INTEROPERABILITY OF SEMANTICALLY-ENABLED WEB SERVICES ON THE WOT

Challenges and Prospects

Mahdi BENNARA – Associate Assistant Professor

Maxime LEFRANÇOIS –Assistant Professor

Antoine ZIMMERMANN –Assistant Professor

Nurten MESSALTI – R&D Engineer

Observations

- The IoT and the WoT:
  - Fragmentation in terms of:
    - data formats
    - device descriptions
    - communication protocols

- Semantic Web and RESTful services
    - A lot of advances in Semantic Web technologies (Validation, Lifting, Lowering)
    - (Distributed) reasoning
    - Lightweight REST APIs
    - Linked Data and REST: Linked RESTful services

Opportunities

- Leveraging the power of Semantic Web and RESTful services to solve IoT and WoT problems
  - Thing oriented nature of WoT aligns well with the Resource oriented nature of REST
  - REST to enable interoperability on the interface level
  - Semantic Web technologies to enable interoperability on the data level
  - Linked Data to enable interoperability on the semantic level

- Ideal recipe of technologies to achieve a mature level of semantic interoperability on the Web and on the WoT in particular

- How to integrate these technologies in a single framework where Things can interoperate with other components regardless of the exchange protocol or the used data format ???

Challenges (1/2)

- Heterogeneity of:
  - communication protocols
    - Wired: Ethernet, USB, RS-XXX, USART, etc.
    - Wire-less: Wi-Fi, GSM/GPRS, Bluetooth, BLE, ZigBee, etc.
    - Industrial & proprietary protocols: Industrial Ethernet, Modbus, Probus, etc.
  - data exchange formats
    - Textual formats: JSON, XML, CSV, etc.
    - Binary formats: CBOR, EXI, BSON, etc.
    - Semantic-aware formats: concrete syntaxes of RDF (JSON-LD, RDF/XML, Turtle)
  - Legacy devices in production that implement ancient technologies

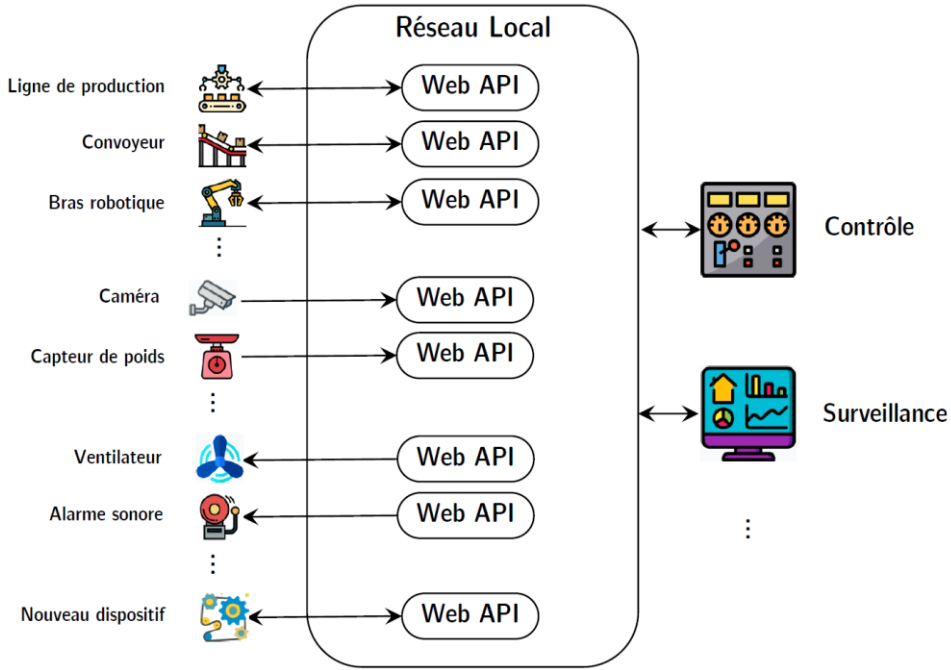
Challenges (2/2)

- Ensuring interoperability without resorting to hardwiring/hardcoding (flexibility)
- Facilitating the deployment phase of new equipment (extensibility)
- Allowing easy (time, cost, expertise) and incremental integration with existing systems
- Abstracting of protocols and data formats of both old and new devices
- Automating device interactions (discovery, selection, etc.)
- Perpetuating the autonomy (limited human intervention) of automated devices

Proposals (1/3)

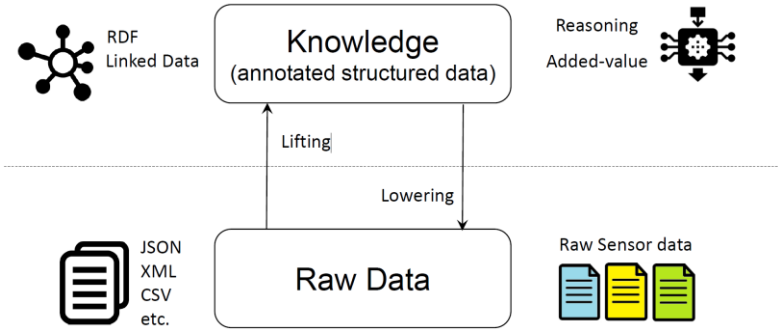
- Implement an intermediary generic middleware layer between devices exchanging data and applications consuming and generating knowledge

