Supporting Semantic Interoperability at the level of the oneM2M Common Service Layer

Talk at oneM2M 15th Technical Plenary – Miami, FL, 20.Jan.2015

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OUTLINE

- What is semantic interoperability?
- Why semantic interoperability?
- What is relevant for the oneM2M Common Service Layer
- The universAAL experience
  - Intro to universAAL
  - Semantic interoperability by the universAAL Middleware
  - Leasons learned

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Semantic Interoperability, what is this?

- A common mistake: immediate thinking about concrete ontologies / domain models without thinking about how to benefit from them
  - ☝ but, concrete ontologies just relevant for concrete use cases and the verticals!
  - however, there are also basic ontologies of general ineterst, e.g. the understanding of physical things, locations and time

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- The general question: Semantic interoperability versus what?
  - ☝ versus syntactic interoperability!
  - even if semantic interoperability may have to build on syntactic interoperability
    - ➢ yes, challenges of data representation, access protocols, and data transmission protocols may necessitate syntactical dependencies

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Semantic Interoperability: A Definition

- Interoperability: ability of two communicating entities to share data and functionality despite having been developed independently
- Semantic Interoperability: sharing data **and functionality** at a semantic level by avoiding domain-specific APIs → reducing syntactical dependencies to one single brokerage API

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On sharing functionality

- Connected “things”
  - May produce data
  - May provide controll functions
  - May expose configurability functions

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On sharing functionality

- Connected “things”
  - May produce data
  - May provide controll functions
  - May expose configurability functions

} Need for APIs specific to “thing“ types!
→ domain-specific syntactic dependency?

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On sharing functionality

- Connected “things”
  - May produce data
  - May provide controll functions
  - May expose configurability functions

  } Need for APIs specific to “thing“ types!
  → domain-specific syntactic dependency?

- To support functionality sharing without such syntactical dependencies
  - “Things” to provide **semantic descriptions** of callable functions
  - Clients to **formulate requests semantically** instead of calling functions syntactically
  - Brokers to compare semantic requests with registered semantic descriptions and call matched functions on behalf of the clients

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Next oneM2M Priorities

1. Omar Elloumi at oneM2M Showcase event

Candidate features for oneM2M next steps

Testing and interoperability
- Test specifications
- (external) certification

Wide-scale deployment enchancements:
- Home Domain Enablement
- API versioning
- Plug and play scenarios
- Any lessons learnt from prototypes and deployment

Security
- E2e security
- Group authentication
- Role based security

Application enablements
- App APIs
- App development guide and SDK
- Service profiling

Interworking
- AllJoyn
- Enhance 3GPP interworking

Big data enablement
- Semantics support and use cases
- Ontology, query, reasoning

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- Semantics support and use cases
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Next oneM2M priorities

2. Guang Lu at ETSI M2M Workshop

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Next oneM2M priorities

2. Guang Lu at ETSI M2M Workshop

Next Generation of Service Delivery and APIs

Semantics Enabled Common APIs

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Next oneM2M priorities

3. Marylin Arndt at MACSI-2014

Application from one domain needs to "speak" with one (several) Application(s) from another

« small story »…
there has been an accident between 2 cars in the town

- traffic jam alerts / real-time warnings to inform on the impacts on the bus transportation
- ambulance priority

an ambulance is urgently needed; while on the road, the traffic lights shall not stop the ambulance
at crossways, one express-bus is given lower priority in the traffic lights management

- health monitoring from the ambulance, in liaison with the hospital, to anticipate the arrival at the hospital

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Next oneM2M priorities

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Application from one domain needs to "speak" with one (several) Application(s) from another

- **Important: Standardizing the data models towards shared ontologies**

« small story »…
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- ambulance priority

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IoT intensifies cross-domain interoperability

Other examples

- Activity monitoring in Ambient Assisted Living to improve diagnosis processes of health domain
  e.g., frequent anomalies in daily activities as possible indication of dementia

- Telemedicine to improve situation recognition in Ambient Assisted Living
  e.g., medical data (pulse, blood pressure) to infer the emotional state in a given situation

➢ Need for shared representation and interpretation of shared data

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Doubling benefit of ontologies

Recall Cisco forecast: **50 billion connected things by 2020**

- Of how many unique types are these things?
- Do we need a specific API for each type?
- Or, avoid this complexity and specify the single semantic-enriched API for brokerage mechanisms?

