Universität Potsdam

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Ontology-based Virtual IoT Devices for Edge Computing

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Heterogeneity of network devices

Source: https://goo.gl/images/tyaQo1

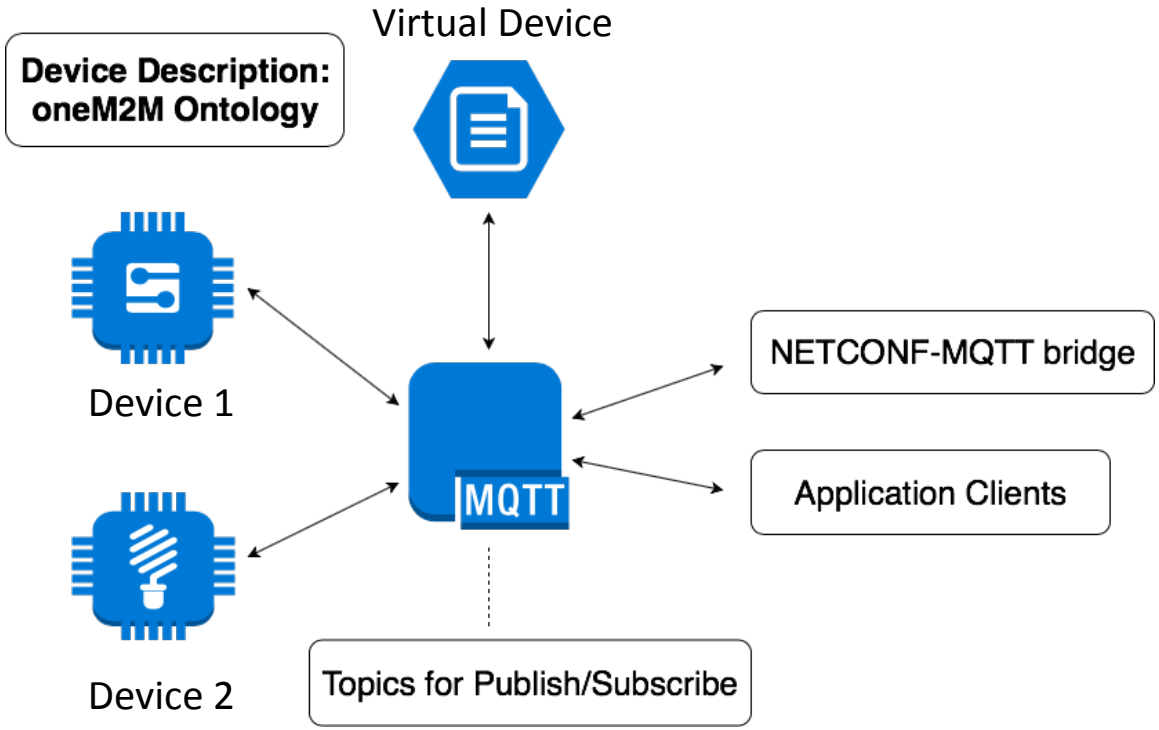
Idea

- aggregate self-descriptive devices at the edge of the network
- furthermore
  - derive new services
  - delegate requests/responses
  - collect and pre-process sensor data
  - generate events

