Multi-Agent Based Context Management in Ambient Intelligence Applications

Alexandru Sorici[1,2] Gauthier Picard[1] Adina Magda Florea[2]

[1]Laboratoire Hubert Curien UMR CNRS 5516, Institut Henri Fayol, MINES Saint-Etienne, France sorici@emse.fr

[2]University Politehnica of Bucharest, Department of Computer Science, 313 Splaiul Independentei, 060042 Bucharest, Romania

May 28, 2015

Outline

Outline

Introduction: Problem

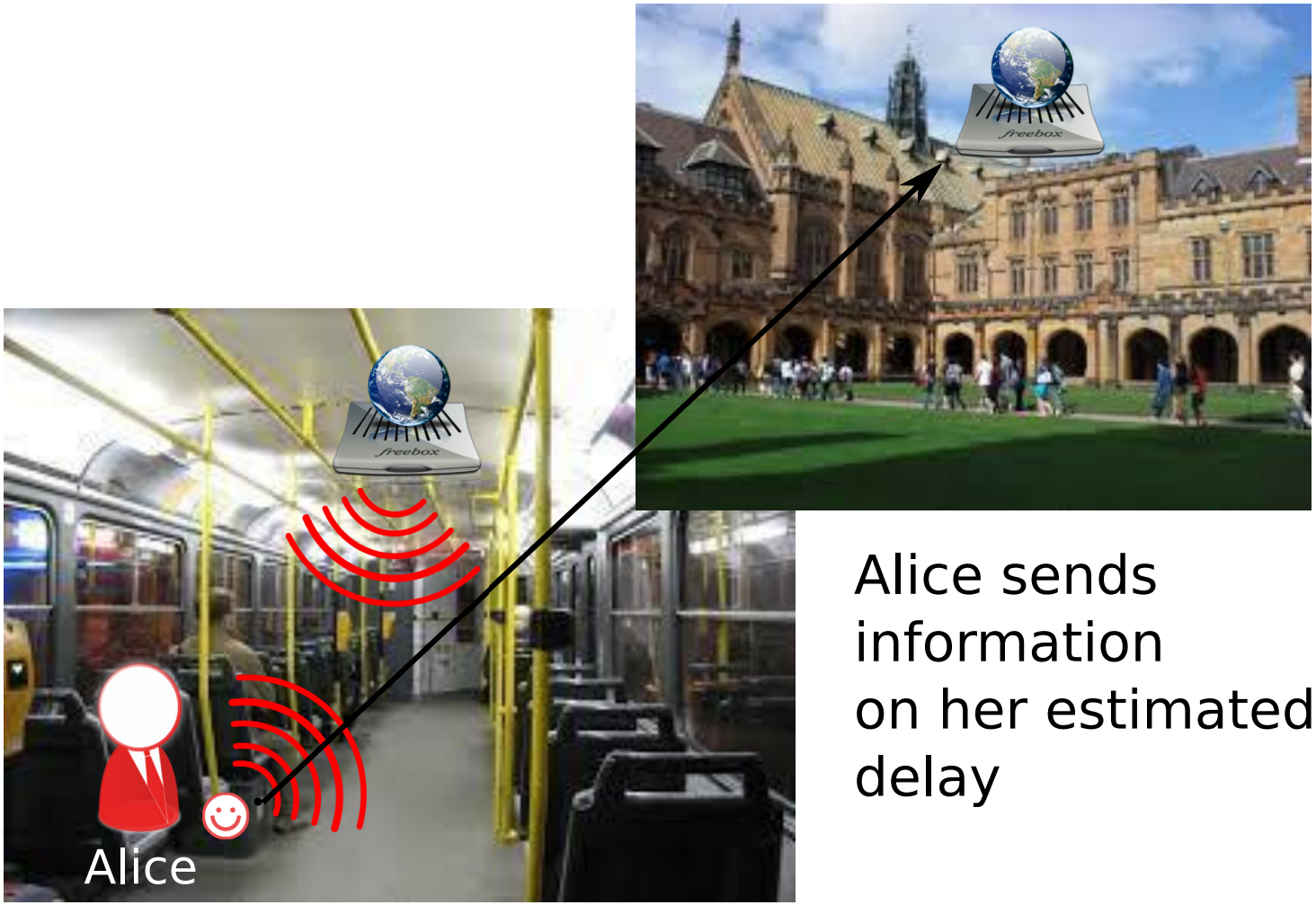
Introduction: Problem

- The Ambient Intelligence vision considers very broad scenarios (e.g. ISTAG Scenarios [Ducatel et al., 2001])
  - User can have short-lived, context-aware interactions with many unrelated and heterogeneous applications and services

Introduction: Problem

- The Ambient Intelligence vision considers very broad scenarios (e.g. ISTAG Scenarios [Ducatel et al., 2001])
  - User can have short-lived, context-aware interactions with many unrelated and heterogeneous applications and services
- Insufficient work on means to effectively **structure** and **dynamically deploy** the **multitude** of **context management services** required by an application

