Lakehead UNIVERSITY

Semantic Web-based Mobile Knowledge Management

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2.1 What does Semantic Web bring to Mobile KM?
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3. How it all fits together?
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4. Conclusions

Part 1

Motivation

Problems
Research Challenges
Goals & Vision

Limitations of Current Knowledge Management Systems

- Users are overwhelmed with information:
    - From Web Search Engines, Social Media, emails, external newslines, DMSs,…
    - But may still lack the information they require
- Users need information:
    - – Filtered by semantics, not just keywords
    - – Tailored to their interests and their task context
    - – In a form appropriate to their current physical context and working environment (mobility)
    - – Aggregated from heterogeneous data sources

Limitations of Current Web Technologies
Journey from Syntactic Web to Semantic Web

- Syntactic Web
    - Computers do the presentation (easy part)
    - People do the linking and interpreting (hard part)
- Semantic Web
    - Machines do the hard part (automatic linking and interpreting)
        - Multi-source feature extraction and linking (linking is power)
        - Annotation via ontologies and metadata
        - Seamless knowledge access and sharing
        - Proactive knowledge delivery
        - Complex queries involving background knowledge

KM: Need for a Change

	Today	Tomorrow
Technology	Isolated proprietary systems	Integrated services
Data access	Limited, Difficult	Any time, any place
Data integrity	Manual/error prone	Systematic mgt. and control
Data availability	Slow	Real time

Goal: Mobile/Pervasive KM (mKM)

Mobile/Pervasive Computing

- Pervasive Computing is an interoperability nightmare!
  - instead of sometimes connecting a handful of devices, dynamically connect/disconnect/reconnect possibly hundreds of devices
- Today, high cost of ensuring interoperation
  - any interaction has to be specifically designed/engineered
  - heavy emphasis on application-specific standardization
  - <u>spontaneous</u> interoperability is next to impossible
- The vision is largely contingent on getting unanticipated "encounters" of devices to work
  - how do you behave in a situation not covered by a standard?
  - not "future-proof"

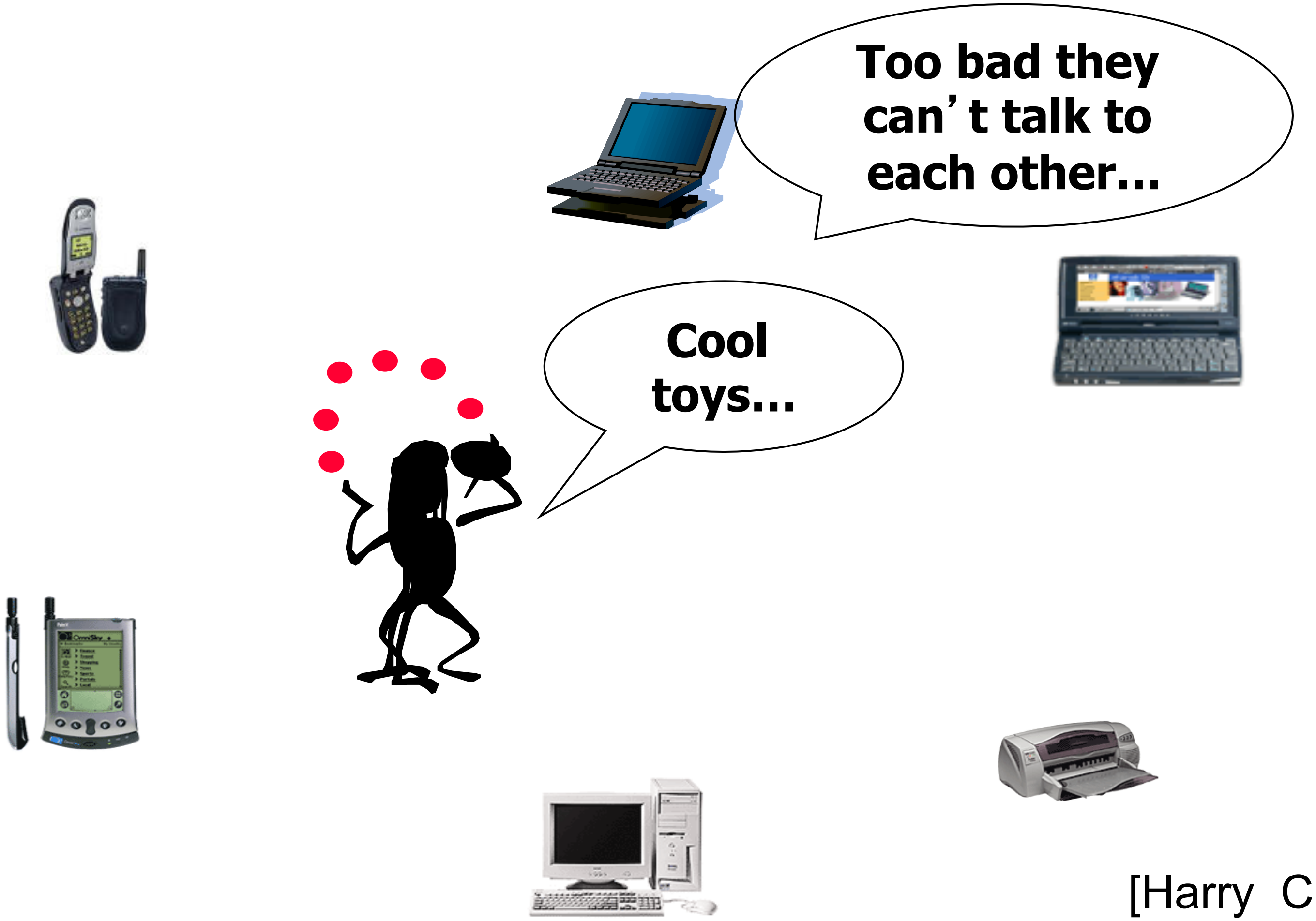
Semantic Web is a good match

It is an "interoperability technology"

Interoperability & Semantic Web

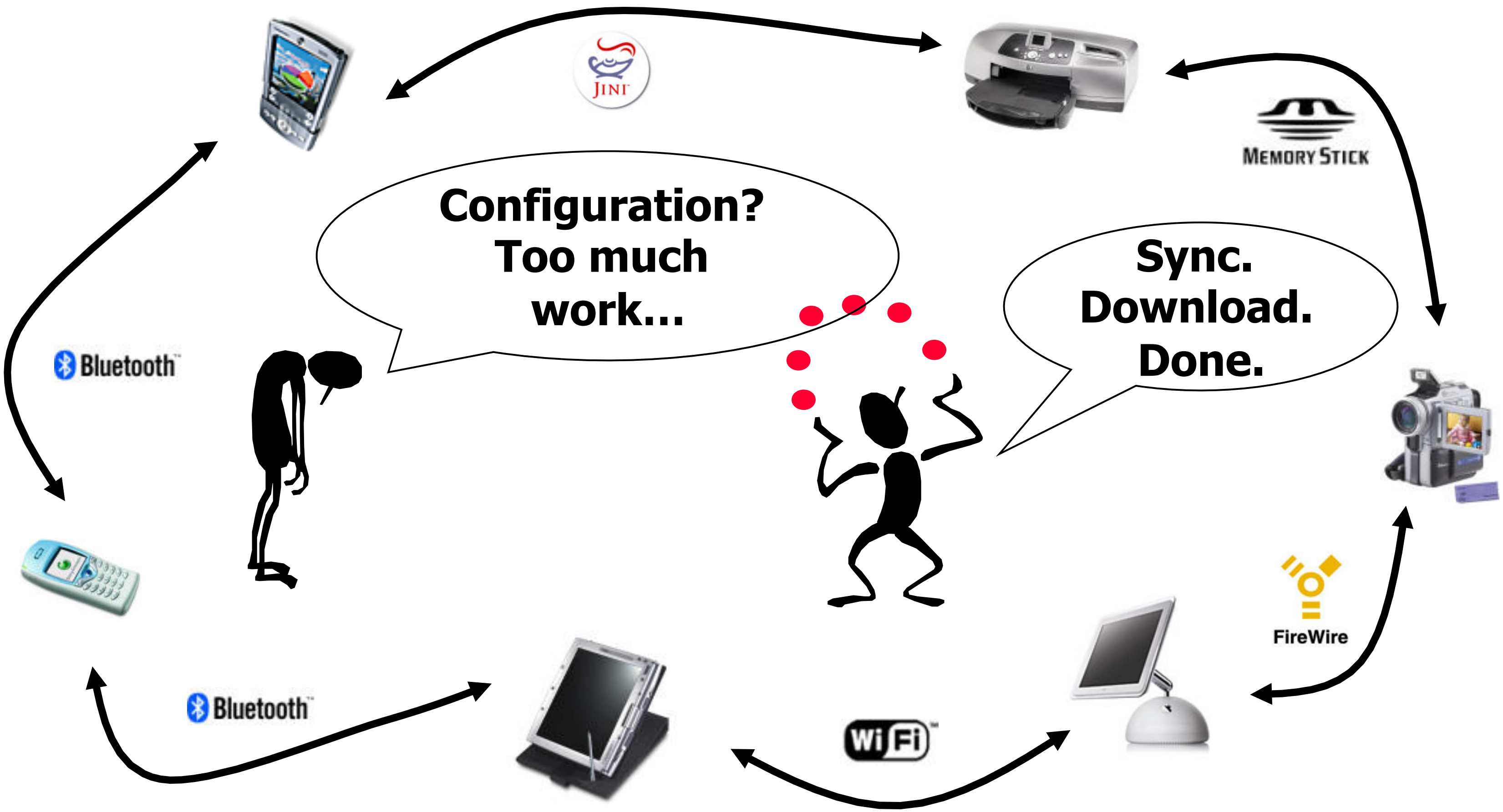
- Semantic Web is an interoperability technology
  - An architecture for interconnected communities and vocabularies
  - A set of interoperable standards for knowledge exchange

Mobile Device Evolution
Yesterday: Gadget Rules



[Harry Chen]

Mobile Device Evolution Today: Communication Rules



[Harry Chen]

Mobile Device Evolution

Tomorrow: Mobile Services Will Rule

[Harry Chen]

Requirements of Mobile Services

Emerging Semantic Web technologies, mobile computing, ubiquitous computing, sensor networks and wireless communication provide new exciting horizons for building smart scalable mobiles services tailored to their users' needs

- Semantic markup and reasoning
  - Web resources from different sources can be linked to commonly agreed ontologies
  - Powerful semantic querying to retrieve required information
  - Open standards for resource sharing and reuse
- Service orientation
  - Most new corporate/ business tasks are conceived as support services
  - Complex tasks are enabled by composing services
- Context-awareness (user/task centric)
  - Ability to recognize user's current context (activity, location, device, environment)

Ingredients

– Well annotated Web resources: Content as a commodity

– Standards that define and support Content re-use

– Semantic Web Tools

✓ *Computational Semantic Web*

- Web-Services based tools: to build seamless search engines
- Digital Repositories: aim to encourage finding, sharing, and repurposing content

✓ *Cognitive Semantic Web*

- Ontologies: to model any domain knowledge
- Agents & Reasoning tools: to manipulate knowledge

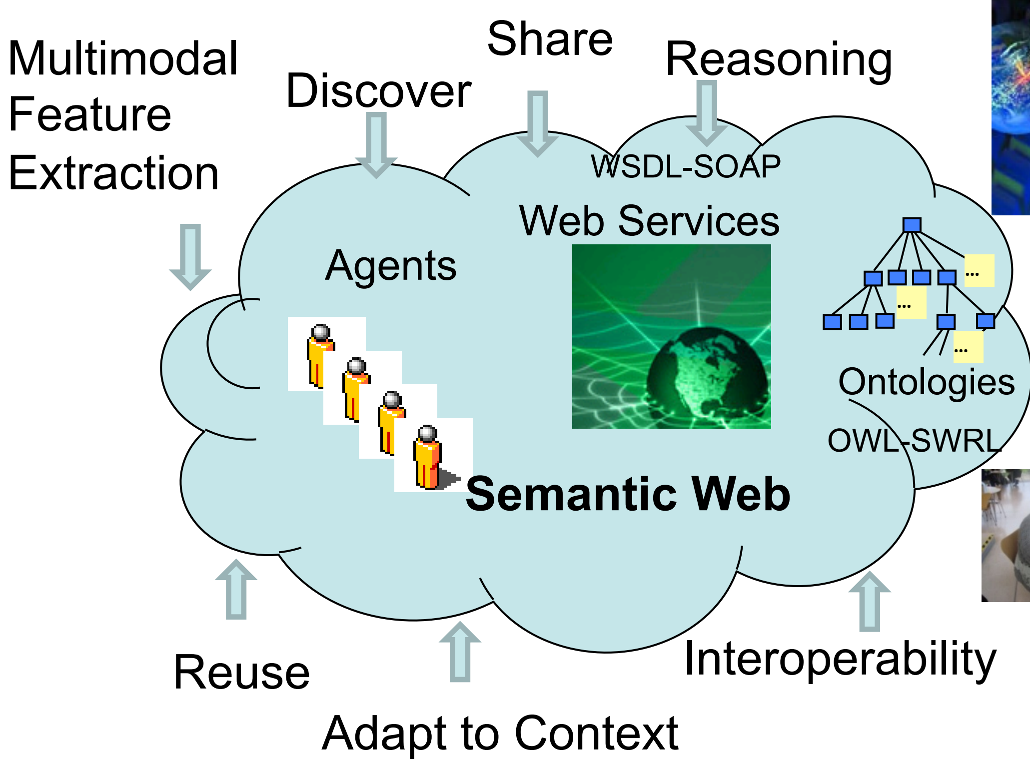
Vision: Semantically Rich mKM

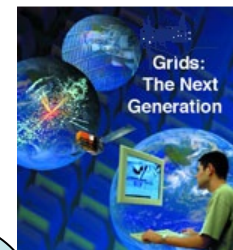
- Information filtering
- Automated decision support
- Semantic driven UI
- Remote data capture & analysis
- Evidence based processing
- Common vocabulary (shared Terminology)
- Feature extraction from unstructured or massive information (images, free text, ...)
- Data/Process Interoperability
- Workflow optimization
- Intelligent portals
- Context-aware processing

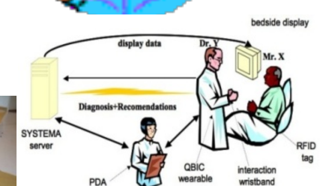
Vision: Semantically Rich mKM

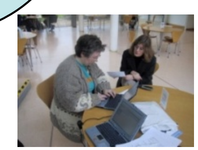
Confluence of enabling technologies: Web Agents, Ubiquitous Computing, Ontologies, Web Services, and Open Standards

Scalable Service Oriented Systems









Research Challenges

- **Resource Adaptation and Interoperability** *(Semantic Web)*
  - Unify data representation for heterogeneous environment
  - Provide basis for communication

- **Resource Proactivity and Mobility** *(Agent Technology)*
  - Design of framework for delivering self-maintained resources for various contexts

- **Resource Interaction** *(Peer-to-Peer, Web Services, grid, cloud computing)*
  - Design of goal-driven co-operating resources
  - Resource-to-Resource communication models in distributed environment
  - Design of communication infrastructure

Research Challenges

- **Scaling Semantic Web stores to database sizes**

- **Information extraction and semantics** *("Web 3.0/ Web 4.0")*
  - can we "retrofit" semantics on the existing Web?

- **Semantic Web information creation**
  - can we avoid retrofitting in the future?
    - tools that help embed the semantics as a resource is created
    - better dynamic integration of structured data into the Semantic Web
  - "Semantic Desktop"

- **Complex localization systems** *(Wireless Communications)*

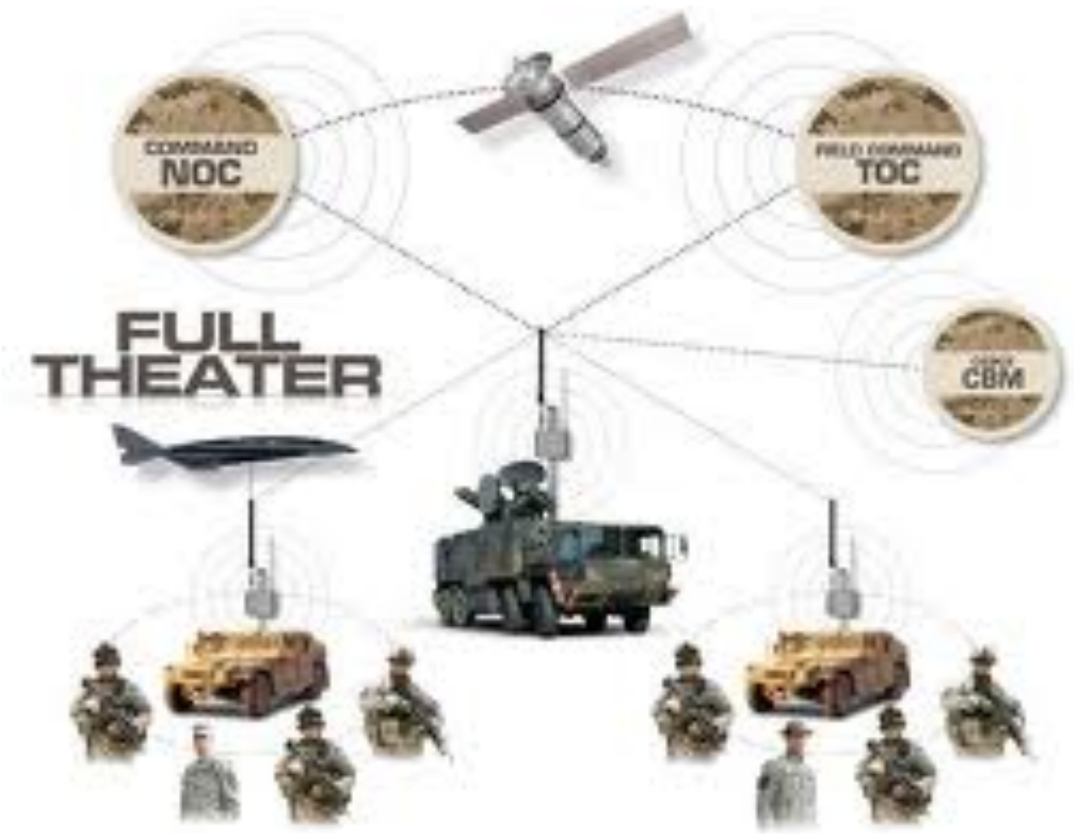
- **Privacy & Security** *(Network Security and Cryptography)*

