Smart, Secure and Sustainable Home: A Socio-Technological Perspective

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ABSTRACT
Technological development has brought us to the verge of truly ubiquitous computing environments, making smart homes more than just a concept of science fiction. However, the introduction of information technology into our homes has to consider the intricate social setting it represents. In this paper, we discuss the complexity of this setting, and provide a testbed for future research endeavors, so that our homes are not only smart and secure, but also sustainable.

Author Keywords
socio-technological systems, ubiquitous computing, privacy, security, ontologies

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces—*User-centered design*; K.4.1 Computers and Society: Public Policy Issues—*Privacy*; I.2.4 Artificial Intelligence: Knowledge Representation Formalisms and Methods—*Semantic Networks*

INTRODUCTION
Recent technological development has brought us closer towards Weiser's vision of information technology permeating our daily lives [32]. Technology does not only dominate our work lives, but has become an integral part of our domestic lives as well. And instead of replacing existing media, new technology is adapted into the existing patterns of use [13].

The "smart" house, or "home of the future", such as the Aware house built by Georgia Tech [20] augments the traditional home with a rich computational and communicational infrastructure, such as "smart" devices and sensors that can detect and interact with the inhabitants of the house in novel ways. These augmented devices can improve life in the house, by e.g. providing a richer environment for entertainment and education, as well as simplifying inventory and utility management. For example, the Cyberfridge [22] can detect its contents and allow trusted parties with access to that information from anywhere. Another example is "smart" hot water and heat management based on the preferences of the inhabitants.

There are obvious advantages of the "smart" home outlined above. However, this focus on the domestic also introduces new challenges "[…]that move design beyond the current focus on information and knowledge work […] and exposes us to the demands of new user groups, including the elderly, the disabled, and the mentally impaired […]" [13].

Furthermore, the home is a nodal point between the public and private [30]. Introducing information technology into that setting, therefore, increases the importance of addressing the enduring concerns towards its effect on privacy and security [25]. Security challenges arise from two factors – first, the home is a private space with a plethora of personal information. Clearly this personal information should be protected from unauthorized access, as data such as tax or medical records or even the whereabouts of the inhabitants of the house can be used in potentially harmful ways. However, in this situation unauthorized access can come from both physical as well as virtual threats and a "digital trespasser" can be as dangerous to the inhabitants as a physical intruder. Unfortunately, the residents of a home usually know little about information security and this is the second factor that poses limitation to the security system. The privacy and security mechanisms need to be transparent and easy to use otherwise users will find ways to circumvent them or simply not use them at all [12].

These challenges are further exacerbated as both the physical and social structures within the home are subject to continuous change [19, 29]. Thus, adding information technology into our homes has to be done considering the multitude of activities our homes support [1]. In other words, information technology within the home has to address the social context of our homes and our needs for privacy and security in order to offer an experience that is sustainable.

While progress is being made addressing these issues, the use of information technology in our homes is still far away from being as "refreshing as taking a walk in the woods." [32]. This document therefore tries to outline a path to be taken towards that goal.

The following section discusses the unique challenges of

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Outline

- Introduction
- Problem Description
- Proposed Approach
- Proof of Concept
- Conclusion

Introduction

- Introduction of Information Technology in the house.

- Smart
- Secure?
- Sustainable?

