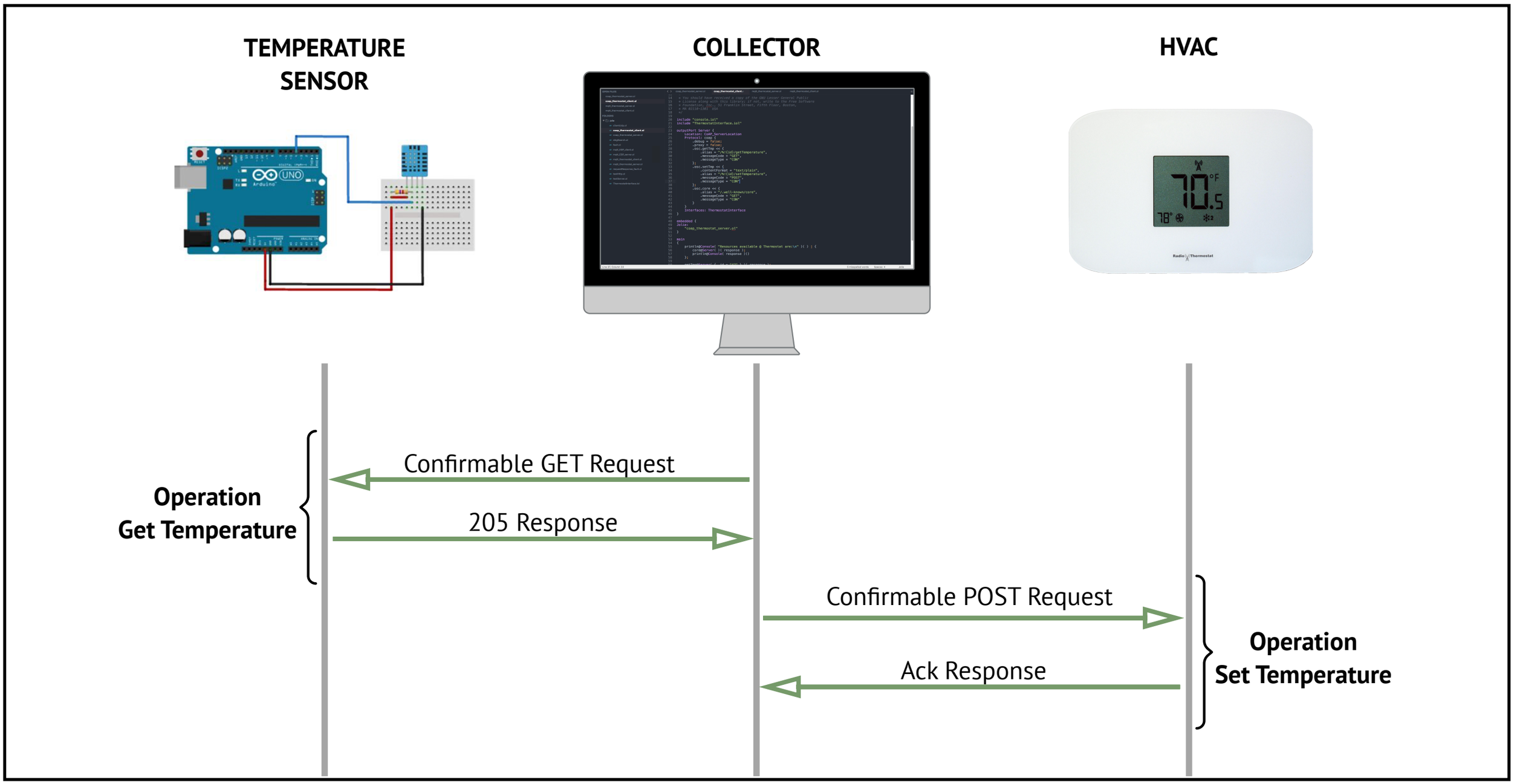
Slide by Saverio Giallorenzo

Case Study – Smart Home Example



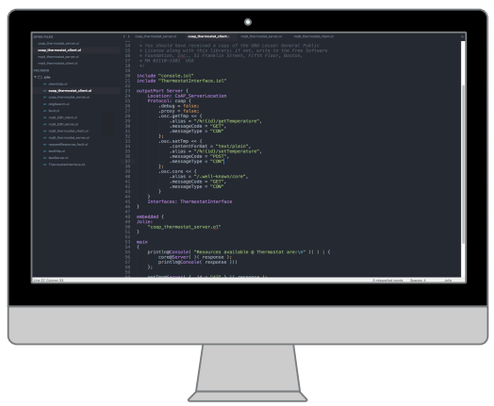
Case Study – Smart Home Example

End to end communication using CoAP over UDP

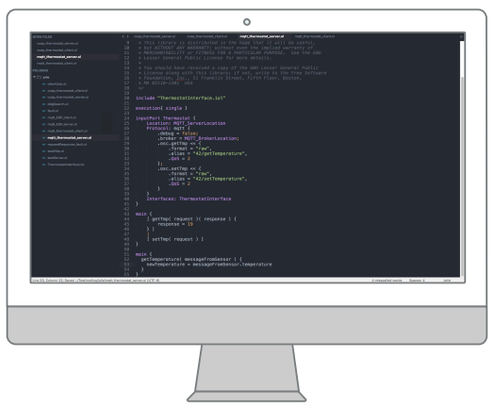


Case Study – Smart Home Example

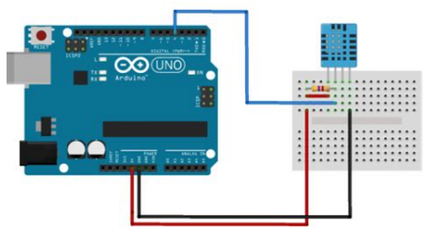
Publish/Subscribe communication using MQTT over TCP



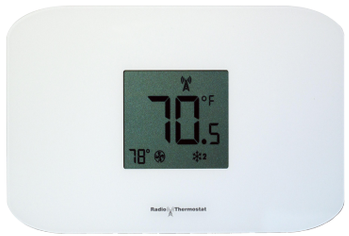
COLLECTOR



BROKER



TEMPERATURE SENSOR



HVAC

Operation Get Temperature

QoS (0,1 or 2) Subscribe

QoS (0,1 or 2) Subscribe

QoS (0,1 or 2) Publish

QoS (0,1 or 2) Publish

QoS (0,1 or 2) Publish

QoS (0,1 or 2) Publish

Operation Set Temperature

QoS (0,1 or 2) Subscribe

QoS (0,1 or 2) Publish

QoS (0,1 or 2) Publih

Case Study – Smart Home Example

```
/*
* Lets define a common interface for the
* different equipped thermostats,
* using the same operations
*/
interface ThermostatInterface {
    OneWay: setTemp( int )
    RequestResponse: getTemp( void )( int )
}
```

Case Study – Smart Home Example

```
/*
* The common behaviour
*/
main {
  getTemp@Thermostat( )( temp );
  if ( temp > 81 ) {
    setTemp@Thermostat( 75 )
  } else if ( temp < 59 ) {
    setTemp@Thermostat( 72 )
  }
}
```

Case Study – Smart Home Example

REQUEST-RESPONSE pattern

Outbound RequestResponse communications send a message and wait for a reply.

```
/*
* T
*/
main {
  getTemp@Thermostat( )( temp );
  if ( temp > 81 ) {
    setTemp@Thermostat( 75 )
  } else if ( temp < 59 ) {
