Tutorial 2

Architectures for IoT Applications in the Energy Domain

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Outline

- **Context**
  - Internet of Things
  - Challenges
  - Energy
  - Issues and challenges

- **Architectures for IoT**
  - oneM2M
  - IoT-A
  - IIC
  - AIOTI

- **Smart Energy Aware Systems (SEAS)**
  - Objectives
  - SEAS Reference Architecture Model (S-RAM)
Context

- Internet of Things
- Energy
- Trends, issues and challenges
Internet of Things – Context (1/4)

- **Smart “objects”**
  - Connecting to Internet
  - Feeding others with collected information

- **Anything can be a “thing”**
  - Uniquely identified
  - Provide empirical data

- **Limitless concept**
  - Domains (health, environment, energy, etc.)
  - Services
  - Lots of potential
Internet of Things – Context (2/4)

- **Monitor different environments**
  - Analyze collected data
  - Manage/control environment

- **Constrained devices**
  - Limited capabilities
  - Required adapted protocols

- **Nature of the traffic**
  - Low volume per endpoint
  - Event-driven or Scheduled at regular interval
  - Energy-, resource- and cost-efficient

- **Different from Human communications**
  - High-volume per endpoint
  - Burst-like

⇒ Internet has not been designed for such traffic
Cisco’s prevision, number of things:

- In 2008, > people living on earth
- In 2020, ~ 50 billion

⇒ Exponential grows of devices and traffic
Internet of Things – Challenges (4/4)

- Manage such amount of devices
  - With different capabilities (Access, hardware, etc.)
  - Specific traffic
  - Required specific protocols (IPv6, CoAP, etc.)

- Architecture
  - Scalable, adaptable and dynamic
  - Automated
  - Develop new business and services

- Protect device and information
  - Access control and storage of data
  - Privacy of data
  - Secure communication

⇒ Dedicated architecture is required
Energy – Context (1/3)

- **Different type of energy sources**
  - Each with advantages and drawbacks
    - (un)limited
    - (ir)regular
    - Hazardous for the planet

- **Increasing needs**

- **Difficulty to manage/monitor**
  - Needs vs Production vs Actual consumption
  - Over-production penalty
  - Understand consuming behavior
Energy – Context (2/3)

- **Energy network**
  - Centered on big production sites
  - With widespread distribution network
  - And consumer at endpoints

- **Desire to**
  - Protect the planet with
    - Better sources
    - Better consumption
  - Decrease pollution
  - Lower waste and losses

⇒ **IoT might help achieve these objectives**
Energy – Electricity (3/3)

Growing usage of local renewable production
⇒ Producer and consumer: “Prosumer”
  • Less reliable
  • Higher demand
  • From rigid to distributed network

Timely issue
• Growing number of devices
• Increasing number of Electric Vehicles
⇒ Effect on peak time consumption
  • Need for better management systems

Optimize consumption
• Influence “prosumer”
  – Via demands (shift or use of alternatives)
  – With tools to better use renewable energies
• At different scale
IoT and Energy – Challenges (1/4)

- IoT can help monitor, manage, optimize and coordinate both production and consumption

- With proper management,
  - Local production and consumption can be balanced
  - Both local and global production can be optimized and coordinated
  - Local behavior can support the main grid when required (e.g. peak time)
  - Etc.

- Create new businesses
  - Flexibility (e.g. negawatts)
IoT and Energy – Challenges (2/4)

- Need for an architecture to interconnect energy actors and better manage energy use

- Properly balancing energy network
  - Real-time and predictive measurement
  - Control capabilities on large distributed volume
  - Involve end-user

- Control load possible for decades but is not widely enough adopted to cope with current challenges

- Required to
  - Find each party
  - Access a resource
  - Learn details from different endpoints
  - Implement technical compatibility to each endpoints
  - Compensate for access and compliance to commitments
IoT and Energy – Requirements (4/4)

- **Need for an architecture**
  - Scalable
  - Dynamic
  - Automated
  - Secure

- **Include prosumer in the architecture and management**

- **Enable different levels of management**
  - Local
  - Global (when possible)
  - Etc.