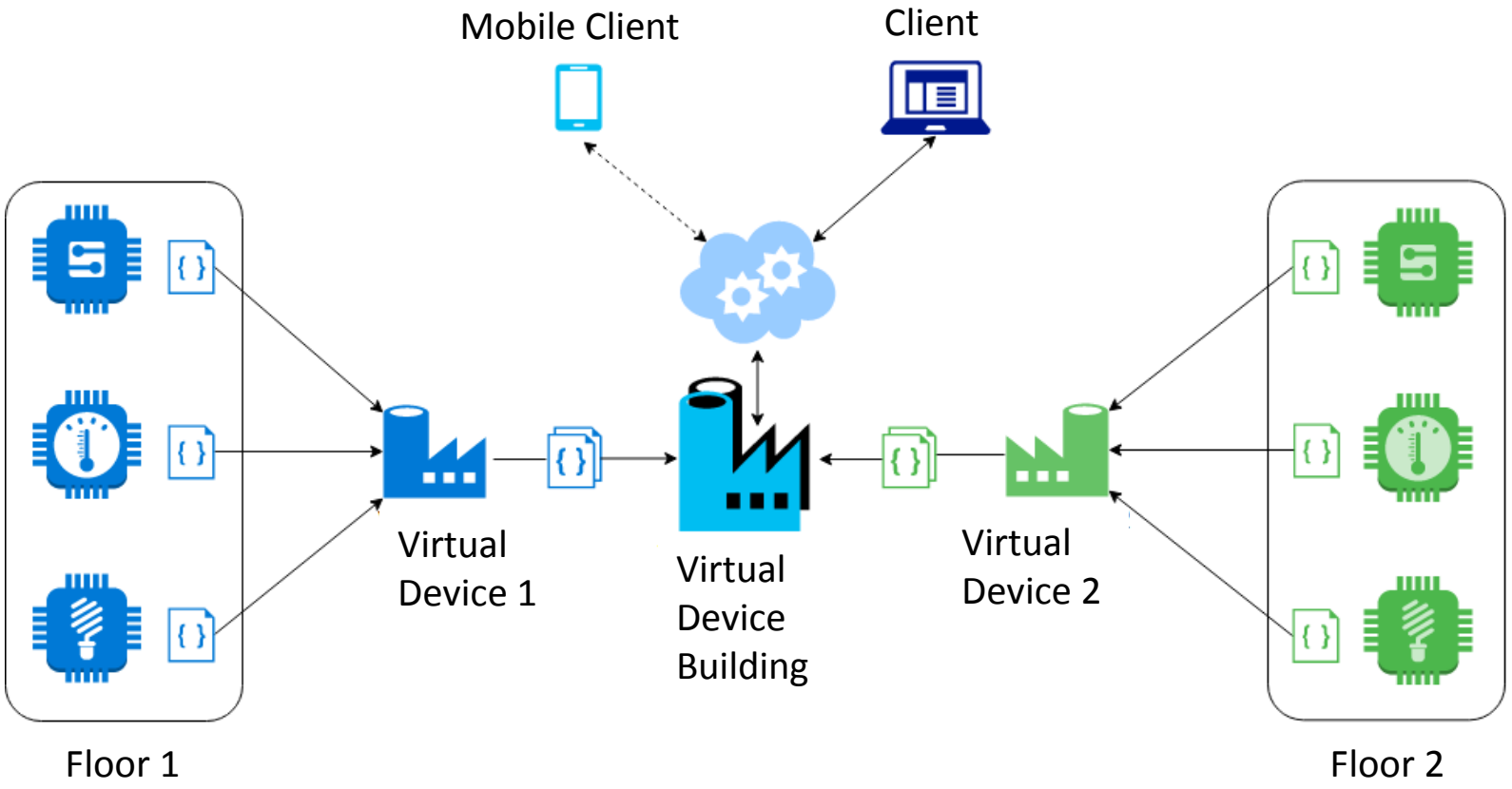
Definition: Virtual Device

- no actuators and no sensors onboard
- deployed at the edge of the network
- hides real devices (information hiding principle)
- aggregate capabilities of real devices
- offer aggregated capabilities

System Architecture of a Virtual Device



Topology of Virtual Devices



Operations and Tasks of Virtual Devices

- Scenario 1: Semantic Deployment
  - collect and aggregate device capabilities from device descriptions
  - infer new system capabilities from device descriptions
  - generate a virtual device description
  - publish this description e.g. to the MQTT broker

- e.g. define a new aggregated capability
  "switch off all lights in the 1st floor"

Operations and Tasks of Virtual Devices

- Scenario 2: Controlling and Measuring Services
  - map aggregated functionalities to the single device functionality
  - delegate controlling and measuring functionalities

- e.g. execute a controlling service

  “switch off all lights in the 1st floor”

Operations and Tasks of Virtual Devices

- Scenario 3: Aggregation of Sensor Data
  - collect and pre-process sensor data
  - aggregate sensor data
  - calculate average value