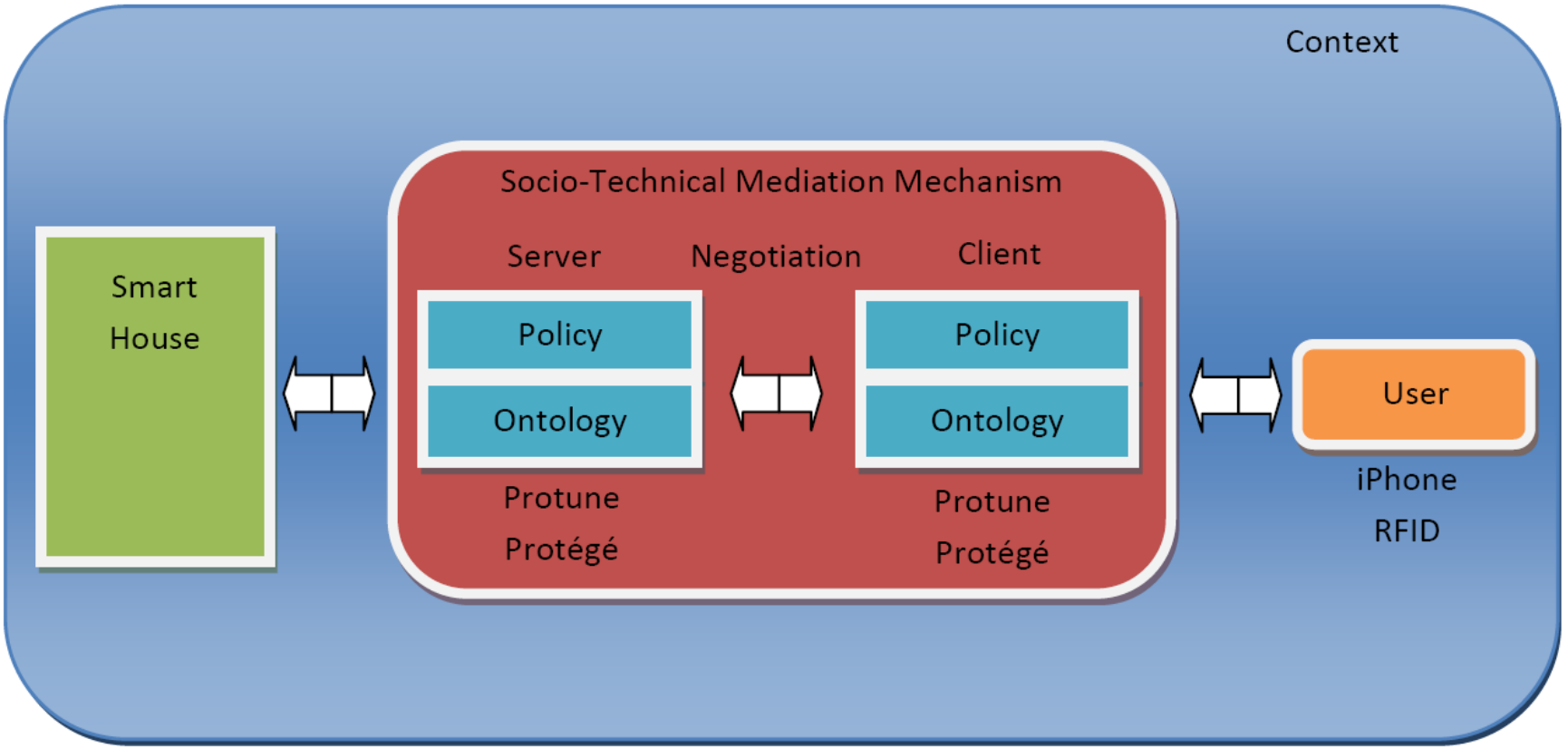
Problem Description

- Home as a Social Place
  - Not well studied
- Technical Constraints and Opportunities
  - House dynamic social place
  - Burden of access control decisions
  - Non-intrusive interaction