    setTemp@Thermostat( 72 )
  }
}
```

Case Study – Smart Home Example

```
/*
* The final, common behavior
*/
main {
  getTemp@Thermostat( )( temp );
  if ( temp > 81 ) {
    setTemp@Thermostat( 75 )
  } else if ( temp < 59 ) {
    setTemp@Thermostat( 72 )
  }
}
```

ONE-WAY pattern

Outbound OneWay communications send a message asynchronously.

Case Study – Smart Home Example

```
/*
* Lets define a common interface for the
* different equipped thermostats,
* using the same operations
*/
interface ThermostatInterface {
    OneWay: setTemp( int )
    RequestResponse: getTemp( void )( int )
}
```

Case Study – Smart Home Example

```
outputPort Coap_Thermostat {
    Location: "datagram://localhost:5683"
    Protocol: coap {
        .osc.getTemp << {
            .contentFormat = "text/plain",
            .alias = "/getTemperature",
            .messageCode = “GET"
        };
        .osc.setTemp << {
            .contentFormat = "text/plain",
            .alias = "/setTemperature",
            .messageCode = "POST"
        }
    }
    Interfaces: ThermostatInterface
}
```

Case Study – Smart Home Example

```
outputPort Mqtt_Thermostat {
    Location: “socket://iot.eclipse.org:1883”
    Protocol: mqtt {
        .osc.getTemp << {
            .alias = "getTemperature",
            .QoS = 2
        };
        .osc.setTemp << {
            .alias = "setTemperature",
            .QoS = 2
        }
    }
    Interfaces: ThermostatInterface
}
```

A special thanks to the SPACES team ...

