Approaching the design of interoperable smart environment applications

Federico Spadini, Sara Bartolini, Riccardo Trevisan
Guido Zamagni, Alfredo D’Elia, Fabio Vergari, Luca Roffia
Tullio Salmon Cinotti
Candidate Smart Environment Application Domains

Domains at different Granularity levels:

- City
- Confined Spaces
  - Private House
  - Public Buildings
  - Specialized Sites
    - Hospitals
    - Museums
    - ...
- Personal Spaces
  - Vehicles
  - ...

... and cross domain...
Smart Environment
from the application designer point of view

An environment with an associated “digital representation” called a Smart Space

Vision
If all information about the surrounding environment is easily available, the variety of applications that can benefit is only limited by fantasy
SS based *digital services* adapt to the environment current state

- Access to the SS is reserved to information processing entities called Knowledge Processors (KPs)
- KPs access the SS through the SSAP (Smart Space Application Protocol)
- SSAP defines a simple set of messages that enable a KP to: join, query, update, subscribe to and leave the SS
Implementation Principles

- Producers are decoupled from the information consumers
- Queries are ontology driven
- The trade-off between **KP-level-of-abstraction versus ontology-level-of-detail** seems to be an important design evaluation parameter
Design Strategy

What comes first?

The Smart Space or the application?
Conventional Design Approach

- Identify the customer’s needs
- Specify the application
- Identify the requirements
  - Which input?
  - Which algorithms?
  - Which output?
- Design the application
Smart Environment Vision

• Identify the “environment owner”

• Give the environment smarts
  • Collect data in the Smart Space (Producers)
  • Enrich data in the Smart Space (Aggregators)

• Sit and Wait

Unanticipated needs emerge

New business opportunities arise:

• Unprecedented context-aware applications are enabled by the Smart Space
Design Strategy

So what does come first?

the smart space ← the application
Adding sensors and actuators to a home

Separate systems for:
- Comfort (lighting)
- Security
- Entertainment
- Power Management
- Heating and air conditioning
Device Galaxy
(legacy devices)

• **Building Automation and Control Networks**
  - e.g. Konnex (EU), LON (US)

• **Home Appliances**

• **Wireless Sensor Networks**
  - Not only IEEE 802.15.4 based, 4+ WSNs in SOFIA usecases

• **Sensors and sensor platforms**
  - e.g.: health, environmental, …

• **Mobile devices**

...
Turning the home into a smart environment using Smart M3

**Legacy device:** an SS-unaware device
- It interacts with the SS through a **legacy adapter**
  - **Legacy adapter:** a KP to interface an SS-unaware entity to the SS

**Smart Object:** a device born to access a SS; it natively embeds a KP

**Aggregator:** a KP to enrich the semantic value of the SS information base

**SS Content:**
- Any type of info concerning the environment which is considered relevant by the “brand” that owns/manages the smart environment
A home turned into a smart environment thanks to Smart M3
Inovation enabled by Smart M3
e.g.: Building Maintenance and Management

- Fault detection:
  - automatic, e.g. based on data correlation
  - by the user arriving at home/office
  - by a passing maintenance person
- Alert generation, e.g. maintenance back office call
- Support to maintenance operators, e.g. guiding
- Support to involved users, e.g. with emergency directions

(Many Sofia Partners: CCC, Nokia, Eurotech, Philips,...)
The Ontology

- Ontology represents the knowledge available in the SS
- Ontology drives the KP through the Smart Space
The Location KP

1. Get the environment uri (i.e. identify the reader location)
2. Get the tag owner uri (i.e. identify the user)
3. Update the semantic connection between the user and its location

The location KP is **technology-specific**

The information stored into Smart M3 is:

- technology independent
- application relevant
- interoperable
Behaviour of the location KP (1 of 3): before entering the smart space

Classes
- Environment
  - Environment_12345
    - Room 1
  - Environment_67891
    - Room 2
- Person
- IdentificationData

Instances
- Person_1234
  - Sara
  - IdentificationData_xyz
    - HasValue: 888
- RFID Reader
  - Room 1
  - Room 2
Behaviour of the location KP (2 of 3): after entering Room 2

Classes
- Environment
- Person
- IdentificationData

Environment_12345
- rdf : type
- HasFriendlyName
- Room 1

Environment_67891
- rdf : type
- HasFriendlyName
- Room 2

Person_1234
- rdf : type
- HasName
- IdentificationData
- ContainsEntity

IdentificationData_xyz
- rdf : type
- HasIdentificationData
- Sara
- HasValue
- 888

RFID Reader
- Room 1
- Room 2
- Sara
- 888
Behaviour of the location KP (3 of 3): after entering Room 1