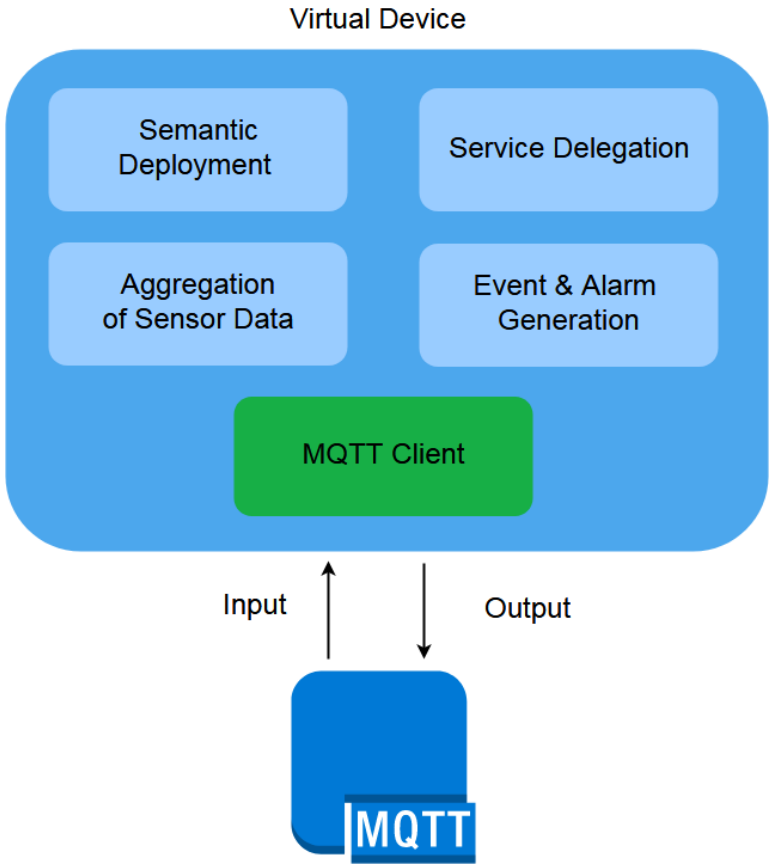
- e.g. calculate an average temperature in the 1st floor per hour

Operations and Tasks of Virtual Devices

- Scenario 4: Alarm/Event Trigger
  - monitor sensor data
  - prove conditions
  - create push events
  - trigger alarms if necessary

- e.g. raise alarm when temperature is over 30° Celcius

Software components of a virtual device



Implementation Scope

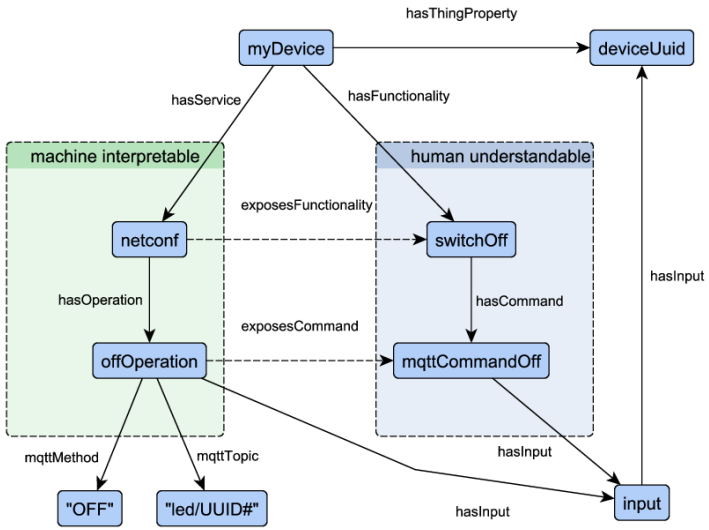
- Scenario 1: Semantic Deployment
- Scenario 2: Controlling and Measuring Services

