



# **A Semantic Web Environment for Mobile, Context-Aware Services**

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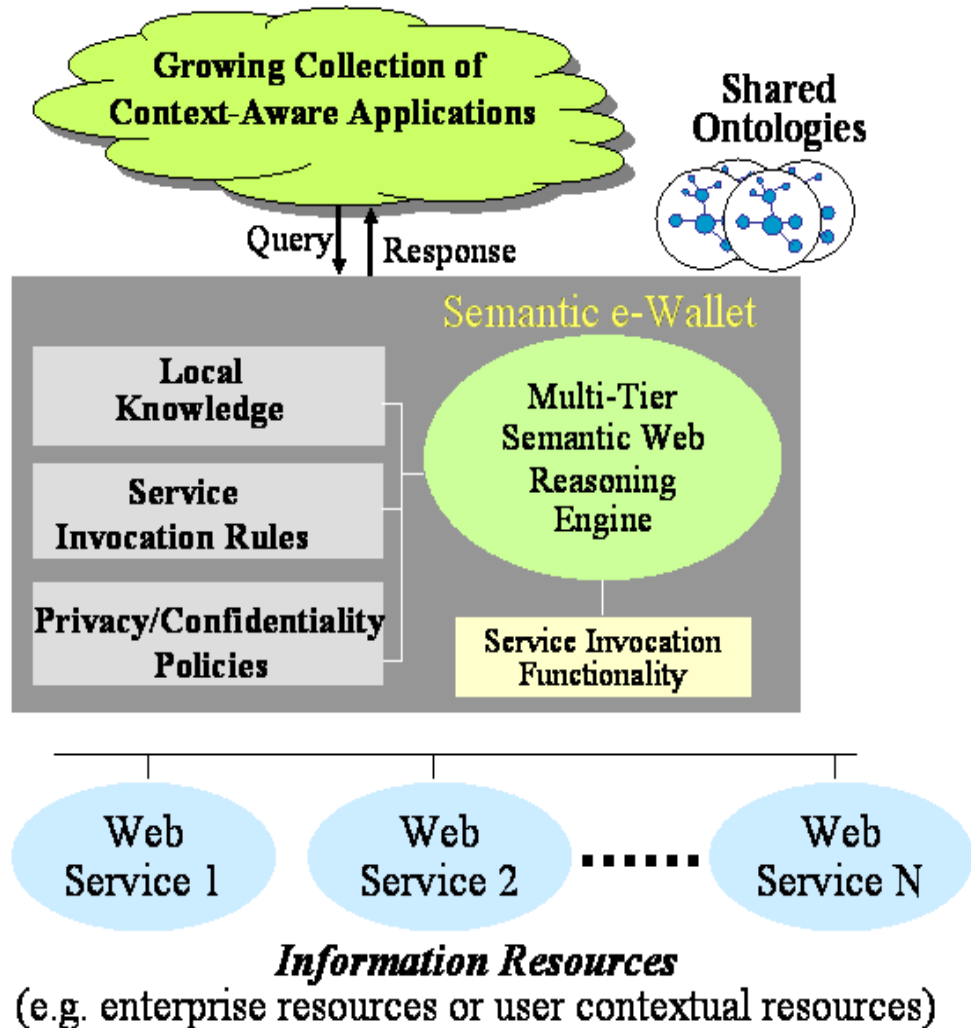


# SW Environment for Context-Aware Services

## Overall Program Summary



- **Objective:** Open Environments for the creation of **Context-Aware Services**
  - Re-use, Security & Privacy, Usability
  - Test drive emerging standards and provide input/feedback
  - Initial focus: mobile & pervasive computing
  - Later also: Inter/Intra-Enterprise scenarios
- **Technical Solution Strategy:**
  - Prototype-driven
  - Identify gaps, propose solutions, complement/improve emerging standards
- **Basic Elements of Research**
  - Extensions of OWL to represent rules – **ROWL engine & Semantic eWallet**
  - Prototype environments, e.g. **MyCampus, InfoBridge, Museum, etc.**
  - Demonstration on **DoD-relevant scenarios** (SONAT, CoSAR-TS)
  - Participation in **SWSA and rules discussion group**
  - **Public release of tools** (2004)