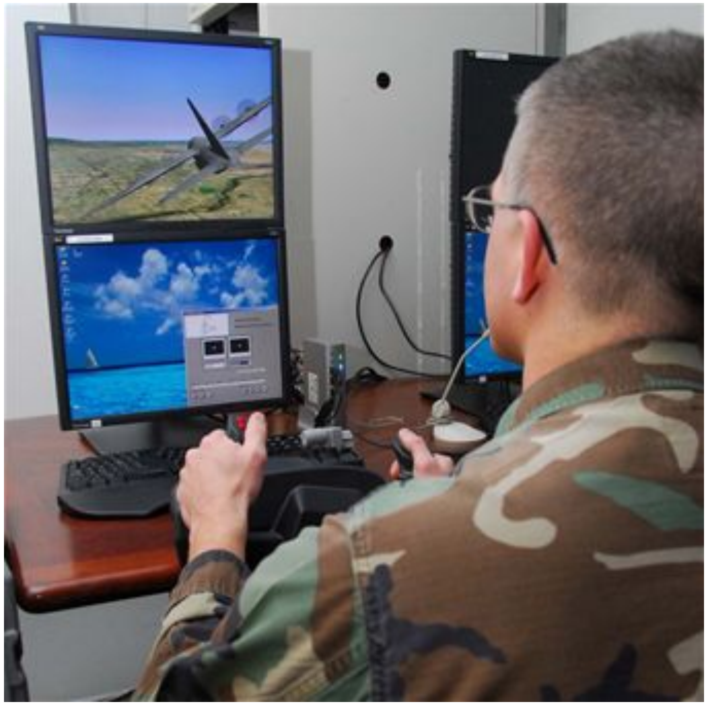
Methodology “General Approach”

- To deliver next generation Mobile Semantic Knowledge technology through:
  - Foundational Research
    - Semi automatic ontology generation and population
      - Natural Language Technology access tools
    - Ontology Mgt (mediation, evolution, inference)
  - Innovative Technology Development
    - A suite of knowledge access tools
    - Open source ontology middleware platform
  - Validated by cases studies/benchmarking/usability activities
  - Supported by a methodology

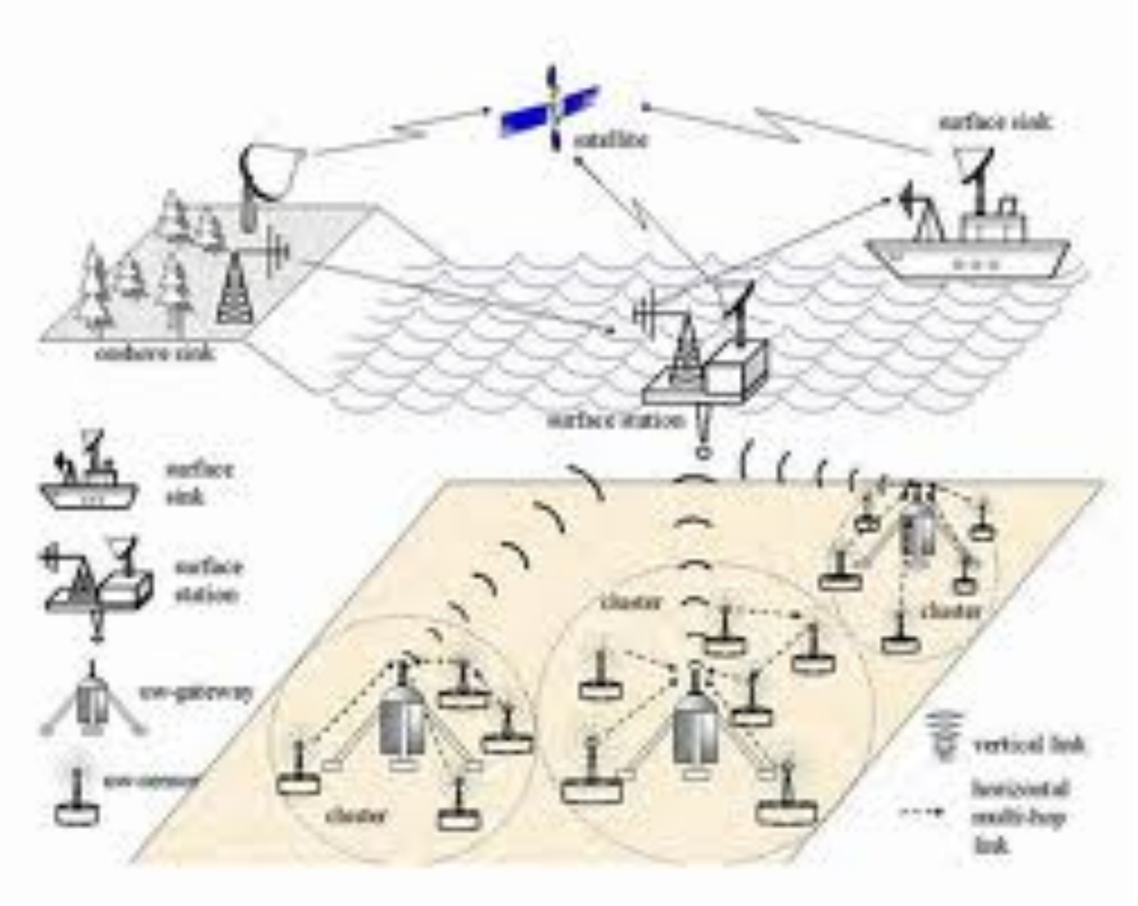
Example of Military Applications

Remote-monitoring and coordination





Under-Water Sensor Networks



Traffic Flow Mgt Using Sensor Networks

Part 2

What does Semantic Web bring to mKM?

Semantic Markup (XML,RDF, RDF-S, OWL, OWL-S)

Rule Markup Languages (Rule-ML and SWRL)

Web Services

Web Agents

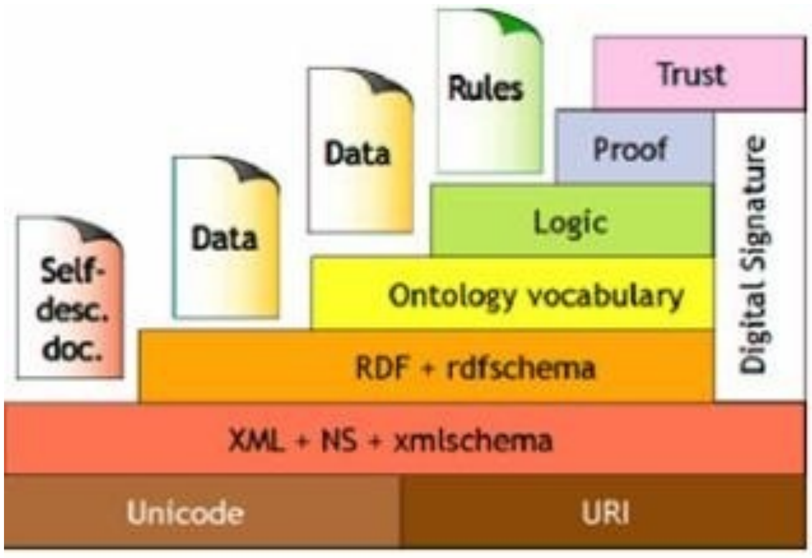
Context-Awareness

Semantic Web - Definition

The **Semantic Web** is an extension of the current web in which information is given well-defined **meaning**, better enabling computers and people to **work in co-operation**.

[Berners-Lee et al., 2001]

Semantic Web Layers (T. Berners-Lee et al.)



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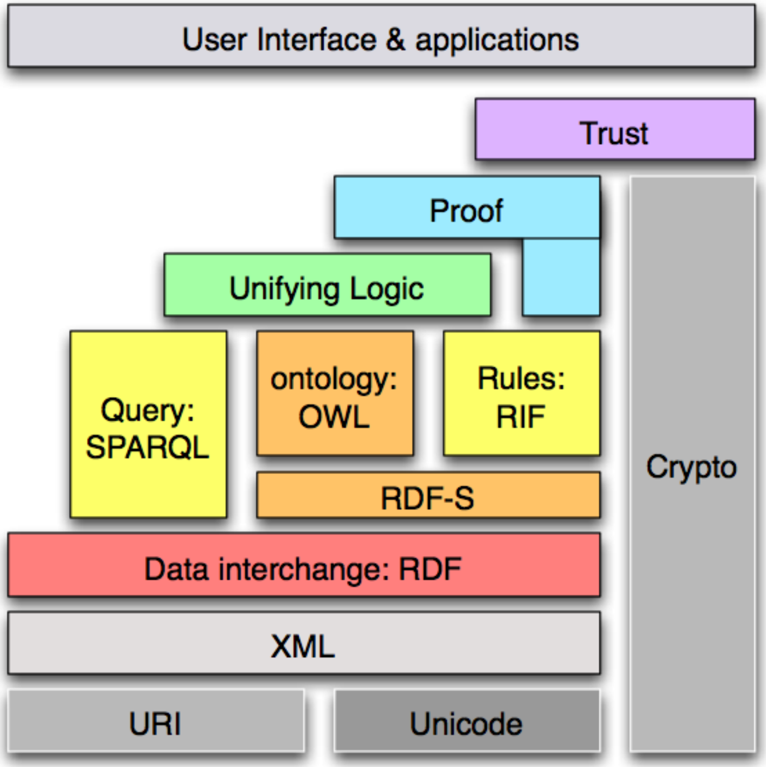


2006

Semantic Web Tools XML, RDF, OWL, SWRL…

- XML: syntax for structured documents, but no semantic restrictions
- XML Schema: language for restricting the structure of XML
- RDF: data model for describing resources
- RDF Schema: is a vocabulary for describing properties and classes of RDF resources
- OWL: adds more vocabulary for describing properties and classes
- OWL-S : Ontology Web Language for Services
- SWRL: for reasoning with Ontologies

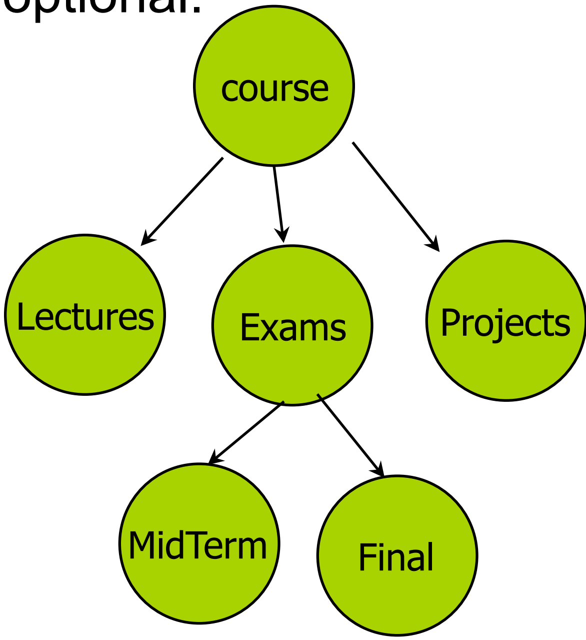
Semantic Web Tools
RIF, SPARQL, GRDDL/RDF…

- RIF: Rules Interchange Format
  - representing rules on the Web
  - linking rule-based systems together
- SPARQL: Query language for (distributed) triple stores
  - the "SQL of the Semantic Web"
- GRDDL/RDFa: Integration of HTML and Semantic Web
  - "embedding" RDF-based annotation on traditional Web pages
- And more…
  - multimedia annotation, Web-page metadata annotation, Health Care and Life Sciences (LSID), privacy, etc.

Exchangeable Metadata in XML

- XML documents are labeled trees
- Storage is done just like an n-ary tree (DOM)
- Tree element = label + Attribute/Value + content
- Document Type definition (DTD): Simple grammar (regular expressions) to describe legal trees (XML-Schema)
- It says what elements and attributes are required or optional.

```
<course Name="...">
      <Lectures>...</Lectures>
      <Exams>
         <MidTerm>...</MidTerm>
         <Final>...</Final>
      </Exams>
      <Projects>...</Projects>
</course>
```



Role of Metadata

- SW-techniques allow you to add metadata to distributed resources just like html allows you to link to such resources.

- Metadata allows to:
  - Annotate
  - Find
  - Select
  - Retrieve
  - combine
  - use/re-use, and
  - share

  resources on the Web

- Metadata is not bound to a fixed schema. You may invent a description format of your own and add personal annotation

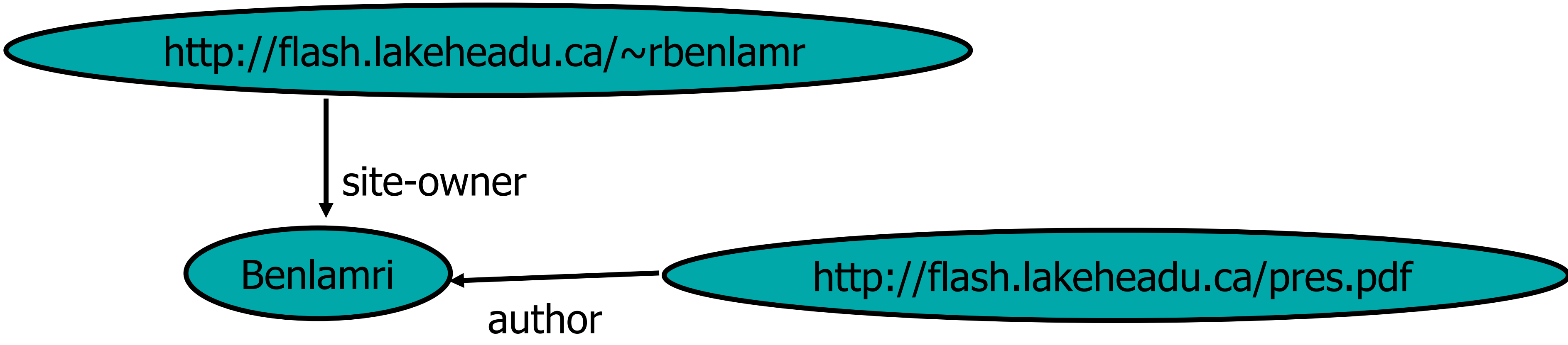
Sample of Metadata in m-Learning

- The display type of a device
- The topic of a of a lecture
- The size of a learning resource
- The author of a learning resource
- The operating system to execute a program

Resource Description Framework (RDF) for Semantic Markup

- RDF provides metadata about Web resources
- Basic building block:

  Subject -> Predicate -> Object triples
  - **subject** is the focus of the statement
  - **predicate** describes a **property** of the subject
  - property value is the **object**.
- So, RDF keeps meta-data external to objects
- It has an **XML syntax**
- Chained triples form a **graph (semantic net)**

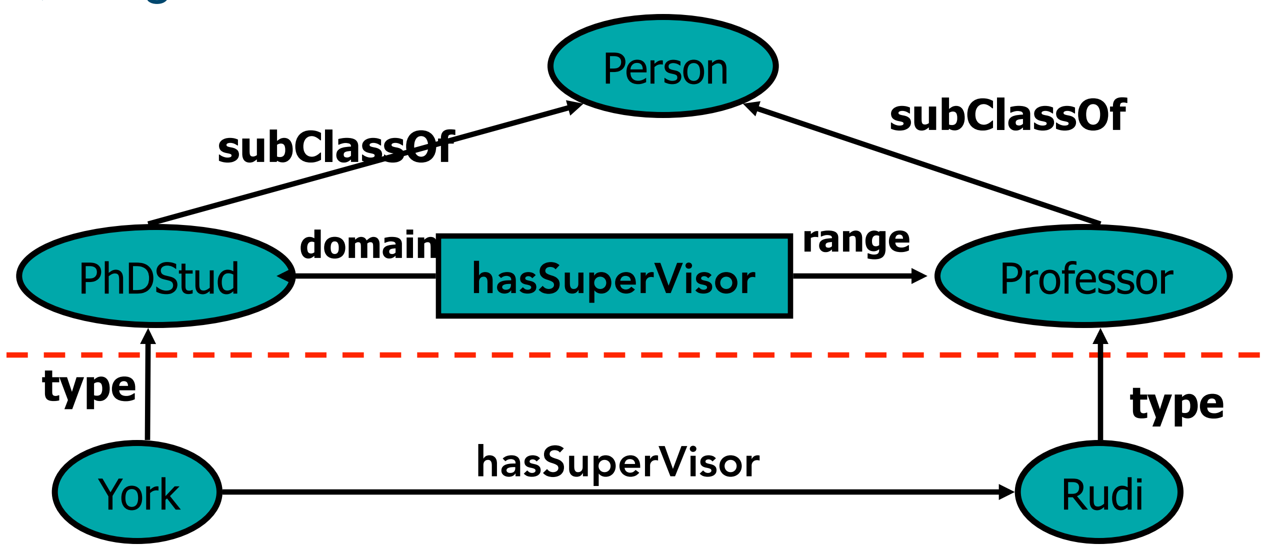


RDF's Resources

- Every resource has a URI, a Universal Resource Identifier
- A URI can be
  - a URL or
  - unique identifier
- We can think of a resource as an object, a "thing". So, RDF URI's can refer to *anything* and not just digital resources (e.g. lecturer, author, student, device, etc.)
- So, RDF, is extendable and doesn't require rigid meta-data structures or proprietary standards or fixed vocabularies

What does RDF Schema add?