- **Different architectures/platforms/systems exist to**
  - Interconnect different nodes and systems
  - Manage energy Demand and Response
  - Collect and analyze data
Architecture for Internet of Things

- State-of-the-Art
  - oneM2M - FA
  - IoT-A - ARM
  - IIC - IIRA
  - AIOTI - HLA
- Which one for the Energy domain?
Functional Architecture (1/4)

- **oneM2M**
  - 8 ICT standards bodies
  - 6 Standard Development Organizations

- **Observation:**
  - Several M2M standardization effort
  - ETSI M2M
  - OMA DM
  - Lightweight M2M

- **Consequences**
  - Scattered effort
  - No common solution
Functional Architecture (2/4)

- Proposition: oneM2M Functional Architecture

- Motivations
  - Prevent duplication of standardization effort
  - Need for a common M2M Service Layer
  - Connect the myriad of field devices with all M2M applications

- Objectives
  - Ensure most efficient deployment of M2M communications systems
  - Develop technical specifications
Functional Architecture (3/4)

Field Domain

Application Layer

Common Services Layer

Network Services Layer

Infrastructure Domain

NoDN

ASN

ADN-AE

ADN-CSE

ASN

ADN-AE

ADN-CSE

MN

MN-AE

MN-CSE

IN

IN-AE

IN-CSE

IN

IN-AE

IN-CSE

IN

IN-AE
Results

- Full technical M2M architecture
- Interconnection with bank systems

No information regarding

- Automation using semantics and ontology (yet)
- Different management levels

Drawbacks

- Focus on M2M
- Few involvement of end user
Internet of Things – Architecture (IoT-A)
- European FP7 Research Project

Observation: Current “smart” solutions
- Used specific application and architecture
- Left little place for interoperation

Consequences
- IoT landscape fragmented
- Not fully using IoT potential
  - i.e. crossing information from different domains
Proposition: Architecture Reference Model

Motivations
- Develop guidelines to build compliant IoT solutions
  - Common understanding of IoT
  - Common foundation (interoperable system)
  - Standardized interfaces
  - Providing best practices

Objectives
- Provide a common Reference model for IoT Domain
- Help develop all IoT-related solutions
Results

- Abstract model to fit to any domain
- Semantic description of each entity
- Several interoperable IoT solutions based on common grounds

No information regarding

- Automation using semantics and ontology
- Any implementation and performance result
- Interconnection with other systems (e.g. bank)
Industrial Internet Reference Architecture (1/4)

- **Industrial Internet Consortium**
  - Composed of several Industry players
  - Aims to promote and accelerate development of industrial internet technologies

- **Observation**: Lots of industrial control systems

- **Consequences**
  - Industrial IoT landscape fragmented
  - Not fully using power of IoT
    - i.e. crossing information from different domains, especially non industrial one
Proposition: Industrial Internet Reference Architecture

Motivations
- Connect industrial systems with people
- Fully integrate them with enterprise systems, business processes and analytics solutions
- Increase optimization, operation and collaboration among different autonomous control systems

Objectives
- Bring these systems online
- Combine them with organizational or public information
- Form large end-to-end systems
- Provide guidelines for
  - Standard-based, open and horizontal architecture frameworks
  - Implementing reference architectures with interoperable and interchangeable blocks
Industrial Internet Reference Architecture (3/4)

**Edge Tier**
- Sensor
- Actuator
- Controller
- Edge GW

**Platform Tier**
- Service Platform
  - Data transform
  - Analytics
  - Operations

**Enterprise Tier**
- User
  - Application
    - Rules & Controls
    - OT User
Industrial Internet Reference Architecture (4/4)

- **Results**
  - High level of abstraction to support any industrial domain requirement
  - Hierarchical node management
  - On going testbeds