Grounding Scenario

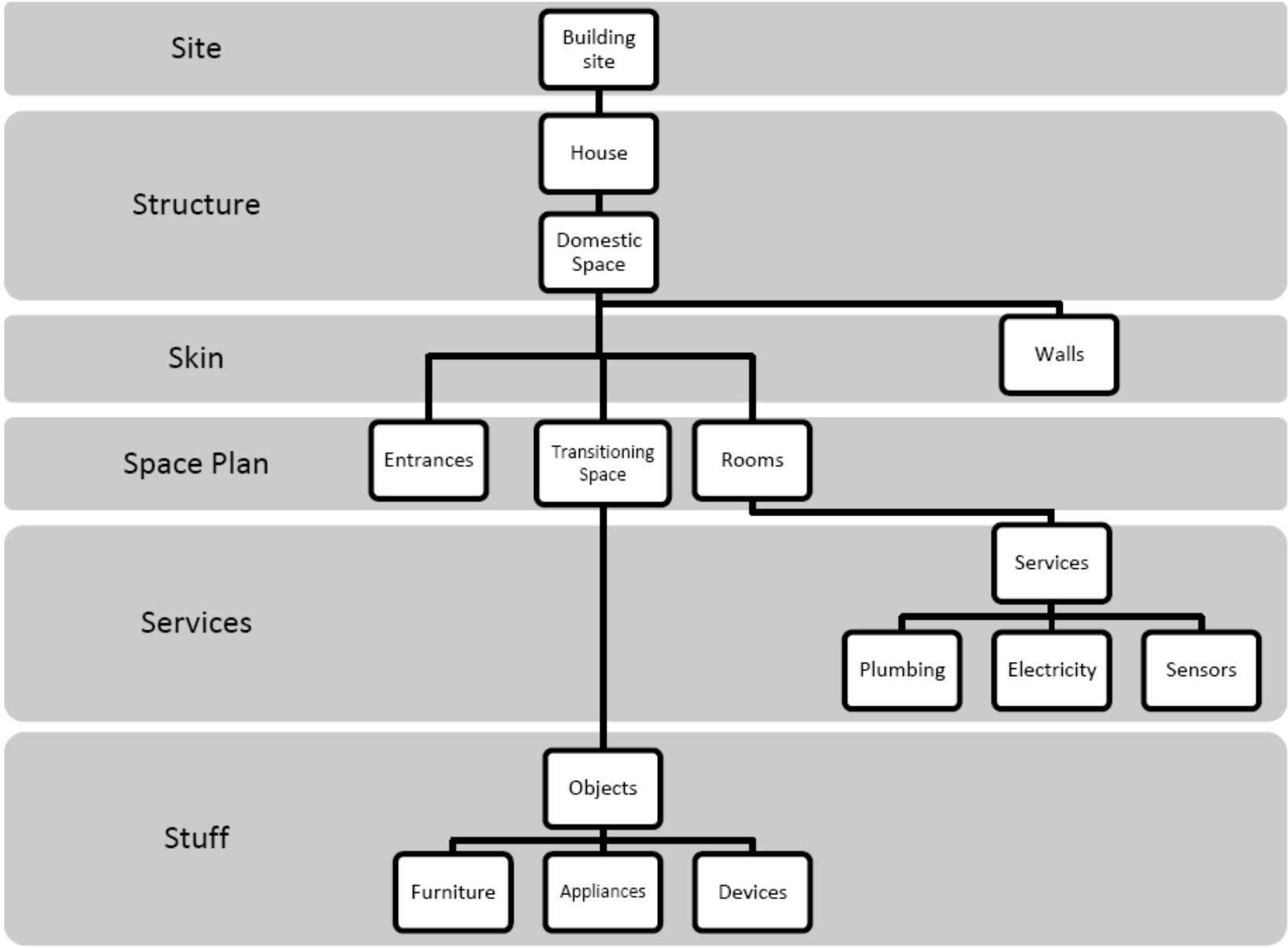
- Joanne is 75 and lives by herself.
- Accident.
- Establishing communication with daughter Helen fails.
- Contact EMTs and provide relevant information.
- EMT use provided information to provide prompt help upon arrival.