Gap between the generic oneM2M and specific Device Ontology

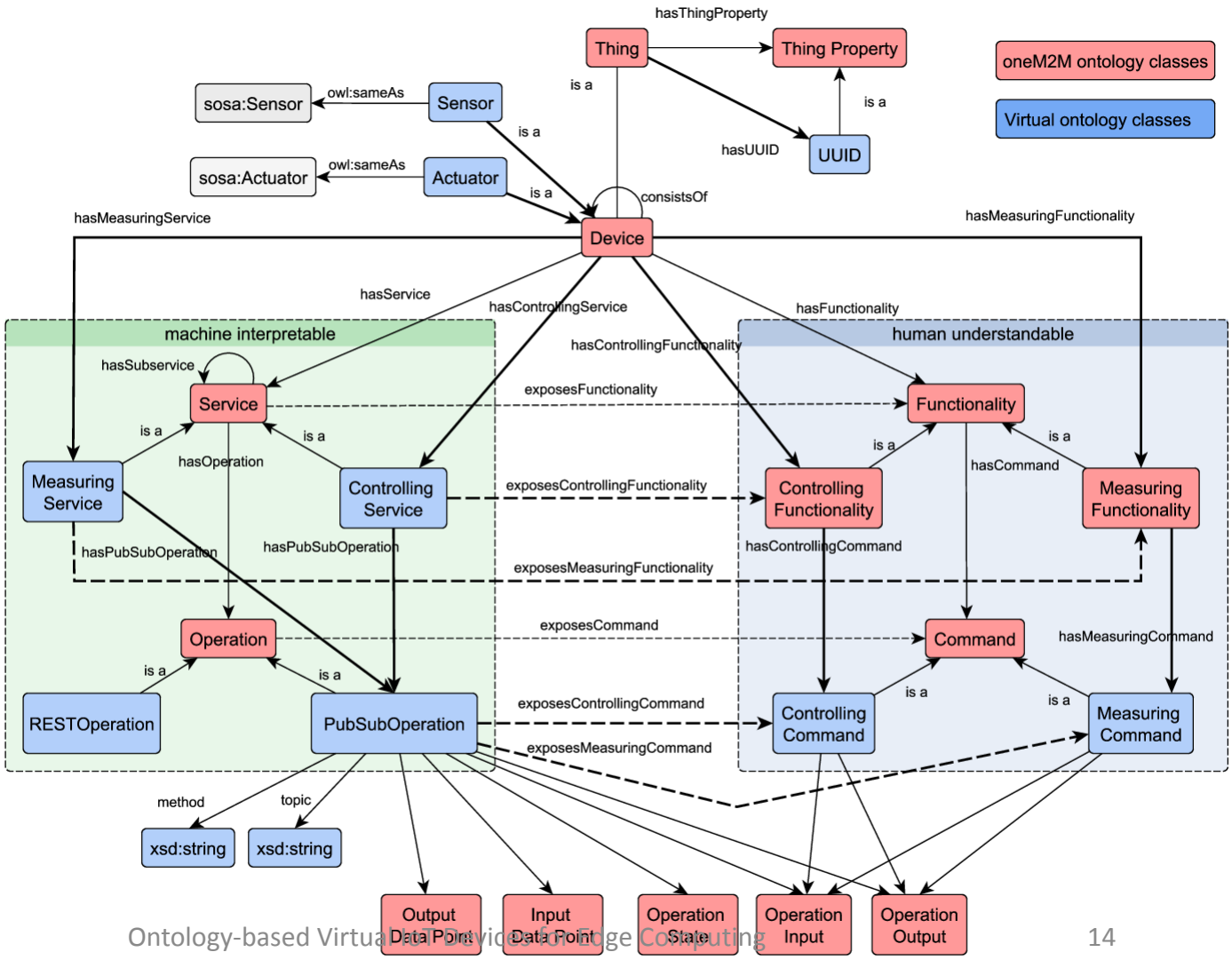
oneM2M Ontology

GAP

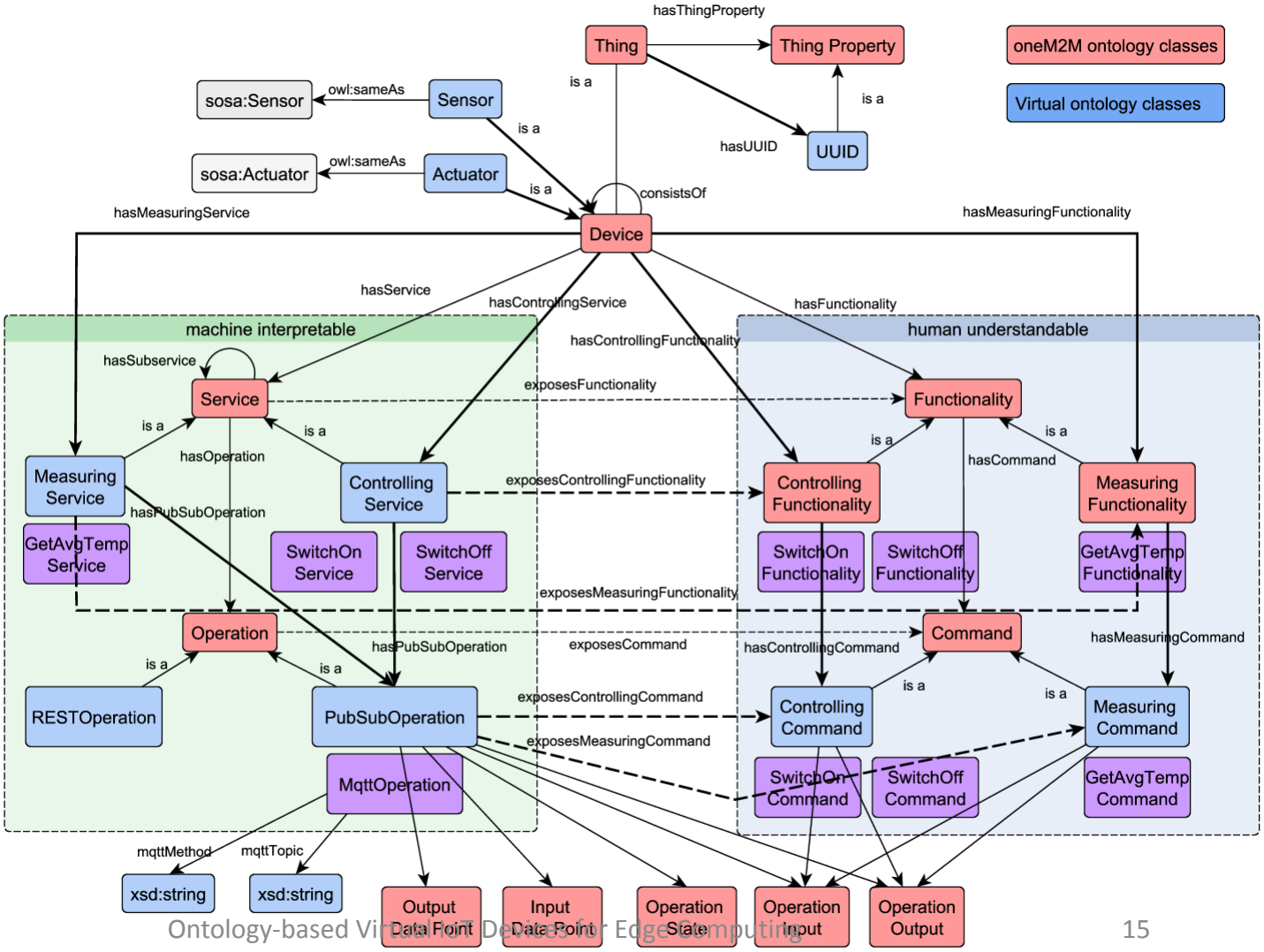
Device Description



Extended oneM2M Ontology 1st level



Extended oneM2M Ontology 2nd level



Inference possibilities

- oneM2M ontology is defined in OWL 2 DL flavour
- OWL constructs: <owl:Restriction>,<owl:someValuesFrom>, <owl:sameAs>, <owl:equivalentClass>, etc.
- SWRL rules
- SPARQL requests

OWL Abstract Class for switchOff Functionality

```
<owl:Class rdf:about="service#AbstractSwitchOffFunctionality">
<rdfs:subClassOf rdf:resource="onem2m#ControllingFunctionality"/>
<rdfs:subClassOf>  <owl:Restriction>
  <owl:onProperty rdf:resource="ext-onem2m#hasControllingFunctionality"/>
   <owl:someValuesFrom>  <owl:Class>
     <owl:oneOf rdf:parseType="Collection">
      <onem2m#ControllingFunctionality rdf:about="dev#switchOff"/>