- **No information regarding**
  - Automation using semantics and ontology

- **Questioning**
  - Centralized solutions ?
  - Application to non industrial scenario (e.g. energy) ?
Alliance for Internet of Things Innovation
- Initiated by the European commission
- Creation of a dynamic European IoT ecosystem to unleash the potential of the IoT

Observations:
- No common European IoT market
- Current systems mainly focused on sensors

Consequences
- IoT landscape fragmented
- Not fully using power of IoT, especially at large scale — i.e. crossing information from different domains
High Level Architecture (2/3)

- **Proposition:** AIOTI High Level Architecture

- **Motivations**
  - Need to foster interoperability
  - Link architecture with semantic interoperability
  - Use ISO/IEC/IEEE 42010 to provide minimal requirements

- **Objectives**
  - A single market for IoT
  - A thriving IoT ecosystem
  - A humand-centered IoT approach
  - Interconnection with non-IoT systems
Results

- Minimal model based on semantic
- Three management levels (device, gateway and infrastructure)
- Domain model derived from IoT-A
- Functional model compatible with oneM2M and IIC architectures

No information regarding

- Interconnection with other systems

New alliance only few documents available
Which one to choose?

- **Energy domain requires**
  - Involvement of prosumer
  - Interconnections with others systems (e.g. bank)
  - An architecture adaptable and scalable
  - Different levels of management, decision and optimization
  - Coordination between each level
  - Automation
  - Mobility management

- None satisfy all these requirements
Smart Energy Aware Systems

- What?
- Why?
- Proposed solution
Smart Energy Aware Systems

■ European Project

■ Goal
• Enable better energy resource management (both production and consumption)

■ Provides the means to do it
• Universal language enabling automatic communications
• Innovative architecture enabling scalable, efficient, dynamic and real-time management
**Enhanced architecture**

**Define an architecture**
- Compatible with IoT architecture model
- Suitable for energy domain and especially electrical network
- Nodes may
  - Move without breaking the architecture
  - Evolve with hardware enhancement

**Hybrid Architecture**
- Interconnect all energy players
- Structured peer-to-peer and client/server models
- Efficiently search for a given resource/information
- Optimizing entities interactions/requests
- Facilitating data analysis

**Requirements**
- Common information model
- Transaction capabilities
- Data transmission
- Field deployment
  - Self configuration
  - Supports discovery
  - Management capabilities
- Security
  - Identity enable
  - Multiple trust levels
  - Multiple level of authorization
SEAS Reference Architecture Model (S-RAM)

SEAS Core Domain

SEAS Field Domain

IP Domain

Non-IP Domain

SFE: SEAS Field Entity
SCE: SEAS Core Entity
SCS: SEAS Core Service
GM: Group Manager
EDO: Energy Distribution Operator
EMO: Energy Market Operator
ES: Energy Supplier
SP: Service Provider
OS: Ontology Service
RS: Registration Service
A3S: Security Service
TS: Transaction Service
FO: Flexibility Operator
Estimation of Photovoltaic Panel Production

- **Simple scenario**
- **Measure production:**
  - Several possibilities
  - Fairly simple
  => EU visualizes its production

- **Estimate future production?**
  - Inform the grid
  => Better knowledge of load shedding capabilities
  => Send demands accordingly
  - Inform the EU
  => Better consumption planning

- **How to realize it?**
S-RAM Proof-of-Concept

1. Registration
2. Search for available Services
3. Exchange information with chosen Service Provider
S-RAM PoC

- **Learning based on previous**
  - Production measurements
  - Cloudiness percentage forecasts

![Graphs showing power vs. cloudiness percentage](image-url)
S-RAM PoC – Production estimation results

![Graph showing power consumption over time](image)

- Estimated
- Measured

Power (Watts)

Time (hour)
What next?

- Finish implementation of Core Services

- Setup different testbeds
  - Implement more services
  - Test automation for deployment and use

- Test interoperability with other architectures
Thank you for your attention