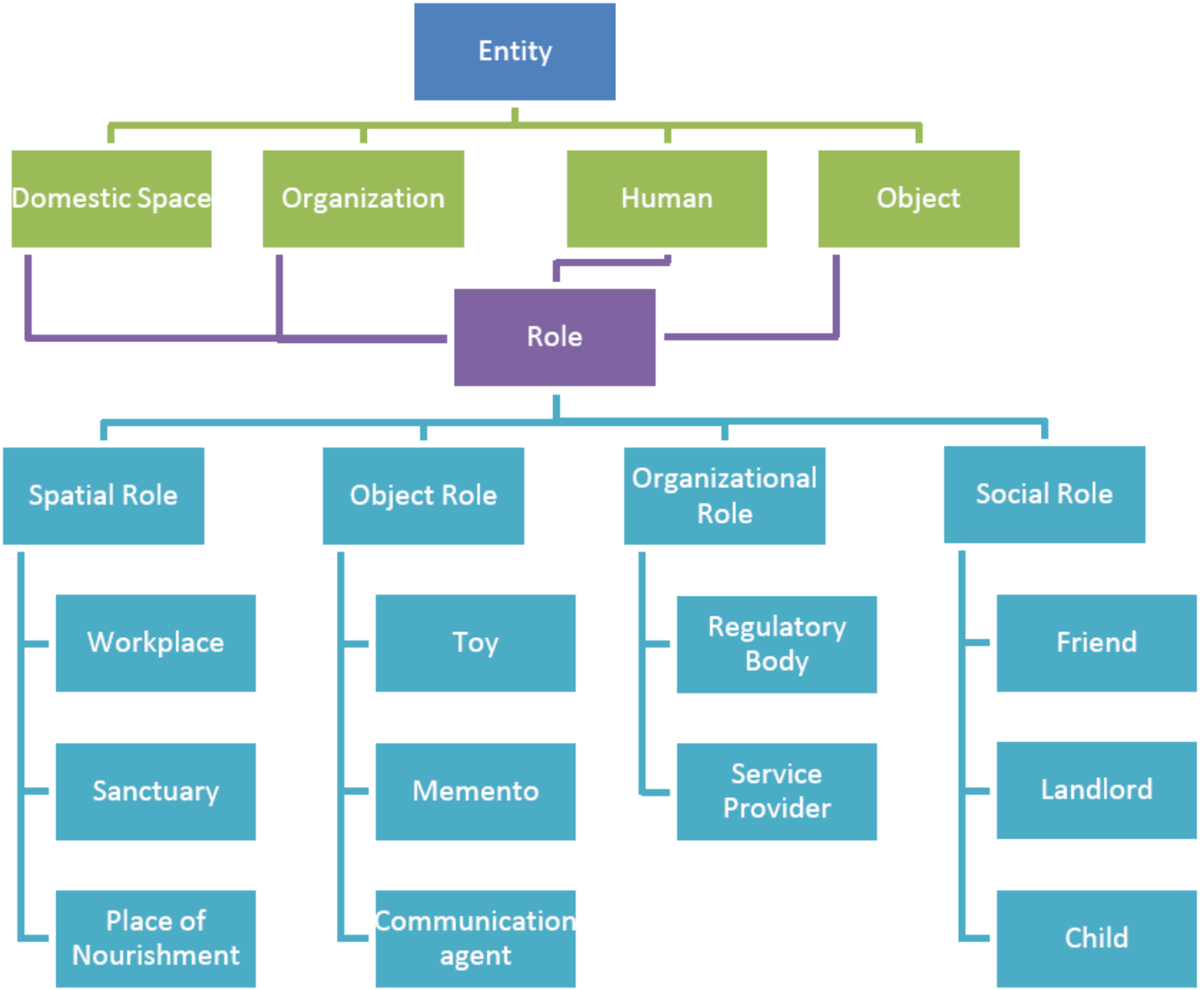
Proposed Approach

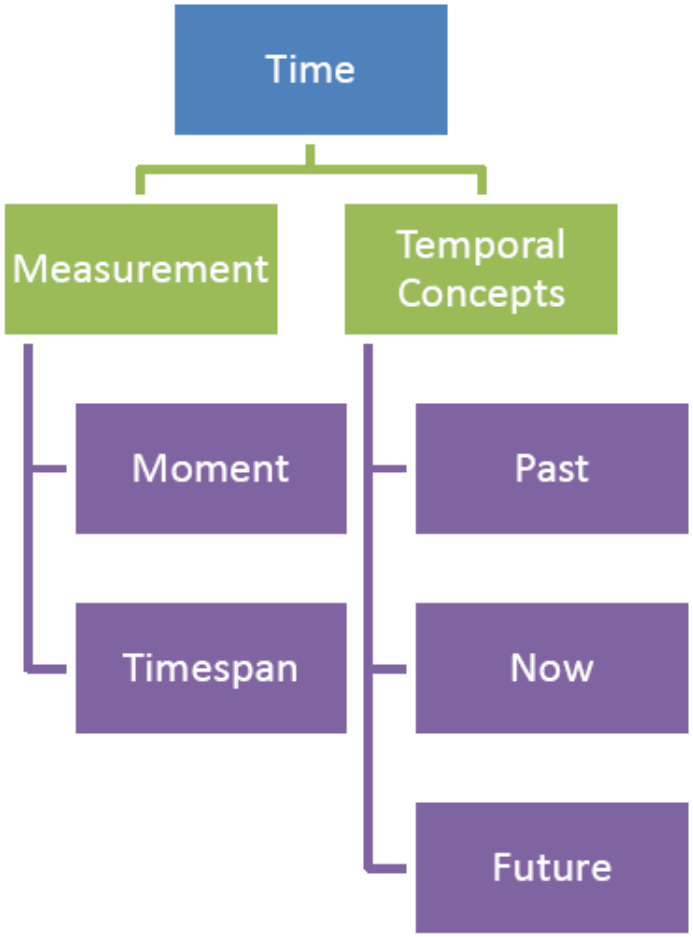


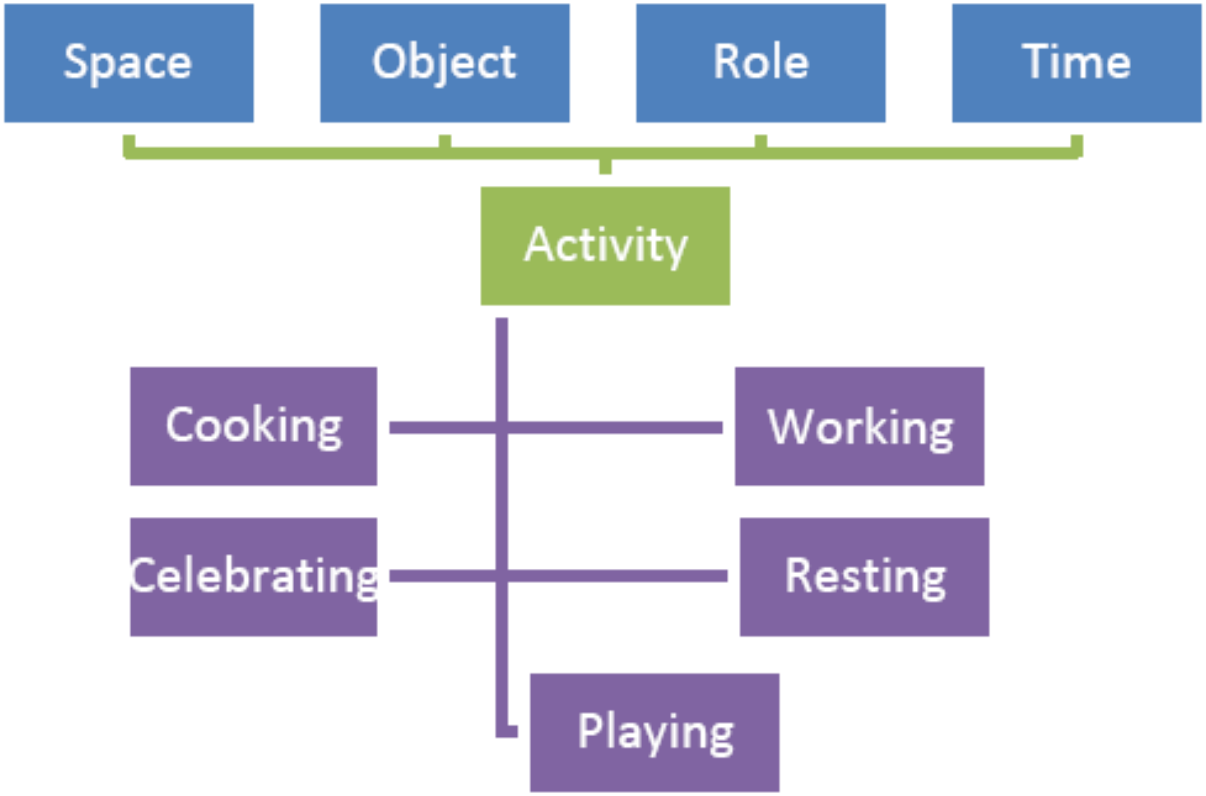
Ontology

- Need to model social context
  - Location
  - Identity
  - Time
  - Activity
- Need to ground privacy & security in social context