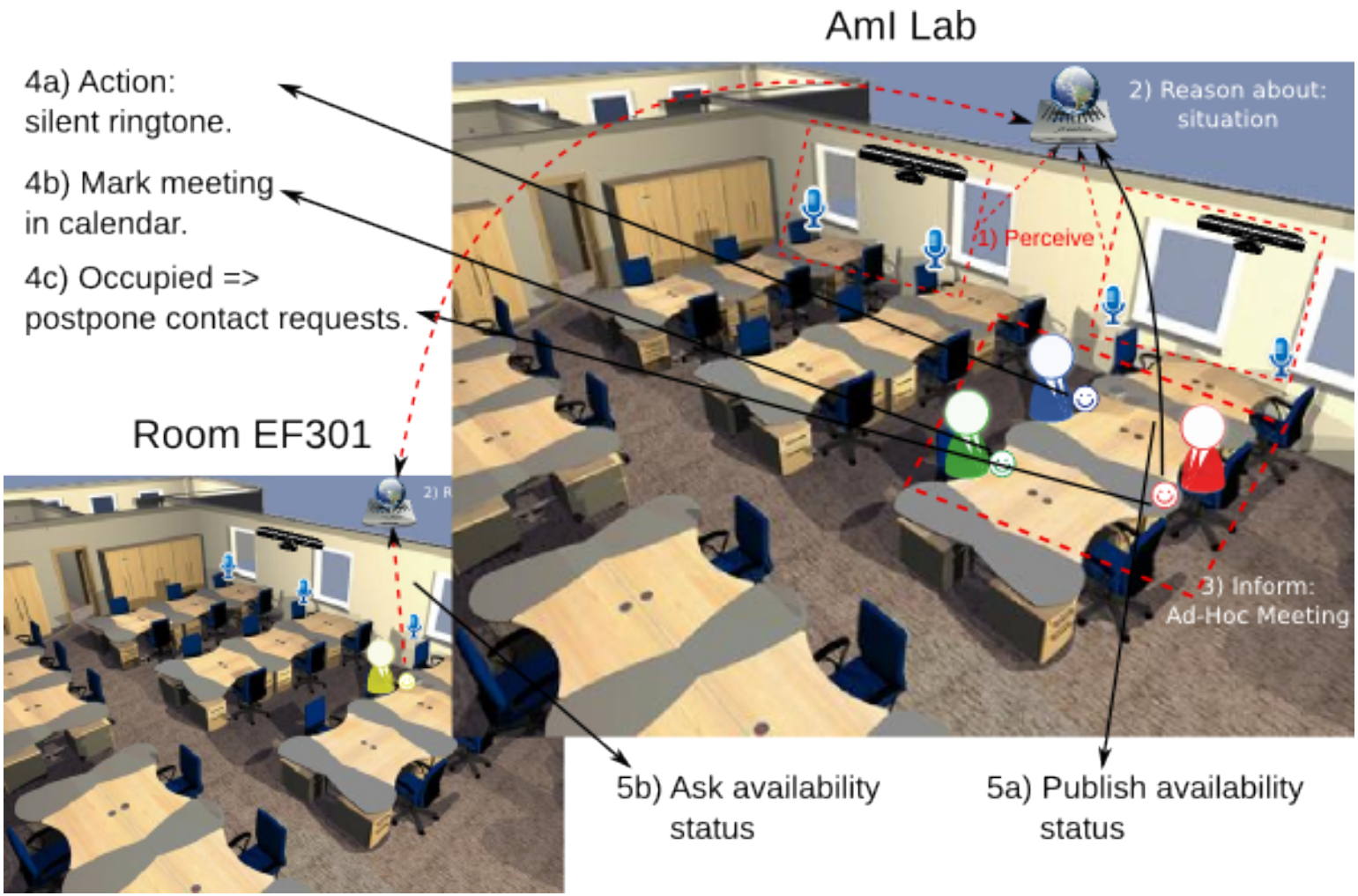
Introduction: Motivational Scenario



Alice sends information on her estimated delay

Introduction: Motivational Scenario

Introduction: Motivational Scenario



Introduction: Issues

- Alice's smartphone interacts with many *different* context-aware services: Tram, University Course Activity Service, AmI-Lab Management Server
- The smartphone uses local context information itself (e.g. Alice's profile)
- Information obtained from one service can both *influence* (e.g. tram speed with class delay time) and *be independent of* (e.g. AmI-Lab interactions) an other service

Introduction: Issues

- Alice's smartphone interacts with many *different* context-aware services: Tram, University Course Activity Service, AmI-Lab Management Server
- The smartphone uses local context information itself (e.g. Alice's profile)
- Information obtained from one service can both *influence* (e.g. tram speed with class delay time) and *be independent of* (e.g. AmI-Lab interactions) an other service

- How does the application **structure the use** of different context information services (tram, university course activity management, AmI laboratory)?
- How can the provisioning process be **configured** and **adapted** to the dynamic usage of context information?

Introduction: Main Goals

- Develop a Context Management Middleware (CMM)
- Focus on expressive modeling, flexible provisioning, ease of deployment/configuration

- **Why these objectives?**

Introduction: Main Goals

- Develop a Context Management Middleware (CMM)
- Focus on expressive modeling, flexible provisioning, ease of deployment/configuration