- Defines **vocabulary** for RDF
- Organizes this vocabulary in a **typed hierarchy**
  - Class, subClassOf, type
  - Property, subPropertyOf
  - domain, range



[Steffen Staab 2006]

Ontology

Ontology in Philosophy

Ontology is a branch of philosophy that deals with the nature and the organization of reality

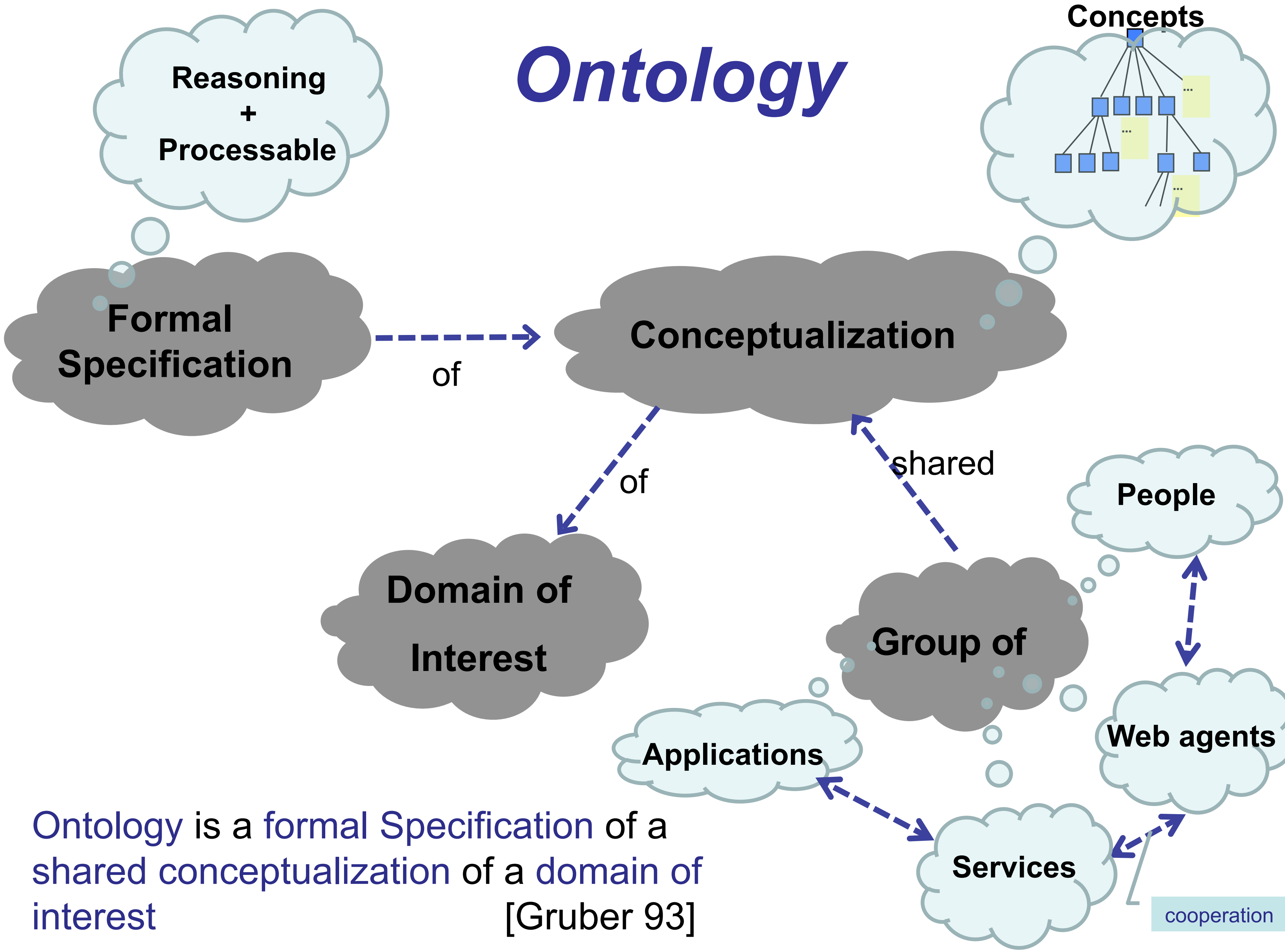
Ontology deals with questions such as:

What characterizes being?
Eventually, what is being?

“ People can‘t **share knowledge** if they do not speak a **common language**.“

[Davenport & Prusak, 1998]

Ontology



Ontology is a formal Specification of a shared conceptualization of a domain of interest [Gruber 93]

Why do we need Ontologies?

- To define web resources precisely and make them more amenable to machine processing
  - To make domain assumptions explicit
  - Easier to understand and update legacy data
- To separate domain knowledge from operational knowledge
  - Reuse domain and operational knowledge separately
- A community reference for applications

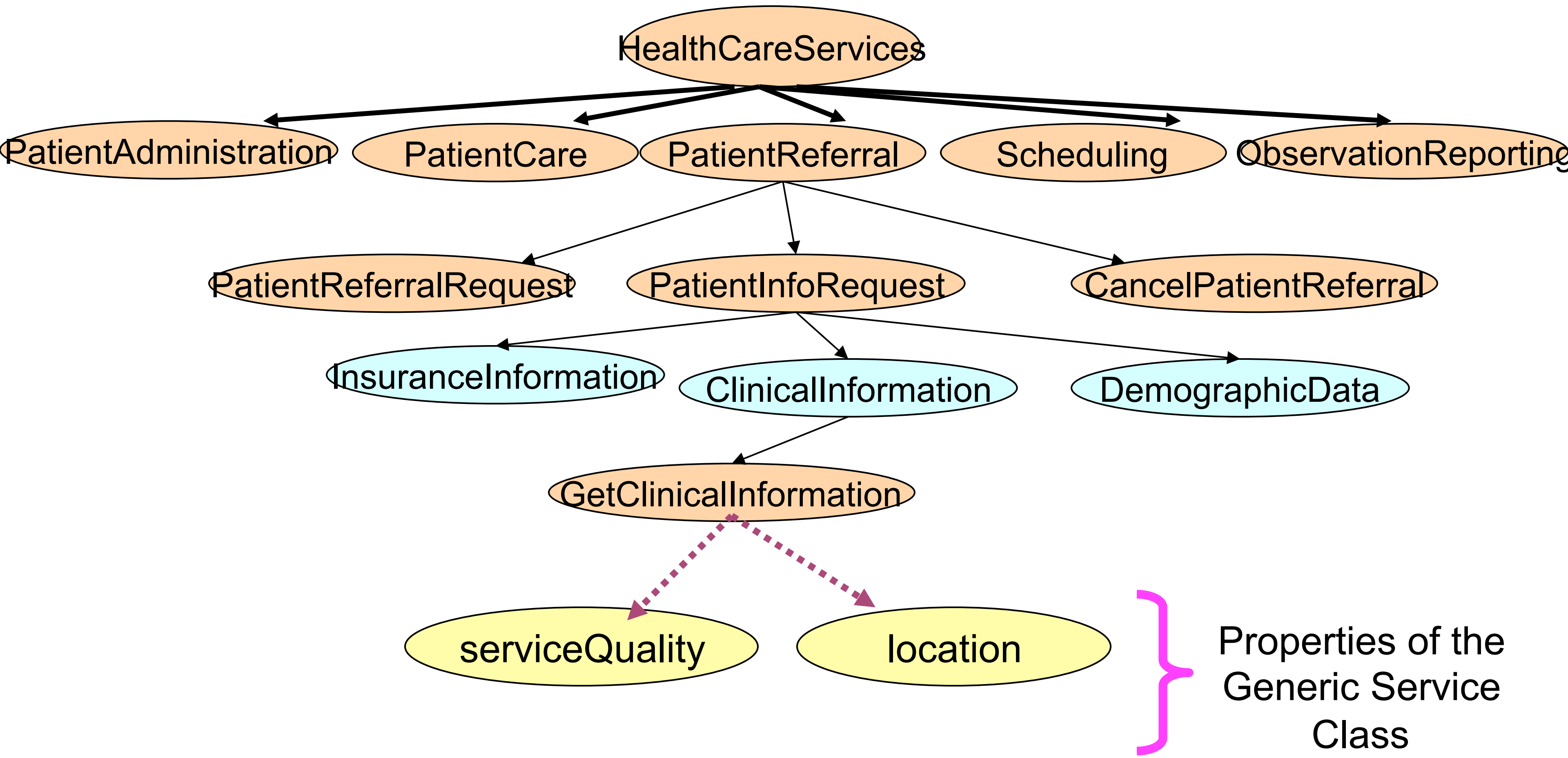
Why do we need Ontologies?

- **To handle legacy knowledge**
  - Automating metadata extraction
    - Using DSL & NLP tools
    - Significant research & technology challenges are outstanding
  - Semi-automatic generation of ontologies
    - Using knowledge discovery
  - Semi-automatic maintenance and evolution of ontologies
    - Building Upper ontologies (ontology matching, alignment & merging)
  - Needs a Multi-disciplinary approach
  - Need to determine appropriate technology mix

Separating Operational from Domain Knowledge

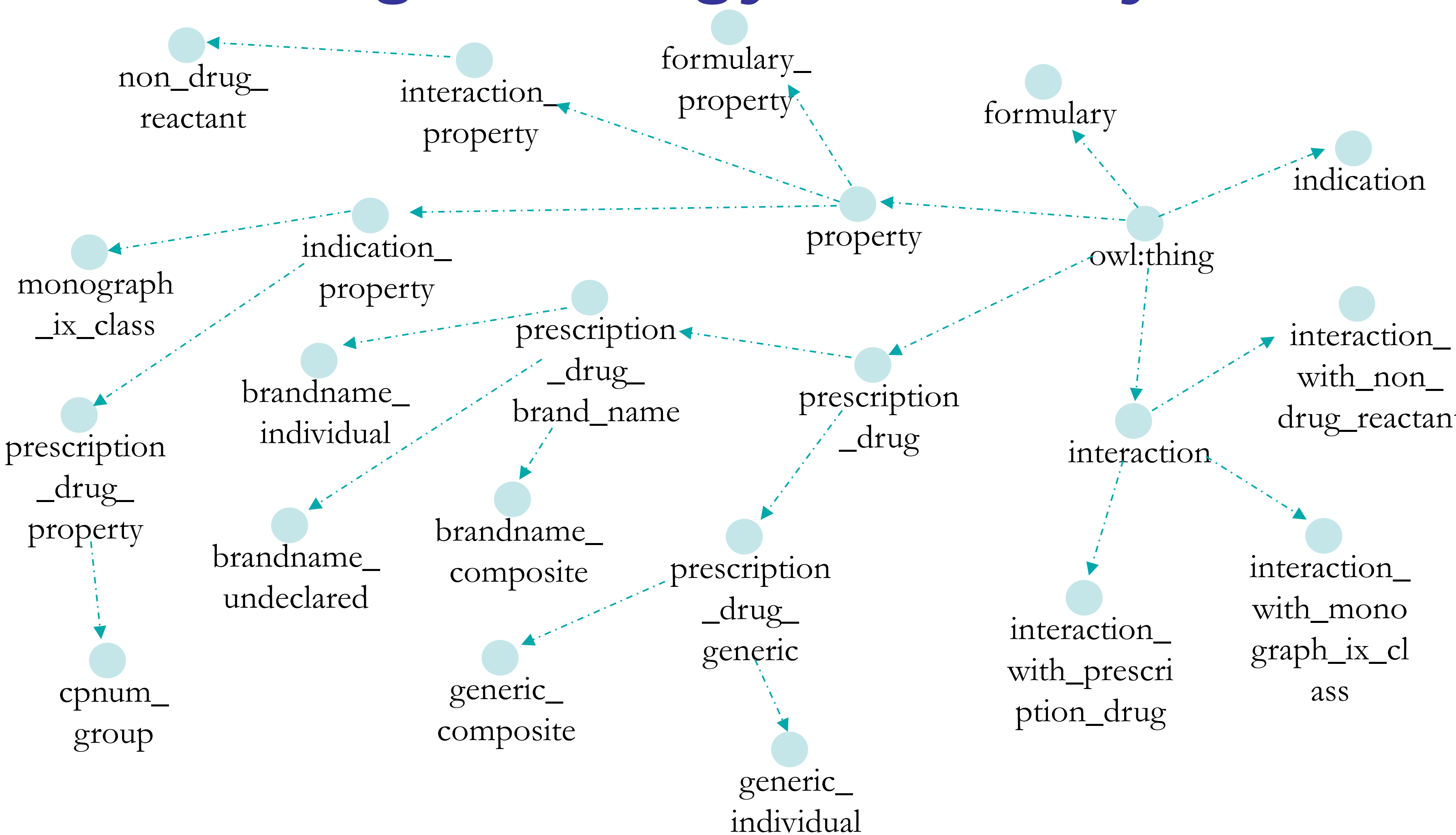
- In H.C. we distinguish between two types of knowledge (ontologies):
  - Operational Knowledge
    - Patient ontology
    - Clinical Pathway ontology
    - Service Functionality Ontology
  - Domain Knowledge
    - Pathology
    - Genomic

An Example Service Functionality Ontology



[Asuman Dogac]

An Example of Domain Ontology
Drug Ontology Hierarchy



Web Ontology Language (OWL)

- OWL is a knowledge representation language to model ontologies so that we can reason about their embedded knowledge
- OWL is based on formal semantics
- OWL has rich modeling primitives:
  - Classes with data & object properties
  - Inverse and equivalence properties
  - Property and cardinality restrictions
  - Boolean combinations
  - Enumerations, etc…

[G. Antoniou & F.Harmelen]

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[G. Antoniou & F.Harmelen]

Web Ontology Language (OWL)

- Semantics is a prerequisite for reasoning support
- Semantics and reasoning support are usually provided by
  - mapping an ontology language to a known logical formalism
  - using automated reasoners that already exist for those formalisms

- OWL is (partially) mapped on a description logic, and makes use of reasoners
- Description logics are a subset of predicate logic for which efficient reasoning support is possible

Reasons Why OWL Matters

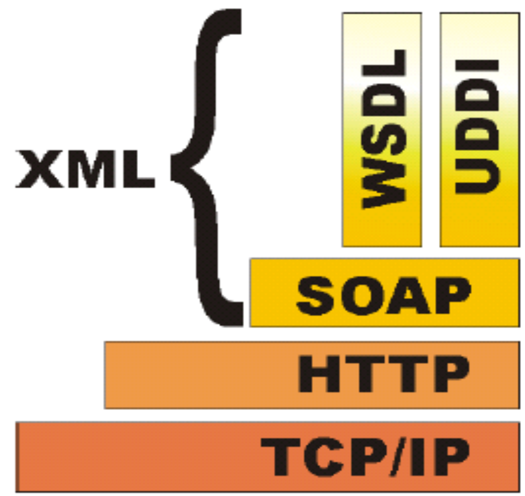
- OWL semantics are model-driven
- OWL semantics are machine-actionable
- OWL semantics are more expressive
- OWL semantics are more precise

Web Services – Contribution of Semantic Web Technology

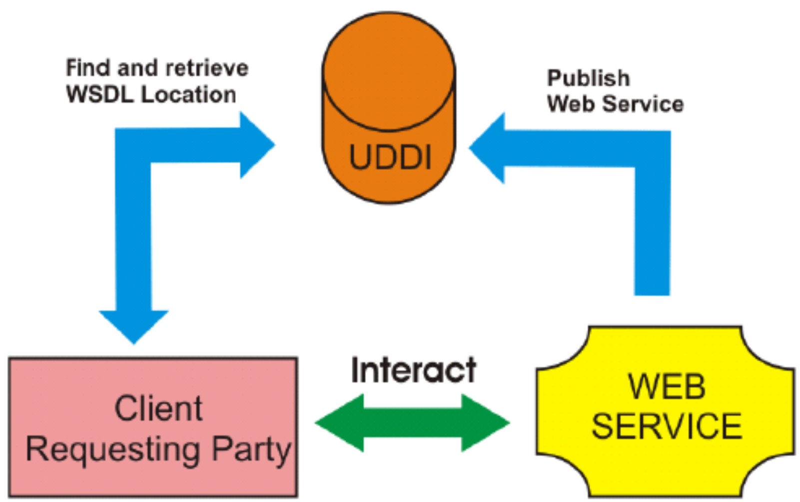
- Web Service: service based, aiming to provide interoperability among distributed loosely coupled components
- Use machine-interpretable descriptions of services to automate:
  - discovery, invocation, composition and monitoring of Web Services
- Share web services across applications (e.g. use of Web Service Description Language - WSDL)
- Web agents can compose simple web services into complex web services

Web Services

- Application to Application
- For Web Services to work, everyone has to agree on a communication mythology, including identifying, accessing, and involving services.
  - SOAP (Simple Object Access Protocol)
  - WSDL (Web Service Definition Language)
  - UDDI (Universal Description, Discovery and Integration)



WSDL and UDDI documents are passed using SOAP over HTTP

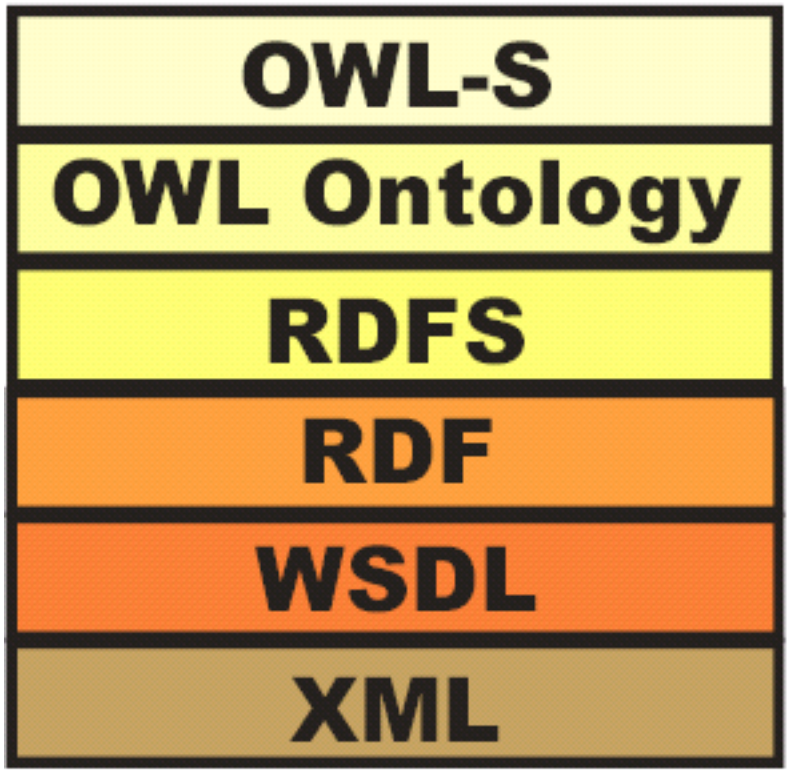


Discovery and invocation of a web service

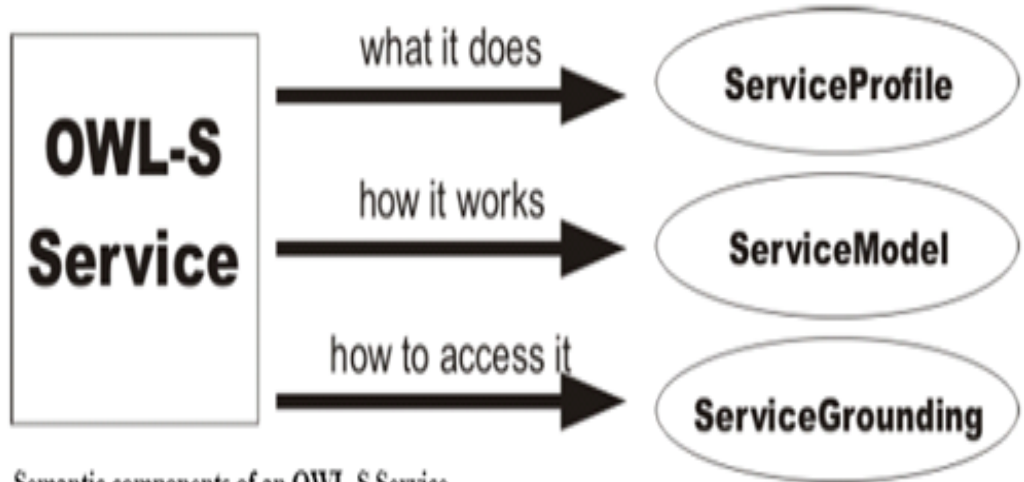
Web Service Composition Approaches

- Industry solution
  - **ebXML (Electronic Business using eXtensible Markup Language)**
  - **BPML (Business Process Modeling Language)**
  - **WSCI (Web Service Choreography Interface)**
  - **WSCL (Web Services Conversation Language)**
  - **BPEL4WS (Business Process Execution Language for Web Services)**
  - **WSFL (Web Services Flow Language)**
- Semantic web solution
  - **Petri Nets**
  - **DAML-S (DARPA agent markup language)**
  - **OWL-S** (Ontology Web Language for Services)

OWL-S & Web Services



Relationships between OWL-S and WSDL



Semantic components of an OWL-S Service

OWL-S enables users and software agents to automatically discover, invoke, compose, and monitor Web resources offering services, under specified constraints.