☝ Benefit from ontologies beyond sharing data, also for sharing functionality!

➢ SI contributes to managing IoT complexity

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Some supporting facts on “semantic technology“

- Mature standards existing since more than 12 years
- Many tools for serialization, parsing, storage, querying, reasoning, ...
- Steady improvement of processing mechanisms
- Despite lasting hesitations on the adoption side, a steady growing developer community

➢ Not scary any more!

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Recall CSL versus verticals

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Possible agenda for an open platform, such as oneM2M CSL

1. Provide the API for semantic brokerage mechanisms

2. Provide the global ontologies on, e.g., physical thing, location, time, ...

3. Remain independent from verticals
   → domain models should be pluggable extensions

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Benefits of semantic technology for the oneM2M CSL

- Unified representation of data regardless of domain and extraction technology (e.g., RDF) that facilitates
  - goal #1 on the agenda (previous slide)
  - serialization and de-serialization of messags across domains and execution environments
  - preserving the history of all data shared via the CSL
- A standard cross-domain query & reasoning language (e.g., SPARQL)
  - History entrepôts can be utilized to improve context-awareness
- Domain models externalizable and sharable (e.g., OWL ontologies)
  - Facilitates all of the goals on the agenda (previous slide)
- All of the above three standards are independent from concrete ontologies
  - Facilitates goals #1 & #3 on the agenda (previous slide)

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Demographic Ageing

Societal Challenge

Dependency Ratio

- From 1:4 to 1:2
- 80+ doubles by 2025

Cost of Care

- Up by 4-8 % of GDP by 2025

Human Resources

- Shrinking work force
- Lacking 20 million carers by 2020

Major Opportunity

Empowerment

- Active Ageing

New Care Models

- Home based
- Integrated care
- Large Efficiency gains

Growth and Markets

- 3000 B€ Wealth
- 85 Million Consumers and growing

EU Policy Targets

European Commission

ICT in support of older people…

At Work

- **Staying active and productive for longer**
- **Better quality of work and work-life balance**

In the Community

- **Overcoming isolation & loneliness**
- **Keeping up social networks**
- **Accessing public services**

At Home

- **Better quality of life for longer**
- **Independence, autonomy and dignity**

ICT in support of older people…

One of the approaches

- **Ambient Assisted Living (AAL)**
- ➢ **Applying the paradigm of Ambient Intelligence to living spaces in order to react to the needs of the inhabitants by providing relevant assistance**

By the way…

- **Ambient Intelligence is in the end IoT with focus to make physical environments intelligent**

EU R&I Path in Support of an established Open Platform for AAL

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Project Goals

An open platform for interoperable AAL solutions mandated to

- Consolidate reusable results from earlier projects
- Be cross-application: not optimized for just specific solutions
- Fill the gaps in the chain from development to deployment to use
- Be targeted at developers, deployers and manufacturers

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Assumptions

- AAL is a multi-vendor market with high interoperability challenge
- Need for an open platform allowing for system evolvement and not restricting the scope of the applications

Peter Nurse (Qualcomm), former chair of oneM2M Technical Plenary:
"There is no growing market chance for closed systems in a networked world!"

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AAL Spaces as Open Distributed Systems of Systems

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Project Result: universAAL as Open Source Software

→ Apache Software License 2.0

- The Middleware (Container, Data Representation, Discovery & Peering, uni- & multicast Messaging, Communication Buses)
- The Managers (Context History Entrepôt, Profiling, Reasoners, Dialog Manager, Space Orchestrator, Space Gateway, …)
- Some concrete Ontologies
- Tools (AAL Studio, universAAL Control Center -- uCC)
- Example AAL Services
- uStore (the open source part on top of Websphere)
- Reference documentation and the Wiki pages
- Training material

http://universaal.aaloa.org/

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The Value of UniversAAL

- Consolidates the state-of-the-art, and achieves to
  - Facilitate the development of AAL services, and
  - Reduce the overhead of system integration in homes
- Offers a major set of features, like semantic interoperability, compose-ability, extensibility, adaptability, configurability, accessibility, …
- Contributes, through tool and documentation support, to lean development and deployment processes
- Enables, through openness, multi-vendor solutions and impedes vendor lock-in