- **Why these objectives?**

Outline

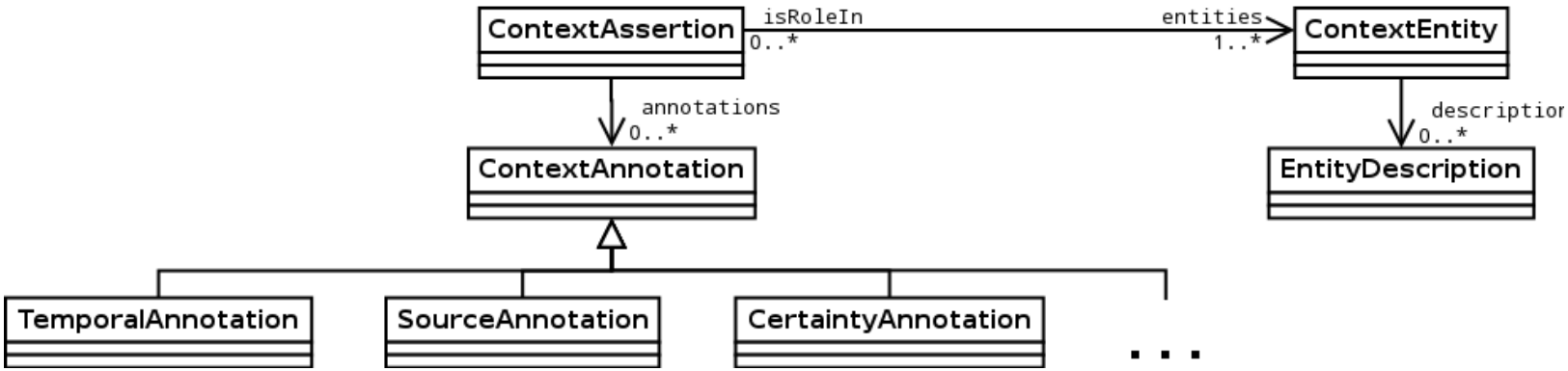
CONSERT CMM

CONSERT Context Management Middleware

- Our approach to the presented challenges and objectives
- Use **MAS**, **Semantic Web** and **service component** based design principals and technologies as a good engineering fit for CMM development

CONSERT CMM - KRR

- CONSERT = CONtext asSERTion
- CONSERT Meta-Model characteristics [Sorici et al., 2015b]:
  - 3 ontology-based modules providing **uniform representation support** for context modeling concerns (content, meta-properties - including QoC, constraint representation)
  - Flexible modeling of content and annotations (statements of variable arity, semantics for annotation combination during inference)



CONSERT CMM - KRR

- CONSERT Reasoning Engine characteristics [Sorici et al., 2015b]:
  - Reasoning cycle which favors temporal inference and a complete view of semantically distinguishable situations
  - Reasoning implementation supporting customizable constraint resolution and derivation scheduling
  - Capability of introspection $\rightarrow$ statistics of **dynamic context information usage**