It helps us to define the pre-conditions and rules that we need to apply to the Web Services being composed

Web Agents – Contribution of Semantic Web Technology

- Information is exchanged between Agents in a Markup language

- Agent negotiation strategies are described in a logical language

- Agents decide about next course of action through inference, based on negotiation strategy and current facts

Part 3

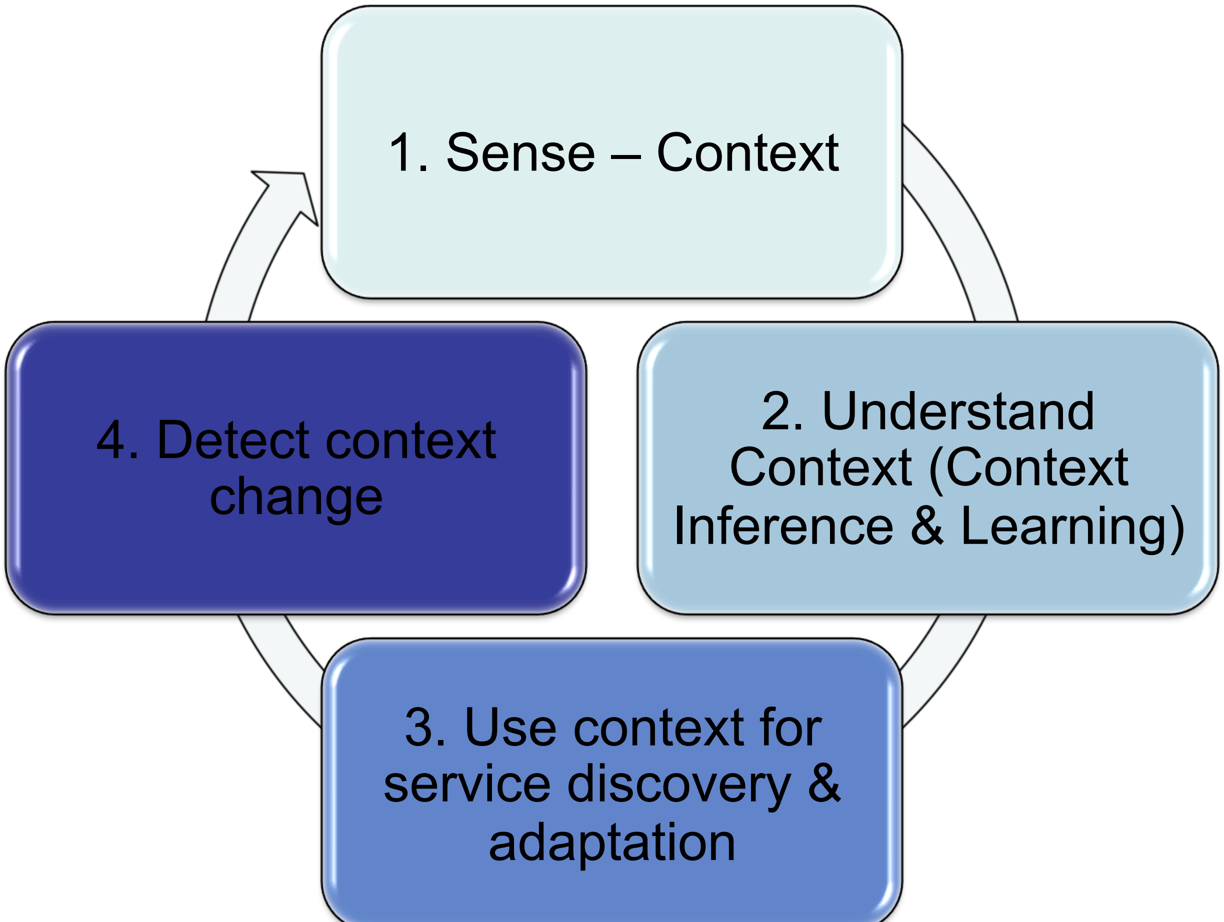
How it all fits together?

Case Study 1

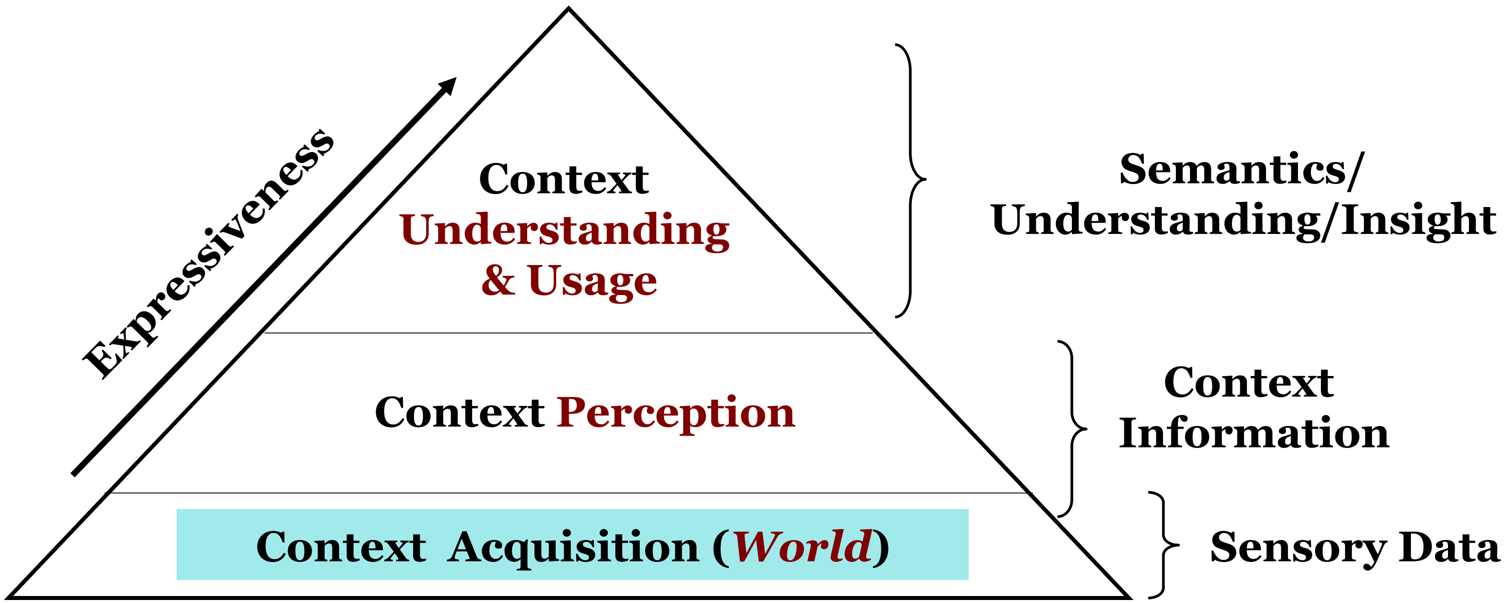
Smart Mobile Learning Spaces on the Semantic Web

Feature Demo

Context Sensing Cycle



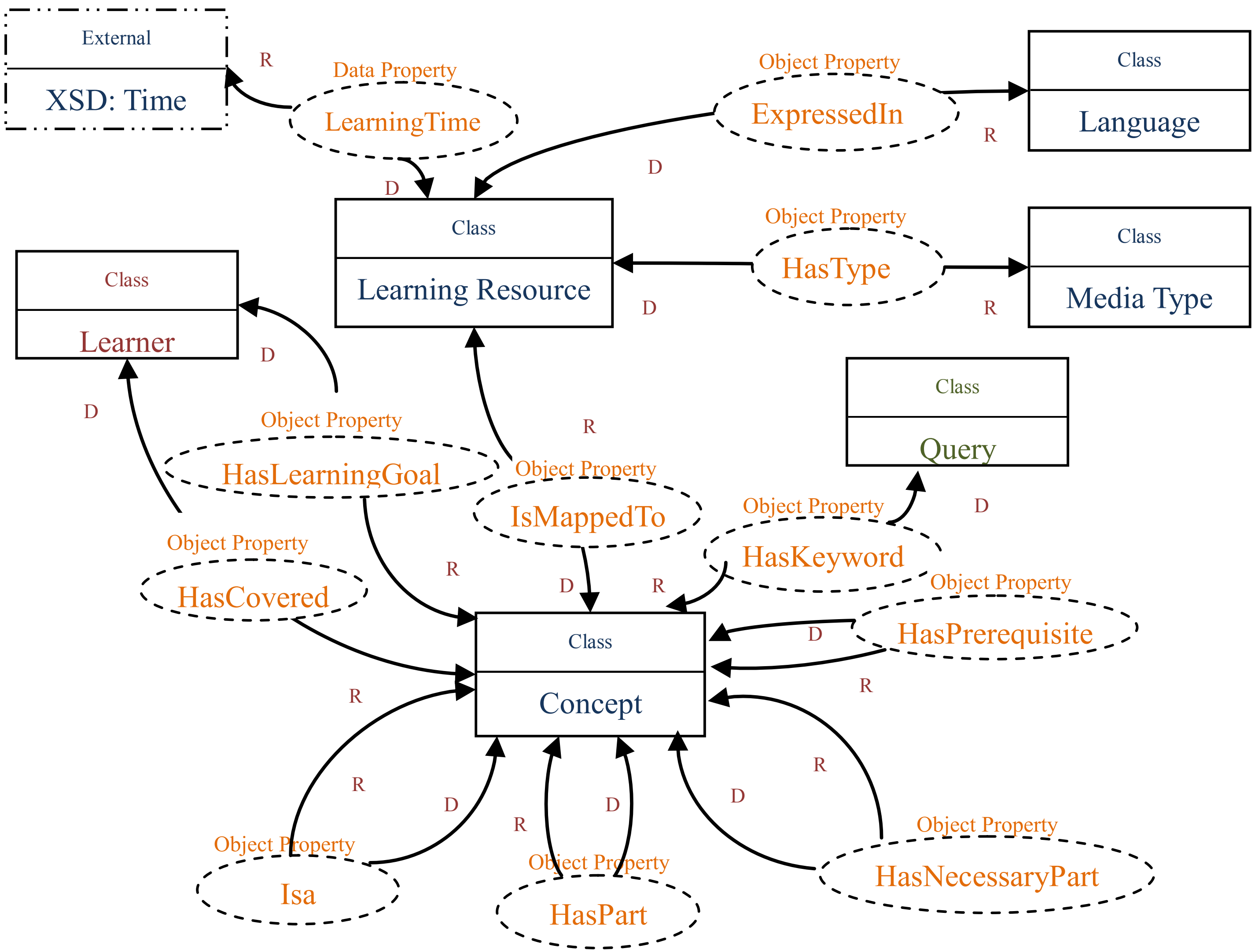
Context Awareness Pyramid



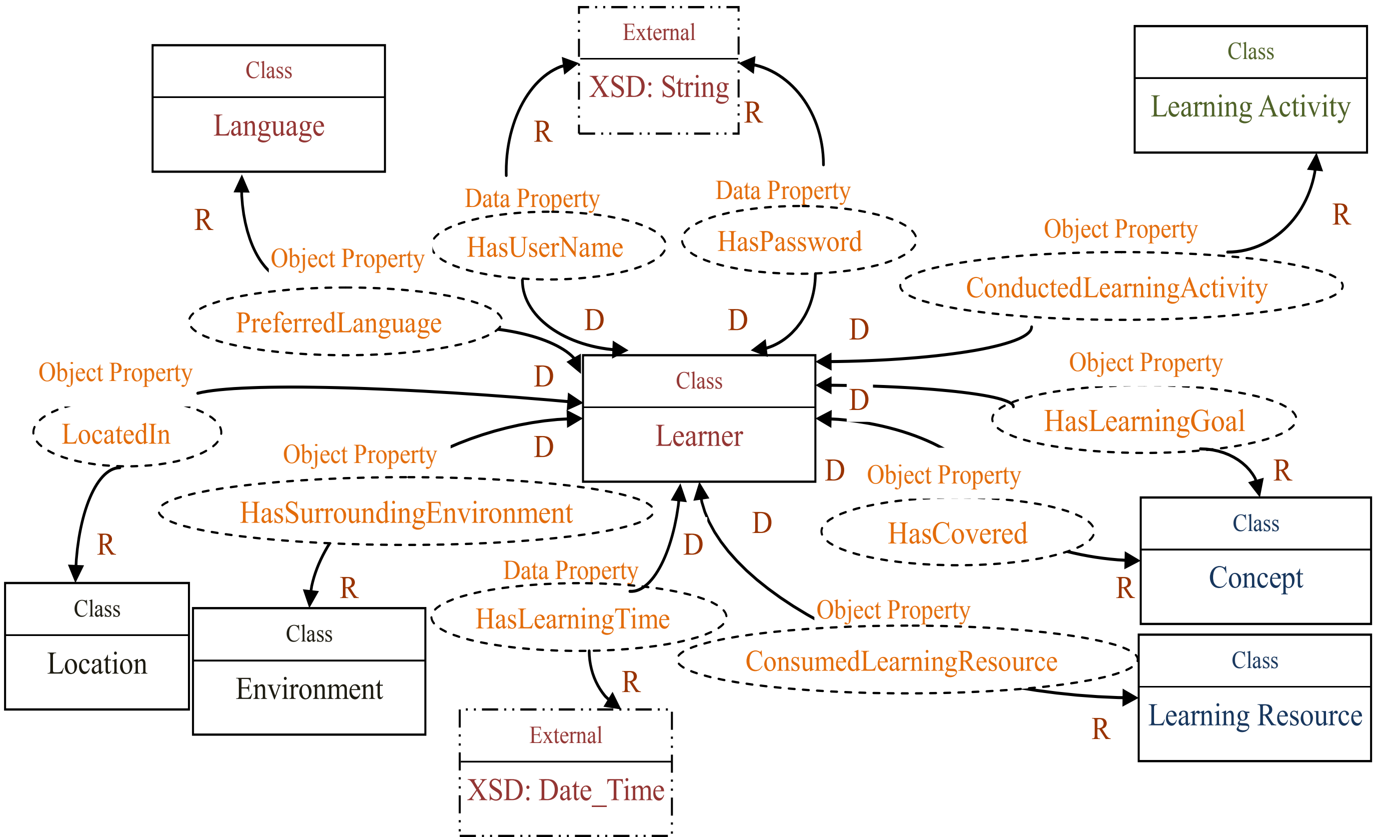
Modeling Atomic Context: Context Atom Attributes

- Context type (Nature of context)
- Context value (Quantized / non quantized(boolean, literal))
- Description (Symbolic description for high level reasoning)
- Time stamp (at acquisition time)
- Source (Sensor ID)
- Confidence (Truth probability)

