Smart Cities: the Challenge of Interoperable Software Architecture

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Smart Cities: the Challenge of Interoperable Software Architecture

Guadalupe Ortiz is a permanent Associate Professor in the Department of Computer Science and Engineering, at the University of Cadiz and member of the UCASE Research Group.

Ongoing research projects:
- Smart Healthy Port: Real-Time Big Data Processing for Intelligent Air Quality Management in Sea Ports
- GANGES: Real-time big data processing for smart water network management
- RCIS: Network in Service Science and Engineering

Currently, her research focuses on trending topics such as the integration of complex-event processing in service-oriented architectures and facilitating context-awareness in the scope of Internet of Things, Smart Cities and Ambient Assisted Living.
Everything is Smart
Everything is Smart

- Smart Data
- Smart Phones
- Smart Houses
- Smart Cities
- Smart Health
- Smart Ports
- Smart Workspaces
<table>
<thead>
<tr>
<th><strong>Smart workspaces</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Human-centered</td>
</tr>
<tr>
<td>• Facilitating smarter living, working and <strong>living experience</strong>.</td>
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</table>

<table>
<thead>
<tr>
<th><strong>At smart homes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Devices, sensors, tools and platforms that learn from the way humans use their homes.</td>
</tr>
<tr>
<td>• <strong>Contextualized and personalized experiences</strong></td>
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</tbody>
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### Smart Health

- Use of smart city tools and infrastructures in the service of health

### Aim: to improve health and quality of life

- Information and communication technologies
- Contextual patient information and use of mobile devices

### Advantages

- Simplify processes and streamline procedures → cost reduction
- Adapting to the patient's context → better treatment
- Prevention of health risks
Interoperability??
Big Data

- Internet
- Information Systems
- Cloud
- Social Networks
- Internet of Things

- Storage Format
- Communication protocols
- Data representation

• Variety
• Volume
• Velocity

- Veracity
- Value

• Social Networks
• Internet of Things
• ...Near real-time

• Internet
• Information Systems
• Cloud
• Social Networks
• Internet of Things
Small Data

Why small?
- Accessible, understandable and actionable in everyday tasks
- Data mining (batch)

Applications
- Data-driven marketing, CRMs, …

Distinctive features
- End-user focused → Context
- Data democratization → Collaboration
Smart Data

Data Collection
- Big Data / Small data

Data Analysis
- Batch / Real Time
- Detection / Prediction

Decision-making and action
- Improvements for Business
- Improvements for Citizenship
Google permits programming it. What can we take into account?

Mobile phones do it!
(Collaborative) Internet of Things

**IoT**
- A network of globally interconnected and uniquely identified things or objects
- IoT platforms

**C-IoT**
- Individual-Business-Community/Infrastructure
- Multiple domains: health, logistics, energy
- Collaboration at sensor/situation of interest/services level
- Prioritization
Outline

- Concepts
- Technologies
- Architectures
- Case Studies
- Conclusion
Service Oriented Architecture and RESTful Web Services
Service Oriented Architecture

**Services**

- A *contract* (user benefits).
- Particular *discoverable functionality* describing what it can do and how to interact with it.

**Service Oriented Architecture (SOA)**

- Software architecture that defines a *decoupled model* of services to support business process requirements.
- They provide functions that can be *reused* by different clients (they only need to know the service description).
RESTful services

• REST: Representational State transfer
• REST is an **architectural style** for services using **web standards**.

Advantages

• Light
• Human readable
• Easy to build

REST Communications

• Everything can be identified as a **resource** and each resource can be identified by a **URI**.
• A resource can be represented in **multiple formats**, defined by a **media type**.
• Standard **HTTP methods** are used to interact with the resource: mainly GET, POST, PUT and DELETE.
• Communication between the client and the endpoint is stateless.
Event-Driven Architecture and SOA 2.0
Event-Driven Architecture

Events

- A change in the state of something.
- Something that occurs (or does not occur).
- A detectable condition.

Event-Driven Architecture (EDA)

- Particular style of event processing.
- Architectural style in which one or more components of a software system are activated upon detection of an event and where these components are decoupled.
- It is based on the publish/subscribe mechanism.
Event-Driven Architecture

Publish/Subscribe systems

- **Heterogeneity**: event generators publish the types of events they offer, and consumers subscribe to them through the interface offered for subscription and receipt of the resulting notifications.

