Concepts and System Structures to Support Collaborating Everyday Items

Thomas Schoch
ETH Zürich, 28-Jan-2005
Outline

- Introduction
- Main contributions
  - Concepts
  - Systems
  - Evaluation
- Conclusions
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Marc Weiser (PARC), 1991
- When almost every object contains a computer then obtaining information about the real world will be trivial

Neil Gershenfeld (MIT), 1999
- Proposes a proclamation of the Bill of Things' Rights
  - things have the right to have an identity,
  - access other objects and
  - detect the nature of their environment
Media Break

Virtual World

Cost of Media Break

Real World

Human intervention required | Human intervention not required

Thesis

- **Current situation**: Available middleware and ubicomp platforms do not properly support applications that make use of *Collaborating Everyday Items*

- **Goal**: Facilitate the development and deployment of such applications

- **Thesis**: The concepts and systems structures presented in this work describe and support a world of *Collaborating Everyday Items* in a substantially better way than would be possible with current means
Requirements

- Support of basic abilities:
  - Identification of smart things
  - Localization of smart things
  - Control of sensors and actuators

- Support of relations:
  - Composition
  - Containedness
  - Location model
  - Neighborhood
  - History

- Implementation and deployment
  - Different identification and localization technologies
  - Programmatic access
  - Real-time requirements
  - Data storage
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Overview of Concepts

- Classification of concepts
  - High-level concepts
  - Concepts for basic abilities
  - Concepts for smart things
  - Concepts for the infrastructure
  - Procedure of registering a smart thing
  - Extensions
  - Application logic
  - Lifecycle
High-level Concepts

Physical Environment (Real World) | Virtual Environment (Virtual World)

Smart Things

- Things
- Representations

Infrastrurcure

- Tag Detection Hardware
- Services

Examples for tags:
- RFID transponders
- Barcode labels
- BT modules
- GPRS modules
- ...

A - Tag
B - Tag Reader
C - Tag Detection Service
D - Managing Services
A+B+C - Tag Detection System
Basic Abilities - Identification

Identifier = Name

Thing → Tag → Representation

denotes

= consists of

connected
Basic Abilities - Localization

Disputation

Locations (LOC)

Symbolic Location Models

Physical Positions Models

[47.5° N, 8.5° E, 420 m] (WPP)

Smart Things (ST)

[2cm, 1cm, 0.5cm] (STPP)

Smart Things Models

World Models

[2cm, 1cm, 0.5cm] (STPP)

Symbolic Location Models

Physical Positions Models

Smart Things Models

World Models

[47.5° N, 8.5° E, 420 m] (WPP)

Smart Things (ST)
Concepts for Smart Things

Location Kitchen

Neighbors

- Cupboard
- Chair
- Table

Neighbors

- Door
- Box
- Top
- Leg

- Armature
- Mug
- Knife

Contains

- Handle
- Pepper Bag

Part of
Concepts for the Infrastructure

Smart Thing

- Attached to Thing
- Detects Tag
- Controls Tag Reader
- Updates Tag Detection Service

- Executed by Representation
- References Hosting Service
- Contacts Location Managers
- Hosts Home Service
Communication channels:
I = Identifier   S = Sensor
L = Location   A = Actuator
Application Logic

- Split between
  - Representation
    - Executed by hosting service
  - Location-dependent services
    - Registers itself for changes at certain location
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Systems Overview

- Concepts verified on three systems
  - Developed iteratively to
    - complete the concepts
    - test different implementation strategies
  - Proof-of-concept
    - Every system implements a subset of the concepts

- Systems
  - Voxi
    - Developed by T. Dübendorfer & K. Römer
  - Wsst
  - Iceo
**Iceo – Infrastructure**

- Representation as Java objects
- Location-dependent services as Jini services
- All four modules implemented for a Bluetooth tag
- Identification and localization only for RFID and Barcode
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Evaluation Overview

- Evaluation should give answers to two questions:
  - Do the concepts and their implementations actually support a developer in developing smart things applications?
    - Implementation of a generic supply chain application with all three systems
  - How can this be efficiently implemented?
    - Qualitative comparison between Jini and Web Services as underlying middleware platform
Supply Chain Application

- **Benefits:**
  - Total stock visibility
  - Quality assurance
  - Additional statistical functions
  - Process automation

Disputation

[Diagram showing flow of goods and various supply chain applications]
Flow of Goods & Information
Iceo Entities

- A location-specific warehouse management service is registered at every location
- Every object (Bottle, Box, Container, Handle) is derived from the same super class

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### Jini vs. Web Services

<table>
<thead>
<tr>
<th></th>
<th>Java/Jini</th>
<th>.Net / SoapUDDI</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory usage of runtime environment (Kbyte)</td>
<td>9564</td>
<td>22824</td>
<td>2.4</td>
</tr>
<tr>
<td>Response time service registration (ms)</td>
<td>$137.6 \pm 18.9$</td>
<td>$421.1 \pm 82.7$</td>
<td>3.1</td>
</tr>
<tr>
<td>Response time service lookup with service ID (ms)</td>
<td>$9.0 \pm 3.3$</td>
<td>$284.4 \pm 21.6$</td>
<td>31.6</td>
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<tr>
<td>Response time service lookup with service name (ms)</td>
<td>$11.2 \pm 3.6$</td>
<td>$546.3 \pm 129.0$</td>
<td>48.8</td>
</tr>
<tr>
<td>Response time service invocation (ms)</td>
<td>$14.4 \pm 1.7$</td>
<td>$159.1 \pm 5.4$</td>
<td>11.0</td>
</tr>
<tr>
<td>Response time test application (ms)</td>
<td>$857.5 \pm 32.8$</td>
<td>$4935.6 \pm 260.8$</td>
<td>5.8</td>
</tr>
</tbody>
</table>

- Voxi & Iceo based on Java/Jini
- Wsst based on .Net Web Services/SoapUDDI

➤ same test environment for both platforms (computer, network)
➤ comparisons of corresponding entities (lookup, invocation, ...)

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Related Work

- Smart thing systems
  - Cooperating Smart Everyday Objects
    - Local interaction, active tag
  - RAUM
    - Simple location tree, no representation
  - Auto-ID Center/EPCGlobal
    - Standards for tag protocols and identifiers
  - SAP Auto-ID Infrastructure
    - Focus on filters, connection to SAP
  - Volkswagen VisuM
    - Linking tag readers with central database

- Adjacent domains
  - Cellular IP
  - ...

- Ubiquitous computing systems
  - Cooltown
  - ...

Main Contributions

- High-level concepts
  - Thing, representation, tag detection hardware, services
- Concepts for basic abilities
  - Identifier, location model,
- Concepts for smart things
  - Containedness, composition, neighborhood
- Concepts for the infrastructure
  - Home service, hosting service, communication channels
- Application logic
  - Representation, location-dependent services
- Recommendations for implementations
  - Three Systems (Voxi, Wsst, Iceo)
  - Supply chain application
  - Quantitative evaluation
Conclusions

- Concepts have been proven to be useful
  - Verified in three different systems
  - Smart supply chain application
  - Results of performance measurements

- Iceo used as underlying system for a smart facility management framework

- Subset of concepts used by Intellion AG for their RFID middleware
Thank you...

... for your attention!

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