Concepts and System Structures to Support Collaborating Everyday Items

RESEARCH GROUP FOR
Distributed Systems

Thomas Schoch

ETH Zürich, 28-Jan-2005

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Disputation

Outline

- Introduction
- Main contributions
  - Concepts
  - Systems
  - Evaluation
- Conclusions

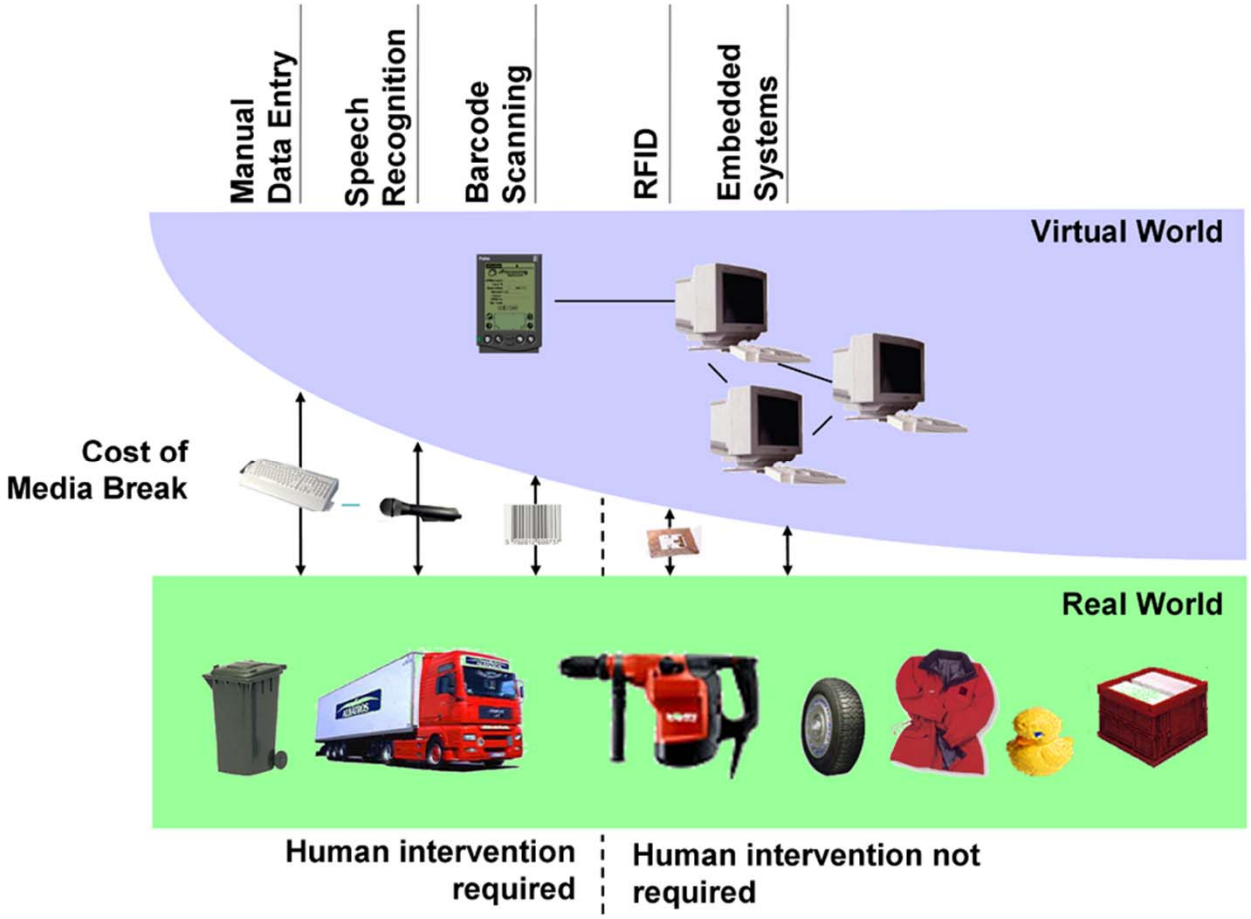
Outline

- Introduction
- Main contributions
  - Concepts
  - Systems
  - Evaluation
- Conclusions

Vision

- 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



Picture taken from: **Fleisch E, Mattern F, Österle H (2002) Betriebliche Anwendungen mobiler Technologien: Ubiquitous Commerce. Computerwoche**

