jOSEF – A Java-Based Open-Source Smart Meter Gateway Experimentation Framework

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http://kn.inf.uni-tuebingen.de
FP7 Project C-DAX

- Cyber-secure Data And Control Cloud for power grids
  - [http://www.cdax.eu](http://www.cdax.eu)
- C-DAX middleware
  - Enables smart grid applications to exchange information securely
  - Implements information-centric networking (ICN) and publish/subscribe paradigms

Motivation

- Targeted use cases of C-DAX
  - Real-time state estimation based on PMU measurements
  - Telecontrol (SCADA)
  - Future retail energy market (REM)
- Integration of smart meter communication as part of REM
- No software available for experiment setups to simulate smart meter communication according to the German regulations

Project partners

Smart Meters and Smart Meter Gateways

► Smart Meter (SM)
  - Communication interfaces for automated meter reading
  - Additional measurements (e.g. voltage, frequency)
  - New features (e.g. dynamic electricity tariffs)

► Smart Meter Gateway (SMGW)
  - Communication module for SM
  - Core component of German SM architecture
  - Rationale
    - Separate communication and metering
    - Reduce complexity of smart meters
Smart Meter Rollout in Germany

► Legal framework in Germany
  ▪ Energiewirtschaftsgesetz (EnWG §21)
  ▪ Regulation “Intelligente Netze“
  ▪ Technische Richtlinie (TR-03109), published by Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik, BSI)
    – Specifications for SMGW

► Rollout schedule in Germany

- SM for producers and consumers
- SMGW for producers > 7 kW
- SMGW for consumers > 20000 kWh/a
- ... > 10000 kWh/a
- ... > 6000 kWh/a

SMGW System Boundaries

Specified by TR-03109

- LMN = Local Metrological Network
- HAN = Home Area Network
- WAN = Wide Area Network
- SM = Smart Meter
- SMGW = Smart Meter Gateway
- EMP = External Market Participant
- CLS = Controllable Local System

Applications
- Gather metering data from SMs
- Time-stamping measurements
- Tariffing
- Storing data for dissemination to EMPs

Protocols
- COSEM
- M-Bus
- SML

Security
- M-Bus encryption
- TLS

Protocol stack: LMN SMGW communication

<table>
<thead>
<tr>
<th>Protocol Type</th>
<th>Wireless</th>
<th>Wired</th>
<th>Open</th>
</tr>
</thead>
<tbody>
<tr>
<td>COSEM model with OBIS codes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M-Bus application protocol</td>
<td></td>
<td>SML application and transport protocol</td>
<td></td>
</tr>
<tr>
<td>M-Bus AES encryption</td>
<td>TLS</td>
<td>TLS</td>
<td>TLS</td>
</tr>
<tr>
<td>OMS authentication and</td>
<td></td>
<td>HDLC over EIA/RS-485</td>
<td>other protocols</td>
</tr>
<tr>
<td>fragmentation layer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wireless M-Bus (wM-Bus)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Applications
- (Read-only) access for end consumers
- Relay control messages between CLS and EMPs

Protocols
- Not specified by TR-03109

Security
- TLS
SMGW: WAN Communication

- **Applications**
  - Forwarding data to legitimate EMPs
  - Remote administration

- **Protocols**
  - RESTful web service
  - HTTP
  - NTP

- **Security**
  - CMS
  - TLS

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Protocol stack: WAN SMGW communication

<table>
<thead>
<tr>
<th>Protocol Stack</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Metering, SMGW Administration</td>
<td>COSEM model with OBIS codes, XML, Crypto Message Syntax (CMS), RESTful web service, HTTP, TLS, other protocols</td>
</tr>
</tbody>
</table>

Overview: Standards and Protocols

► Companion Specification for Electricity Metering (COSEM)
  ▪ Object oriented modelling system
  ▪ IEC 62056-6-2

► Object Identification System (OBIS)
  ▪ Numeric code system
  ▪ Identification of COSEM objects
  ▪ IEC 62056-6-1

► Smart Message Language (SML)
  ▪ Communication protocol for smart meter access
  ▪ Described in BSI TR-03109-1 appendix IV
  ▪ Inclusion in IEC 62056-5-3-8 planned

A = 1: Energy medium
B = 0: Channel
C = 1: Quantity
D = 8: Measurement type
E = 1: Tariff
F = 255: Billing period