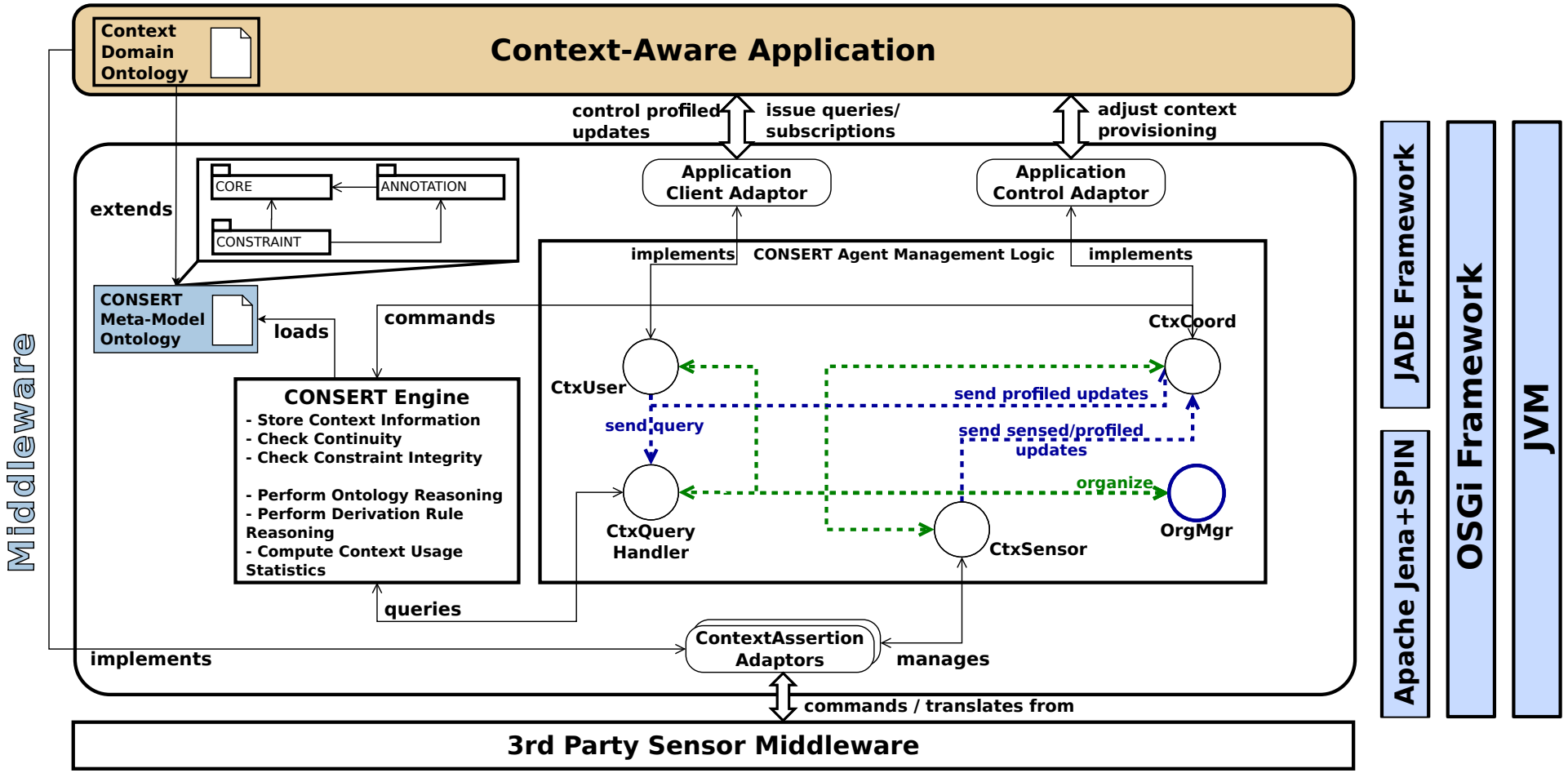
CONSERT CMM - Provisioning

- **Multi-Agent Based Architecture**
- **Key aspect**: use **MAS design principles** as a **good fit** for an **engineering problem**
- **Why Agents?**
  - Conceive the provisioning units as: **autonomous, reactive, proactive** and **socially interacting** entities
  - Use existing, mature development frameworks (JADE) to tackle communication infrastructure

  $\Rightarrow$

  - **Good encapsulation** of the logic for each provisioning aspects with **potential for increased provisioning autonomy**
  - **Message based communication** with complete handling of success and failure cases

CONSERT CMM - Provisioning



CONSERT CMM - Provisioning

Multi-Agent Based Architecture: 4 provisioning agents + 1 management agent

Provisioning Agents

- **CtxSensor Agent**: manage interactions with sensors (based on sensing policies), communicate with CtxCoord to send updates and receive provisioning tasking commands
- **CtxCoord Agent**: coordinate processing of context information
  - Create and control CONSERT Engine
  - Use coordination policies to determine *what* sensor updates and inferences are active and *how* (e.g. with which frequency) updates must be sent

CONSERT CMM - Provisioning

Provisioning Agents

- **CtxQueryHandler Agent**: disseminate context information, answer to queries and subscriptions. Can work in local or federated mode.
- **CtxUser Agent**: connection with application logic
  - Send queries and subscriptions
  - Act as prosumer: provide *static* or *profiled* ContextAssertions

Management Agent

- **OrgMgr Agent**:
  - Control deployment and life cycle of provisioning agents (i.e. create, start, stop, destroy provisioning agents)
  - Maintain overview of distributed deployment (if the case) + manage query/updates routing

CONSERT CMM - Provisioning

Context Management Unit (CMU): unit of control encapsulation

- **Instances** of context provisioning agents can be grouped into **mangement units** that are assigned to handle a specific *provisioning aspect* (acquisition, coordination, context consumption)

- E.g.:
  - CtxSensor + CtxUser agents can be grouped and deployed on a *prosumer* machine (e.g. Alice's smartphone)
  - CtxCoord + CtxQueryHandler - grouped and deployed on a coordination machine (e.g. the AmI-Lab management server)

CONSERT CMM - Provisioning

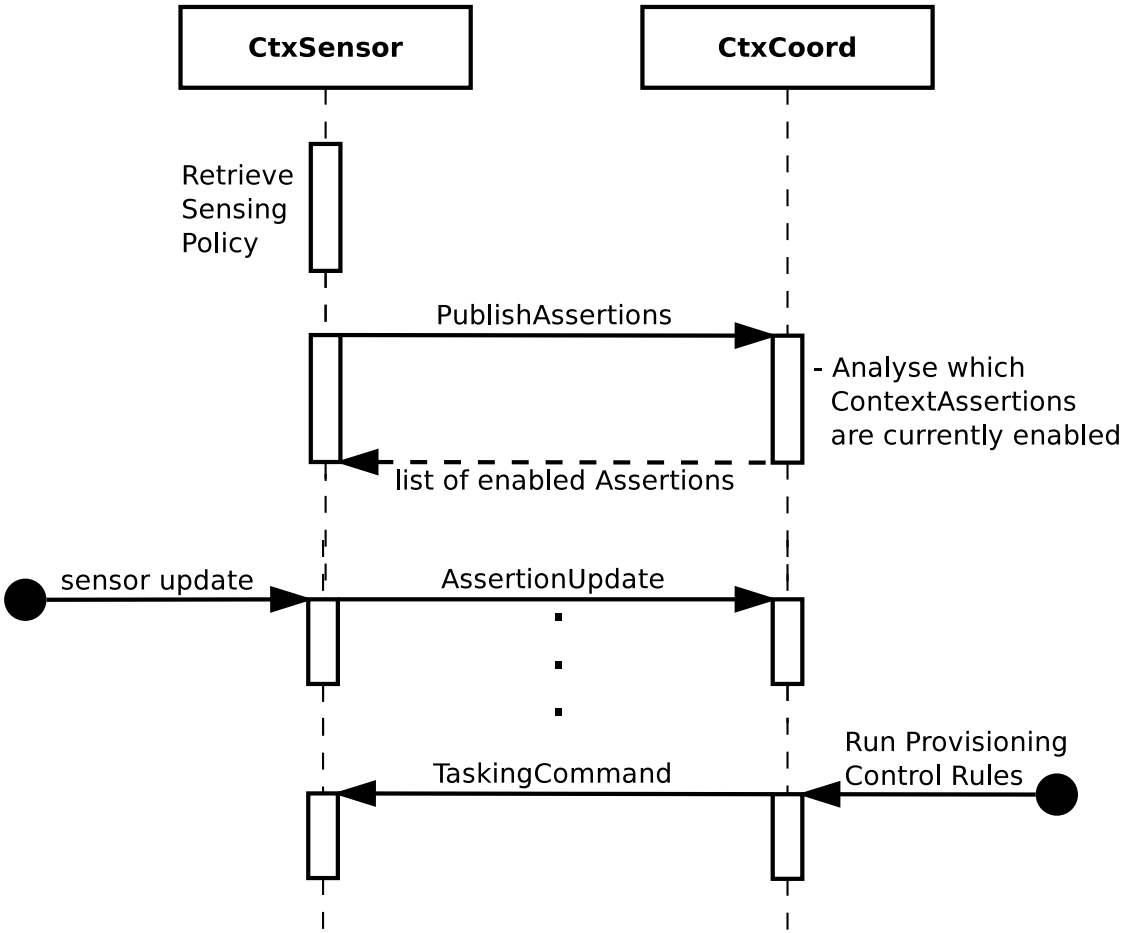
Context Provisioning Policies [Sorici et al., 2015a]