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

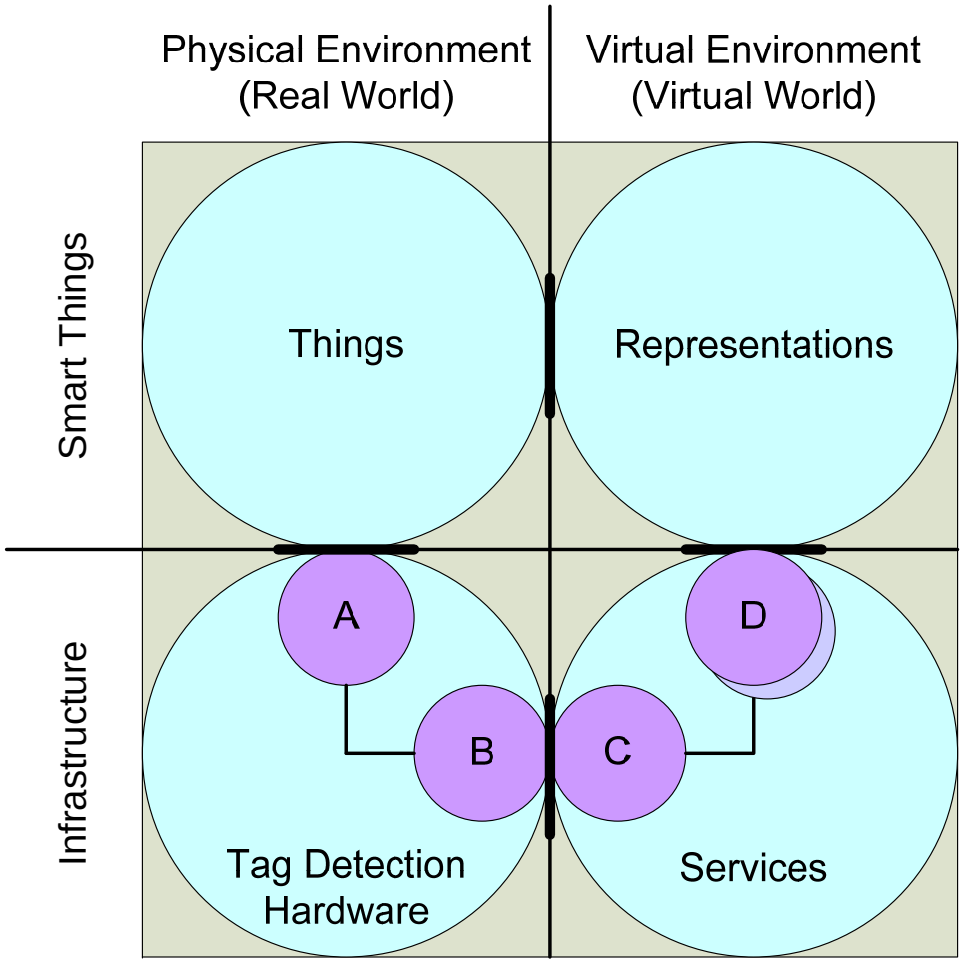
Outline

- Introduction
- Main contributions
  - Concepts
  - Systems
  - Evaluation
- Conclusions

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

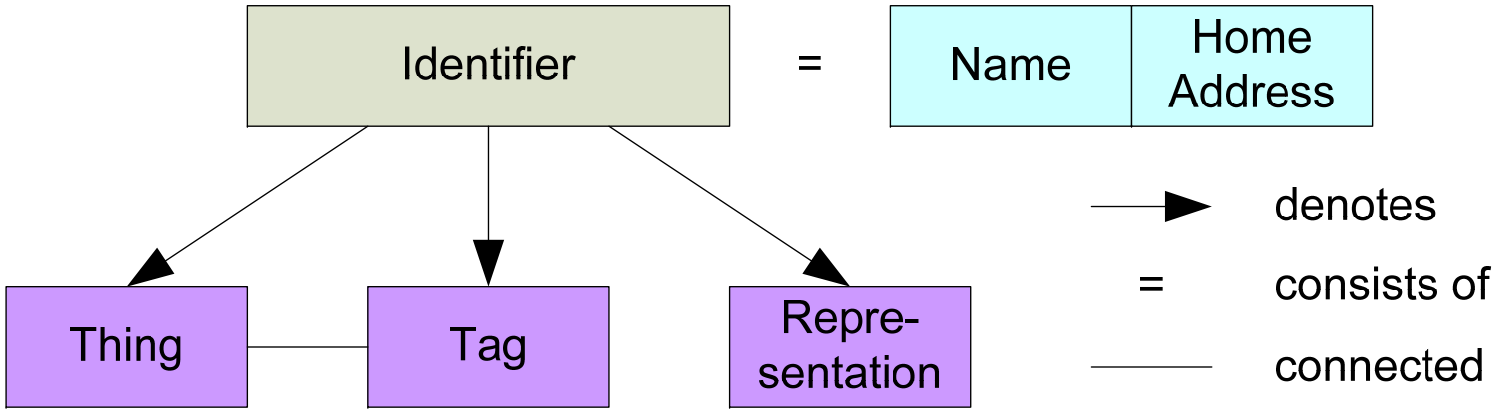


Examples for tags:
- **RFID transponders**
- **Barcode labels**
- **BT modules**
- **GPRS modules**
- **…**

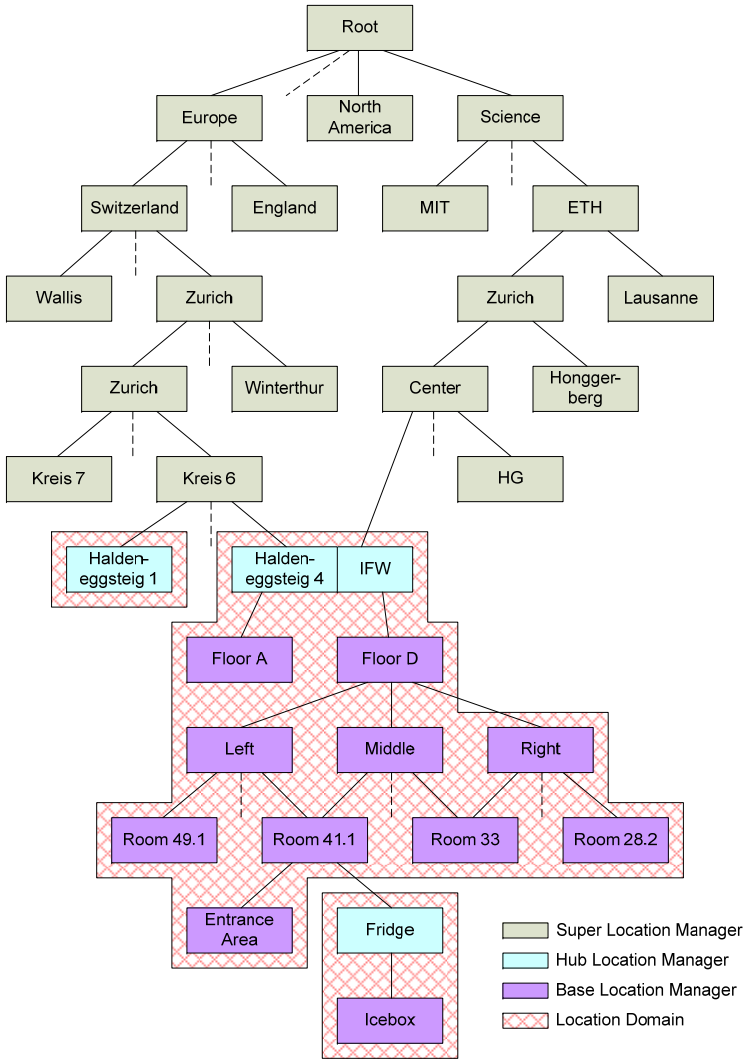
A - Tag
B - Tag Reader
C - Tag Detection Service
D - Managing Services

