Semantic interface for machine-to-machine communication in building automation

Daniel Schachinger, Wolfgang Kastner
Contents

1. Motivation
2. Requirements
3. Interface definition
4. Feasibility evaluation
5. Conclusion
Motivation

- **Building automation (BA) in the Internet of Things (IoT)**
  - Smart homes and buildings
  - Smart communities
  - Smart factories
  - ...

- **Requirements**
  - Horizontal system integration
  - Vertical system integration
  - Interoperable communication
  - Autonomous communication
  - ...

Semantic interface
Motivation

- Machine-to-machine (M2M) communication
  - Autonomous
  - No human intervention

- Technologies
  - Low-cost
  - Scalable
  - Reliable

Motivation

- Internet protocol suite
- Reuse existing technologies
- Service orientation
  - Autonomy
  - Interoperability
  - Flexibility
- Web services
  - REST
  - WS-*

Motivation

- Complex management applications
- Machine-processible semantics
- Common understanding
- Semantic Web standards
- Existing Ontologies
  - ThinkHome
  - BASont
  - M3
  - ...

Motivation

- Results of this work...
  - ... semantic interface for M2M communication
  - ... based on (Semantic) Web standards
  - ... ontology for semantic modeling
  - ... definition of relevant services
  - ... scope is BA domain
  - ... M2M between BA devices
Requirements

1. Architectural needs
   - Potentially high number of connected devices
   - Requirements are application-dependent
   - Internet protocol suite solves most issues
     - BA domain with moderate latency
     - Bandwidth is sufficient
     - Mobility by wireless technologies
     - Scalable and reliable protocols
     - Secure transmission
Requirements

2. Application layer services
   - Vertical and horizontal integration
   - Bidirectional communication

- Identification services
- Publication services
- Observation services
- Data services
- Querying services
- Status services

Building automation system

Semantic interface
3. Considerations regarding semantics

- **Building**
  - Zones
  - Structure
  - Orientation

- **Automation system**
  - Resources
  - Devices
  - Location
  - Topology

- **Sensing**
  - Precision
  - Placement
  - Dependency
  - Interval
  - Values

- **Parameter**
  - Ranges
  - Units
  - Types
  - Energy
  - Impact
  - Conditions
  - History
  - States

- **Actuating**
3. Considerations regarding semantics
3. Considerations regarding semantics
3. Considerations regarding semantics
3. Considerations regarding semantics
Interface definition

1. Protocol selection
Interface definition

2. Application services
   - 12 services
   - Header fields
     - Message ID
     - Content type
     - Sent date
     - Expires date
     - Reference ID
Interface definition

3. Semantic modeling

- Common understanding
- Local knowledge bases
- Platform-independent representation
- Ontology reuse (previous work)
  - Building: Zones, zone delimiters, ...
  - Automation system: BA resources, appliances, ...
  - Parameter: Units, values, parameter types, ...
  - Sensing: Data service, parameter configuration, ...
  - Actuating: Control service, states, conditions, ...

M2M communication
Shared knowledge
Feasibility evaluation

- Proof-of-concept implementation
  - KNX installation as BAS
  - Web application as demo BMS
  - Semantic core as message broker
Feasibility evaluation

- Functional capability
  - Atomic test cases
  - Test scenarios

```sparql
SELECT (?f as ?function) ?c ?t ?u
WHERE {{ ?f rdf:type colibri:DataService.
    BIND ('sensing' AS ?c).
        ?t rdfs:subClassOf colibri:EnvironmentalParameter.
        OPTIONAL {?p colibri:hasUnit ?u. }}
    UNION { ?f rdf:type colibri:ControlService.
        BIND ('actuating' AS ?c)
        OPTIONAL { ?f colibri:controlsParameter ?p. [...] }}
    ORDER BY ?function

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX colibri: <https://[...]/colibri.owl#>
```
Feasibility evaluation

- Hardware requirements
  - Memory
    - 25MB after garbage collection (<= 21,000 triples)
  - Transmission time
    - Comparable to other non-critical BA communication
  - Processing time
    - Ontology reasoning as performance bottleneck

→ Feasible for constrained hardware (Raspberry Pi)
Conclusion

- Semantic interface for M2M communication in BA
  - Existing M2M combined with semantic modeling
  - Service set based on WebSocket
  - Automatic message interpretation
  - Feasible for constrained hardware

- Outlook
  - Improvement of proof-of-concept implementation
  - Detailed performance evaluation (throughput, response times, content encodings, ...)
  - Investigate ontology reasoning over message contents
Thank you!