Introduction to Platforms of services for the Internet of Things

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Outline

1. Internet of Things (IoT)
2. IoT distributed architecture
3. IoT reference architectures
4. IoT Platforms
5. Middleware for the IoT
6. Interaction models and standard protocols
7. Conclusions
Internet of things, Internet of everything

Image extracted from [Shelby, 2010]
“Everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet to achieve some useful objective.”

[Whitmore et al., 2014]

“Interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless large-scale sensing, data analytics and information representation using cutting-edge ubiquitous sensing and cloud computing.”

[Gubbi et al., 2013]
IoT impacts the Internet

- High heterogeneity
- Huge number of connected objects


- Huge volume of produced data: 44 billion \((10^9)\) of Giga byte in 2020
From IoT silos to Internet Openness

Image extracted from http://www.libelium.com/
Opportunity to build new mass services

Libelium Smart World

- Smartphones Detection
  - Detect iPhone and Android devices and in general any device which works with WiFi or Bluetooth interfaces.
- Air Pollution
  - Control of CO2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.
- Forest Fire Detection
  - Monitoring of combustion gases and preemptive fire conditions to define alert zones.
- Wine Quality Enhancing
  - Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.
- Offspring Care
  - Control of grazing conditions of the offspring in animal farms to ensure its survival and health.
- Sportsmen Care
  - Vital signs monitoring in high performance centers and fields.
- Structural Health
  - Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.
- Radiation Levels
  - Distributed measurement of radiation levels in nuclear power stations surroundings to generate leakage alerts.
- Electromagnetic Levels
  - Measurement of the energy radiated by cell stations and WiFi routers.
- Traffic Congestion
  - Monitoring of vehicles and pedestrian influence to optimize driving and walking routes.
- Water Quality
  - Study of water suitability in rivers and the sea for fauna and eligibility for drinkable use.
- Golf Courses
  - Selections irrigation in dry zones to reduce the water resources required in the green.
- Waste Management
  - Detection of liquid presence outside tanks and pressure variations along pipes.
- Water Leaks
  - Detection of liquid presence outside tanks and pressure variations along pipes.
- Smart Roads
  - Warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.
- Smart Lighting
  - Intelligent and weather adaptive lighting in street lights.
- Intelligent Shopping
  - Getting advices in the point of sale according to customer habits, preferences, presence of allergic components for them or expiration dates.
- Noise Urban Maps
  - Sound monitoring in bar areas and noisy zones in real time.
- Vehicle Auto-diagnosis
  - Information collection from CarData to send real time alarms to emergencies or provide advice to drivers.
- Item Location
  - Search of individual items in big surfaces like warehouses or harbours.

Image extracted from http://www.libelium.com/
Internet of Things (IoT)

IoT heterogeneity requires standardization

- Protocols, API, architectural patterns independent of the application domains
Standard organizations related to the IoT

IoT SDOs and Alliances Landscape
(Vertical and Horizontal Domains)

Source: AIOTI WG3 (IoT Standardisation) – Release 2.0

Image extracted from AIOTI Alliance for internet of things innovation
Platforms for IoT
Some standardization organizations for the IoT

**IETF**
- Constrained RESTful Environments (CoAP)
- IPv6 over Low-power WPAN (6LoWPAN)
- Transport Layer Security: TLS/DTLS profile suitable for constrained IoT devices

**OASIS** publish/subscribe (MQTT and AMQP)

**oneM2M** - Standards APIs and services for M2M and the Internet of Things interoperability

**W3C** Web of Things
- Rich metadata that describe data (XML Schemas)
- Interaction models exposed to applications (http/REST APIs)
- Semantics of things (SAN, SSN Semantic ontologies for Actuators/Sensors)

**IoT security foundation** (guide for privacy and trust)
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Complex distributed system
Several level of Infrastructure

IoT distributed architecture

Platforms for IoT
Cloud for IoT

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. (NIST definition)

Image extracted from https://iot.eclipse.org/
Fog computing model

Fog definitions

Cisco definition [Cis, 2015]
The fog extends the cloud to be closer to the things that produce and act on IoT data. Any device with computing, storage, and network connectivity can be a fog node.

NIST definition 2018
Fog computing is a layered model for enabling ubiquitous access to a shared continuum of scalable computing resources. The model facilitates the deployment of distributed, latency-aware applications and services, and consists of fog nodes (physical or virtual), residing between smart end-devices and centralized (cloud) services.
Consider fog computing when

- Data is collected at the extreme edge (e.g., vehicles, factory, roadways)
- Thousands of things across a large geographic area are generating data
- It is necessary to analyze and act on the data in less than a second.
  - Cloud computing latency 100ms
  - Fog computing, latency ms, real time analysis and control
- Local caching, analysis, filtering: reduce offloading
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**Reference Architecture**

**Software Architecture**

- “The software architecture of a system is the *set of structures* needed to reason about the system, which comprise software elements, relations among them, and properties of both” [Bass et al., 2012]

- Software architecture = an abstraction — i.e. omits certain information
  - Elements interact with each other by means of *interfaces* that partition details into public and private parts
  - Architecture focuses on the *public side* of this division

**Reference Architecture**

A Reference Architecture (RA) is an *architectural design pattern* that indicates how an abstract set of relationships realises a set of requirements. (OASIS definition)