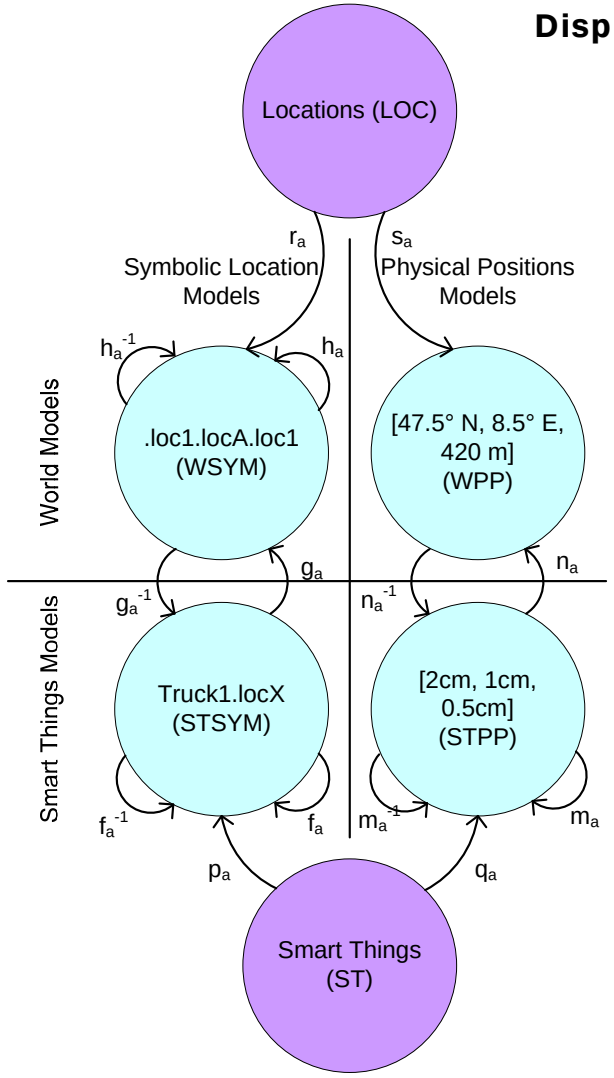
A+B+C - Tag Detection System

Basic Abilities - Identification

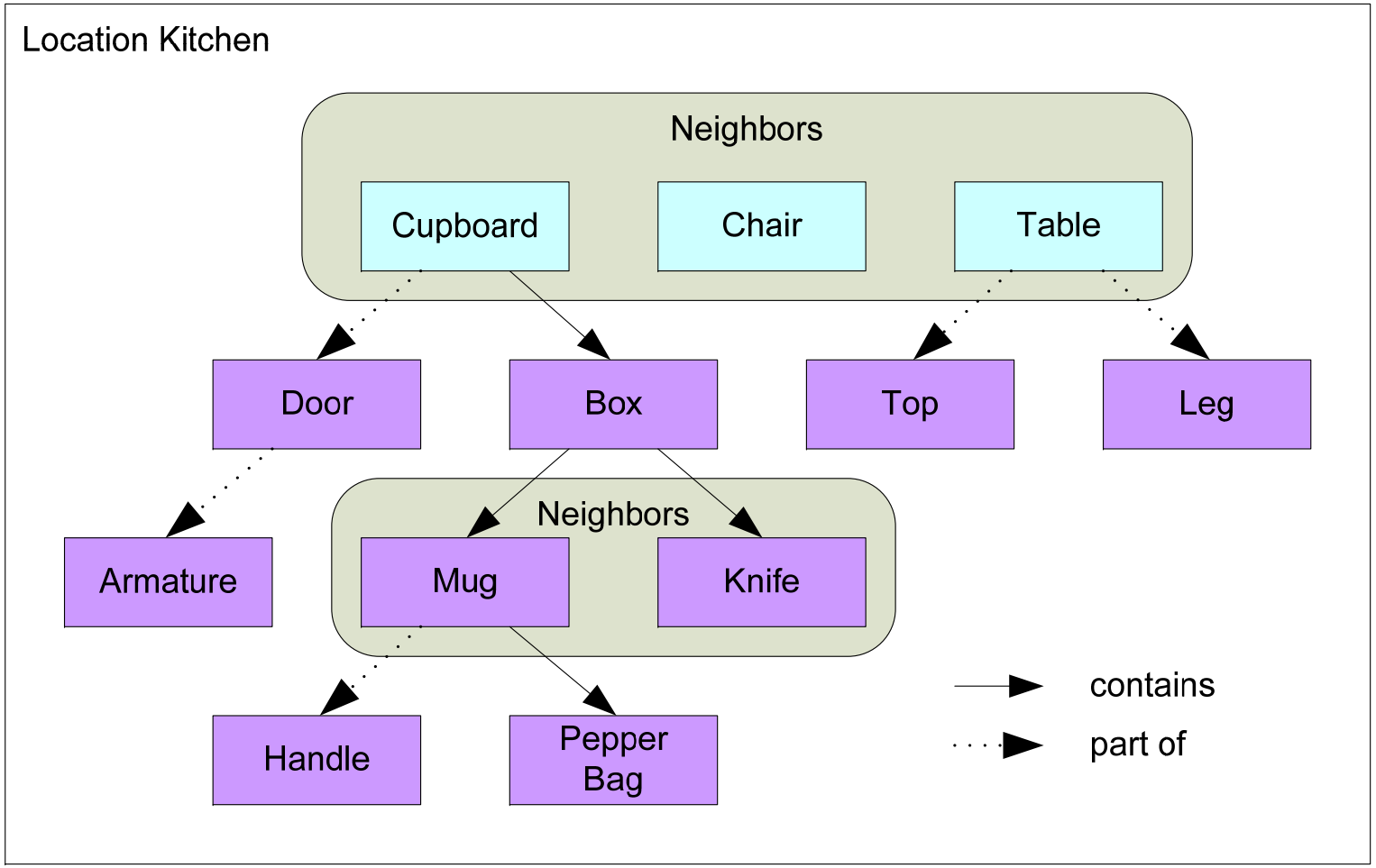


Basic Abilities - Localization

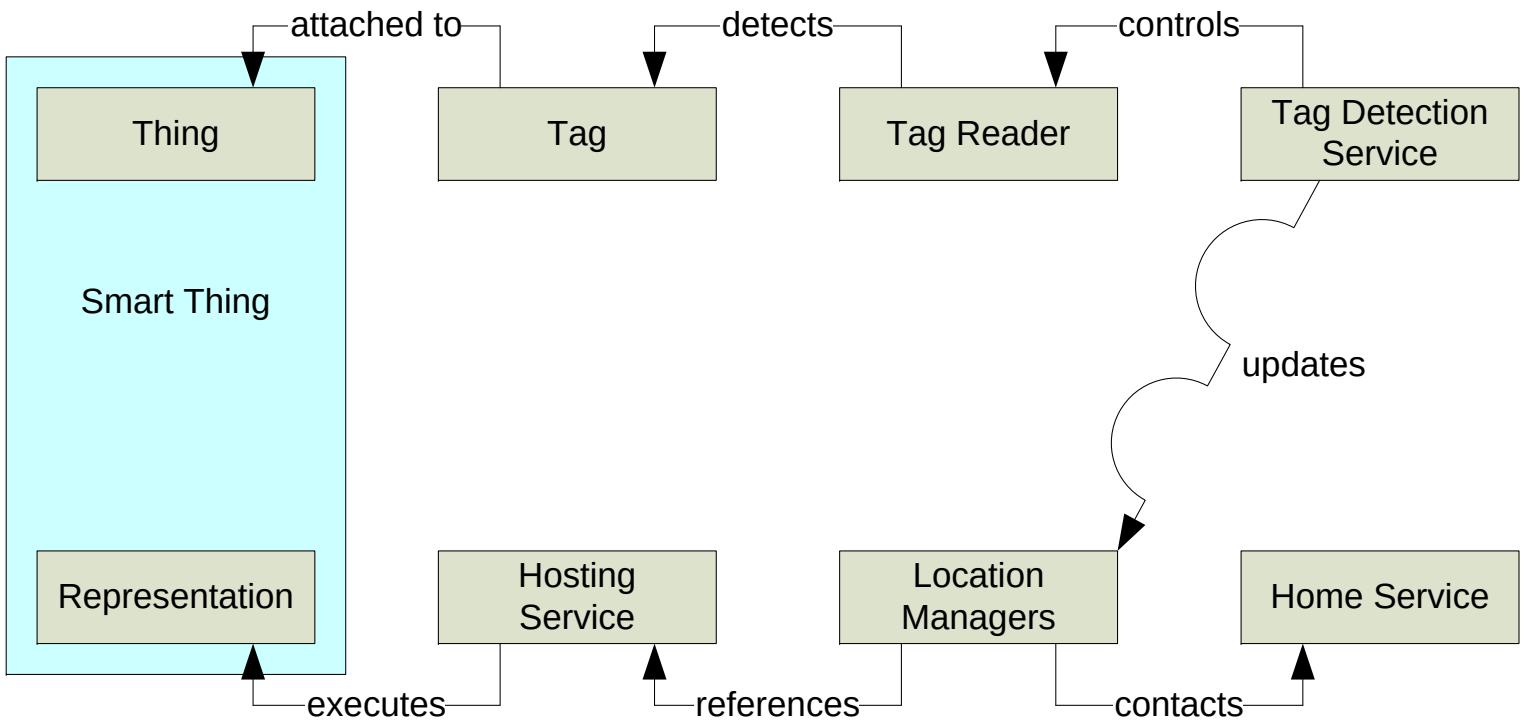




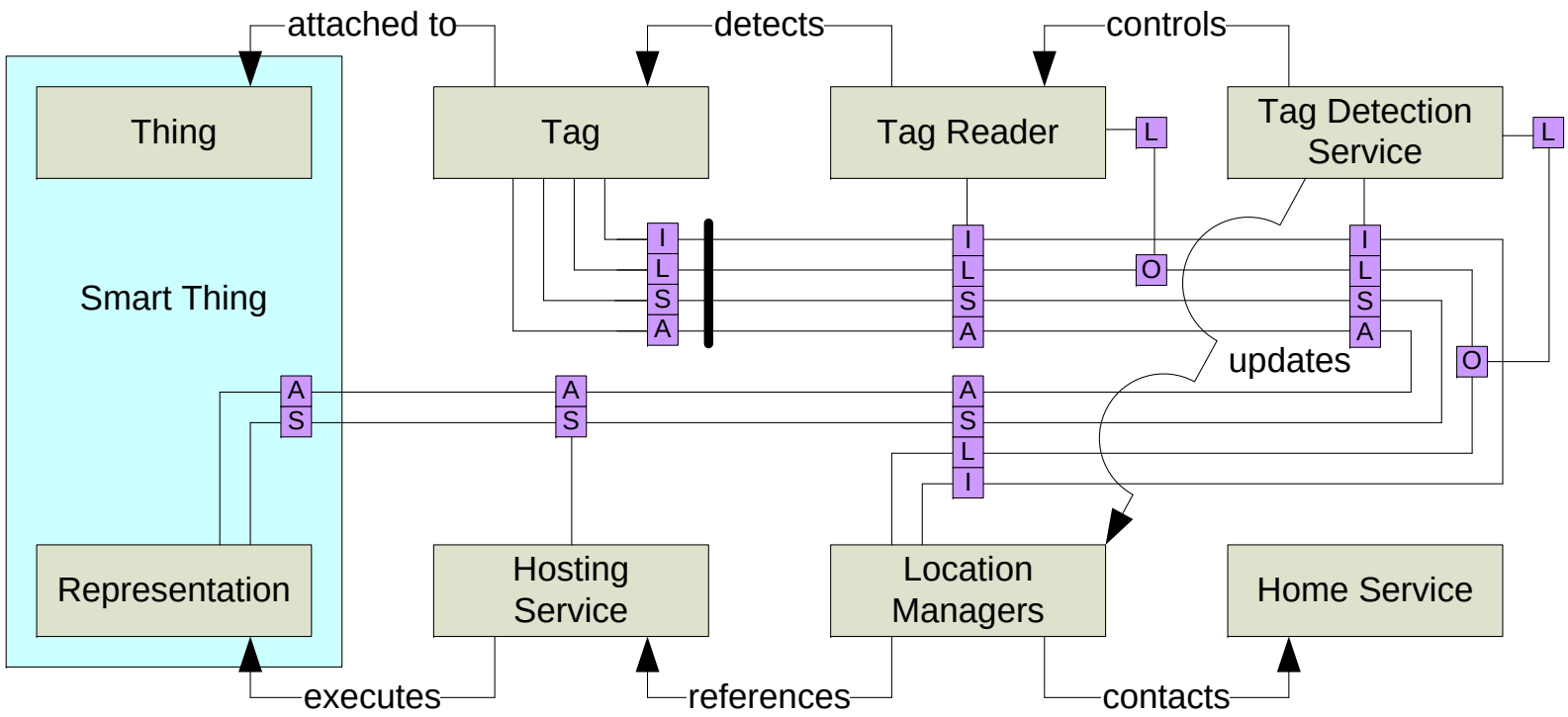