- **Rules are critical**
  - Capture user preferences – e.g. decision rules, security and privacy
  - Solution: Rules in OWL (**ROWL**): Syntax & XSLT stylesheets for Jess & contribution to SWRL discussions
- **Privacy and security are critical**
  - Solution: **Semantic e-Wallet**
    - Gatekeeper and clearinghouse to information sources for a user
    - Extension of ROWL for representing **privacy rules** and **service invocation rules** – incl. XSLT stylesheets and multi-layer reasoning engine running on top of Jess
- **Services are critical**
  - Solution:
    - **Sources of contextual information modeled as web services**
    - Integrating **eWallet and web service composition**
- **Usability is Critical**
  - Solution:
    - **Rule Editors**
    - Complemented with case-based reasoning



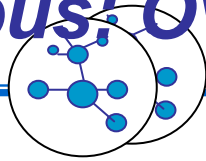
- Campus as “everyday life microcosm”
- Enhance campus life through a growing collection of context-aware agents/applications that users access over the WLAN:
  - Obtain information about users by querying their e-Wallets
    - Automatic identification of available sources of contextual information – modeled as web services
      - Dynamic Service invocation rules
    - Subject to user privacy preferences
      - Access control rules
      - Obfuscation rules
        - » Abstraction
        - » Modification
      - Including Context-Sensitive Policies





# SW Environment for Context-Aware Services

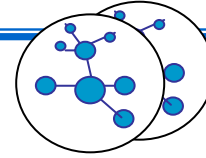
## MyCampus: Overall Architecture



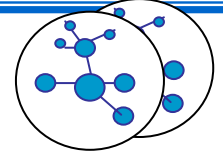
Contextual Ontologies



Personal Preference Ontologies

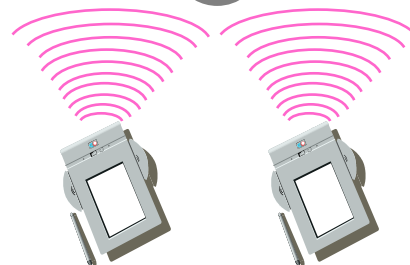
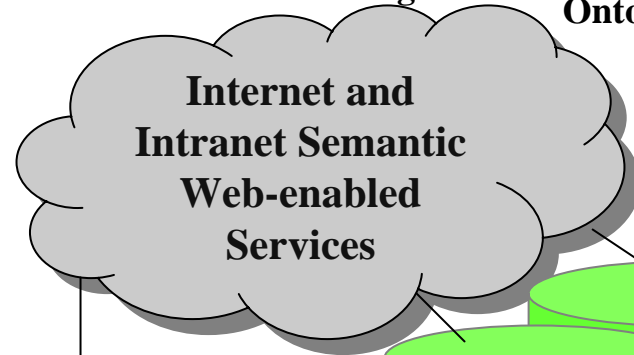
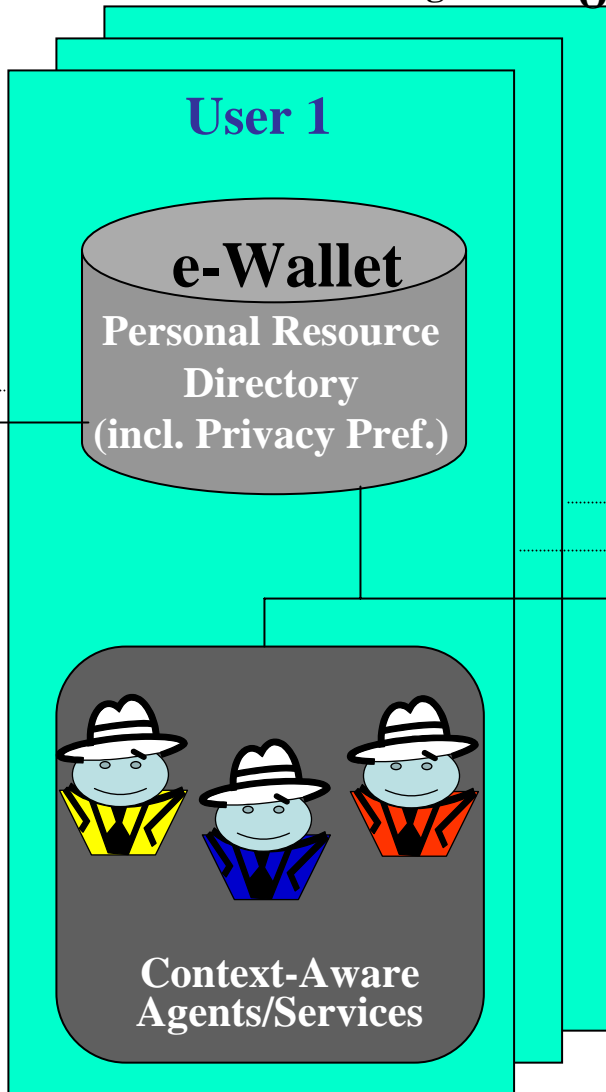
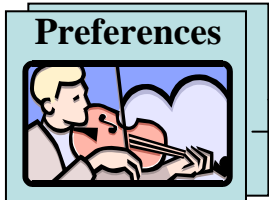