- Guide the behavior of provisioning agents (especially CtxCoord and CtxSensor)
- Consist of a set of **parameters** (key-value attributes) and a set of **control rules** (developer defined)
- Implemented using Semantic Web Technologies
  - Ontology-based parameter vocabulary
  - SPARQL-based rule definition

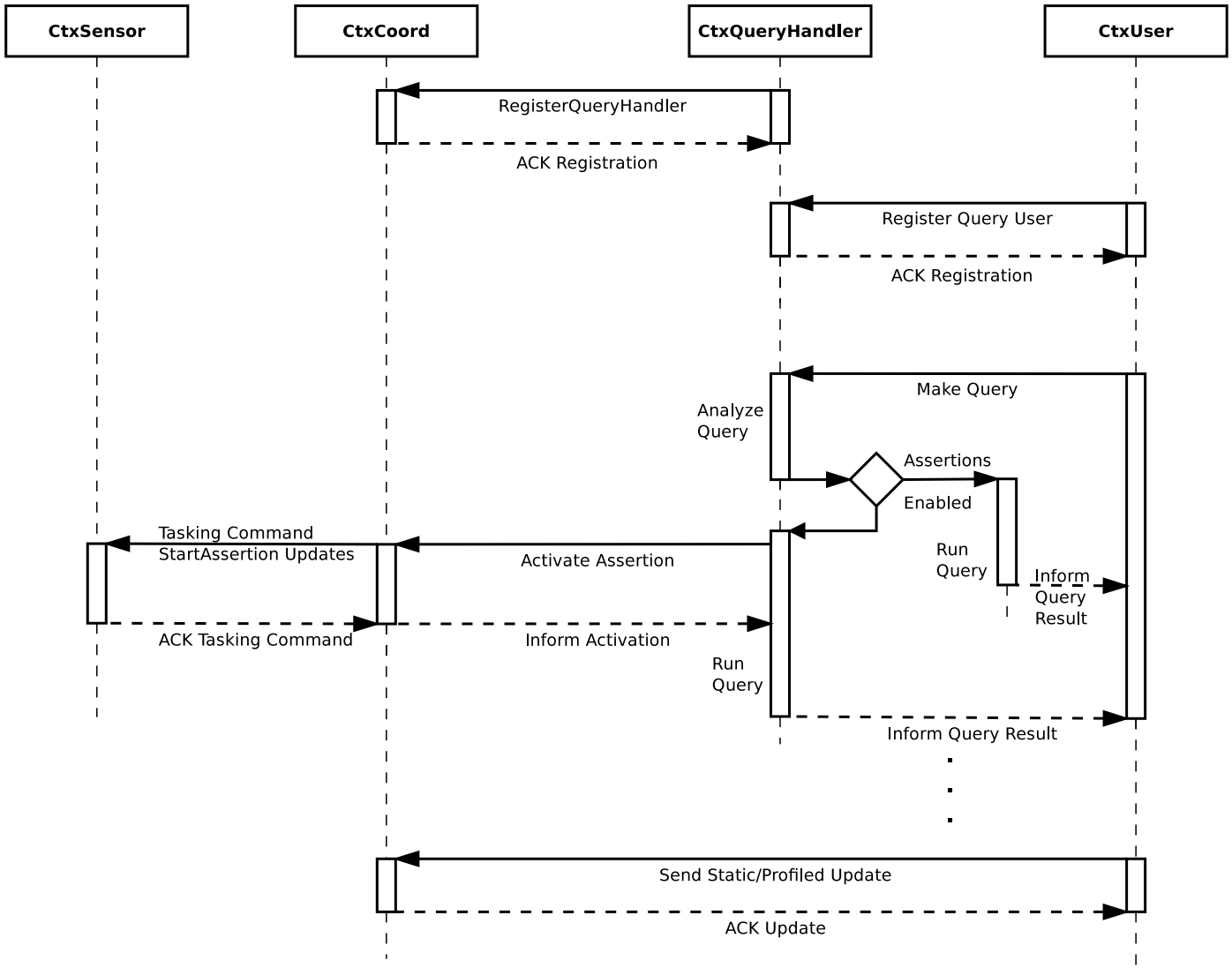
CONSERT CMM - Provisioning

- **Sensing Policies** (CtxSensor agents)
  - Specify initial settings for **how** sensed ContextAssertions are updated
  - 2 parameters: **update-rate**, **update-mode** (change-based, time-based)
- **Coordination Policies** (CtxCoord agents)
  - **Control Parameters**:
    - Setup CONSERT Engine (e.g. active inferences, constraint resolution service configuration, TTL, OBSERVATION_WINDOW)
    - Set enabled ContextAssertion updates and update-modes
  - **Control Rules**: alter control parameters according to **dynamic use of context information**