Classes

- Environment
- Person
- IdentificationData

ContainsEntity

Environment_12345

Environment_67891

HasFriendlyName

Room 1

Room 2

HasFriendlyName

Person

IdentificationData

Person_1234

HasIdentificationData

IdentificationData_xyz

HasValue

Sara

HasName

888

ContainsEntity

RFID Reader

Sara

888

Room 1

Room 2

ContainsEntity

Ontology Class

Class Instance

Literal

Property
## Discomfort Index

<table>
<thead>
<tr>
<th>Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 21</td>
<td>No discomfort</td>
</tr>
<tr>
<td>From 21 to 24</td>
<td>Less than half of the population feels discomfort</td>
</tr>
<tr>
<td>From 25 to 27</td>
<td>More than half population feels discomfort</td>
</tr>
<tr>
<td>From 28 to 29</td>
<td>Most population feels discomfort and deterioration of psychophysical conditions</td>
</tr>
<tr>
<td>From 30 to 32</td>
<td>The whole population feels a heavy discomfort</td>
</tr>
<tr>
<td>Over 32</td>
<td>Sanitary emergency due to the the very strong discomfort which may cause heatstrokes</td>
</tr>
</tbody>
</table>

**THOM INDEX:**  
\[ TI = T - (0.55 - 0.0055RH)(T - 14.5) \]  
where T is Temperature in °C and RH is the air Relative Humidity.
Discomfort Index KP

For every known place:

- Get the temperature from Smart-M3
- Get the humidity from Smart-M3
- Evaluate the TI
- Update the TI value in Smart M3

The Discomfort Index KP:

- Provides “rich” information abstracted from row data
- It is independent from:
  - Sensor technology
  - Physical space structure
  - User and application
Demo KPs

Consumers

Health Care Monitoring

Smart M3

Alarm Generator and Announcer

KP

Heart Rate (HR)
Skin Temperature
Thom Index
(\textit{User})

Wellness Announcer (User)

Temperature Humidity
(\textit{Environment})

Location
(\textit{User})

Environmental Sensors

Physiological on Body Sensors

Update
Subscribe
Query

Thom Index

Location
(\textit{User})

Heart Rate (HR)
Skin Temperature
Respiration Rate
(\textit{User})

Temperature Humidity
(\textit{Environment})

Heart Rate (HR)
Skin Temperature
Respiration Rate
(\textit{User})

Demo KPs

Consumers

Thom Index

Temperature Humidity
(\textit{Environment})

Location
(\textit{User})

Environmental Sensors

Physiological on Body Sensors

Demo KPs

Consumers

Health Care Monitoring

Smart M3

Alarm Generator and Announcer

KP

Heart Rate (HR)
Skin Temperature
Thom Index
(\textit{User})

Wellness Announcer (User)

Temperature Humidity
(\textit{Environment})

Location
(\textit{User})

Environmental Sensors

Physiological on Body Sensors

Demo KPs

Consumers

Thom Index

Temperature Humidity
(\textit{Environment})

Location
(\textit{User})

Environmental Sensors

Physiological on Body Sensors
Consumers

• Consumers may poll or subscribe to the SS
• Consumers may benefit by the cross-domain nature of the Smart Space
• Consumers from multiple domains may benefit by the same smart space

Consumers are expected to generate ROI to the “space owner”
Actors involved in “demo” development

- Federico and Riccardo, supported by Jukka and Hannu, at the infrastructure (Smart M3 and NoTA)
- Sara at the legacy devices
- Alfredo at the ontology
- Guido at the legacy adapters (producer KPs)
- Fabio at the applications (consumer KPs)
- Luca at the aggregators (semantic enhancement KPs)

In order to navigate safely in the Smart Space, KP people need to understand the ontology.

No need for interaction between producers aggregators and consumers (in principle, tbv)
Current set up: interoperability supported at information level only
Next step: NoTA - Smart M3 Integration

Smart-M3 will be one of the services offered by NoTA

- NoTA provides interoperability at service and connectivity level
- Access to Smart M3 over NoTA is transport independent
An experiment: “NoTA adapter”

This configuration was adopted when NoTA access to Smart-M3 was not available.
Using NoTA adapter to “join” Smart-M3

1. Subscription to SIB service registration
   Event and service discovery

2. AN DIP connection to SN

3. TCP socket connection on port 10010

4. SSAP Join request

5. Join request forwarding over NoTA

6. Join request forwarding over TCP

7. Smart M3 side

8. Join confirm forwarding over NoTA

9. Join confirm forwarding over TCP

KP side

TCP/IP

RDF store

NoTA adapter

SN

NoTA

KP

SIB service

RM service

Kö P

NoTA adapter

TCP/IP

AN

NoTA

DIP

TCP/IP

RDF store

TCP/IP

TCP/IP

TCP/IP

TCP/IP

TCP/IP
Current goal: Discovering and connecting to Smart M3 through NoTA
Conclusions

- **Smart M3** interoperable information store opens up innovation for novel applications
- **Smart M3** works at the information level; by combining NoTA connectivity, service and information levels can be managed
- Tools like stub generators and code generators will increase KP development productivity by simplifying Ontology use
- Today’s open source launch is expected to speed up the verification and deployment of **Smart M3**