Personal Resource Ontologies



Service Ontologies

Semantic Web-enabled Context Resources





# SW Environment for Context-Aware Services

## e-Wallet Reasoning Engine

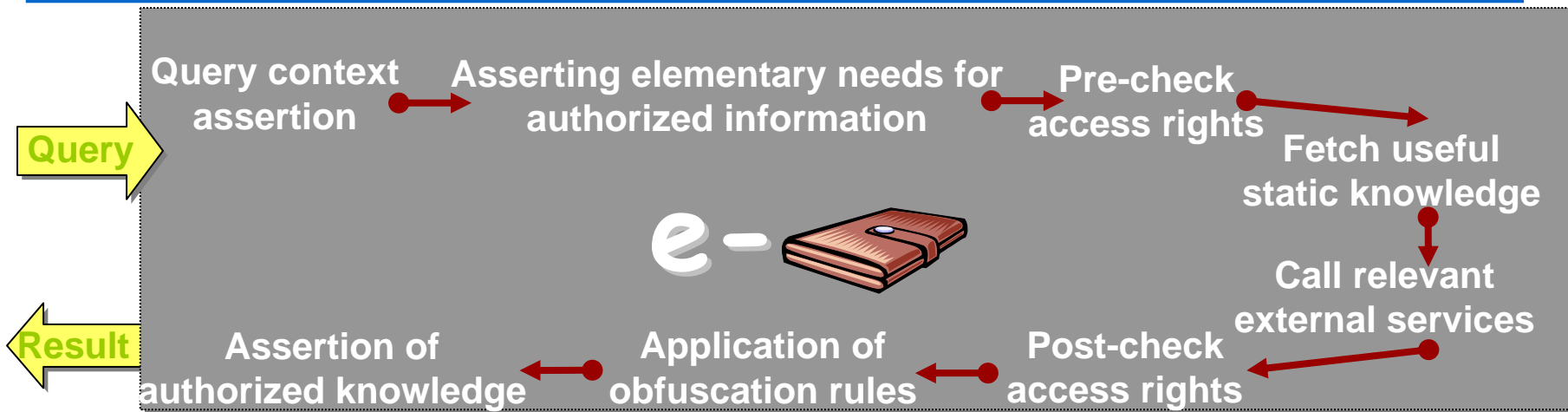


- *Semantic e-Wallet.*

- Unified front end to a set of resources modeled as services
  - e.g. resources of an individual user or an organization
- Acts as both **clearinghouse and gatekeeper to a user's resources**, which are modeled as web services
  - e.g. individual user or an entire organization
- Relies on:
  - Resource identification rules
  - Security & privacy/confidentiality policies, e.g.:
    - **Access control policies**
      - » “Only my colleagues can access my calendar and only on weekdays”
    - **Obfuscation policies**
      - » “My classmates can only see the building I am in but not the actual room”
- Includes **policies whose enforcement requires accessing external resources (e.g. context-sensitive policies)**
- Also supports **updating & rollback functionality**