Context Provisioning Protocols - Sensing Chain



Context Provisioning Protocols - Request Chain



CONSERT CMM - Deployment

- **Idea**: create **link** between **multi-dimensionality of context information** and **CMU** assigned to service it

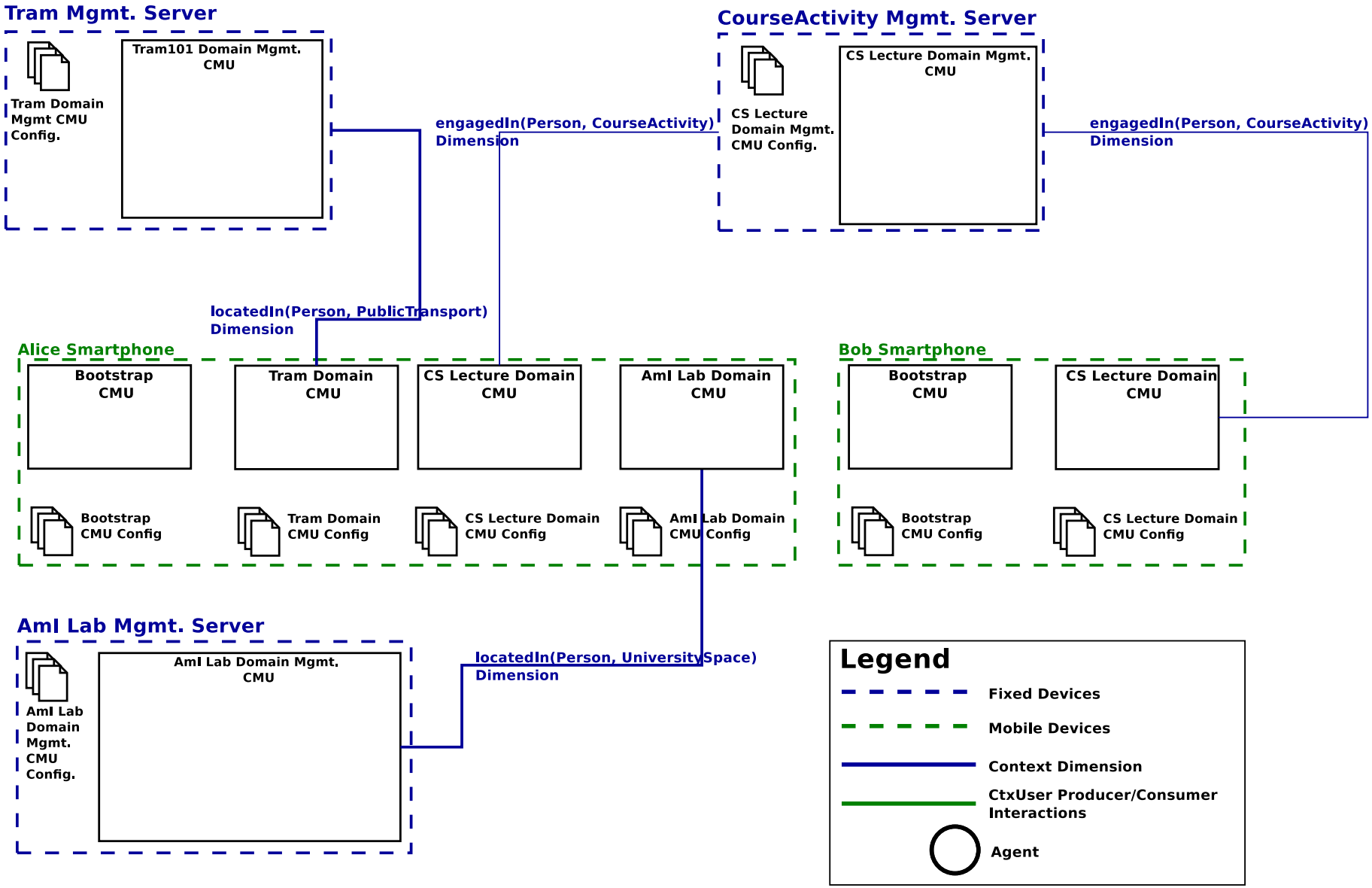
CONSERT CMM - Deployment

- **Idea**: create **link** between **multi-dimensionality of context information** and **CMU** assigned to service it