1.0.1.8.1.255 OBIS code
**Smart Meter Simulator**
- Data source
- Server, COSEM model
- Generates fake metering data based on standard load profiles
- XML-based configuration

**Minimal SMGW**
- Client for SM simulator → meter reading
- Client for RESTful web service → meter data delivery
- Graphical user interface (GUI)

**RESTful web service**
- Data sink
- Server accepting metering data
- Role: external market participant
jOSEF: Implementation

- Implemented in Java

- COSEM Object Model
  - Minimal implementation
  - Simplifications: Only required classes and functions implemented

- SML
  - Based on jSML by Fraunhofer ISE (OpenMUC)
  - Modifications for SML v1.04 support

- XML schema based on working draft of BSI TR-03109

- Additional libraries used
  - Jersey: (RESTful web service)
  - jFreeChart (Visualization)
1. SMGW sends SML message to SM
   ▪ Request all COSEM object IDs
   ▪ Discover data model of SM

2. SM sends SML message containing list

3. SMGW sends SML message requesting details about metering objects

4. SM sends SML message containing metering objects

   ▶ Steps 1+2 only initially or upon reconfiguration

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Meter data received in COSEM over SML is converted to XML representation of COSEM.

SMGW sends COSEM/XML data to RESTful web service end point using HTTP.
Example Scenario

![Diagram showing the protocol stack and entities involved in a smart meter scenario.](image)

- **Entities**:
  - SM (Smart Meter)
  - SMGW (Smart Meter Gateway)
  - EMP (Energy Management Platform)

- **Protocol stack**:
  - COSEM
  - SML
  - XML
  - HTTP

- **Connections**:
  - TCP from Host A to SM
  - HTTP from SMGW to EMP

- **XML example**:
  ```xml
  <dev count="1">
    <dev id="UTB1429882966913">
      <objects count="5">
        <object id="1.0.1.8.1.255" class-id="3" version="0">
          <attributes count="3">
            <attribute id="1">
              <value>
                <string>1.0.1.8.1.255</string>
              </value>
            </attribute>
            <attribute id="2">
              <value>
                <ulong>32051550</ulong>
              </value>
            </attribute>
          </attributes>
        </object>
      </objects>
    </dev>
  </dev>
  ```

- **Identifiers**:
  - **Smart meter ID**
  - **Metering object ID**
  - **Electricity consumption in Wh**

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Limitations

- Missing features
  - HDLC serial link support in LMN
  - Tariffing
  - Remote administration
  - Pseudonymization

- Deviations from TR-03109 specification
SMGW GUI

Minimal Smart Meter Gateway

Main Menu

Client View

Object List
- 0.0.40.0.0.255-15
- 0.0.42.0.0.255-1
- 1.0.1.8.1.255-3
- 1.0.2.8.1.255-3
- 1.0.1.8.0.255-3

Attribute List
- 1-1.0.1.8.1.255
- 2-356250
- 3-ScalerUnit[scaler: -6, unit: 30]

Visualization

- Start painting diagram

Smart Meter Simulator Settings
- Server IP: localhost
- Server Port: 33333
- Server ID: 1
- Client ID: 10
- Username: 
- Password: 

Manual Request

Choose request type: GET
Select index: 1
Enter parameter: 
Send request

Automatic Requests

- Retrieve data from Smart Meter Simulator
- Interval in seconds: 2
- Filter by medium: Electricity
- Filter by class id: Register

RESTful Webservice Settings

- RESTful Webservice URL: http://localhost:8080/RestServ
- Interval in seconds: 5

Connect
Disconnect

SMGW GUI (Data Visualization)

Object with logical name [1.0.12.7.0.255] and class id [3]

Value of attribute 2 in unit [35] (Volt)
SM-Simulator (Text console UI)

Welcome to the Smart Meter Simulator user interface!
Menu:
[0] Exit.
1
View server settings:
-> Server is listening on port [33333]
-> Server is not using authentication for clients
Menu:
[0] Exit.
2
View simulator settings:
-> Simulated annual power consumption in kWh [1000.0]
-> Simulated annual power infeed in kWh [1000.0]
-> Simulation-time of a 'realtime-quarter-hour' in seconds [4]
-> Simulation resolution in miliseconds [1000]
Menu:
[0] Exit.
0
Closing program...
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