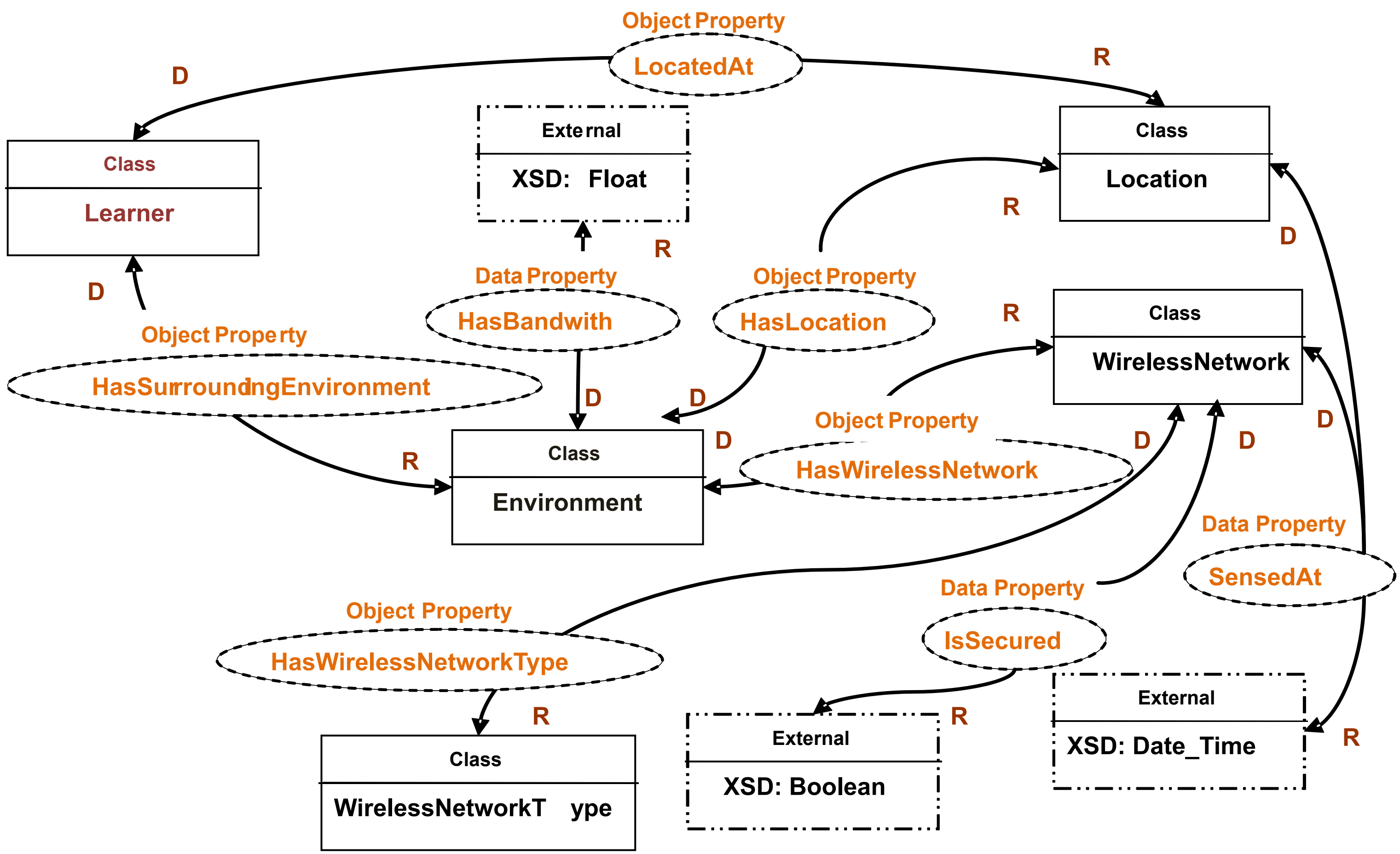
Domain Ontology



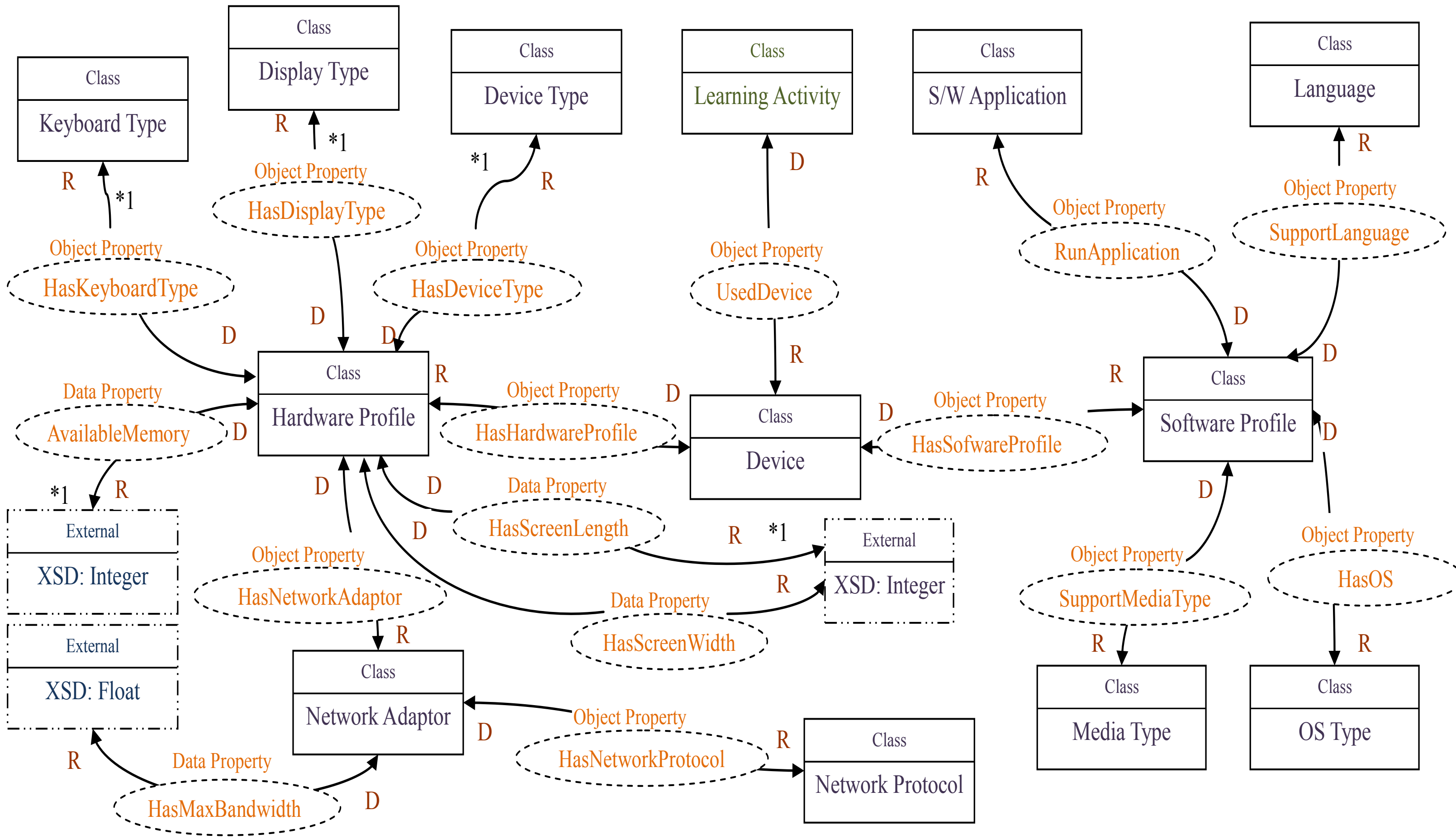
Learner Ontology



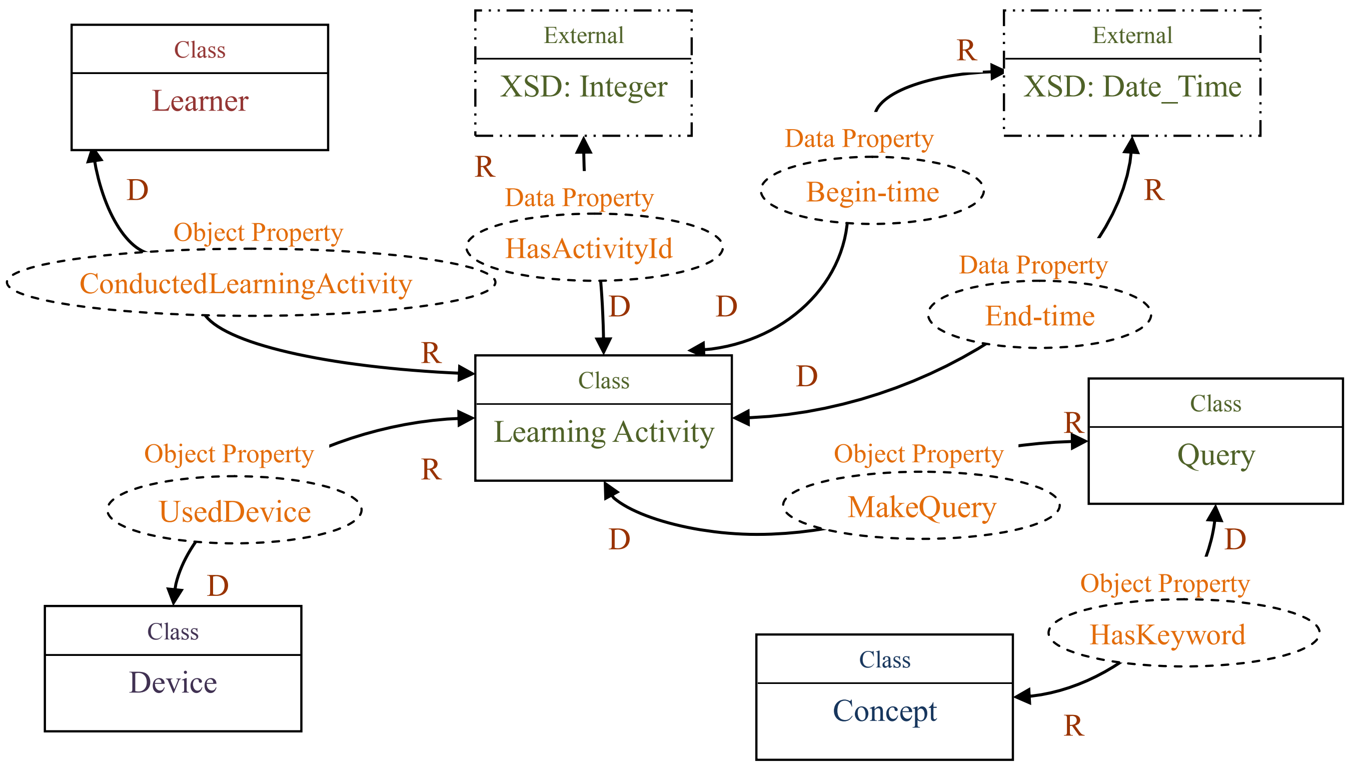
Environment Ontology



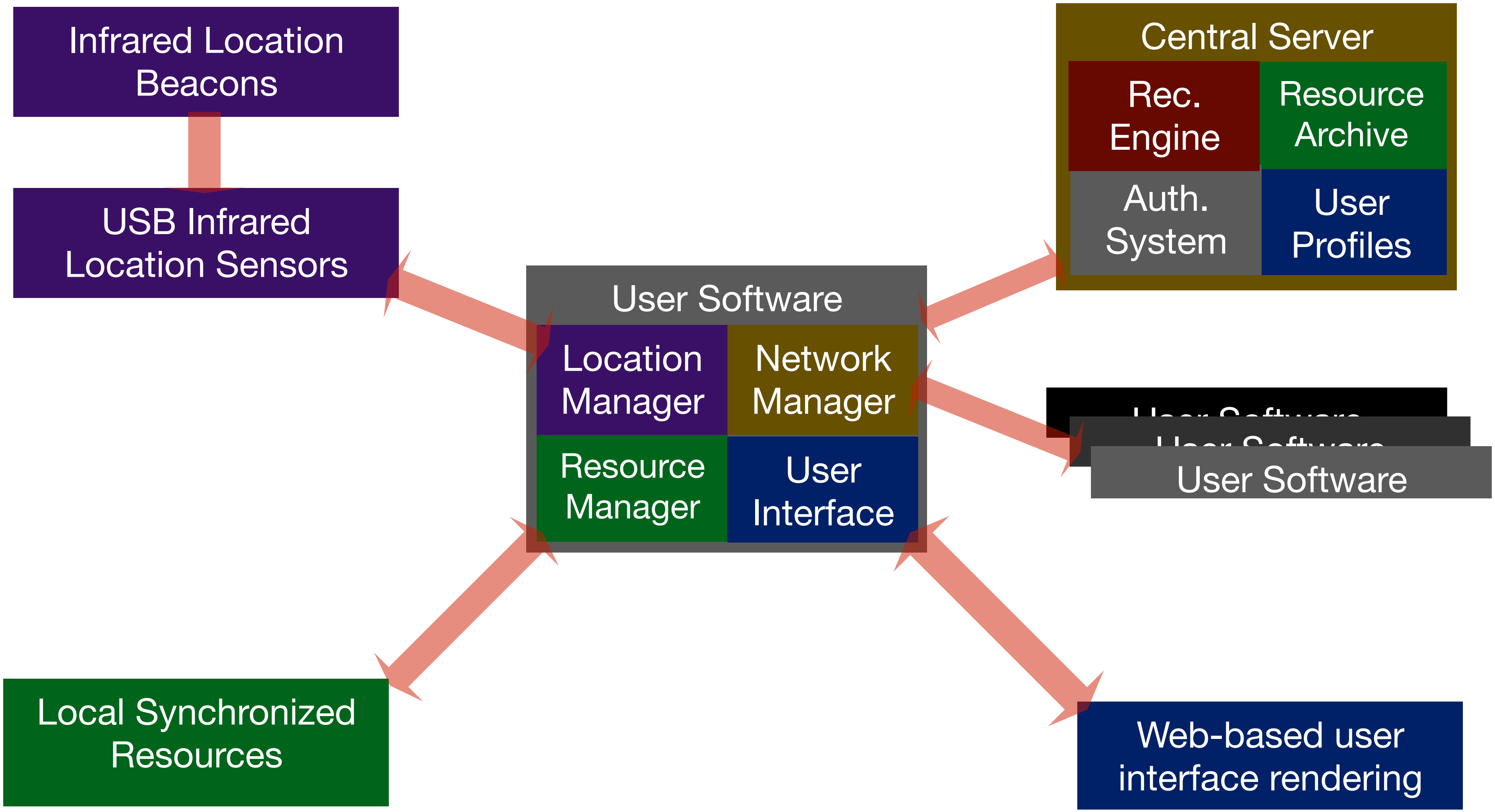
Device Ontology



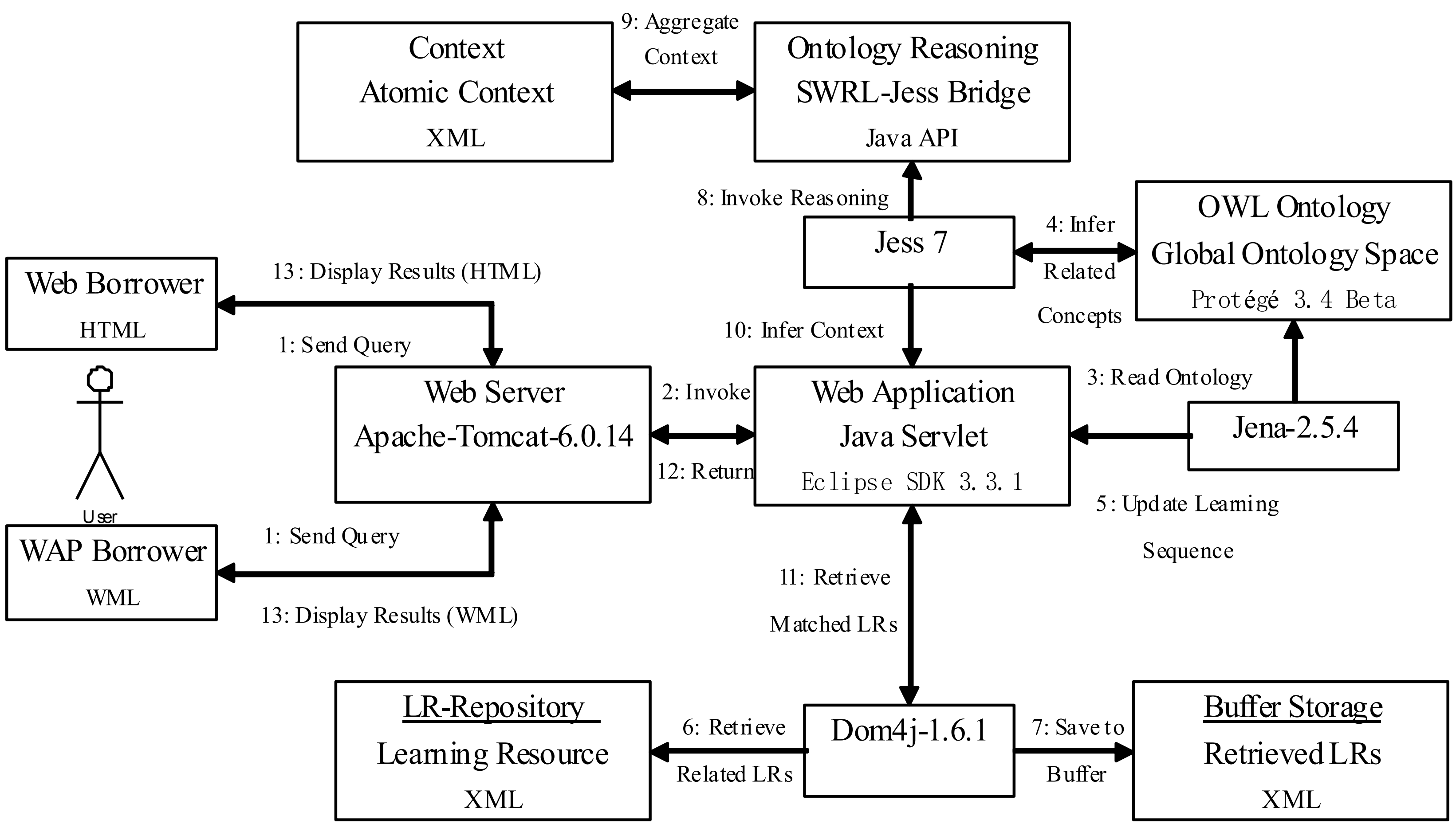
Activity Ontology



System Overview

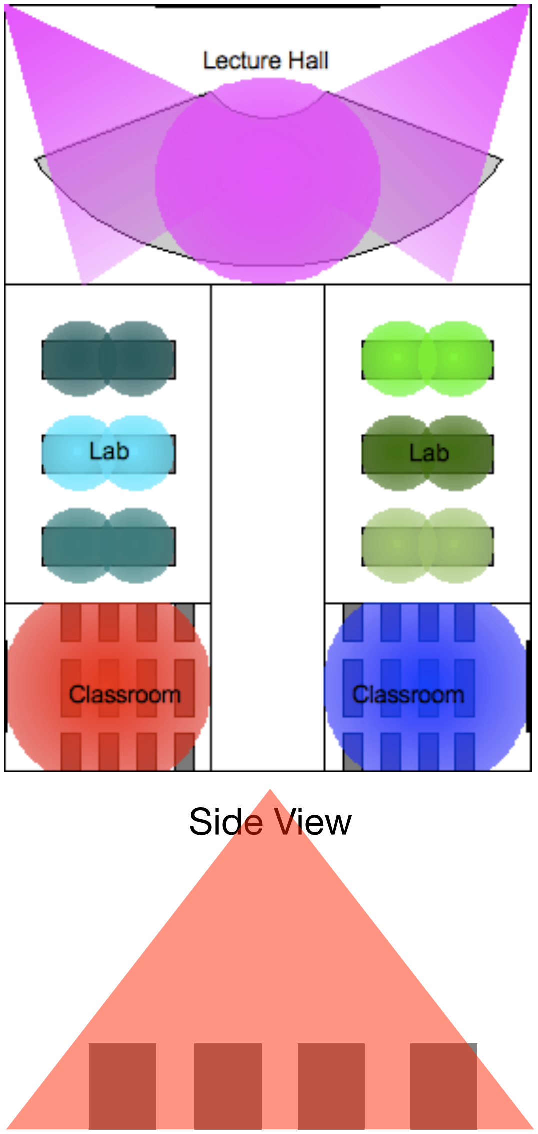


System Implementation

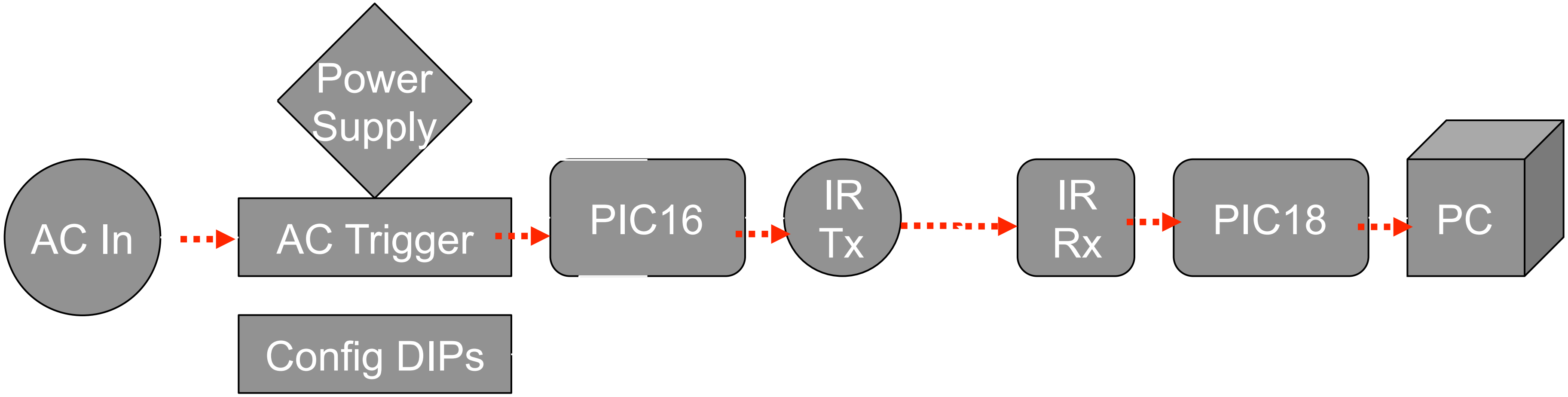


Location Awareness

- ✓ Unidirectional microcontroller-based transmitters
- ✓ Easily installed and configured
- ✓ Minimum 1 per room
- ✓ Transmit unique ID
- ✓ Complements existing wireless networks