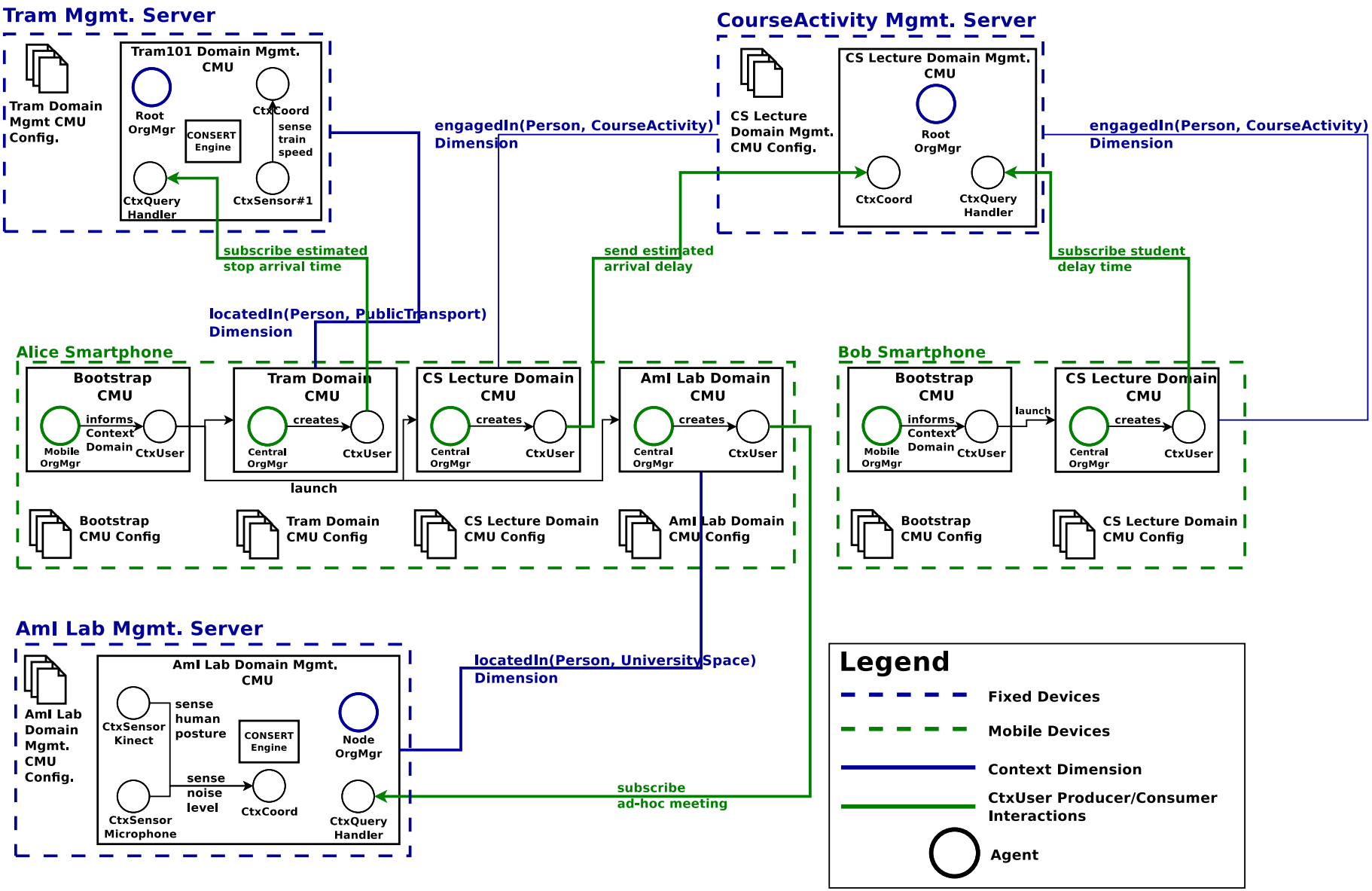
- **ContextDimension**: a *privileged direction* (e.g spatial, activity-related) along which an application structures its context provisioning process.

- **ContextDomain**: a *logical partition* of the global application context model along a chosen ContextDimension