## e-Wallet: Sample Scenario



*Example : Query from John inquiring about Mary's location*

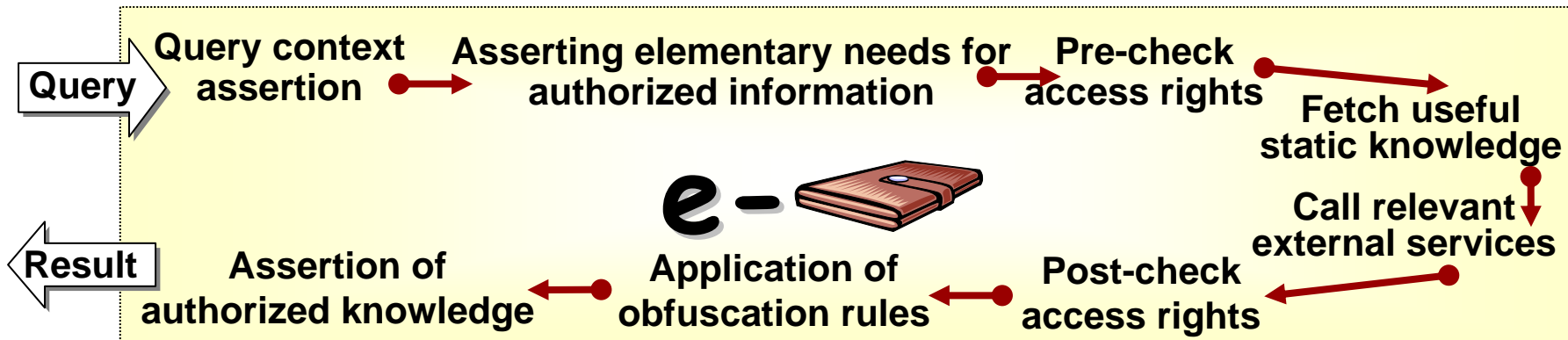
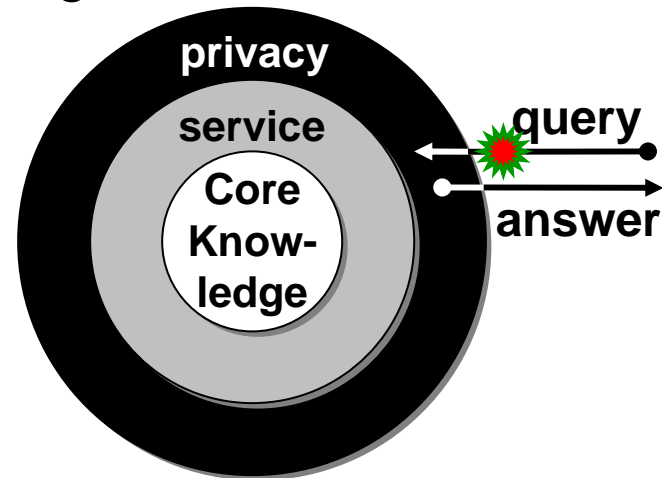
- the sender of the query is John
- John's query requires accessing Mary's location
  1. Is John allowed to see Mary's location given what we know about the context of the query?
  2. Mary said she only allows colleagues to see her location when she is on campus
  3. John is a colleague of Mary
- Access location tracking functionality or Mary's calendar
- Is Mary on campus?
- Mary is willing to disclose the building but not the room she is in
- Mary is in Smith Hall



# SW Environment for Context-Aware Services e-Wallet Implementation - I



- Three-layer architecture: *security through typing*
  - Core knowledge: static & dynamic knowledge of user
  - Service Layer: invoke external sources of knowledge: web services and personal resources
  - Privacy layer: enforce privacy rules on external requests: *access control & obfuscation rules*
  - Backward chaining migration: privacy rules, service rules, static migration rules