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ReAAL
The EU CIP ICT PSP Project

Will open platforms be able to help achieving AAL market breakthrough?

make it ReAAL

real-life piloting with UNIVERSAAL
involving 6000 users
in 9 EU countries

Expected Results

ReAAL will

- validate the role of common open platforms in putting interoperability standards in place
- measure the related socio-economic impact
  - a multidimensional evaluation framework will allow to also consider the ethical, legal, market, quality of life, and user experience impacts in addition to the socio-economic impact
- analyse the effectiveness of pilots' value chains and derive replication guidelines
- publish findings and recommendations, esp. lessons learned and best practices on technical and organisational aspects of deployment and public procurement in a public knowledge portal to serve as the ultimate reference for future roll-outs

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Goal: Implement semantic brokerage

- Brokerage cases based on communication patterns
  - Publish / subscribe → Event-based
  - Request / response → Call-based / “RPC“

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Event-based Communication

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Semantics in Event-based Communication (I)

- Overview

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Semantics in Event-based Communication (II)

- Events as reified RDF statements
  - rdf:subject, rdf:predicate, rdf:object
    - Values based on the domain ontology
  - additionally: who, when, confidence, validity duration, …
    - Values based on a fixed data model defined by universAAL

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Semantics in Event-based Communication (III)

- Subscriptions as OWL Class-Expressions restricting the event properties:
  - Role of domain ontologies & uAAL data models similar to the the case of concrete events
  - ➢ Subscribers state which class of events they are interested in

- universAAL Matchmaking: find out if the concrete event at hand is an instance of the specified class of events?
  - Ontological inference, e.g. based on class hierarchies
  - ➢ Intelligent system behavior

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Call-based Communication

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Semantics in Call-based Communication: Semantic RPC

- Overview

See "Goal-based Service Utilization Using SPARQL and OWL-S" under
http://www.ai.sri.com/daml/services/owl-s/extensions.html

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Semantic RPC – Client-side (I)

- Goal: Service clients should focus on the “what“s independently from the “how“s
  - Formulate requests not by calling interface operations, but by specifying the meaning of what is expected (communicate goals to the broker)

    The consequence of invoking a service is a realization of one or more real world effects. These effects may include:
    1. information returned in response to a request for that information,
    2. a change to the shared state of defined entities, or
    3. some combination of (1) and (2).

    [OASIS Reference Model for SoA]

  - *Equivalent to what the OWL-S community calls “**process results**”*

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Semantic RPC – Client-side (II)

- Thesis: SQL-like query languages provide an appropriate formalism for goal-based communication
  - Rely only on a data model
  - No technological / methodical requirements on the processing phase
  - Start with a speech act (delete, insert, select, update) and specify what is expected to be achieved, unambiguously, just based on the data model

- In the context of Semantic Web → SPARQL

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Semantic RPC – Client-side (III)

- A first attempt to formulate the following request in SPARQL (see the example scenario in the beginning of the article The Semantic Web, Scientific American, 2001)

  "...the phone rang. When Pete answered, his phone turned the sound down by sending a message to all the other local devices that had a volume control."

```
MODIFY GRAPH your:graph
DELETE { ?device vol:volumeLevelPercentage ?oldvol }
INSERT { ?device vol:volumeLevelPercentage 10 }
WHERE {
    ?device a vol:DeviceWithVolumeControl ;
            phw:occupies ?loc .
    ?loc phw:isIn some:loc .
    FILTER ( ?oldvol > 10 )
}
```

assuming that *(1)* by setting the volume level to 10%, sounds will be turned down sufficiently, and *(2)* "local" can be resolved as being in the specific location `some:loc`

- Problem 1: no distinction between service requests & data queries
- Problem 2: `your:graph` (a local graph at execution time) not identifiable at request time

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Semantic RPC – Client-side (IV)

- Approach: Service classes explicitly included in domain ontologies → data view of classes of services