Concepts for Smart Things



Concepts for the Infrastructure



Concepts for the Infrastructure



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

Outline

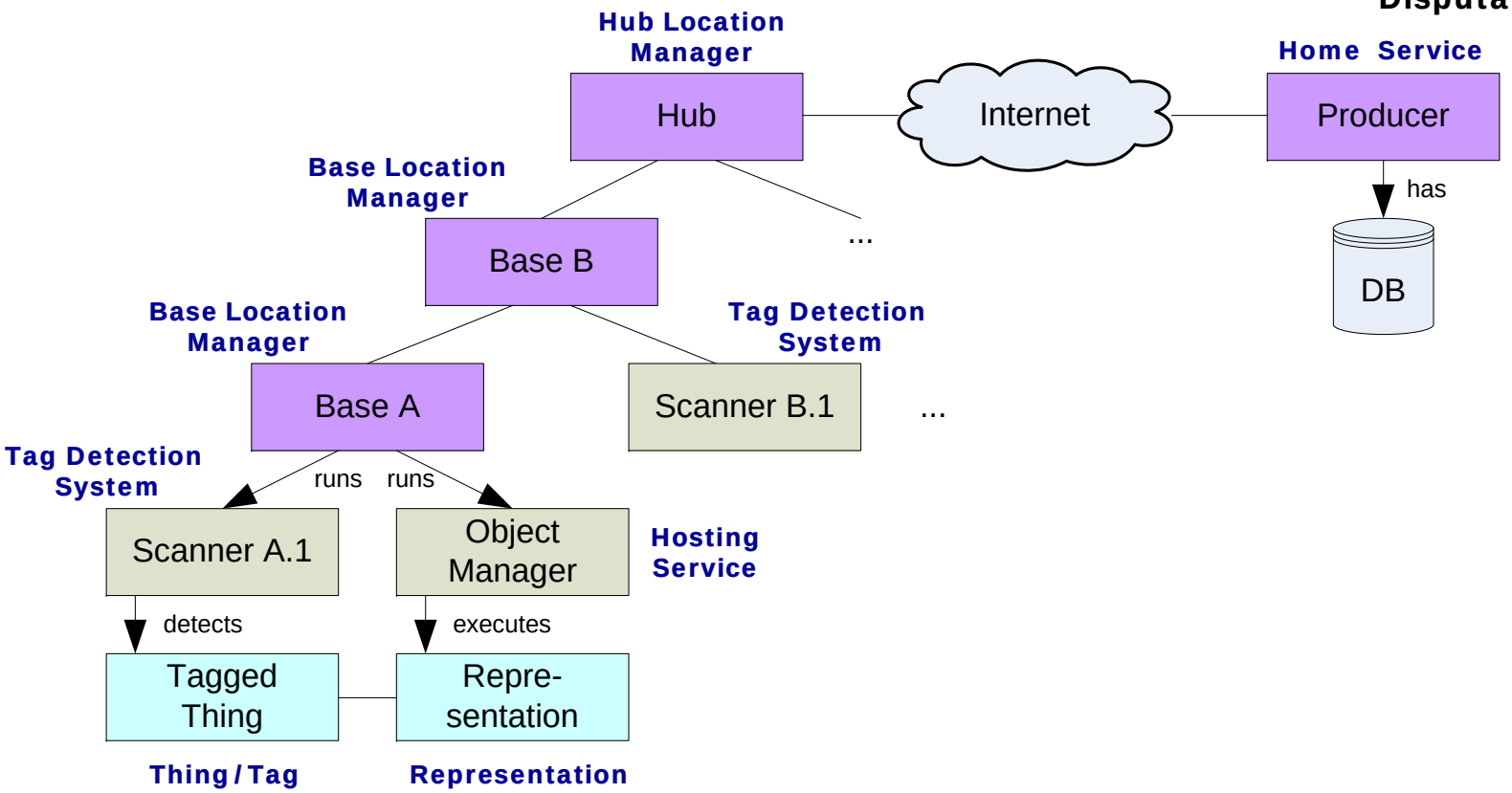
- Introduction