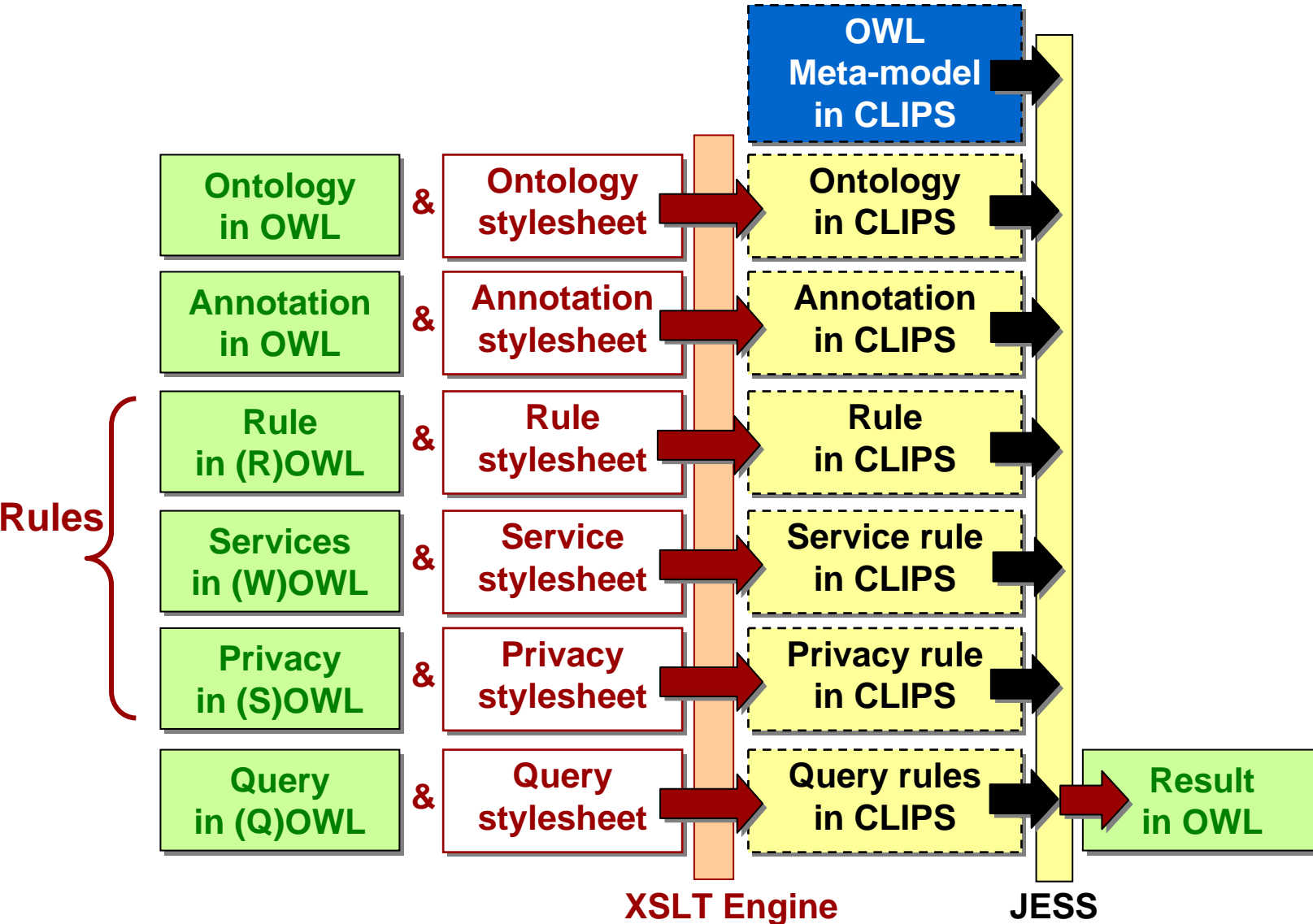






# SW Environment for Context-Aware Services

## e-Wallet Implementation - II





# SW Environment for Context-Aware Services

## Rule Editors



FACTS RULES ONTOLOGY

Decision rule #1 when giving a talk the screen is public

Body (condition): Add a root element

- Person, ?person
  - activity: Talk, ?talk

Head (conclusion): Add a root element

- Person, ?person
  - has\_screen: PublicScreen, aPublicScreen
  - availability: LowAvailability,

Mozilla

File Edit View Go Bookmarks Tools Window Help

http://localhost:8080/my Campus/interface?action=S

Home Bookmarks Yahoo Google AltaVista Home CMU CiteSeer Sophia Home

Info e-Wallet Services Exit

(back to list of services)

Name: people can only know whether I ar

Targeted knowledge:

- Person, ?owner
  - location: ?location

Restricting conditions:

- Place, http://www.cmu.edu
  - include: ?location
- EWallet, ?ewallet
  - sender  Variable  Reference /  Instance of Person
    - ID: owner OK
- not Query, ?query
  - sender: ?owner

Obfuscation:

- Person, ?owner
  - location: http://www.cmu.edu

Activity  
City  
CurrentTime  
EWallet  
Group  
Query  
LegalEntity  
Man  
ManageableEntity  
Person  
Team  
Time  
Woman