The main purpose of a RA is to provide *guidance for the development of concrete architectures*. 
... and its ecosystem

WSO2 architecture

Image extracted from http://wso2.com/solutions/iot/, WSO2 is an open-source technology provider for digital business
IoT-A Architecture Functional view

Image extracted from http://www.iot-a.eu/
IoT-A Service and Virtual-Entity abstraction levels

Image extracted from http://www.iot-a.eu/
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**What is an IoT platform**

IoT platforms — i.e. a software that enables straightforward provisioning, management, and automation of connected devices within the Internet of Things universe.¹

¹ https://www.kaaproject.org/what-is-iot-platform
IoT platform multi layer view

[Diagram showing layers of an IoT platform with components such as Reporting, Visualization, Analytics, Rule Engine, Alerting, Data Collection, Messaging, Identity Management, Configuration Management, Software Updates (OTA), Communication, Infrastructure, IOT Gateway, Camera, Sensor, Meter, Wearable, Medical device, Vehicle, etc.]

Image extracted from https://www.kaaproject.org/what-is-iot-platform
Big actors propositions for the IoT

Cloud IoT platform

- Google IoT
- Amazon IoT platform
- Oracle Internet of Things Cloud Service
- Azure IoT (Microsoft)
- Samsung IoT platform

Free software to be deployed everywhere

- Eclipse IoT
- Fiware (also available as a Cloud service)
- Data distribution service
Amazon IoT platform

AWS IoT

AWS IoT DEVICE SDK
Set of client libraries to connect, authenticate and exchange messages

AUTHENTICATION & AUTHORIZATION
Secure with mutual authentication and encryption

DEVICE GATEWAY
Communicate with devices via MQTT, WebSockets, and HTTP/11

RULES ENGINE
Transform device messages based on rules and route to AWS Services

REGISTRY
Assign a unique identity to each device

DEVICE SHADOWS
Persistent device state during intermittent connections

AWS IoT API

APPLICATIONS
Applications can connect to shadows at any time using an API

AWS SERVICES
With these endpoints you can deliver messages to every AWS service.

Image extracted from https://aws.amazon.com/fr/iot-platform
Samsung Artik platform (closed in may 2018)

Image extracted from https://horovits.files.wordpress.com/2015/05/samsung-smartthings-opencloud-sami-architecture.png
Eclipse IoT vision and tools

Image extracted from https://iot.eclipse.org/
FIWARE

- Real-time processing of context events (Perseo)
- Business Intelligence (Knowage)
- Creation of Application Dashboards (Wirecloud)
- Big Data Context Analysis (Cosmos)
- Cloud Edge (FogFlow)
- Development of Context-aware applications (Orion, STH-Comet, Cygnus, QuantumLeap, Draco)
- Connection to the Internet of Things (IDAS, OpenMTC)
- Connection to robots (Fast RTPS, Micro XRCE-DDS)
- Documents exchange (Domibus)
- Context Processing, Analysis, Visualization
- Core Context Management (Context Broker)
- Interface to IoT, Robotics and third party systems
- Data/API Management Publication Monetization
- Real-time Processing of media streams (Kurento)
- Handling authorization and access control to APIs (Keyrock, Wilma, AuthZForce, APIInf)
- Publication and Monetization of Context Information (CKAN extensions, Data/API Biz Framework, IDRA)

Image extracted from https://iot.eclipse.org/
DDS Data Distribution Service (OMG)

![DDS Diagram](https://iot.eclipse.org/)

Image extracted from https://iot.eclipse.org/
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Middleware

Middleware is computer software that connects software components or applications. It is used most often to support complex, distributed applications. Middleware support application development and delivery. It describes a piece of software that connects two or more software applications so that they can exchange data.
Middleware for the IoT

Master the growing complexity of interactions

- Master the heterogeneity
- Handle many interaction levels
- Facilitate the development through abstractions, patterns and API
Middleware for IoT challenges

- **Massive scale**: Continuous vast flows of data
  - Filter data

- **Complex systems**: Involving connected objects, mobiles, cloudlets [Satyanarayanan et al., 2009], clouds
  - Reduce the complexity
  - Software engineering (design process, code generation, specific APIs)

- **Open access**: Decoupled producers and consumers
  - Ensure privacy
  - Qualify data/context (QoC)

[Blair et al., 2016, Stankovic, 2014]
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Basic interaction patterns in distributed systems

- Asynchronous event (push)
- Synchronous call
- Buffered messages (pull)
Publish/subscribe example

Domain (GDS, Global Data Space)

Topic: "Temperature"

Topic: "Pression"

Writer

Writer

Writer

Reader

Reader

Reader

Reader
REST API

- REST interactions to interact with sensors/actuators
  - Resource oriented
  - Universal Resource Identifier (URI)
  - XML/JSON... data representations
  - Resources linked to other resources (in resource representations)
Constrained Application Protocol (CoAP)

- Rest-Like APIs for constrained devices
  - Low memory
  - Battery consumption concern (periodical wakeup)
Interactions overall picture

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Conclusions

- **Agenda of next topics**
  - “Platforms - devices” and “Platforms - applications” interactions
  - Play with devices and platforms
  - Explore platform features
Fog Computing and the Internet of Things: Extend the Cloud to Where the Things Are.
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