Location Awareness (cont)

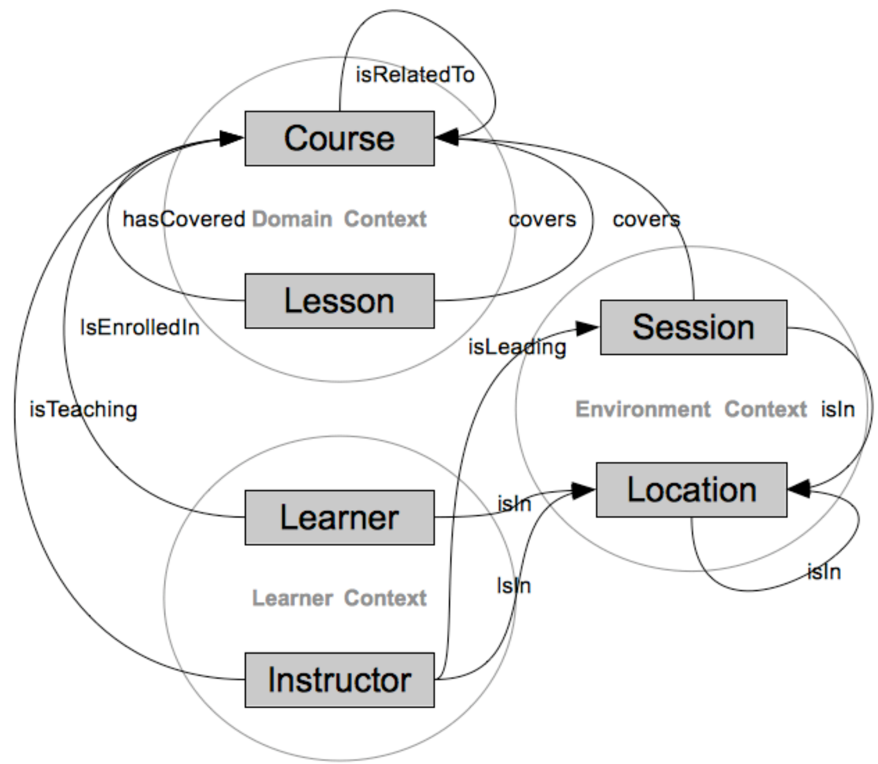


- ✓ Simple hardware designs for beacons and USB receivers
- ✓ Minimizes distribution and implementation costs
- ✓ Other receivers

Learning Recommendations

- Central server provides learning services that extend beyond the classroom

- Ontology-based recommendation engine relates lessons to other lessons, labs, and related courses



Case Study 2

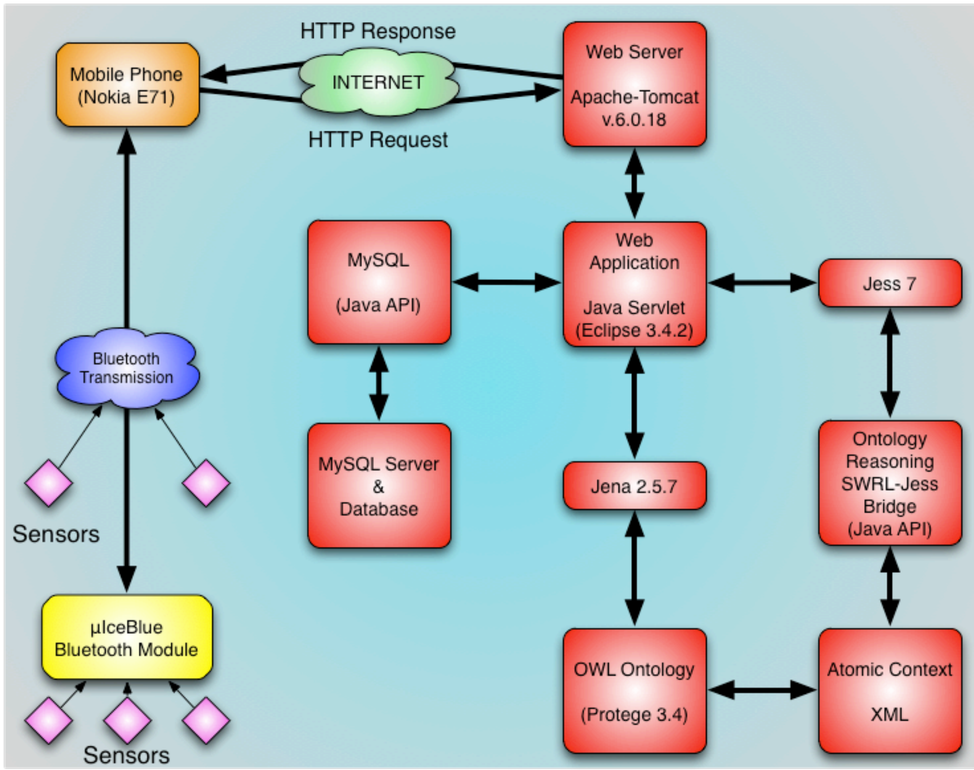
Health Care Monitoring on the Semantic Web

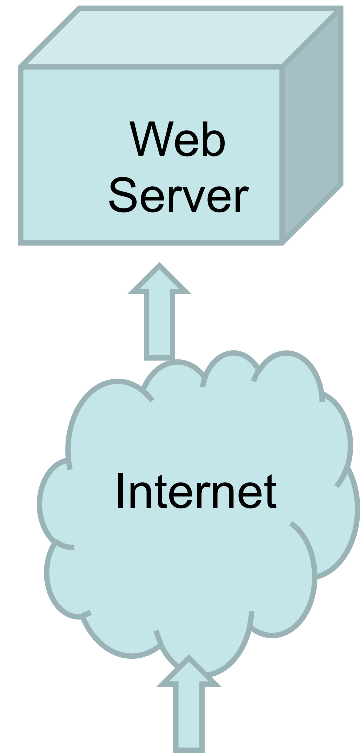
Feature Demo

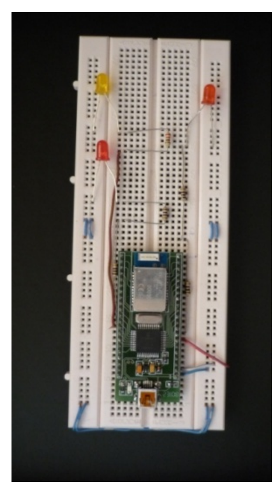
Overview

- ✓ Mobile platform to monitor patients from outside of the hospital
- ✓ Utilizes cell-phone networks to transmit sensor data to the server
- ✓ Allows for the mobility for patients who are of non-critical status yet still require a level of monitoring
- ✓ Actions can be carried out based on sensor data, as specified by a medical professional

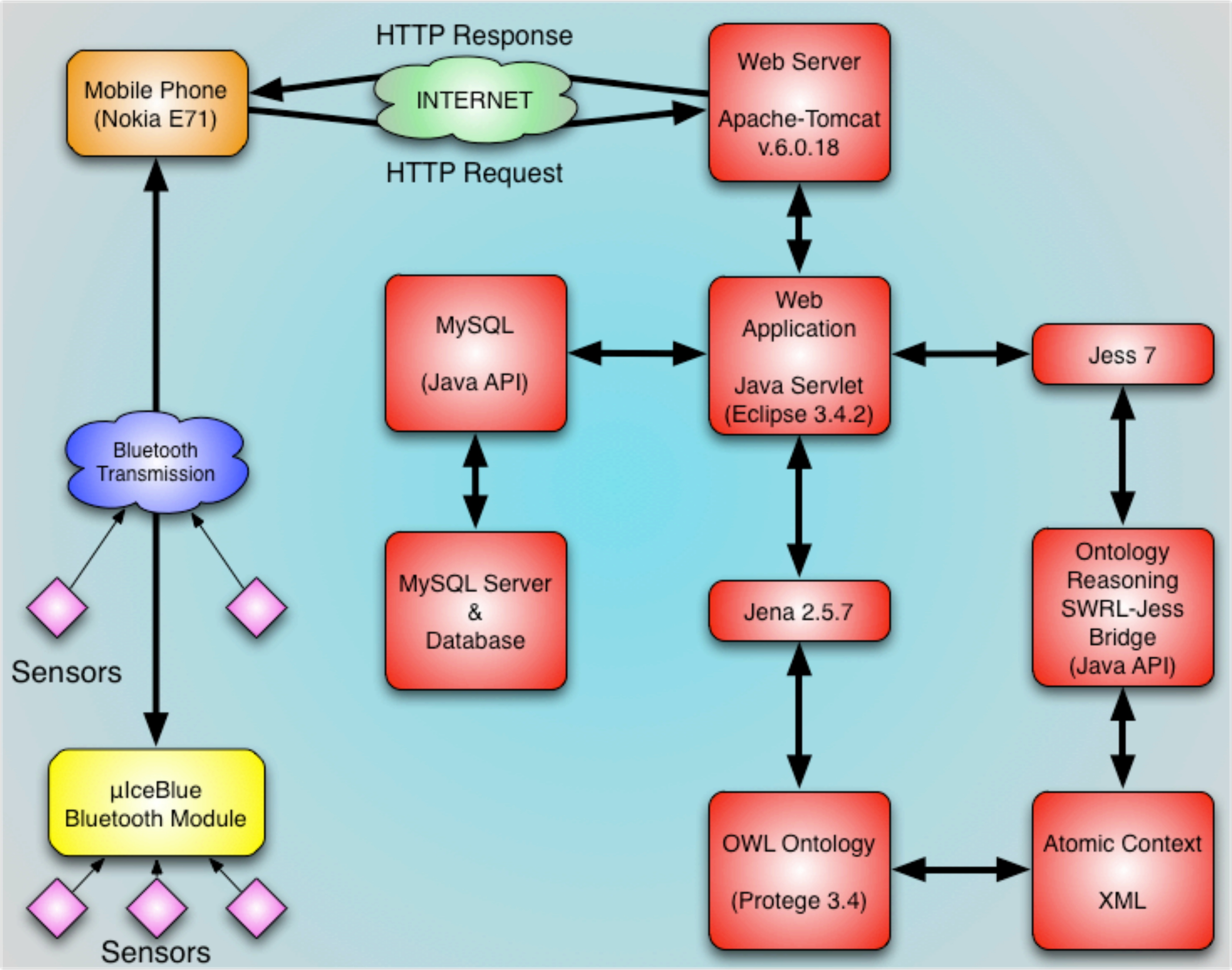
System Architecture







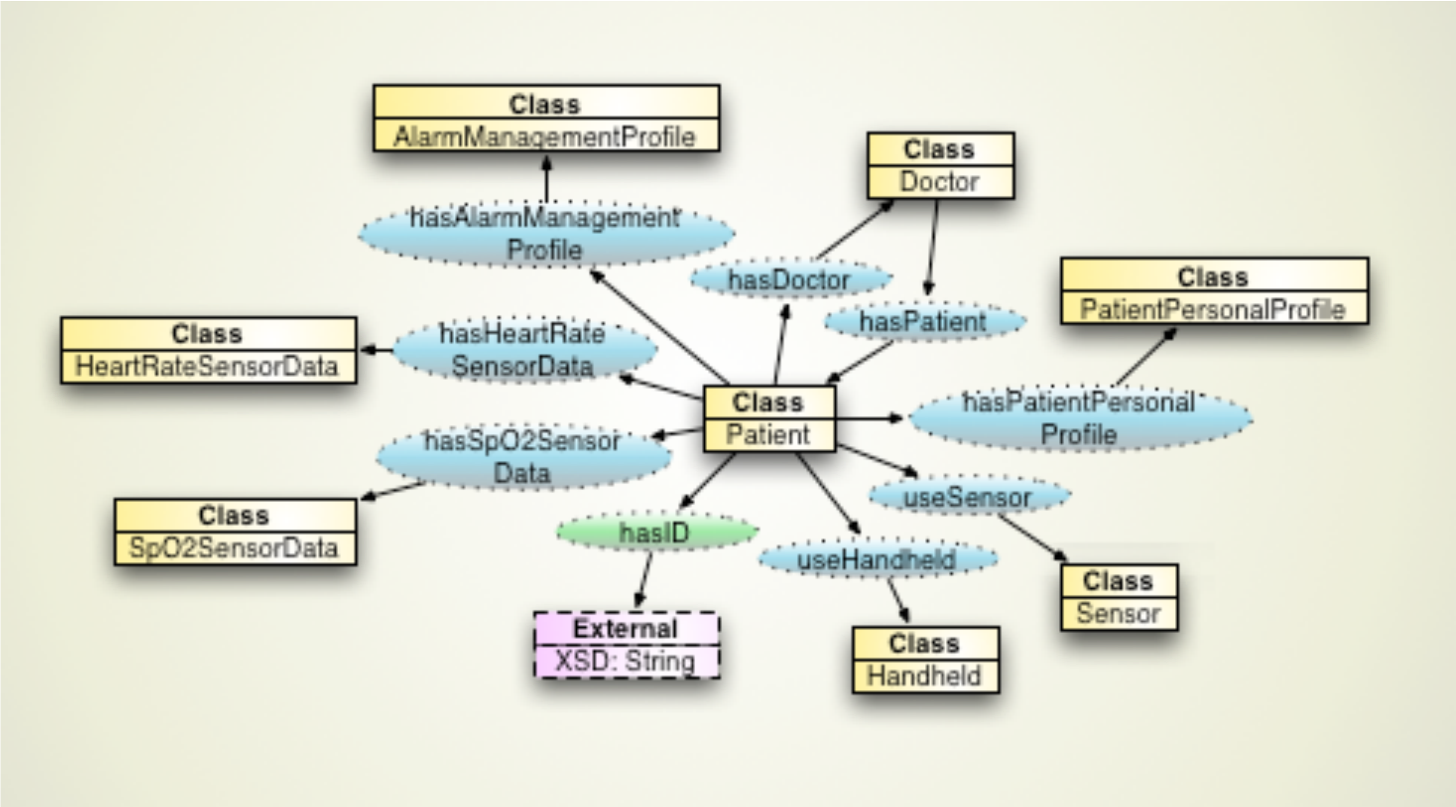
System Architecture



Wearable Sensor

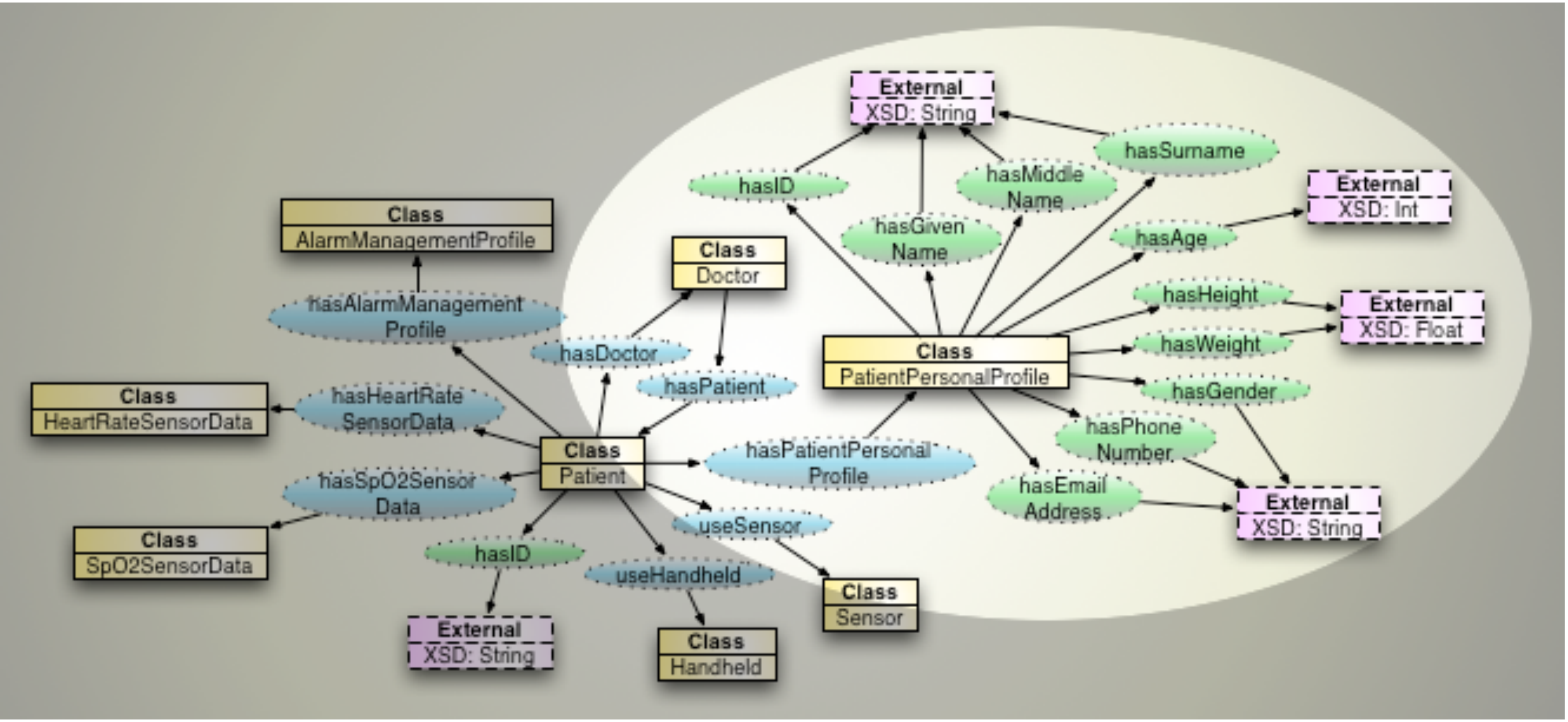
- Blood-oxygen saturation (SpO2)
- Heart Rate
- Bluetooth transceiver
  - 2.4 GHz
  - 30 meter range