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Semantic RPC – Client-side (V)

- Data view of service classes, a partial example:

- SPARQL queries to be made against this data view
  - SELECT clause can be used for specifying the expected outputs from this graph
  - DELETE and INSERT clauses can be used for specifying effects in this graph
  - The conditions in the WHERE clause narrow down the scope of the above results in the context of the referenced ontology

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Semantic RPC – Client-side (VI)

- Second attempt: Introducing a new clause ‘CALL’
  - To distinguish service requests from data queries
  - To select the “data view” and provide an entry point in the WHERE-clause (substitutes `your:graph` from the first attempt)

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  - To select the “data view” and provide an entry point in the WHERE-clause (substitutes `your:graph` from the first attempt)

```
CALL ?s
DELETE { ?device vol:volumeLevelPercentage ?oldvol }
INSERT { ?device vol:volumeLevelPercentage 10 }
WHERE {
    ?s a vol:VolumeControl ;
       vol:controls ?device .
    ?device phw:occupies ?loc .
    ?loc phw:isIn some:loc .
    FILTER ( ?oldvol > 10 )
}
```

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  - To distinguish service requests from data queries
  - To select the “data view” and provide an entry point in the WHERE-clause (substitutes `your:graph` from the first attempt)

```
CALL ?s
DELETE { ?device vol:volumeLevelPercentage ?oldvol }
INSERT { ?device vol:volumeLevelPercentage 10 }
WHERE {
    ?s a vol:VolumeControl ;
       vol:controls ?device .
    ?device phw:occupies ?loc .
    ?loc phw:isIn some:loc .
    FILTER ( ?oldvol > 10 )
}
```

```
CALL ?s
SELECT ?d
WHERE {
    ?s a vol:VolumeControl ;
       vol:controls ?d .
    ?d phw:occupies ?l .
    ?l phw:isIn some:loc .
}
```

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Semantic RPC (recall)

- Overview

See “Goal-based Service Utilization Using SPARQL and OWL-S” under
http://www.ai.sri.com/daml/services/owl-s/extensions.html

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Semantic RPC – Server-side (I)

- Selected Ontology for describing services: OWL-S

See http://www.daml.org/services/owl-s/

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Semantic RPC – Server-side (II)

- Problem during Matchmaking
  - OWL-S profiles have no relevance to the goal-based service requests
- Approach: use the data view to specify the semantics of process IOEs more accurately
  - Inputs possibly influence the scope of “process:Result”s
    - By being incorporated in filtering functions that select a sub-graph from the data view
  - Inputs can also be used in the specification of effects
  - Outputs can return the value of a node that is in the scope of “process:Result”s (before or after applying the effects)
  - Effects can apply changes to nodes that are in the scope of “process:Result”s (add, delete or change nodes)
- How to apply: embed SPARQL in OWL-S profiles as “Expression Language“

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Semantic RPC – Server-side (III)

- Solution: OWL-S profiles extended by SPARQL
  - Example:

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Semantic RPC – Server-side (III)

- Solution: OWL-S profiles extended by SPARQL
  - Example:

```
server:MyVolumeControl a owl:Class ;
  rdfs:subClassOf vol:VolumeControl ;
  rdfs:subClassOf [
    a owl:Restriction ;
    owl:onProperty vol:controls ;
    owl:allValuesFrom [
      a owl:Restriction ;
      owl:onProperty phw:occupies ;
      owl:allValuesFrom [
        a owl:Restriction ;
        owl:onProperty phw:isIn ;
        owl:hasValue our:flat
      ]
    ]
  ] ;
  owl:oneOf (
    server:getControlledDevices
    server:getDeviceByLocation
    server:getVolumeLevelOfDevice
    server:setVolumeLevelOfDevice
  ) .
```

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Semantic RPC – Server-side (III)