CONSERT CMM - Deployment



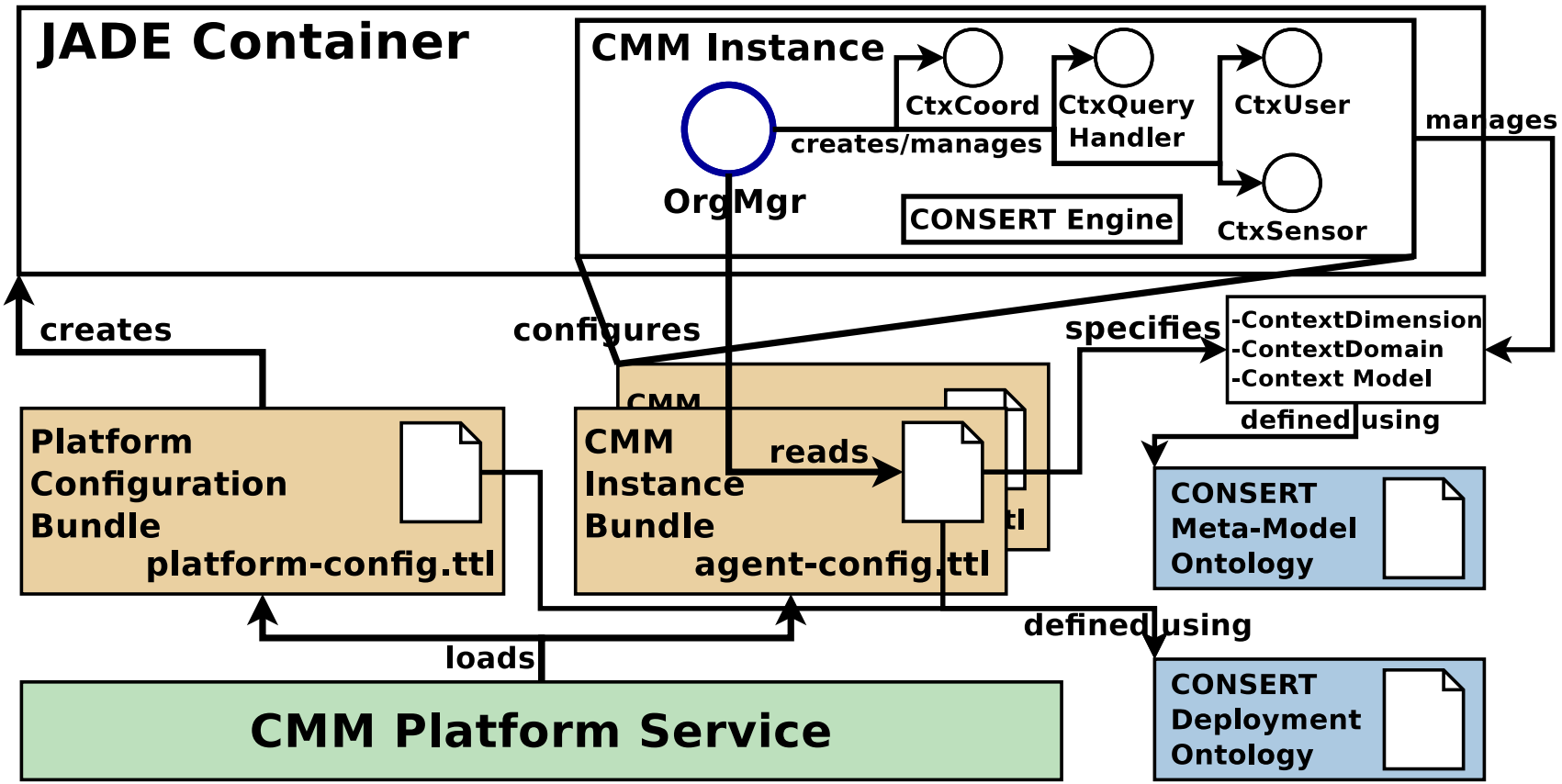
CONSERT CMM - Deployment



CONSERT CMM - Deployment

- ContextDimensions + ContextDomains + CMUs allow us to consider two deployment schemes:
  - **Centralized**:
    - a single (default) ContextDomain
    - a single CMU handling context provisioning
  - **Decentralized**:
    - one or more ContextDimensions and ContextDomains
    - ContextDomains can be organized in a *flat* or *hierarchical* manner
    - Comprises both fixed and mobile nodes $\Rightarrow$ multiple CMUs

CONSERT CMM - Deployment



Outline

CONSERT CMM - Conclusions

- Focus on:
  - **Flexibility** of the **context model** and the **deployment scheme**
  - **Provisioning adaptability** through **policy based specifications**
  - **Ease of development / configuration** through use of declarative policies and service component based design
- Implementation: use of Semantic Web, MAS and OSGi technologies as a **good engineering fit** for middleware goals
- **Why**: good response to the need of **supporting context-aware application development**

CONSERT CMM - Future Work

- Current validation through implementation of the AmI-Lab scenario using a simulated environment (using the iCasa platform[1])
  - $\Rightarrow$ need to perform real time experiment in AmI-Lab

[1] http://adeleresearchgroup.github.io/iCasa/

CONSERT CMM - Future Work

- Current validation through implementation of the AmI-Lab scenario using a simulated environment (using the iCasa platform[1])
  - $\Rightarrow$ need to perform real time experiment in AmI-Lab
- From experience developing the scenario
  - Need for tooling (e.g. context model IDE, syntactic sugar for derivation rule writing, automated code generation for simple query/subscription usage)

[1] http://adeleresearchgroup.github.io/iCasa/

CONSERT CMM - Future Work

- Current validation through implementation of the AmI-Lab scenario using a simulated environment (using the iCasa platform[1])
  - $\Rightarrow$ need to perform real time experiment in AmI-Lab
- From experience developing the scenario
  - Need for tooling (e.g. context model IDE, syntactic sugar for derivation rule writing, automated code generation for simple query/subscription usage)
- Exploit multi-agent potential for autonomy by introducing Context Level Agreements (CLAs)
  - CtxCoord, CtxSensor agents have individual goals (e.g. reduce workload, save energy) which are valued against request characteristics (e.g. required accuracy, needed freshness) from a CtxUser
  - Established CLAs influence *where* and *when* CMUs are deployed

[1] http://adeleresearchgroup.github.io/iCasa/

References I

Ducatel, K., Bogdanowicz, M., Scapolo, F., Leijten, J., and Burgelman, J.-C. (2001).
Scenarios for ambient intelligence in 2010.
Office for official publications of the European Communities.

Sorici, A., Picard, G., Boissier, O., and Florea, A. M. (2015a).
Policy-based adaptation of context provisioning in ami.
In *Ambient Inteligence, 2015 6th International Symposium on*, volume in print. Springer.

Sorici, A., Picard, G., Boissier, O., Zimmermann, A., and Florea, A. (2015b).
Consert: Applying semantic web technologies to context modeling in ambient intelligence.
Computers & Electrical Engineering.

THANK YOU!

Questions?

CONSERT CMM - Decentralized Deployment