Architecture and Interoperability Standards for the Internet of Things

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Summary

➢ Background
➢ Principles and use of Open Messaging Interface (O-MI) and Open Data Format (O-DF)
➢ Reference Implementation
➢ Applications
➢ Comparison with other standards
➢ Conclusion
Background

- **DIALOG** platform: first IoT implementation in the world (Aalto University, 2001)

- **PROMISE**: interoperability requirements from 10 industrial IoT cases in different application domains (2004-2008)

- Standardisation Work Group established with The Open Group in 2010

- **Open Messaging Interface (O-MI)** and **Open Data Format (O-DF)** published in 2014
Sensor data pushed to virtual/real servers
Data collected into vertical silos
M2M communication limited to local network
- **Huge amounts of data** (Big Data) collected that is difficult to use
- **Interoperability** is hard to achieve, even with REST APIs
- IoT requires **communication between systems and organizations**, not just local M2M communication
- Systems (including Intelligent/Smart Products) rather than sensors
- **Horizontal integration** as easy as vertical integration
- IoT data collected **as and when needed**
- Establish **two-way, time-limited** information flows between trusted entities and the physical product(s)
Lifecycle Management (CL\textsubscript{2}M)

- Lifecycle view: IoT is about managing all information about any product/Thing.
- Information is distributed over systems (devices, servers, applications, ...).
- Information is distributed over organizations (companies, individuals, authorities, ...).
- Product (and its parts) are unique instances.
- How manage identities, access rights, ...?
- IoT should provide necessary capabilities for CL\textsubscript{2}M.
Open Platform 3.0 Use Cases

Knowledge driven Behavior

Products

Building energy management

Co-generation

Fabricated Objects

Intelligent Utility energy management

Intelligent traffic management

Energy

Services

Moving Objects

Open Platform Use Cases

Utility Objects

Intelligence

Human Objects

Content

Retail

Multi-media

Lifestyle services

Wearable services

Medical services

Medical research

Smart appliances

Financial Services

Point of sale charging

Social networks

Social marketing

Citizen services

Consumer buying

Red connections: O-MI & O-DF
Published by The Open Group on October 16th, 2014

Open Messaging Interface (O-MI): communication

Open Data Format (O-DF): payload

May be used independently of each other (as HTTP and HTML)

Publish available information and services

Discover available information and services

Read/write of immediate and historical information, alerts, other events, ...

Subscribe to information using Observer Design Pattern

Specified using XML schema

Can be transported by "any" underlying protocol: HTTP, HTTPS, FTP, SMTP, XMPP, file transfer, USB sticks, plain sockets, ...

Usable as Standardized IoT REST API as well as M2M, M2S, etc.
Read current and historical information, alerts, other events, …

Write information, such as sensor values, setpoints, alerts, other events, …

Subscribe to information: ad hoc, loosely coupled, \textit{time-limited} (regular interval vs. event-based), with or without callback, piggy-backing for handling firewalls and mobility, etc.
Open Data Format (O-DF)

- **Generic** format for representing "anything" in the IoT
- **Same structure** used for publishing, discovering, querying and retrieving information
- **Extensible** in similar ways as class inheritance in object-oriented programming for domain-specific vocabularies
- **Taxonomy** may be provided by e.g. **UDEF** (an Open Group standard, is a common classification framework for business information that provides a standard way of mapping data between systems)