Basic System Ontology

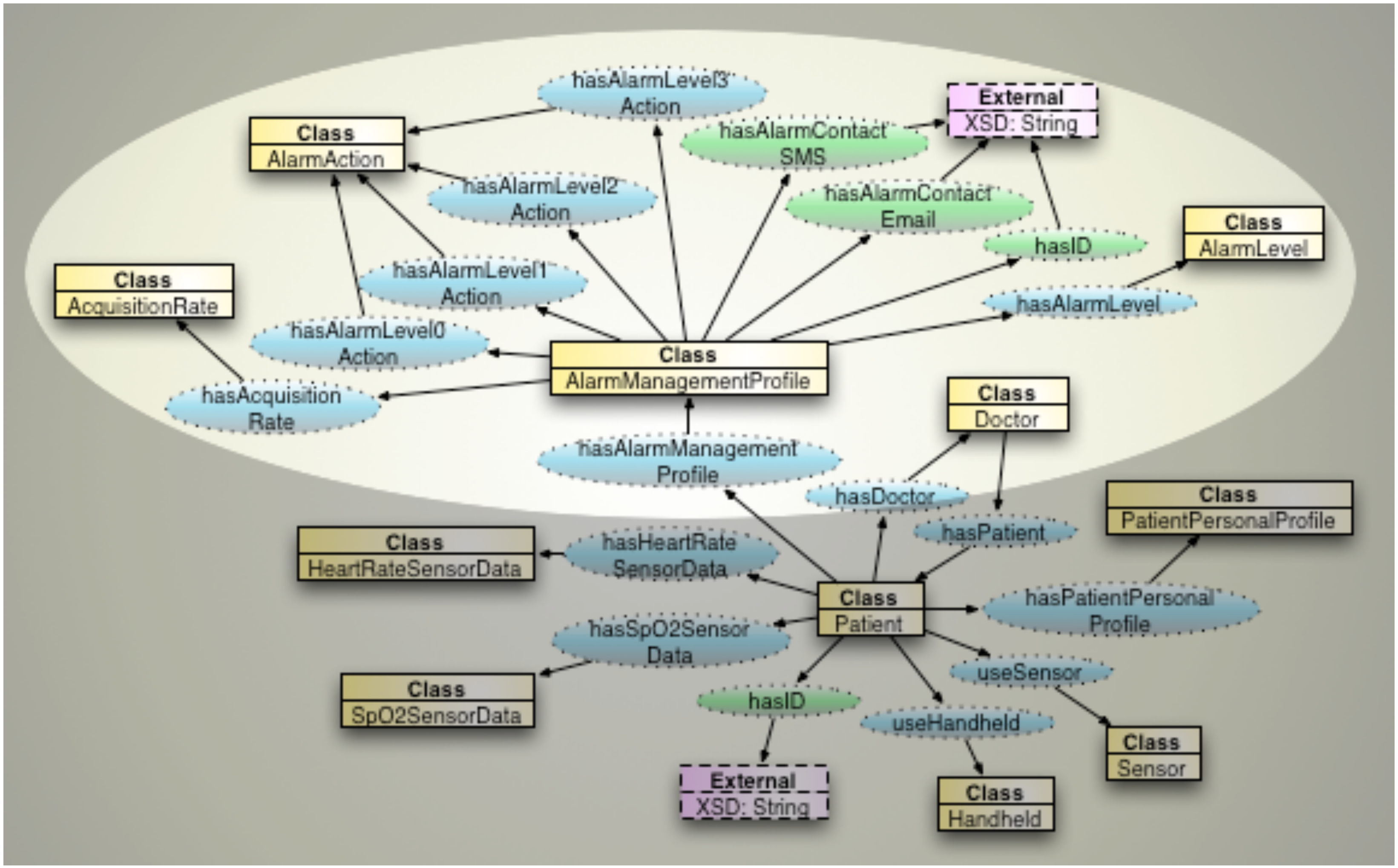


- Classes – Yellow
- Object Properties – Blue
- Datatype Properties – Green
- Datatype – Pink

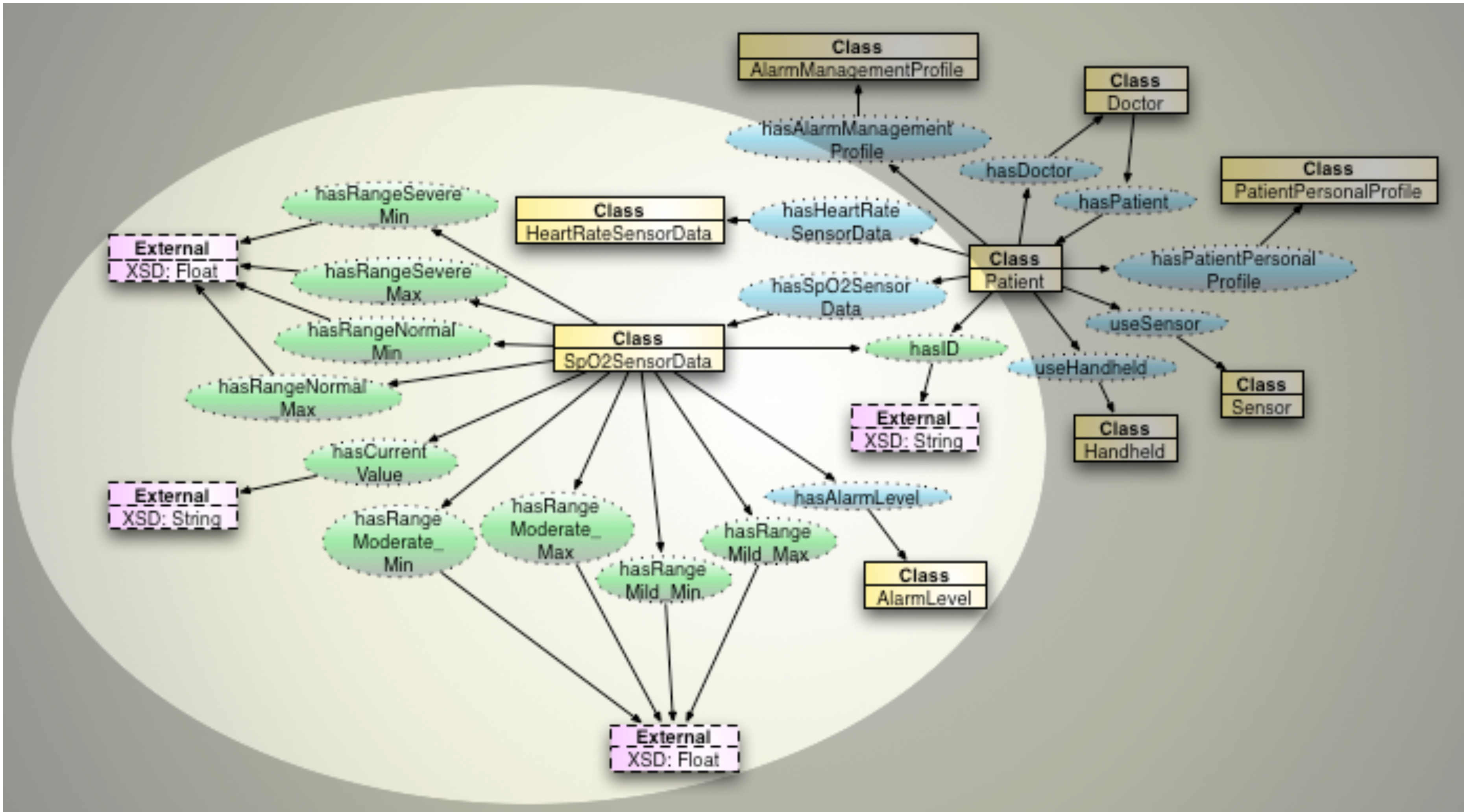
Patient Personal Profile



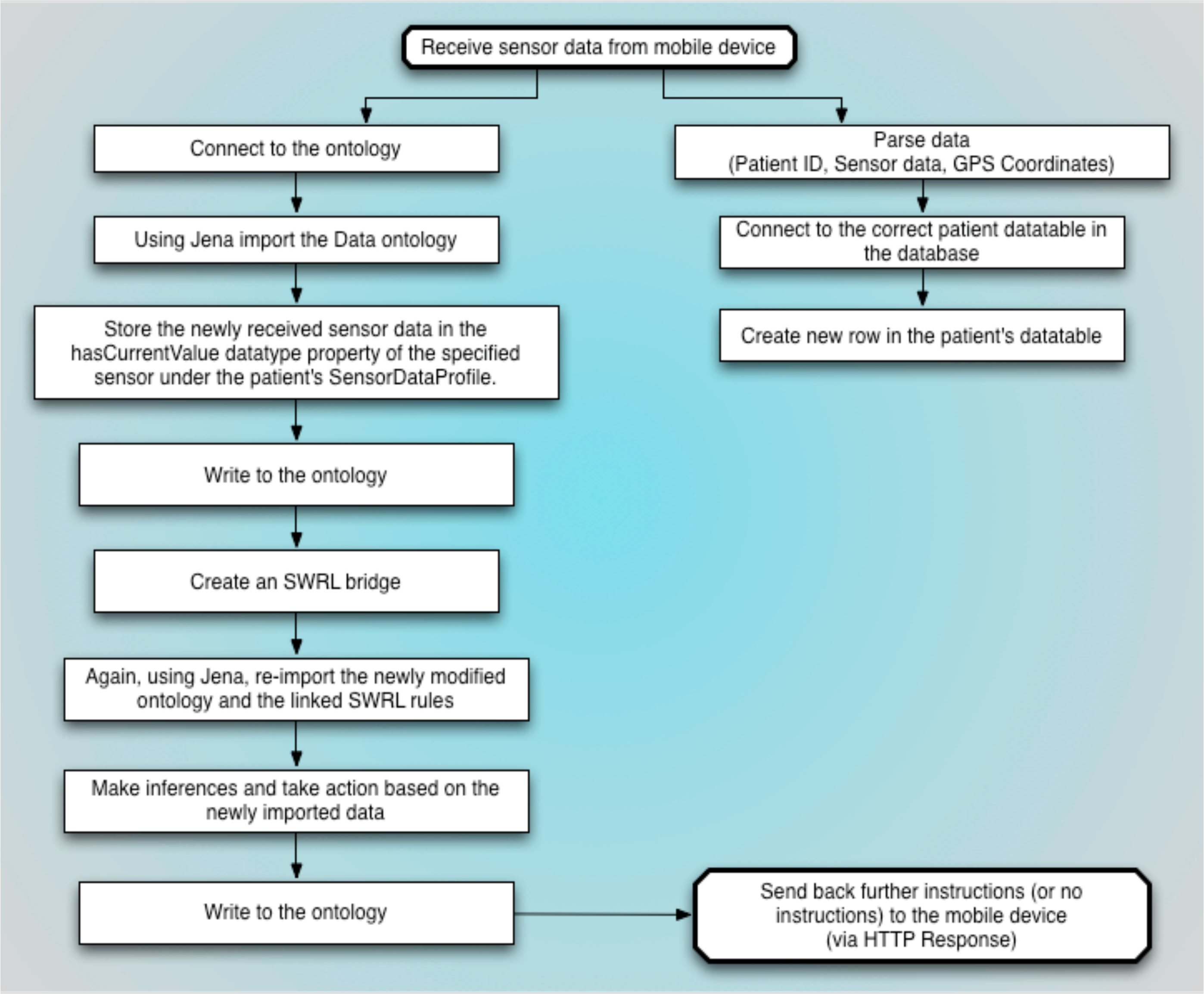
Alarm Management Profile



Sensor Data Profile



Reasoning – Flow Chart



Case Study 3

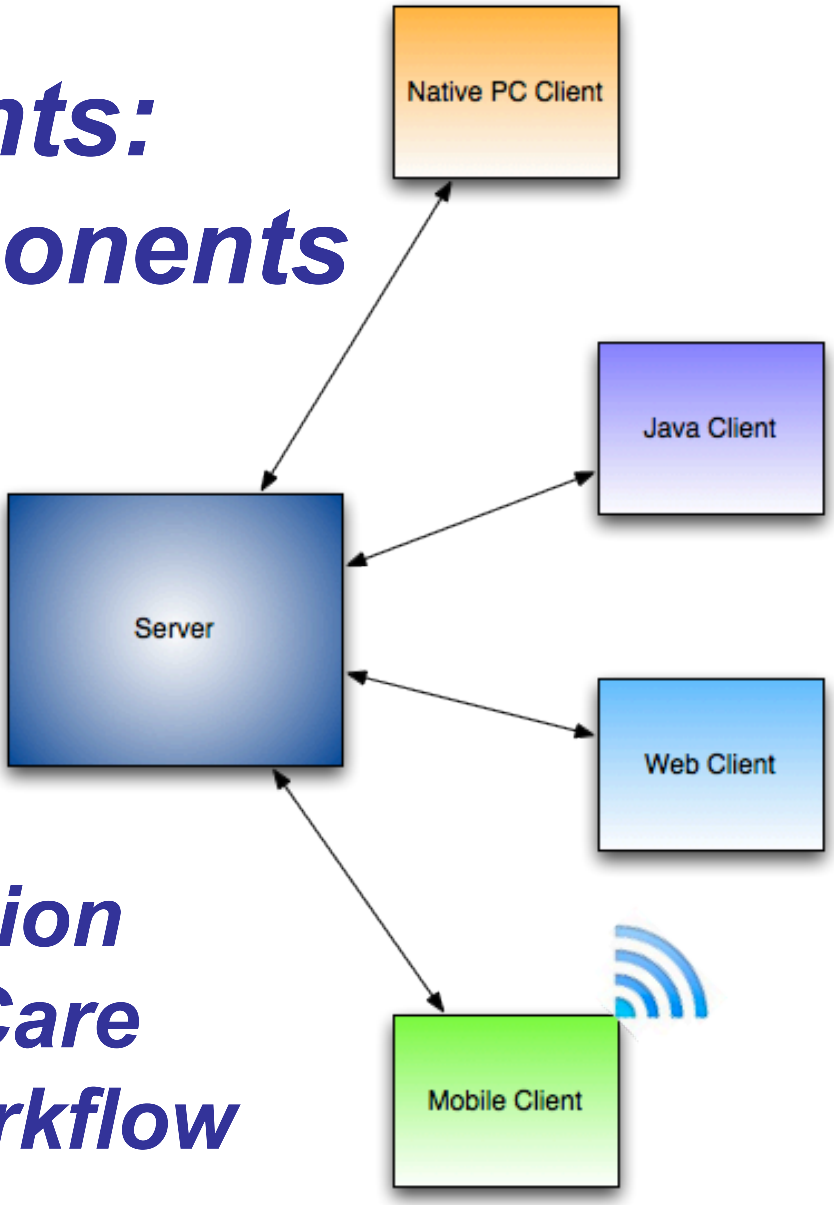
Mobile Health Care Collaboration on the Semantic Web

in collaboration with

Thunder Bay Regional Hospital

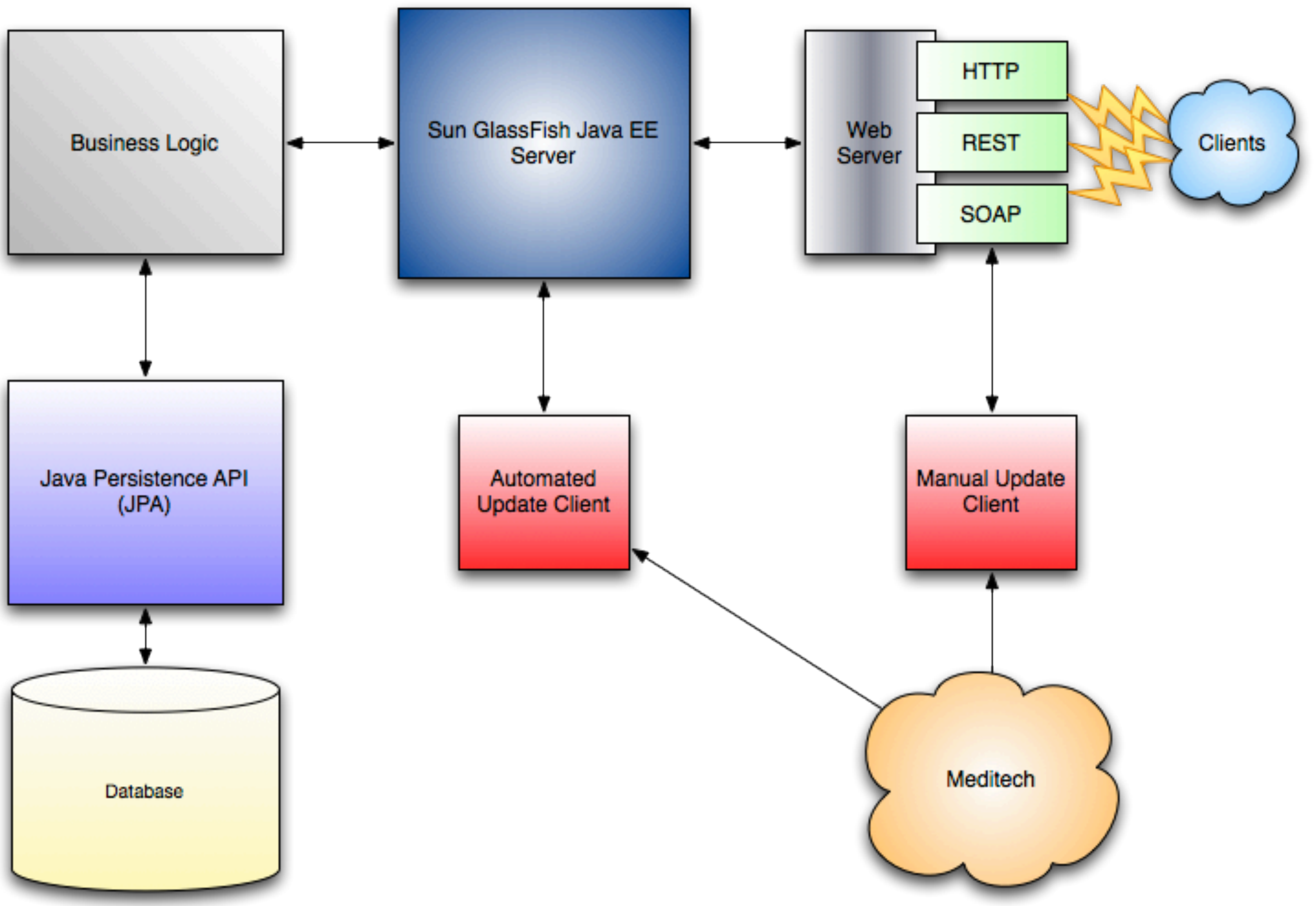
Feature Demo

Northern Lights: Functional Components

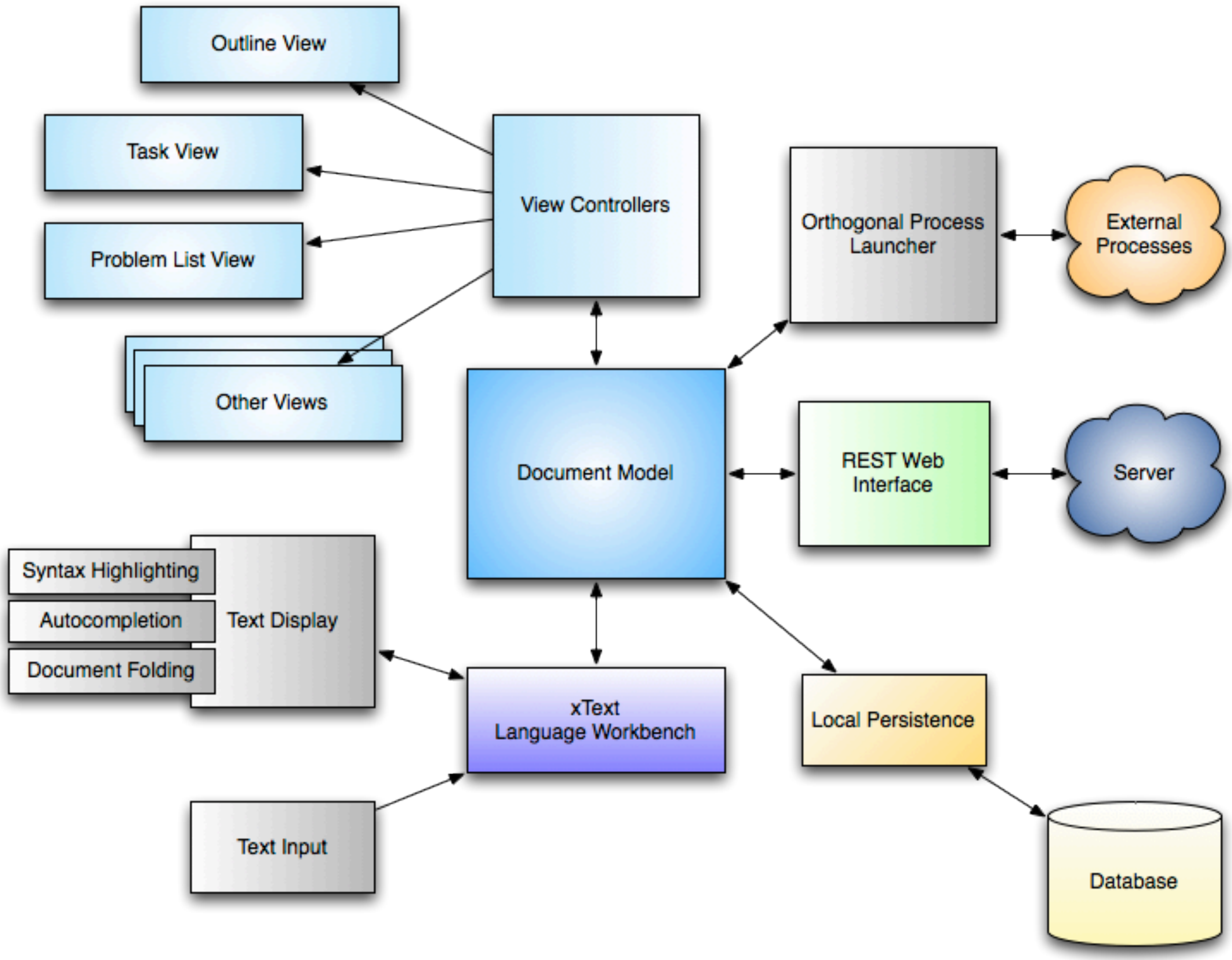


Medical Documetation System for Health Care Collaboration and Workflow Automation