      <onem2m#ControllingFunctionality rdf:about="dev#turnOff"/>
     </owl:oneOf>
    </owl:Class>  </owl:someValuesFrom>
 </owl:Restriction> </rdfs:subClassOf>
</owl:Class>
```

SWRL Rule for switchOff Functionality

```
onem2m:Device(?d)
  ^ service:hasControllingFunctionality(?d, ?f)
  ^ swrlb:containsIgnoreCase(?f, "switchOff")
  -> AbstractSwitchOffFunctionality(?f)

onem2m:Device(?d)
  ^ service:hasControllingFunctionality(?d, ?f)
  ^ swrlb:containsIgnoreCase(?f, "turnOff")
  -> AbstractSwitchOffFunctionality(?f)
```

SPARQL Request for switchOff Functionality

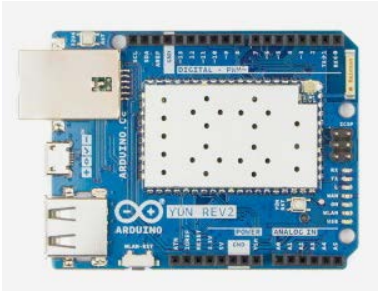
```
PREFIX onem2m:
<http://www.onem2m.org/ontology/Base_Ontology/base
_ontology#>

SELECT ?functionality ?type
WHERE {
  ?functionality rdf:type owl:NamedIndividual.
  ?functionality rdf:type
      onem2m:ControllingFunctionality.
  FILTER REGEX (?functionality, „off", "i").
}
```