- Main contributions
  - Concepts
  - Systems
  - Evaluation
- Conclusions

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

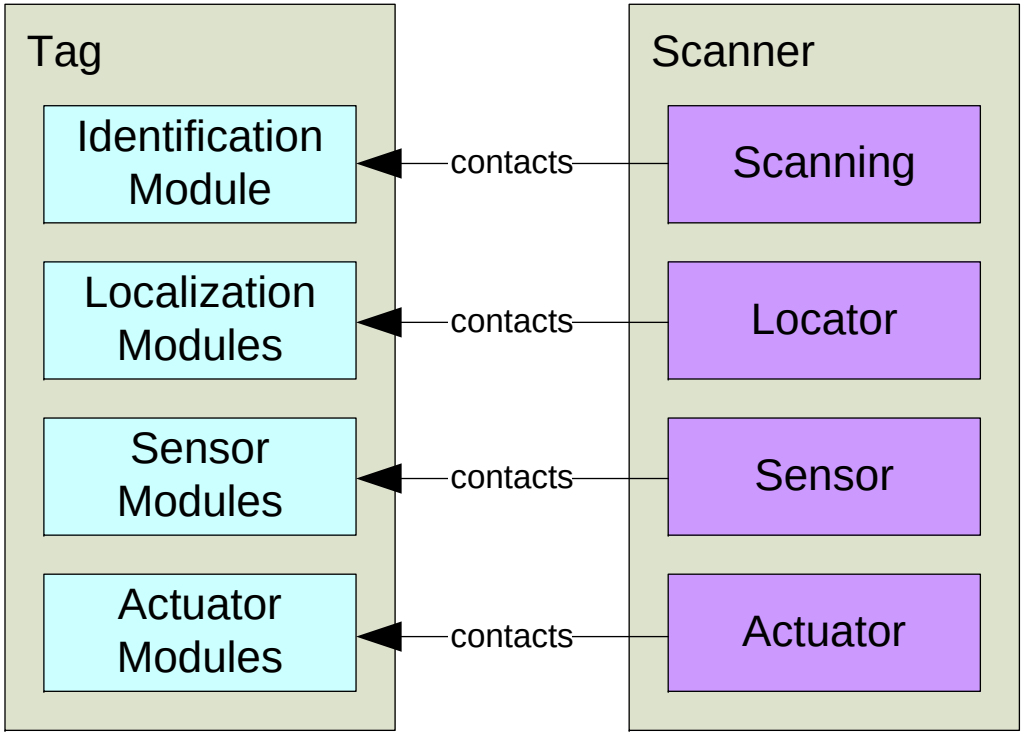
- Systems
  - Voxi
    - Developed by T. Dübendorfer & K. Römer
  - Wsst
  - Iceo