Site
Building site
Structure
House
Domestic Space
Skin
Walls
Space Plan
Entrances
Transitioning Space
Rooms
Services
Services
Plumbing
Electricity
Sensors
Stuff
Objects
Furniture
Appliances
Devices


Entity
Domestic Space
Organization
Human
Object
Role
Spatial Role
Object Role
Organizational Role
Social Role
Workplace
Sanctuary
Place of Nourishment
Toy
Memento
Communication agent
Regulatory Body
Service Provider
Friend
Landlord
Child


Time
Measurement
Temporal Concepts
Moment
Timespan
Past
Now
Future

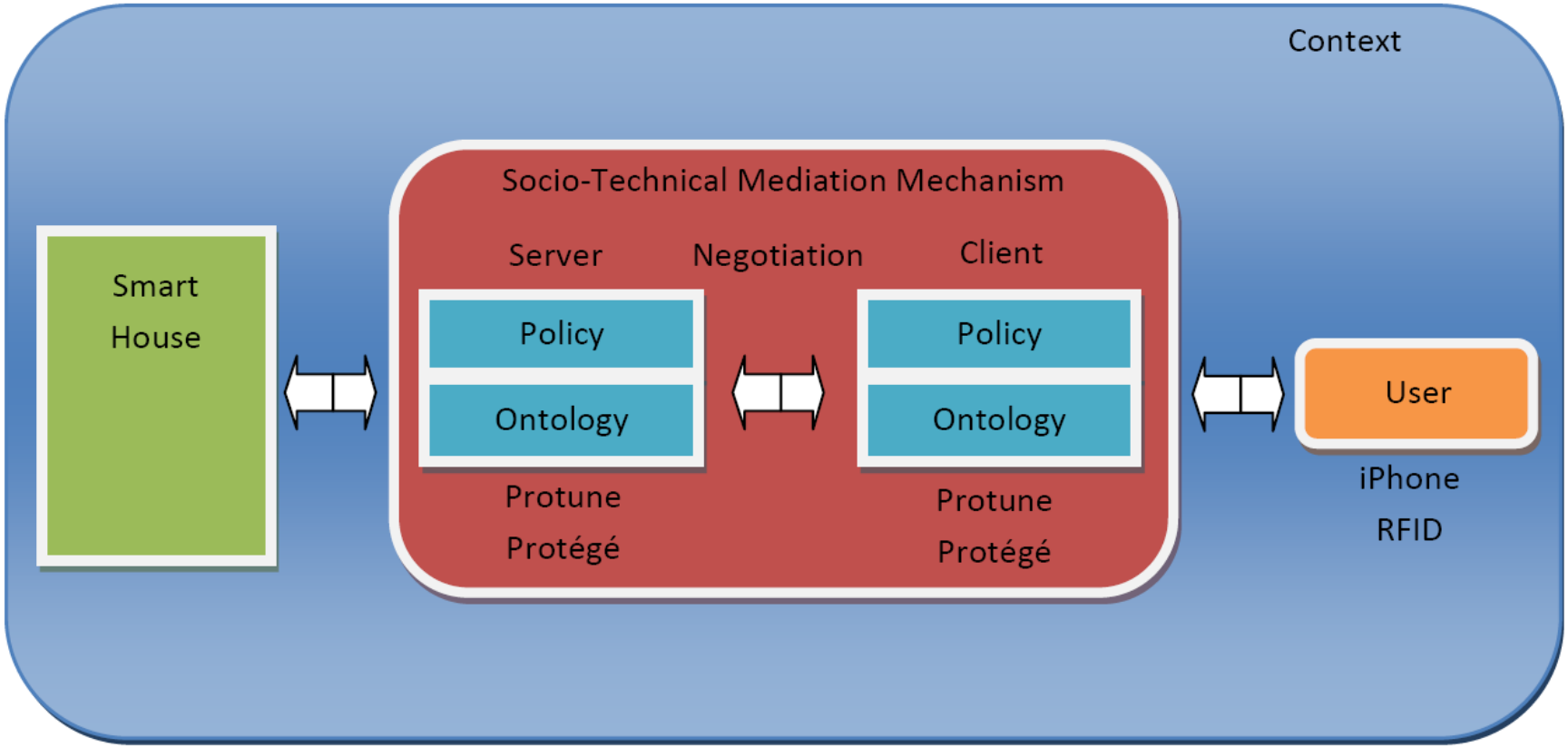

Space
Object
Role
Time
Activity
Cooking
Working
Celebrating
Resting
Playing


Identity
Time
Privacy need
Activity
Location

Policy

- A policy is a collection of relational statement or rules about concepts defined in the ontology.
- Example:
  - In case of ***emergency***, contact ***family member***. If contact is not established, escalate by contacting ***emergency medical services***.
  - Disclose ***medical records*** only to ***trusted medical providers.***
- Supports sustainable interaction between individuals, while maintaining security and privacy

Mediator



- Model interactions as negotiations
- Burden of sustainable interaction (conflicts)