- **Asynchrony**: notifications are sent asynchronously by event-generating publishers to all subscribers who are interested in them (decoupled publishers and subscribers).
<table>
<thead>
<tr>
<th>Comparative SOA/EDA</th>
<th>SOA</th>
<th>EDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction</td>
<td>Loosely coupled</td>
<td>Decoupled</td>
</tr>
<tr>
<td>Cardinality</td>
<td>One-to-One</td>
<td>Many-to-Many</td>
</tr>
<tr>
<td>Paradigm</td>
<td>Request/Response</td>
<td>Event/Notification</td>
</tr>
<tr>
<td>Communication</td>
<td>Synchronous</td>
<td>Asynchronous</td>
</tr>
</tbody>
</table>
Event-Driven Service Oriented Architectures (SOA 2.0)

- Communications between users, services and applications are event-driven.
- Event-driven communication allows a faster response to changes in real time.
- Events in the system trigger the launch of system services.
Enterprise Service Bus versus Microservices Architectures
Enterprise Service Bus (ESB)

- **Integration** element (multi-protocol and multi-purpose) in SOA.
- It combines web services, messaging, transformation, data routing and enrichment, security policies, among others.

Advantages

- They can **integrate EDA** and **SOA**.
- Ideal for working in **heterogeneous** environments: different technologies and protocols: from the most modern to the most conventional (legacy).
- They **reduce** the total **cost** of management and maintenance.
Microservice Architectures

**Features**
- A single application as a set of **small services**.
- Each service runs in its own process.
- Services communicate with **lightweight mechanisms** (REST API over HTTP).
- **Deployment is independent**.
- There is hardly any centralized management.

**Advantages**
- Scalability, evolution, maintenance
- Security, consistency, data traffic
Internet of Things
It proposes the use of a network of **globally interconnected things** or objects uniquely identified through an address scheme.

- Very present in Smart World
- Several computational layers:
  - Cloud computing
  - Fog computing
  - Edge computing
Complex Event Processing
Complex Event Processing (CEP)

- Technology that allows **processing, analysing and correlating** large quantities of events.
- To detect and respond in **real time** to **critical** or relevant business **situations**.
- **Event patterns** will infer new, more complex events ("**situations**") with greater semantic meaning.

**Advantages**

- Improved **quality of decisions**.
- **Rapid** response.
- **Prevention** of information **overload**.
- **Reduction** of human **effort**.
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CARED-SOA Architecture

DOI: 10.1109/ACCESS.2017.2679338
COLLECT Architecture (Overview)

DOI: 10.1016/j.eswa.2017.05.034
COLLECT Architecture (fog node)

DOI: 10.1016/j.eswa.2017.05.034
Predictive CARED-SOA

DOI: 10.1109/ACCESS.2019.2960516
Air4People
(Motivation)

DOI: 10.3217/jucs-024-07-0846
Air4People
(Architecture)

DOI: 10.3217/jucs-024-07-0846
Air4People (Screenshots)

DOI: 10.3217/jucs-024-07-0846
SWAT (Motivation)

DOI: 10.1007/978-3-319-91764-1_18
SWAT (Software Architecture)

DOI: 10.1007/978-3-319-91764-1_18
SWAT (Prototype)

DOI: 10.1007/978-3-639-91764-1_18
SWAT (Hardware Architecture)

DOI: 10.1007/978-3-319-91764-1_18
AlergiApp (Motivación)

DOI: 10.1007/s11042-021-10759-6
AlergiApp
(Architecture)

DOI: 10.1007/s11042-021-10759-6
AlergiApp (Screenshots)

DOI: 10.1007/s11042-021-10759-6
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Endless Case Studies and Application Domains

- E-Health domain
- Sustainability
- Energy consumption
- Natural resources management
- Mobility
- Traffic
- Pollution
- Emergencies
- Economy
- Governance
- Security
- Wellness
- ...
SMART CITIES require INTEROPERABILITY

Technologies

Software Architectures

All parties Collaboration
Smart Cities: the Challenge of Interoperable Software Architecture

- Thank-you very much for your attention
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