Internet Explorer

Name: people can only know I am on campu

Targeted knowledge:

- Person, ?owner
  - location: ?location

Restricting conditions:

- EWallet, ?ewallet
  - owner: Person, ?owner
- Place, http://www.cmu.edu
  - include: ?location

View Tools



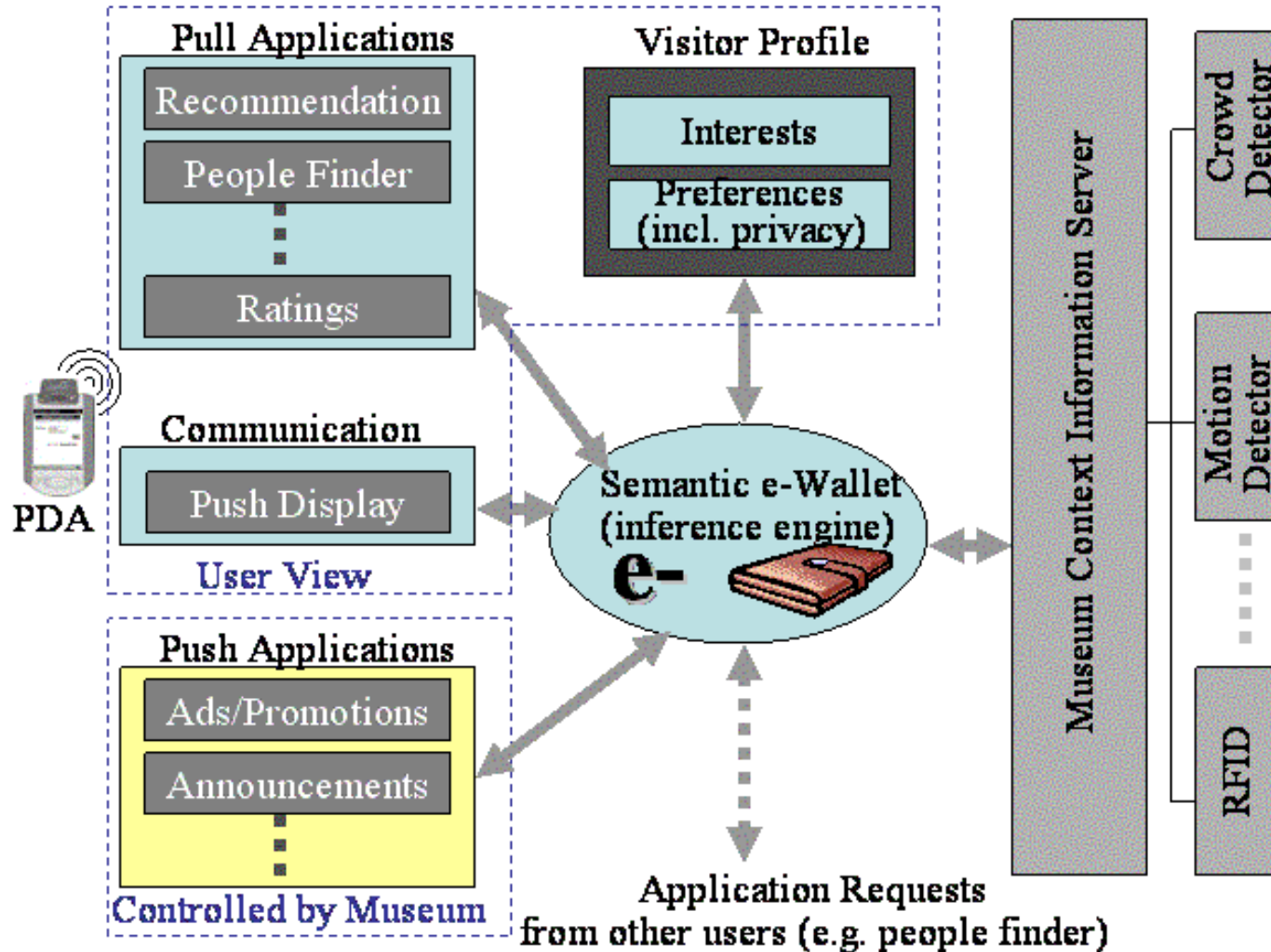
# Sample Context Aware Applications

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- Context-Aware Restaurant Concierge
- Meeting Scheduler with Obfuscation Rules
- People Finder with Privacy Preferences
- Location-Sensitive Services
  - Movies, weather, etc.
- Context-Aware Message Filtering and Delivery
- Remote slide viewing with access control rules
- P2P context-aware poster application
- Context-Aware reminder application
- etc.