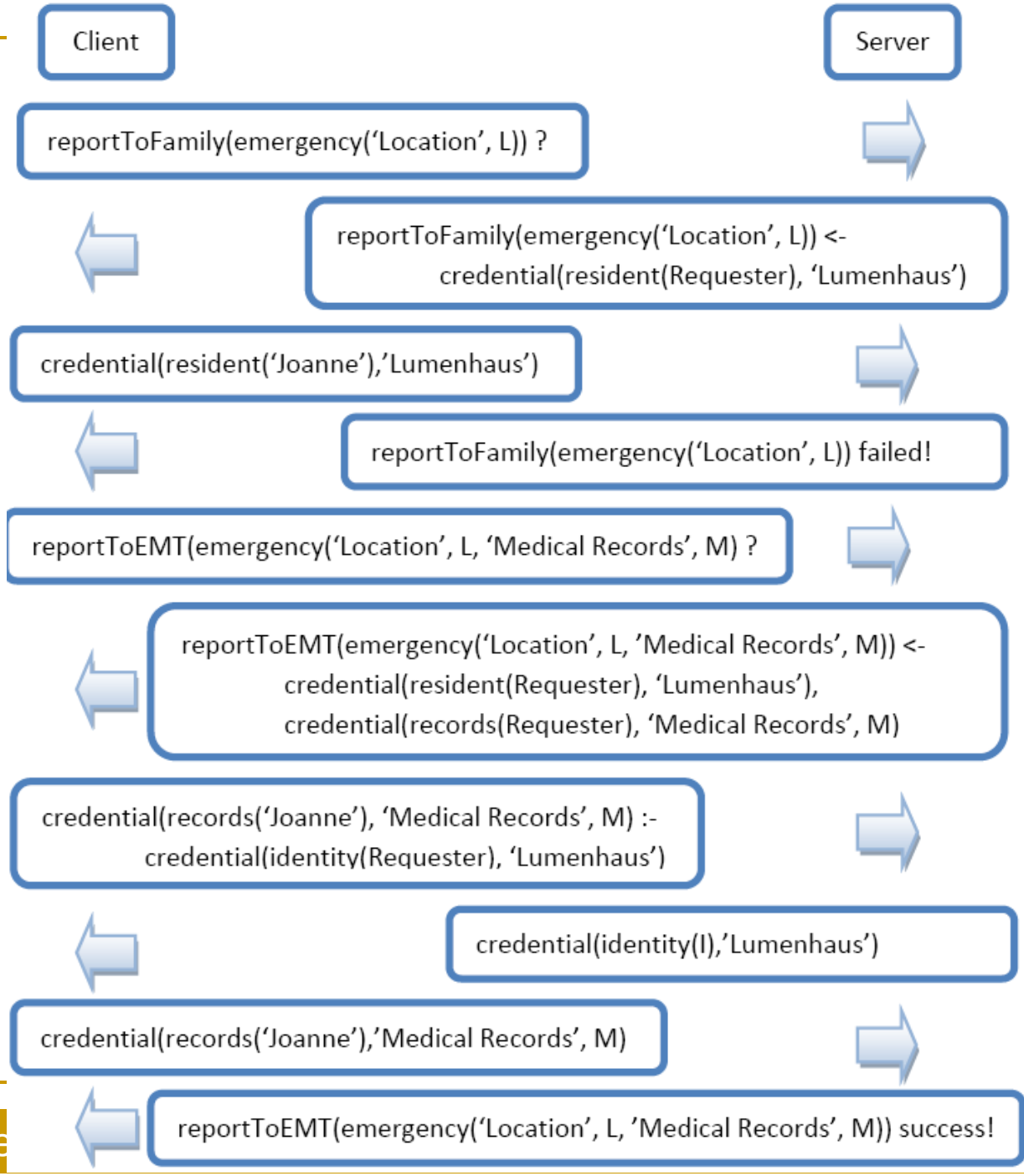
Proof of Concept

- Protégé, OWL-DL, SUMO
- The Protune framework features:
  - a trust management language supporting (possibly user-defined) actions
  - an extensible declarative metalanguage for driving decisions about information disclosure
  - a parameterized negotiation procedure, that gives a semantics to the metalanguage and provably satisfies some desirable properties for all possible metapolicies
  - general ontology-based techniques for smoothly integrating language extensions
  - advanced policy explanations in order to answer why, why-not, how-to, and what-if queries

Ontology

```
<owl:Class
  rdf:about="#FamilyMember">
  <rdfs:subClassOf
    rdf:resource="&Sumo;SocialRole>
</owl:Class>
<owl:Class
  rdf:about="#Resident">
  <rdfs:subClassOf
    rdf:resource="&Sumo;SocialRole>
</owl:Class>
<owl:Class
  rdf:about="#RecordOwner">
  <rdfs:subClassOf
    rdf:resource="&Sumo;SocialRole>
</owl:Class>
<owl:Class rdf:about="#EMT">
  <rdfs:subClassOf
    rdf:resource="&Sumo;SocialRole>
</owl:Class>
<owl:Class
  rdf:about="#MedicalRecord">
  <rdfs:subClassOf
    rdf:resource="&Sumo;Attribute>
  <rdfs:subClassOf
    rdf:resource="&Sumo;Proposition>
</owl:Class>
```

```
<owl:Class
  rdf:about="#Report">
  <rdfs:subClassOf
    rdf:resource="&Sumo;IntentionalProcess>
