Middleware and Software Engineering for the Internet of Things

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Middleware and Software Engineering for the Internet of Things
SUMMARY

1. Motivations

2. A framework for context dissemination with Multiscalability, QoC management and privacy protection

1. Application scenario

2. Conclusion and perspectives
CHAPTER 1

Motivations
CHAPTER 1: Motivations

1.1 Middleware for the Internet of Things

Middleware for IoT: master the growing complexity of interactions

Context producers: Sensors, Smart objects

Heterogeneity

Dynamicity

Large size

Decoupling

Context consumers: Context-aware applications
CHAPTER 1: Motivations
1.1 Middleware for the Internet of Things

Today, several environments:
- dedicated
- separated
- fully controlled
Next, new services with added-value:
- mutualize existing context sources
- Appearance of new context sources
- extension of computing resources
(R1) **Multiscale**  
Distributed context management on various network infrastructures exposing multiple scales

(R2) **Quality of Context**  
Open and flexible choice of the relevant QoC metadata

(R3) **Privacy**  
Respect the privacy of the context owners and do not reveal more information than necessary

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**Toward a new generation of context managers**
Disseminate context data at multiple scales
Context is imperfect by nature [Henricksen et al., 2002]
- incorrect - does not reflect the real state of an entity
- inconsistent - presence of contradictory information
- incomplete - some aspects of the context are not known

Approach: Add meta-data representing the Quality of Context (QoC)
- Accuracy : how exactly the provided context data mirrors the reality
- Freshness : age of context information
- Precision : how detailed is a measurement
- etc.
Impact on the acceptance of the IoT
- The user must be able to control **what, why, when, where** and **how** to share information
Ease application development with
  - Abstractions
  - Patterns
  - API

Model-driven engineering
  - Code generation
  - Model at runtime
CHAPTER 2
A framework for context dissemination with Multiscalability, QoC management and Privacy protection
Loose coupling of producers and consumers in space and time

Publish/subscribe communication model

Producers: publish notifications
Advertise the set of notifications they are willing to publish

Consumers: react to notifications
Subscribe to receive notifications of interest

Context dissemination using a Distributed Event-Based System (DEBS)
2.1 muDEBS: Multiscale Distributed Event-based System

https://fusionforge.int-evry.fr/www/mudebs/
Enables Multiscale-QoC- and Privacy-awareness
Contract model for producers and consumers of context data
- Part of muCONTEXT
https://fusionforge.int-evry.fr/www/mucontext/

Producer contract
- Multiscale specification
- QoC guarantees
- Privacy requirements

Consumer contract
- Multiscale dissemination
- QoC requirements
- Privacy guarantees

muDEBS routing filters
CHAPTER 2
2.3 Multiscalability model

■ Viewpoint
■ Dimension

Measurement of a particular characteristic of a system view for a particular viewpoint

■ Scale

Orders of magnitude or sets of elements

Example: Dimensions and scales for the geography viewpoint

![Diagram showing dimensions and scales for geography viewpoint](image-url)
2.4 QoC model

- **Producer**
  - QoC guarantees

- **Consumer**
  - QoC requirements

- **Expressed using QoCIM**
  - Meta-model for QoC modeling
  - Generic, expressive and computable
  - Extensible list of QoC criteria: Define QoC criteria corresponding to application needs
CHAPTER 2
2.4 QoC modeling using QoCIM

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Derived from U.S. Privacy Act and European directives for data protection
- **Purpose**: for what goal the data is used
- **Retention**: how long the data is retained
- **Visibility**: who is authorized to access data
- **QoC**: at what QoC level are data delivered

Attributed-Based access control (ABAC)
- Flexible approach
- Authorization rules may consider any characteristic of subject, resource, action or environment including context

Follow **XACML** standard
- Producer privacy requirements $\rightarrow$ XACML policy
- Consumer privacy guarantees $\rightarrow$ ABAC information
- Match ABAC info with XACML policy at routing time
CHAPTER 2
2.6 Context contract in action
Model-driven engineering: generate code from QoC, privacy and multiscale models

Data type
- Context model
- QoC Guarantees
- Privacy Requirements
- Multiscale report

Data type
- ozone O3
- Freshness (<1h), accuracy (>90%)
- Purpose: User Guidance
- User GPS coord, username, smartphone

Advertizes
- sulfur dioxide SO2
- nitrogen dioxide NO2
- ozone O3
- Line 88
- Station Jean-Jaures
- Freshness: 9h35, accuracy: 95%
- For non-commercial use
- Sensor GPS coord, PollutionStation
CHAPTER 3
Building Applications
CHAPTER 3
3.1 Design process: from models to code

Domain Specific Models:
Multiscale characterization, Context, QoC and Privacy
4ME collaborative app used by association members
- register to leisure activities
- contact members sharing common interests
- be informed of their current locations and arrange to meet on the road while heading to the activities’ premises in the city

2 leisure activities
- **Easy Cooking**: on last Friday of each month at 12:30 pm in Montaudran district in the city of Toulouse
- **Play Soccer**: every Friday at 12:30 pm near Capitole place of the Toulouse Downtown district

Registration/unregistration possible until last minute
Dynamic adaptation: If context changes, 4ME app
- recommends a new itinerary
- notifies of what participants can be met on the way

Visibility scopes
- MuDEBS joinscope operation
- Configure 2 scope graphs and organize context brokers accordingly
  - Scope graph 1: Area of an activity location modeled by *administration area* dimension of *geography* viewpoint
  - Scope graph 2: Members registered to an activity modeled by *membership* dimension of *user* viewpoint
- Multiscoping to filter users'position according to geographical areas and activity interests
**QoCIM-based routing filters**
- Variable number of QoC criteria
- 2 types of filters
  - Criterion-based: test the presence of a QoC criterion
  - Value-based: test the value of a given QoC criterion

**Privacy protection**
- Positions delivered for a given purpose accepted by the user
- **Producer side**: Each activity member indicates privacy requirements, depending on purpose and situation
- **Consumer side**: Activity teacher app subscribes to locations of participants with a low level QoC, for activity purpose and when users are on their way
Scope graph 1 for **administration area** dimension of **geography** viewpoint

Part of a scope graph

Viewpoint **geography**

Dimension **administration area**

Scale **neighborhood/district/city/country/continent**
Scope graph 2 for *membership* dimension of *user* viewpoint

Viewpoint *user*

Dimension *membership*

Scale *subgroup/group/community*
On the way to the **Play Soccer** activity

- **Activity district**
- **Friend position** (in activity district)
- **Approximate friend position** (outside activity district)
- **User position**
CHAPTER 3
3.3 Solution view
CHAPTER 3
3.4 Frameworks

Define QoC criterion
Define Context model
Define biparty privacy/QoC models
Multiscale characterization
Detect situation from context data
Enforce privacy/qoc contracts
Deploy components
Distribute context data according to scopes

http://anr-income.fr
CHAPTER 4

Conclusion and perspectives
CHAPTER 4
Conclusion and perspectives

Contributions

- Software engineering: Design process, meta-models, languages and frameworks
- Context contracts with QoC and privacy rules
- Multiscale characterization for multiscoping
- Content based filters
  - Context filter, QoC filter, privacy filter, multiscale filter

Perspectives

- Semantic matching between producers and consumers contracts
- Discovery service according to QoC and privacy rules
- Situation identification with quality evaluation