Domain Ontologies (e.g. exhibits, tours, visitors, locations, preferences)





# SW Environment for Context-Aware Services

## Technical Progress



- **What technical problems were there and when/how did you overcome them?**
  - Limitations of OWL
    - Rules: **ROWL** and contribution to SWRL discussions
    - Services: Contribution to SWSA
      - Security and Privacy
    - **Semantic e-Wallet** reasoning engine – **enforcing context-sensitive policies** that require accessing external services
  - Usability
    - **Editing tools** to specify context-sensitive policies
- **Measures of Success**
  - myCampus:
    - Anecdotal evidence that MyCampus environment **significantly reduces the time it takes to develop new context-aware applications – built a dozen applications**
    - User testing – several days at a time/10-20 users
  - **Semantic Web technologies are increasingly viewed as central to:**
    - Pervasive computing, e.g. Wireless World Research Forum
    - Privacy & Security policies, e.g. JRC P3P prototype
    - Future enterprise architectures – different companies we are talking to
  - **Dozens of downloads of ROWL**
  - **Context-aware museum tour guide pilot** seems promising
  - **18 peer-reviewed publications + “best selling” book on Mobile Commerce**
- **Did you meet your original or revised programmatic goals?**
  - Absolutely



# SW Environment for Context-Aware Services Milestones and Accomplishments



## 2002

- **Semantic Web Demonstrator for mobile, context-aware services – MyCampus**
  - Ontologies & initial set of context-aware applications
- Contribution to **Semantic Operational Net Assessment (SONAT)** demonstration – context-aware message delivery functionality

## 2003

- **ROWL: Rule extension of OWL**
- **Semantic e-Wallet**
  - Service invocation rules
  - Privacy/confidentiality rules
    - Access control policies
    - Obfuscation policies
  - Multi-layer reasoning engine for automated service identification and access and for enforcing privacy policies – incl. Context-sensitive policies
  - Support for updates & rollbacks
- Evaluation on CMU's campus
  - A dozen context-aware applications & associated ontologies
- Public release of OWL Semantic Web Engine
- Context-Aware message delivery functionality used in support of Coalition Search and Rescue – Task Support (**CoSAR-TS**) - demonstrator developed by AIAI, West Florida, BBN and Sparwar

## 2004

- **Public release of ROWL and associated reasoning engine**
- **Standalone e-Wallet tool**
- Contributions to **SWSA** discussions and **rule discussion group**
- **Integration of eWallet and planning functionality**
- Ongoing work with several end-user organizations
  - e.g. **Context-aware museum tour guide for national science museum**



# SW Environment for Context-Aware Services

## Transition/Handoff



- **Tools & software released:**
  - OWL Semantic Web Reasoning Engine
  - ROWL – Rule Extension of OWL, incl. reasoning engine
  - Semantic e-Wallet (upcoming)
- **Influence on specs**
  - Contributions to SWSA and rule group discussions
- **Publications:** 18 peer-reviewed publications & Mobile Commerce book
- Numerous tutorials, keynotes, panels as well as courses
- **DoD Contributions:** context-aware message filtering application used in SONAT and CoSAR-TS demos
- **Additional impact:**
  - Context-aware office scenario for the Institute for Information Industry (III)
  - **Context-aware museum tour guide** – pilot in largest natural science museum in Taiwan (nearly 3M visitors/year)
  - Ongoing negotiations with other prospective end-user organizations
  - Member of Joint Committee
  - DERI advisory board
  - 2004 IBM Best Privacy Faculty Award



# SW Environment for Context-Aware Services

## Remaining Issues



Issue	Remediation
SemWebCentral	-OWL Engine & ROWL: later this month -eWallet: early 2005