Iceo – Infrastructure



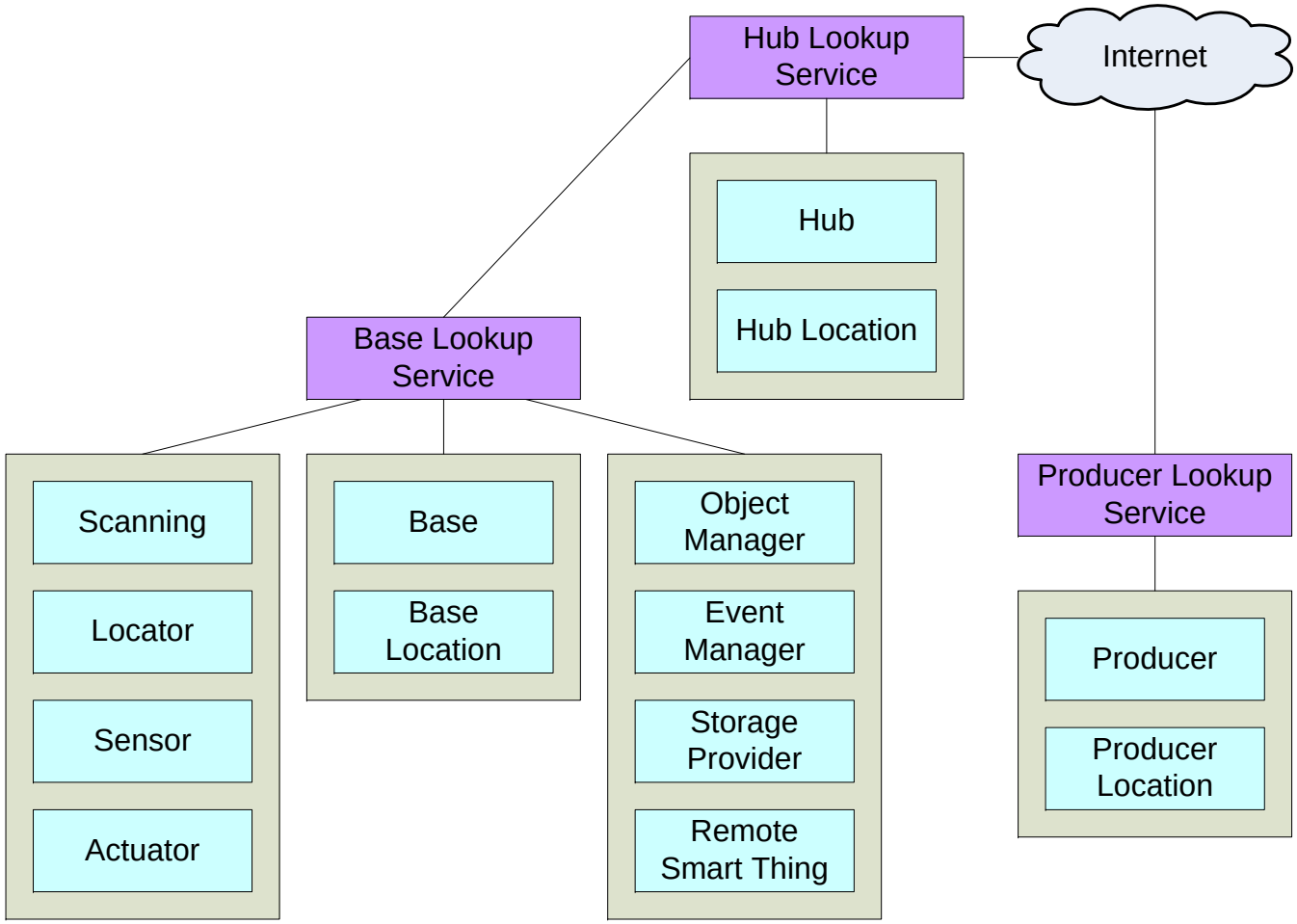
- Representation as Java objects
- Location-dependent services as Jini services