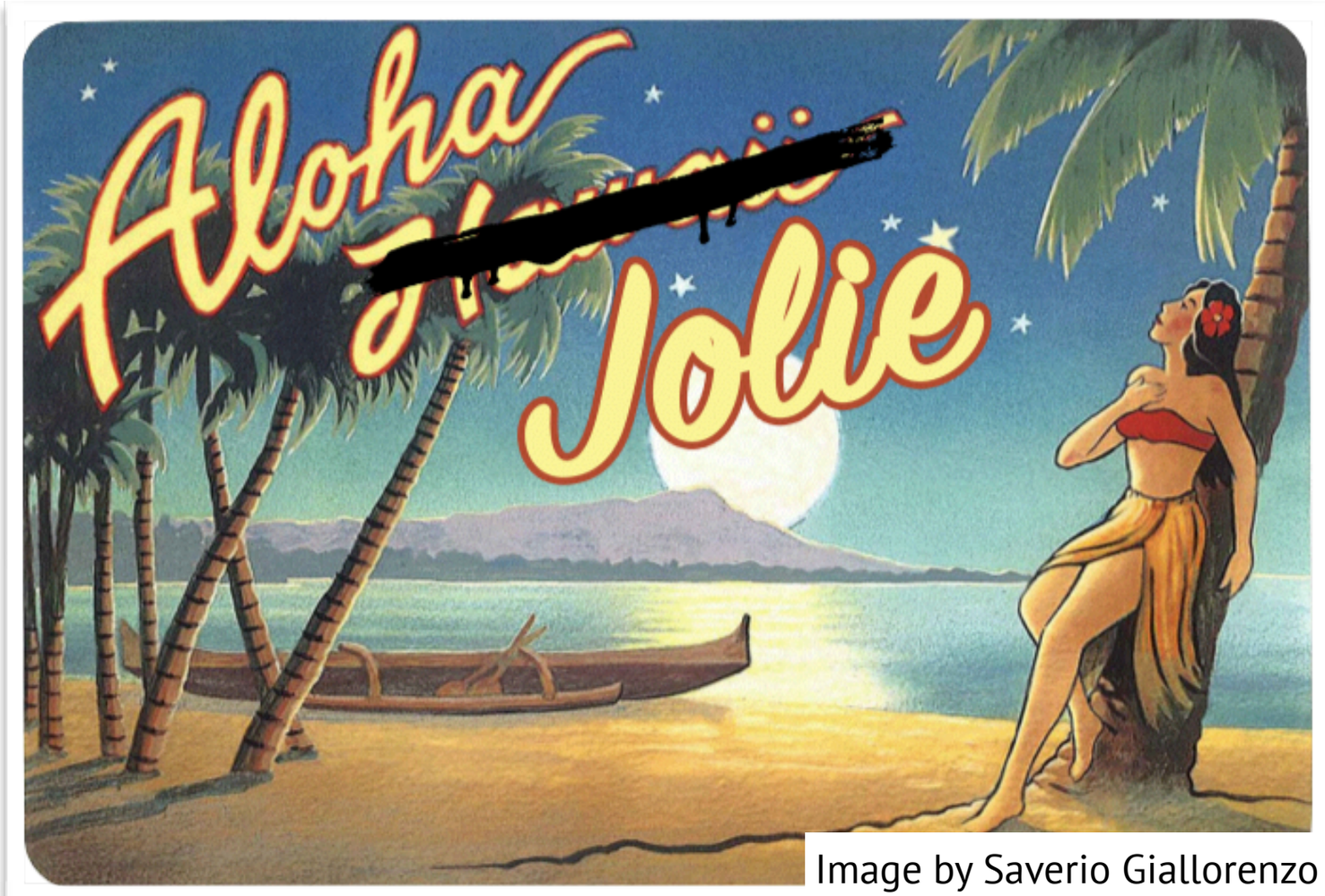


Image by Saverio Giallorenzo

... so long, and thanks for all the fish ...