Other payloads may be used with O-MI and O-DF may be used without O-MI.

```xml
<?xml version="1.0" encoding="UTF-8"?>

<omi:omiEnvelope xmlns:omi="omi.xsd" version="1.0" ttl="-1">
  <omi:write msgformat="odf">
    <omi:msg xmlns="odf.xsd">
      <Objects>
        <Object>
          <id>SmartFridge22334411</id>
          <InfoItem name="FridgeTemperatureSetpoint">
            <value>3.5</value>
          </InfoItem>
          <InfoItem name="FreezerTemperatureSetpoint">
            <value>-20.0</value>
          </InfoItem>
        </Object>
      </Objects>
    </omi:msg>
  </omi:write>
</omi:omiEnvelope>
```
<?xml version="1.0" encoding="UTF-8"?>
<omi:omiEnvelope version="1.0" ttl="10">
  <omi:response>
    <omi:result msgformat="odf">
      <omi:return returnCode="200"></omi:return>
      <omi:requestId>REQ654534</omi:requestId>
      <omi:msg xmlns="odf.xsd">
        <Objects>
          <Object>
            <id>SmartFridge22334411</id>
            <InfoItem name="DoorStatus"><value>open</value></InfoItem>
            <InfoItem name="Temperature"><value>9.87</value></InfoItem>
            <InfoItem name="ConsumedElectricalPowerMesure">
              <description>Power consumption and timestamp.</description>
              <value unixTime="5453563">15.5</value>
            </InfoItem>
          </Object>
        </Objects>
      </omi:msg>
    </omi:result>
  </omi:response>
</omi:omiEnvelope>
Published as Open Source

Plan: disseminate through iot.eclipse.org

Implements:
- URL-based discovery and read operations
- Web GUI for more advanced operations

Written in Scala Programming Language

Implementations in other languages exist

Data publication and acquisition for instance with simple Unix Shell Script
Applications

Tens of different real-business applications have been addressed by involved partners over the years

Today:
- Sensing of Buildings
- HVAC machine control
Challenges:
• Long lifecycle(s)
• Component instances with their own lifecycles, manufacturers, ...
• Failure of one sub-system must not make the whole system fail

Objectives:
• CL$_2$M of building, parts and systems
• Fault detection, alarms
• Continuous optimization of different systems when considering conflicting objectives (energy consumption, energy prices, local energy production, comfort, weather, ...)

Smart Grid
Energy prices, forecasts, control commands etc.
Enabling Boundaryless Information Flow™ in Open Platform 3.0

Social behavior analytics
Lifestyle behavior analytics
Usage and viewing preferences and behavior data aggregation and analytics

Buyer and seller history analytics
Apparel sales

Customer buying behavior analytics
Business supply chain

Data feeds collection and data aggregators (Data Fabric).
Visualization Analytics

Citizen activity and preferences analytics
Event and crowd behavior analytics
Real-time event analysis

Multi-channel (Closed loop) data collection and processing
Real-time analytics response
Energy usage pattern analytics

Semantic Linked Open Data (W3C)
Master Data Management (MDM)

Vehicle driver usage analytics
Citizen, crowd, corporate activity and behavior analytics

Performance analytics
Marketing Analytics

Point of sale charging

Knowledge driven Behavior
Content
Human Objects
Intelligence
Medical services
Medical research

Moving Objects
Services
Utility Objects
Smart appliances

Medical data analytics
Medical History-Patient Statistical analysis
Medical Research Analytics

Customer preferences and behavior analytics

Performance analytics
Marketing Analytics

Patient and Medical Data aggregation and analytics

Red connections: O-MI & O-DF

Open Platform Use Cases
M2M standards such as MQTT, CoAP, ...

- Binary, using TCP/UDP as underlying protocols
- Firewall challenges (although simplified by e.g. WebSockets)
- Not intended nor suitable for System-to-System communication

Most standards use **Pub/Sub** model (centralised) rather than **Observer** (peer-to-peer)

**REST APIs**

- REST is not a standard
- IoT REST APIs are (all?) proprietary

Exhaustive comparison impossible

Conclusions

- O-MI & O-DF is the same for IoT as HTTP & HTML for the Web
- IoT is about Systems of Systems (not only M2M)
- O-MI & O-DF enable the Creation of IoT Systems of Systems without programming
- Keep it simple! O-MI: 21 pages, O-DF: 10 pages
  - O-MI & O-DF are mature: the result of a long process and many iterations involving numerous people, organizations, domains and applications
  - I didn't have time to write a short letter, so I wrote a long one instead.
- O-MI & O-DF are generic, compact, complete and extensible
Interoperability challenge

Think this is difficult?

Open Messaging Interface (O-MI)
Open Data Format (O-DF)
Open Group Standards for the Internet of Things (IoT)

Internet of Things, Cyber-Physical Systems

Things, money, languages, ...
Thank You!