Iceo – Comm. Channels

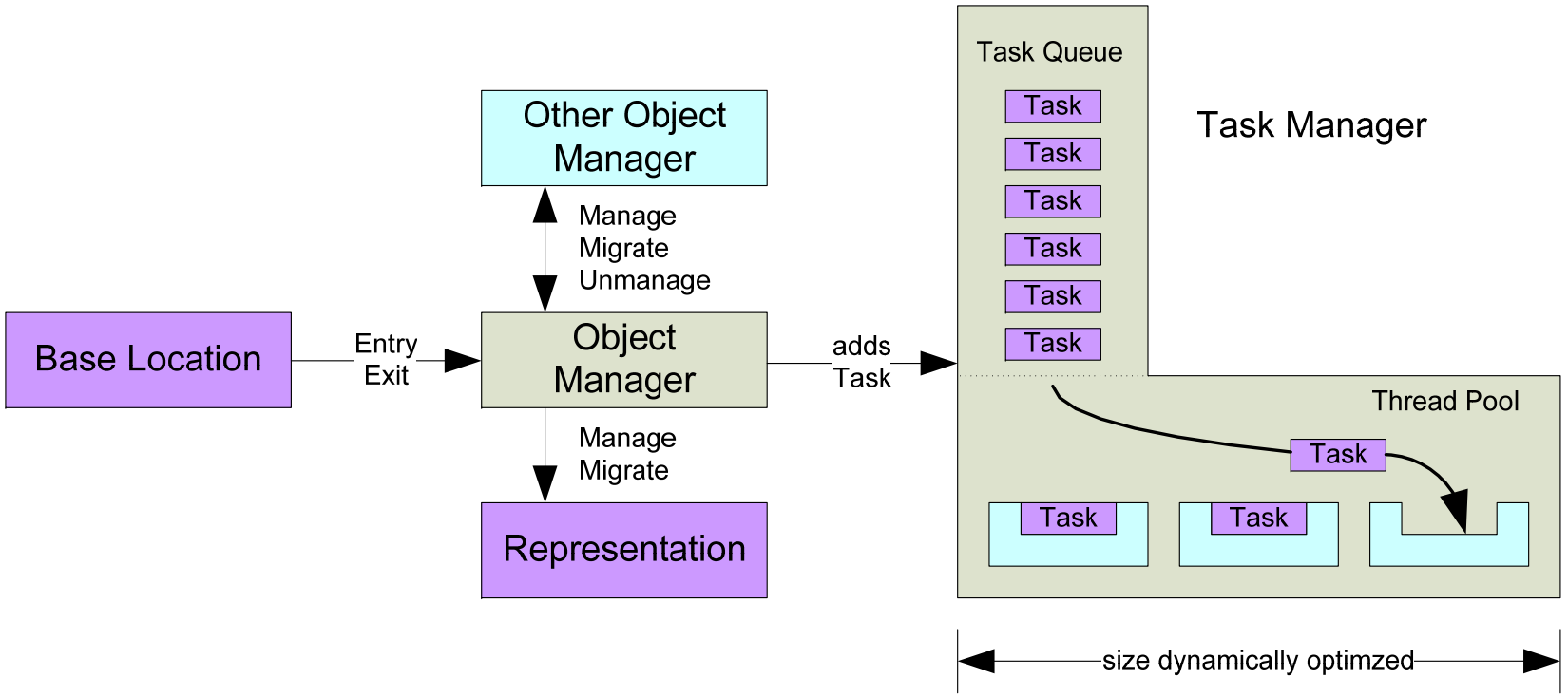


- All four modules implemented for a Bluetooth tag
- Identification and localization only for RFID and Barcode

Iceo – Registered Services



Iceo – Object Manager



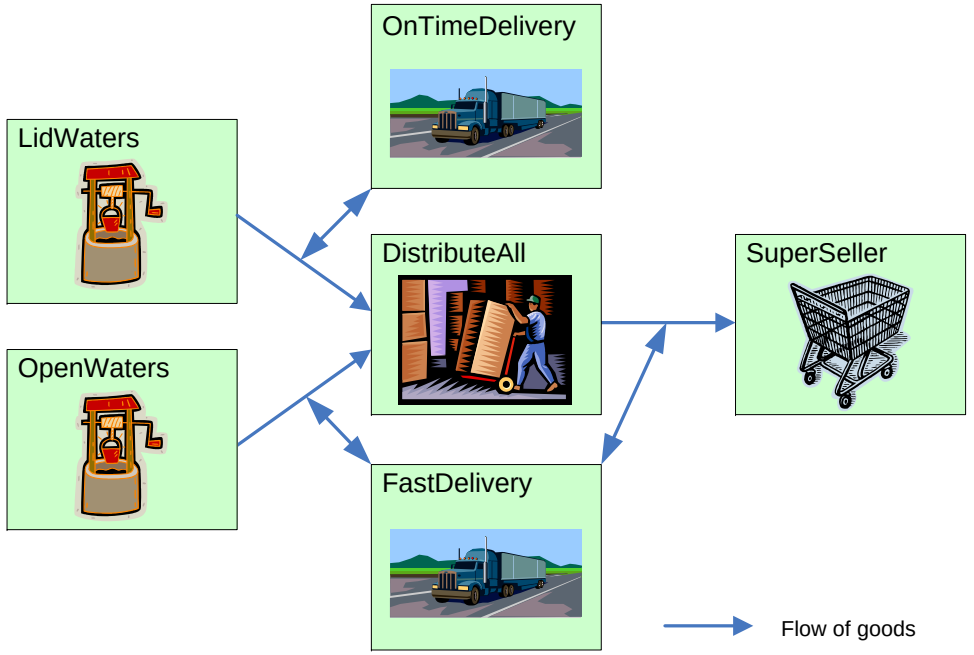
Outline

- Introduction
- Main contributions
  - Concepts
  - Systems
  - Evaluation
- Conclusions