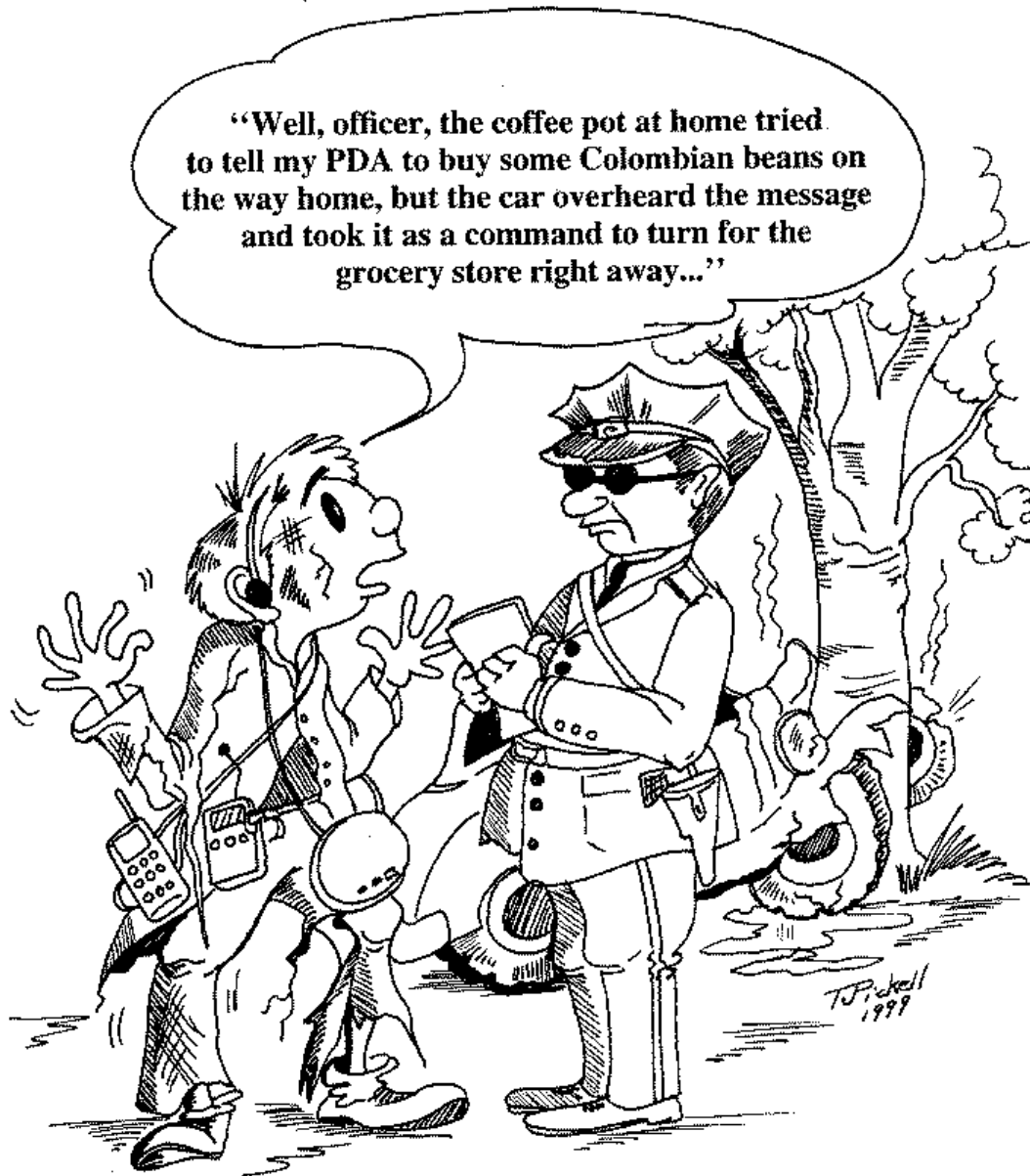
# SW Environment for Context-Aware Services

## Summary

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- Demonstrated the **relevance** of the Semantic Web to mobile and pervasive computing
- Developed and published tools
  - OWL Engine
  - ROWL – Rules in OWL
  - Semantic e-Wallet
    - Privacy & Service identification rules
    - Context-sensitive policies
- Contributed to discussions within:
  - Rules working group
  - SWSA
- Contributed to DoD-relevant demos: **SONAT** and **CoSAR-TS**
- **Continuing to work with several end-user organizations**
  - Mobile & Pervasive Computing
  - Intra- and inter-enterprise solutions



*...Why we need the Semantic Web...*