Implementation

- Python, RDFLib incl. SPARQL
  - No Python Implementation of SWRL
- Virtual Device on Raspberry Pi 3B

Evaluation on IoT Devices

- CC2538 Development Kit from Texas Instruments
  - Light Sensor
  - Led
  - 6LoWPAN
- Arduino Yún Rev 2
  - Light Sensor
  - Humidity Sensor
  - Relay
  - Wi-Fi



Conclusion on Virtual Device

- information hiding principle
- reduce complexity
  - aggregate capabilities of real devices
- scalable architecture
- model-driven

Conclusion on Ontology

- oneM2M Base ontology must be extended
- only core vocabulary/schema is not enough
- describe the capabilities not only things (how vs. what)
- further classification of things and functionalities needed, e.g. subclasses, abstract classes, patterns
- but leave space on customization

Thank you!
Any questions?

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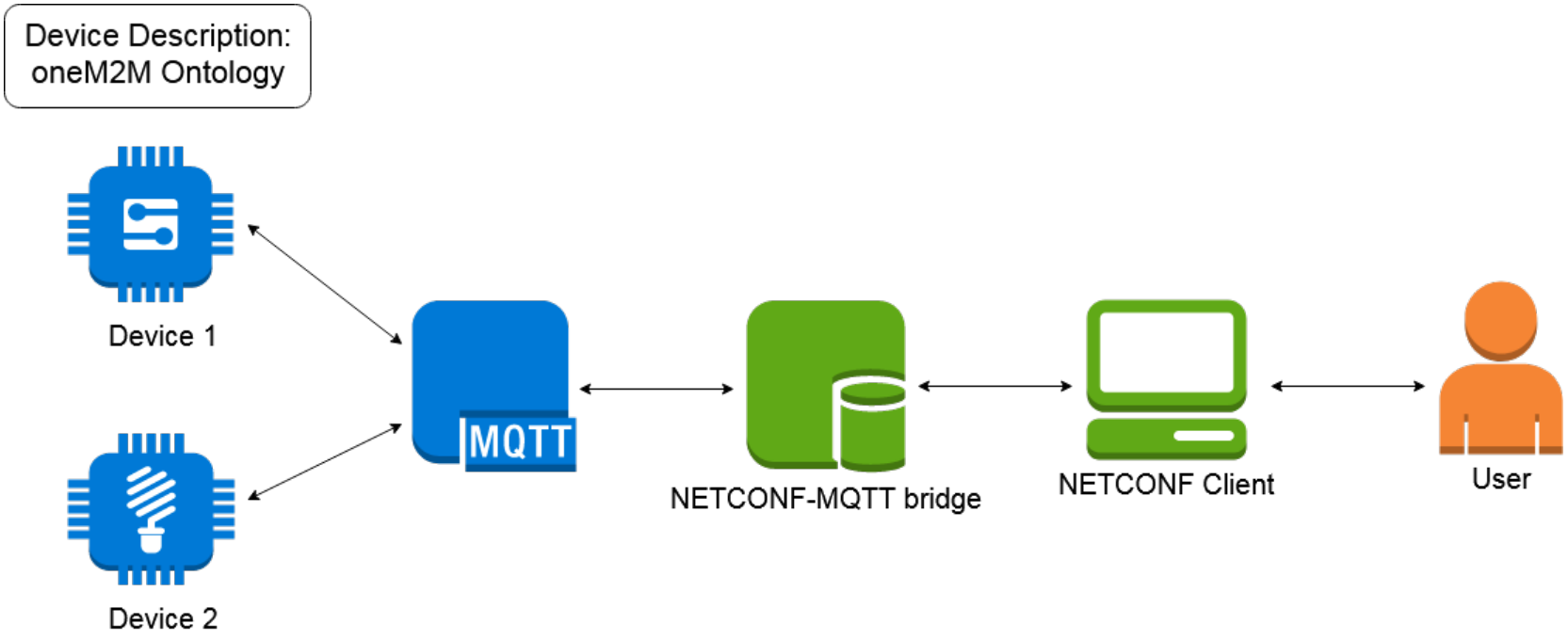
An ontology-based NETCONF-MQTT bridge



Introduced at InterOSS-IoT 2018, Bilbao, Spain