Evaluation Overview

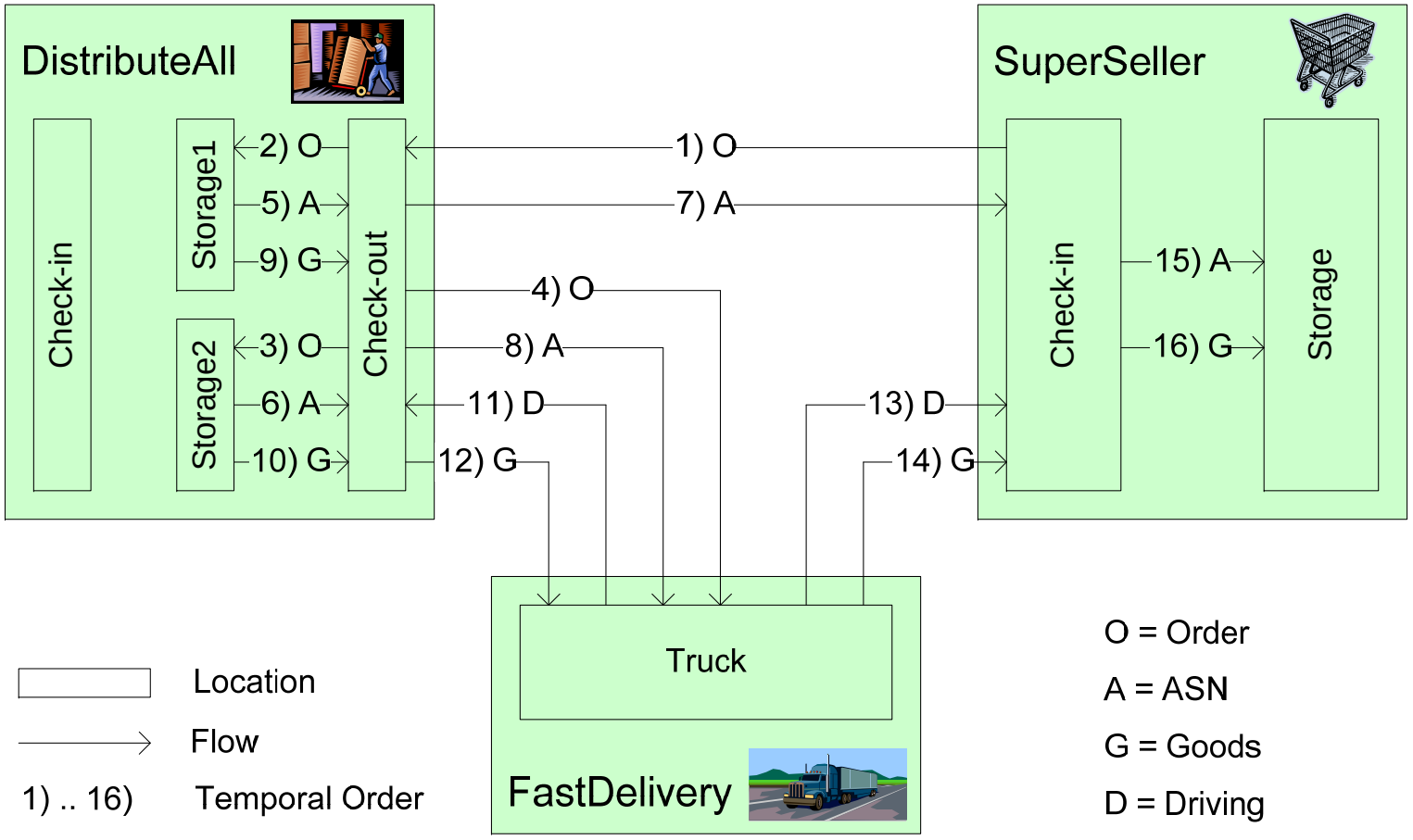
- Evaluation should give answers to two questions:
  - Do the concepts and their implementations actually support a developer in developing smart things applications?
    - Implementation of a generic supply chain application with all three systems
  - How can this be efficiently implemented?
    - Qualitative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

Supply Chain Application

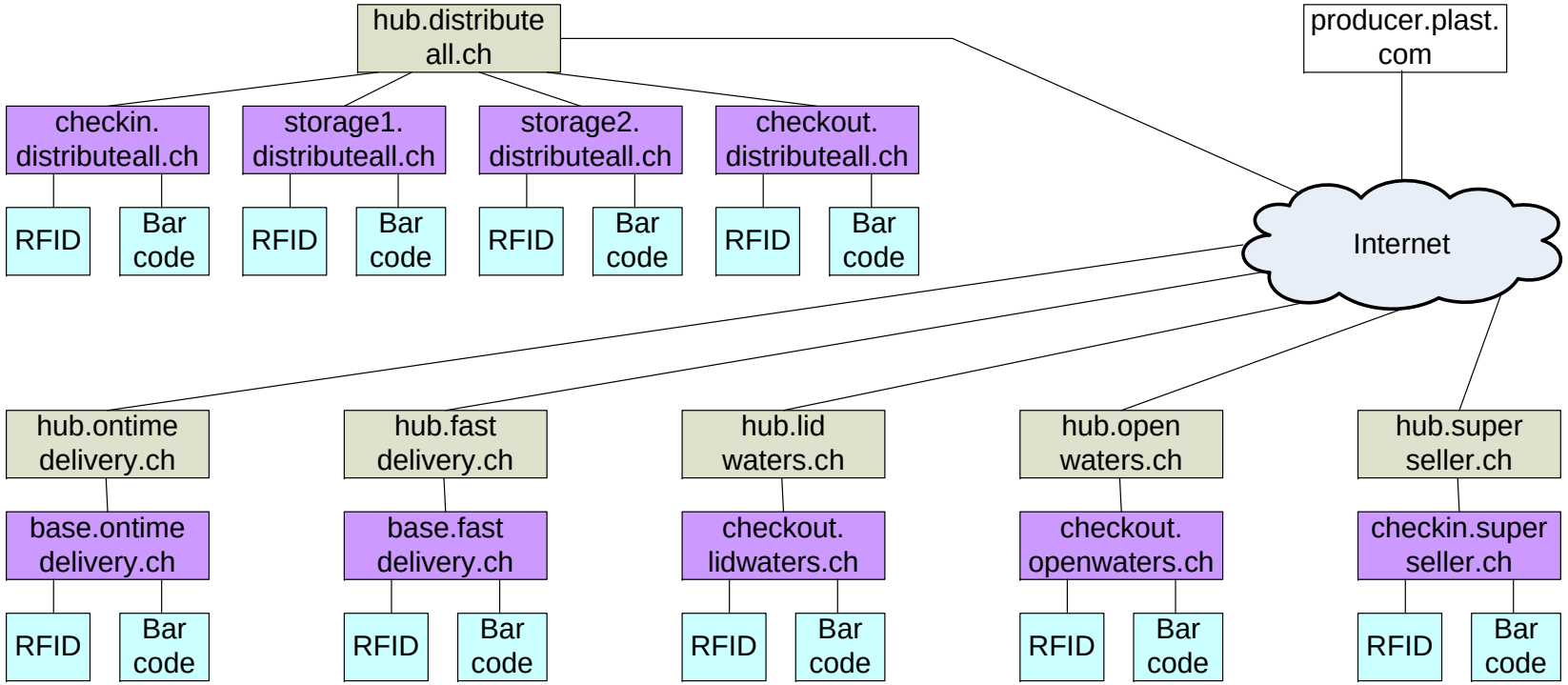


- Benefits:
  - Total stock visibility
  - Quality assurance
  - Additional statistical functions
  - Process automation

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**

Jini vs. Web Services

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

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

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

Outline

- Introduction
- Main contributions
  - Concepts
  - Systems
  - Evaluation
- Conclusions

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!

Thomas Schoch

schoch@inf.ethz.ch