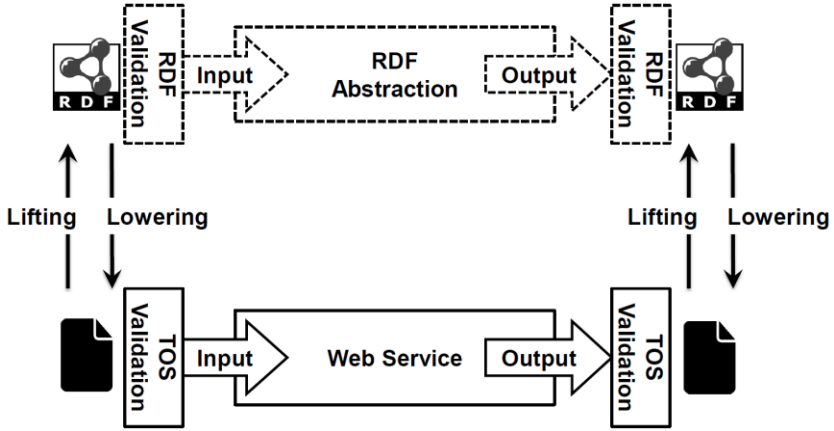
- Things capabilities and data is exposed as Web APIs:
  - Follow a Plug and Play approach
  - Expose Thing interfaces as Web services
  - Describe their properties, actions and events using standards: W3C's WoT TD
  - Monitoring applications can communicate with Things as Web clients

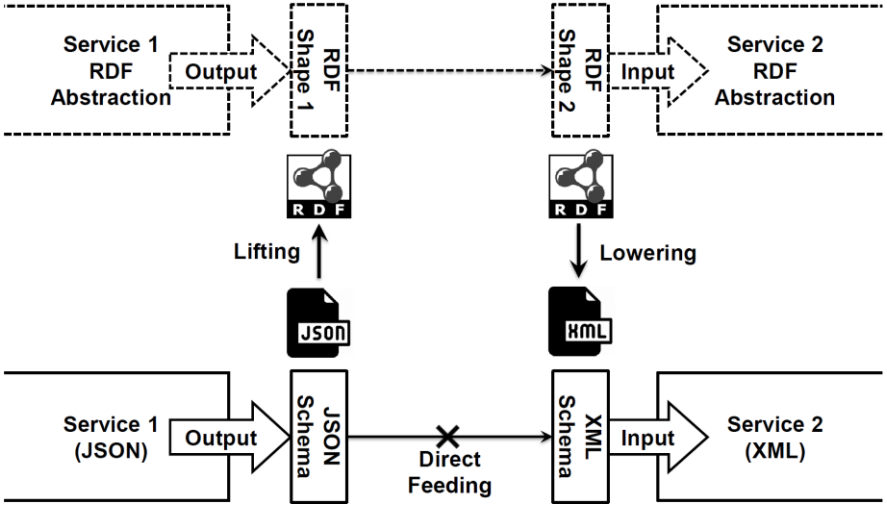


Proposals (2/3)

- From Raw Data to Knowledge and back
  - Lift raw sensor data to RDF
  - Lower RDF into data to feed to sensors
  - Validate exchanged RDF using shapes



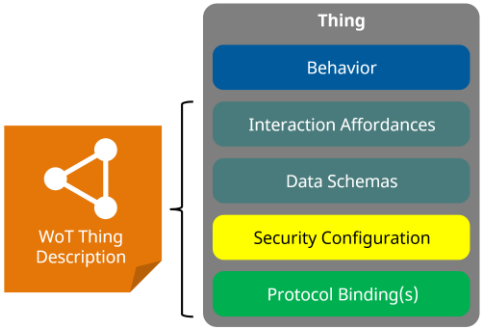


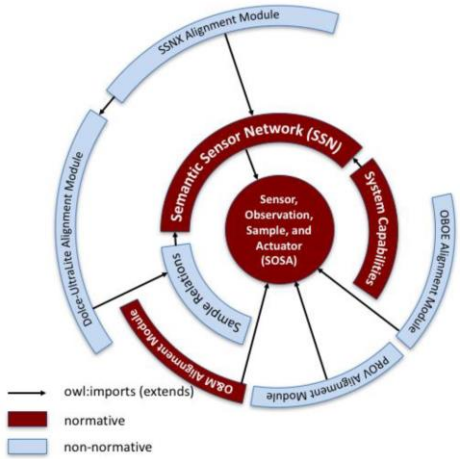


Proposals (3/3)

- Leveraging standardization works done in the W3C's WoT working group:
  - WoT Architecture
  - WoT Thing Description
  - WoT Protocol Binding Templates

- Layered Ontologies and Semantic Negotiation
  - Relevant in constrained contexts
  - Lift/Lower only what is necessary
  - Selective reasoning





Summary

We aim to:

- Facilitate extensibility:
  - deployment only requires implementing RDF-enabled service interfaces
  - extensible layered ontologies
- Allow an easy and incremental integration:
  - through semantic-aware gateways
  - lifting and lowering rules can be reused
- Ensure flexibility: generic interfaces help avoid resorting to hardwiring/hardcoding
- Overcome heterogeneity: RDF abstraction layer masks the underlying data format
- Ensure autonomy: making data machine readable/understandable/processable

Discussion starters:

- Are the standardization efforts not enough? or too many?
- Should low-cost manufacturers invest in interoperability-enabling capabilities?

Contact : mahdi.bennara@emse.fr

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