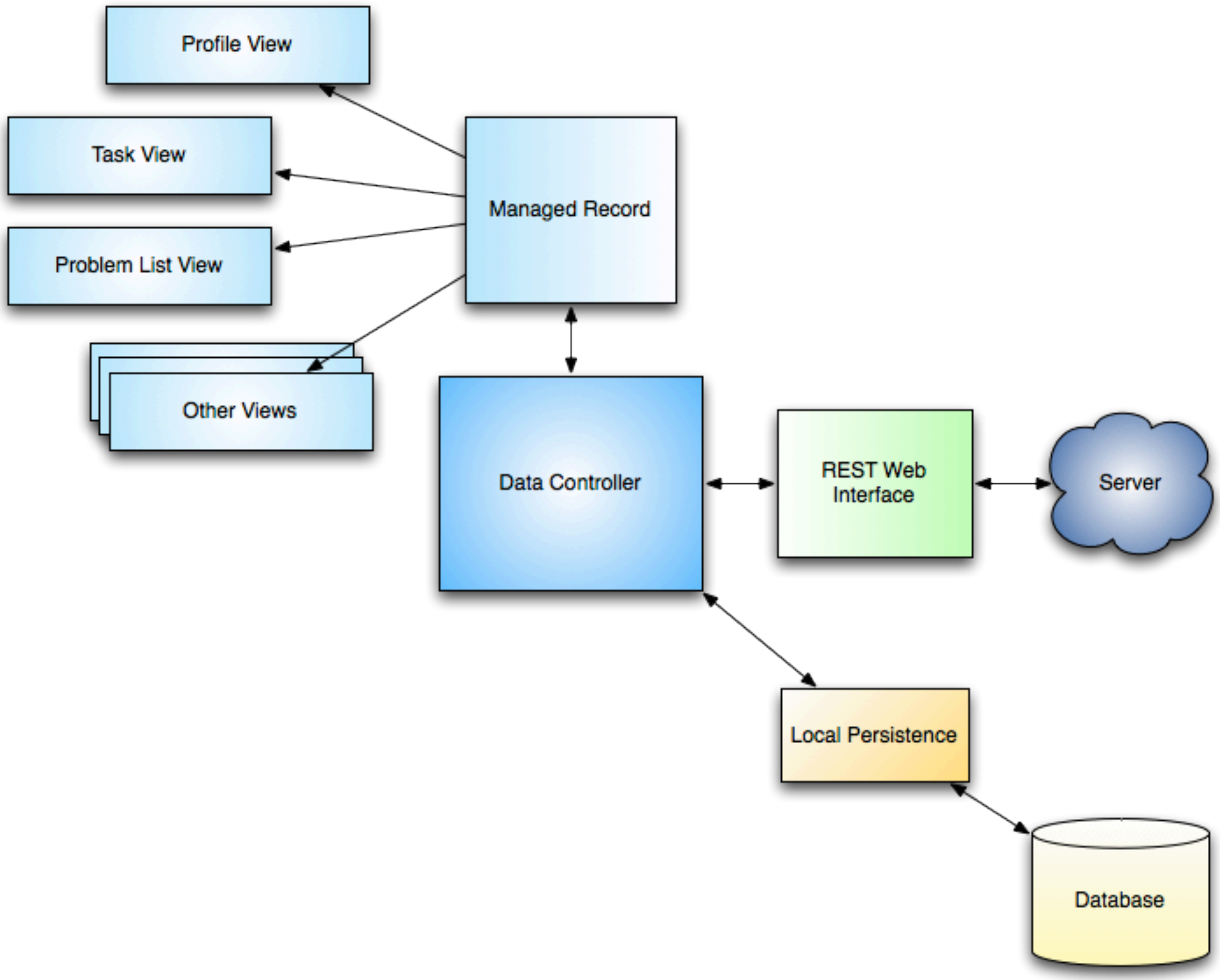
Northern Lights: Server Architecture



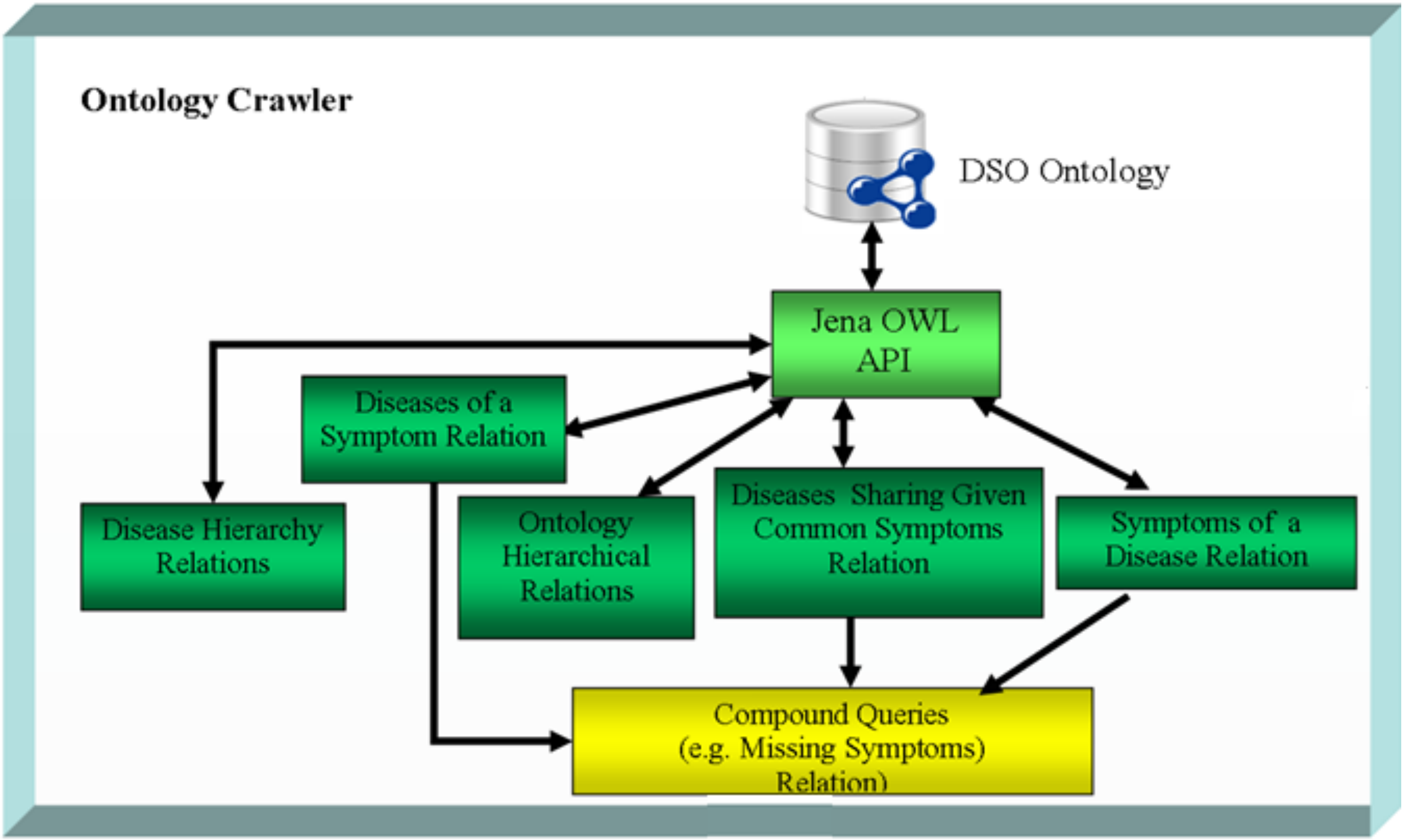
Northern Lights: Client Architecture



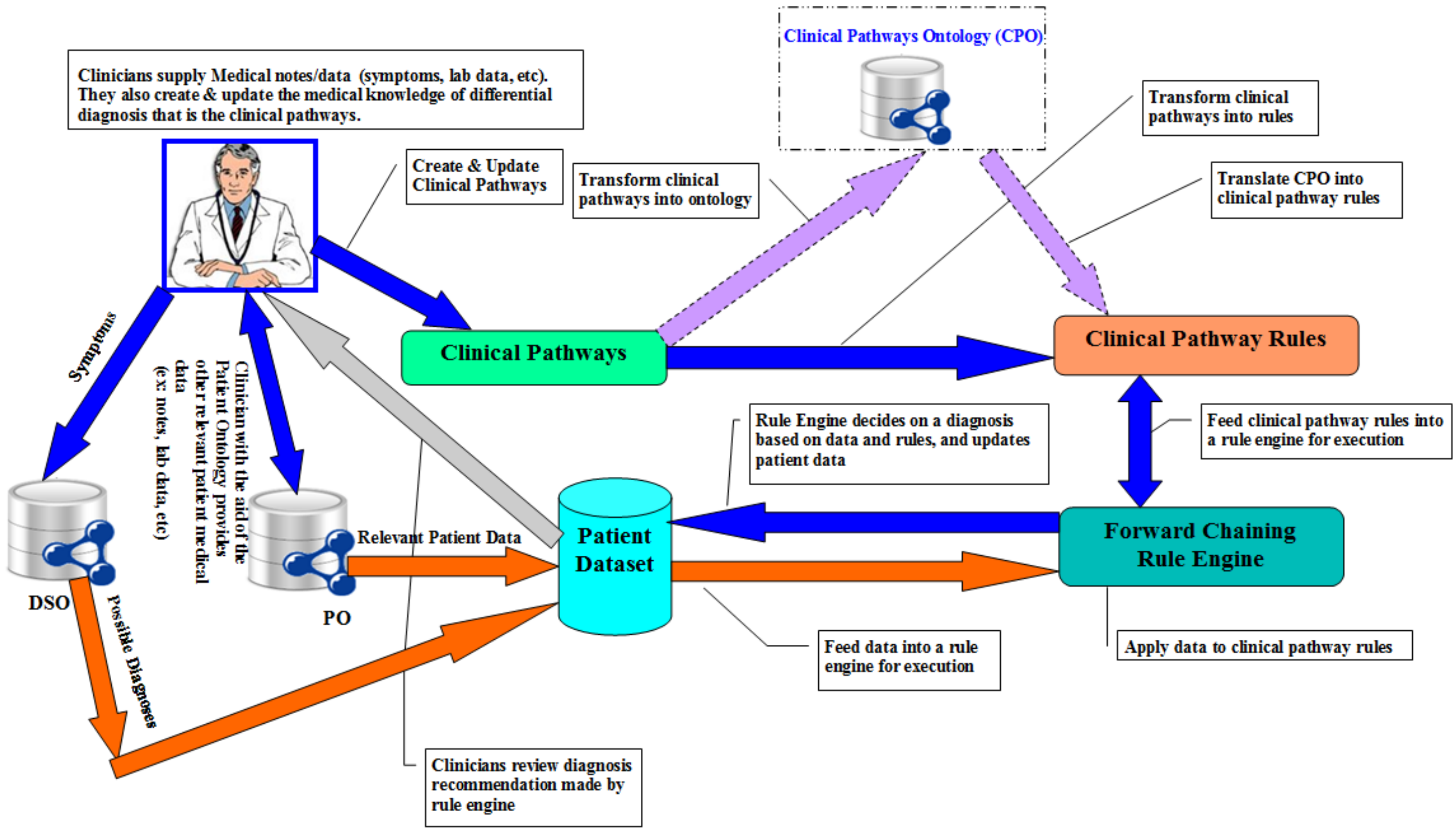
Northern Lights: Mobile Client Architecture



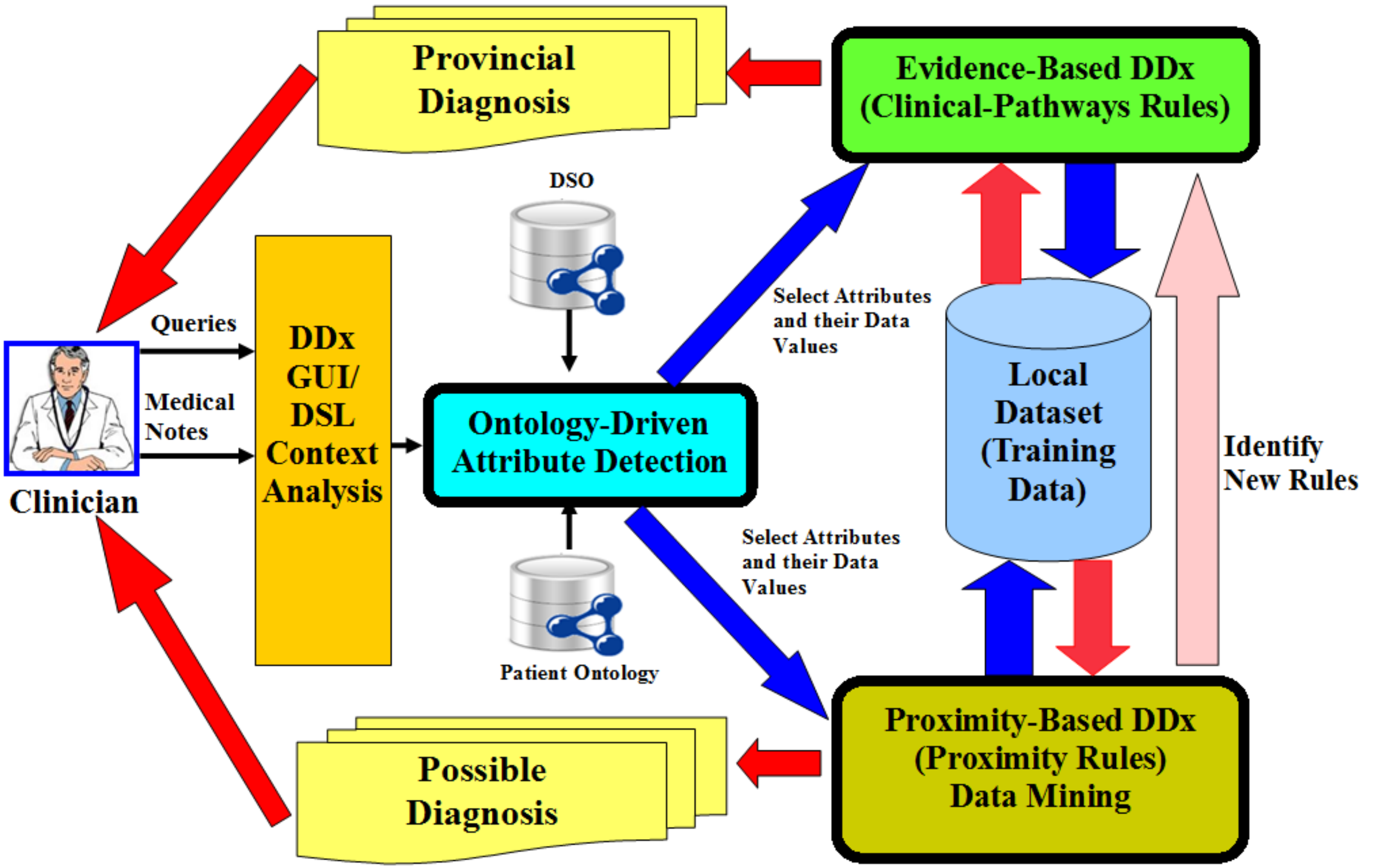
Upper-Ontology Design for Medical Diagnosis



Ontology-based Reasoning for Medical Diagnosis



Evidence-based & Proximity-based Reasoning for Medical Diagnosis



Conclusions

- Ontologies provide a shared understanding of a domain, hence allowing semantic interoperability

- SW provides an infrastructure where knowledge, organized in conceptual spaces (based on its meaning) can be semantically queried, discovered, and shared across applications

- Ontologies are useful for improving the accuracy of searches for both resources and services

Conclusions (2)

- Services across applications can be integrated by resolving differences in terminology through mappings between ontologies

- Automated reasoners can deduce (infer) conclusions from the given knowledge
  - Logic can be used to uncover ontological knowledge that is implicitly given
  - It can also help uncover unexpected relationships and inconsistencies
  - Logic can also be used by intelligent agents for making decisions and selecting courses of actions

Conclusions (3)

- SW provides Web agents with:
  - Agent communication languages
  - Formal representation of intentions (negotiation strategies)
  - Logic to reason based on current facts and negotiation strategies
- The intrinsic possibility of connecting ontologies and theories allow systems and people to use each others experience
- Extra policies can possibly detect and neutralize problem patterns within merged ontologies. Further research is needed here

Thank you

Questions?