</owl:Class>
<Human rdf:about="#Joanne">
  <rdf:type
    rdf:resource="&Sumo;Human"/>
  <livesIn
    rdf:resource="#LumenHaus"/>
  <owns
    rdf:resource="#MedicalRecords"/>
  <hasLocation
    rdf:resource="#Kitchen"/>
</Human>
<Human rdf:about="#Helen">
  <rdf:type rdf:resource="&Sumo;Human"/>
  <daughterOf rdf:resource="#Joanne"/>
</Human>
```


Client
Server
reportToFamily(emergency('Location', L)) ?
reportToFamily(emergency('Location', L)) <-
credential(resident(Requester), 'Lumenhaus')
credential(resident('Joanne'),'Lumenhaus')
reportToFamily(emergency('Location', L)) failed!
reportToEMT(emergency('Location', L, 'Medical Records', M) ?
reportToEMT(emergency('Location', L, 'Medical Records', M)) <-
credential(resident(Requester), 'Lumenhaus'),
credential(records(Requester), 'Medical Records', M)
credential(records('Joanne'), 'Medical Records', M) :-
credential(identity(Requester), 'Lumenhaus')
credential(identity(I),'Lumenhaus')
credential(records('Joanne'),'Medical Records', M)
reportToEMT(emergency('Location', L, 'Medical Records', M)) success!

Conclusion

- Technological developments bring ubiquitous computing into the home.
- Complex social structures may hinder deployment of technology.
- We hope to fully implement and deploy our framework within the lumenHAUS, to further gain insight.