- Solution: OWL-S profiles extended by SPARQL
  - Example:

```
server:getDeviceByLocation a server:MyVolumeControl ;
  service:presents [
    a profile:Profile ;
    profile:has_process server:getDeviceByLocationProcess ;
    profile:hasInput server:deviceLocation ;
    profile:hasOutput server:devicesToReturn ;
    profile:hasResult [
      a process:Result ;
      process:withOutput [
        a process:OutputBinding ;
        process:toParam server:devicesToReturn ;
        dv:fromSPARQLS """FOR EACH CALL:
          Select ?d WHERE {
            server:getDeviceByLocation vol:controls ?d .
            ?d phw:occupies ?l .
            ?l phw:isIn passedValueFor(server:deviceLocation)
          }"""^^xsd:string
      ]
    ]
  ] .
```

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Semantic RPC – Server-side (III)

- Solution: OWL-S profiles extended by SPARQL
  - Example:

```
server:setVolumeLevelOfDevice a server:MyVolumeControl ;
  service:presents [
    a profile:Profile ;
    profile:has_process server:setVolumeLevelOfDeviceProcess ;
    profile:hasInput server:theDevice ;
    profile:hasInput server:newVolumeLevel ;
    profile:hasResult [
      a process:Result ;
      process:hasEffect [
        a dv:SPARQLS ;
        expr:expressionBody """FOR EACH CALL:
          DELETE { ?d vol:volumeLevelPercentage ?p }
          INSERT { ?d vol:volumeLevelPercentage
                      passedValueFor(server:newVolumeLevel) }
           WHERE {
             server:setVolumeLevelOfDevice vol:controls ?d .
             ?d vol:volumeLevelPercentage ?p .
             FILTER { ?d = passedValueFor(server:theDevice) }
           }"""^^xsd:string
      ]
    ]
  ] .
```

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Implementation of Semantic RPC

- universAAL Matchmaking: find out if the expected result in the concrete service request at hand is among the results that can be achieved by utilizing any of the registered services
  - Service utilities can be parametrized and hence may have several different results

- Derive the needed values for any existing input parameters during matchmaking
  - E.g., there is a match if the value x is passed for the input parameter y

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Implementation

- Brokers: The communication buses of the universAAL middleware, namely the context and service buses
- Publishers & Subscribers as well as Requesters & Responders remain independet from each other except for the chosen ontology
  - Esp. Requesters formulate their requests goal-based, focusing on what should be achieved (The expected effects and / or return values)
- Interoperability is guaranteed at a semantic level (no dependency on syntactical interfaces and development / execution environment)
  - Ontological inference, e.g. based on class hierarchies → intelligent system behavior
- There is one common API across domains that can stay valid for longer periods
- Verticals can just concentrate to agree on their domain models
- Data fusion and service composition across domains is faciliated

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Future extensions

- Protocol extensions
  - Preciser spec of server-side capabilities, stopping and undoing process execs, ...
- Composite service requests
  - The case of “CALL ?s1, ?s2, …“
- “On-the-fly service composition“ by the broker, when registered service profiles do not match directly
  - Working out an execution strategy
  - Cf. “query optimization“ in the theory of relational database systems
- In natural language processing: mapping humans’ statements to SPARQL-based service requests

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OUTLINE

- ✓ What is semantic interoperability?
- ✓ Why semantic interoperability?
- ✓ What is relevant for the oneM2M Common Service Layer
- The universAAL experience
  - ✓ Intro to universAAL
  - ✓ Semantic interoperability by the universAAL Middleware
  - Leasons learned

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Assessment

- Proof of concept is given (since 2008)
  - Ca. 40 real-life apps being ported in ReAAL, few already operational
- Critique: shift of problem from a-priori defined APIs to agreed ontologies
  however
  - Some overhead anyhow needed even for just sharing data
  - Looser coupling → more independence → surprising interoperability achievements
  - Declarative by nature → mapping one ontology to another and achieving interoperability without necessarily involving vendors
  - Certain level of intelligence given already at the level of brokerage and by specific platform managers
- Shift of paradigm in programming → perceived by today's developers as complex
  however

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Standardization potential

- In the case of event-based communication
  - Events as extended reified RDF statements
  - Communication protocol with the broker

- In the case of semantic RPC
  - The concept of data view of service classes
  - Extensions to SPARQL
  - Extensions to OWL-S
  - Communication protocol with the broker

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THANK YOU FOR YOUR ATTENTION!

Supporting Semantic Interoperability

at the level of the oneM2M Common Service Layer

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