Semantic Interoperability In Ad Hoc Networks: Enriching SQWRL Queries in Support of Geospatial Data Retrieval from Multiple and Complementary Sources

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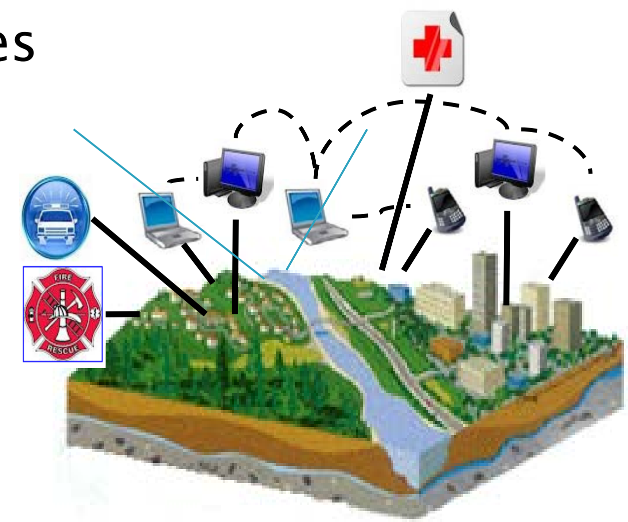
Introduction and context

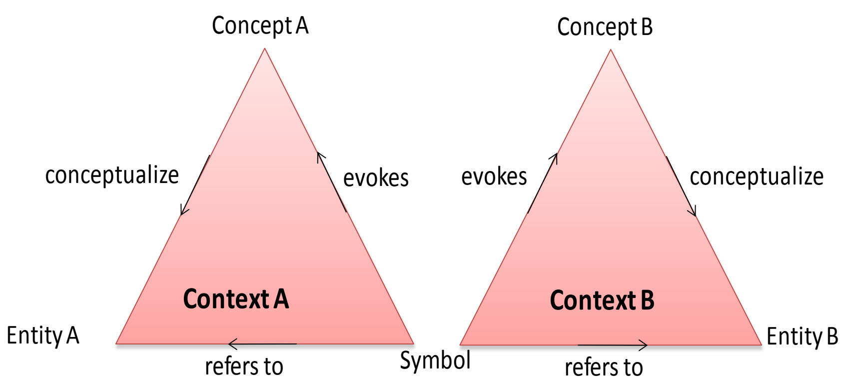
- Needs for integration of spatial and non spatial data for informed decision-making
  - Application example: disaster management:

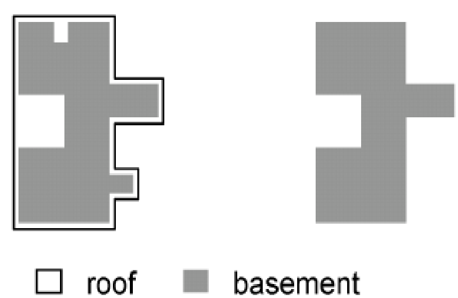
- Advances in spatial information, communication and Internet technologies
  - Huge amount of data are available through diverse sources of data
  - Sharing and reusability of the geospatial information is made possible through distributed systems



Semantic heterogeneities

- However, sharing and reusability of these data are constrained by different types of heterogeneities among spatial databases
- Semantic heterogeneities is one of the main obstacles for efficient sharing and reuse of geospatial information

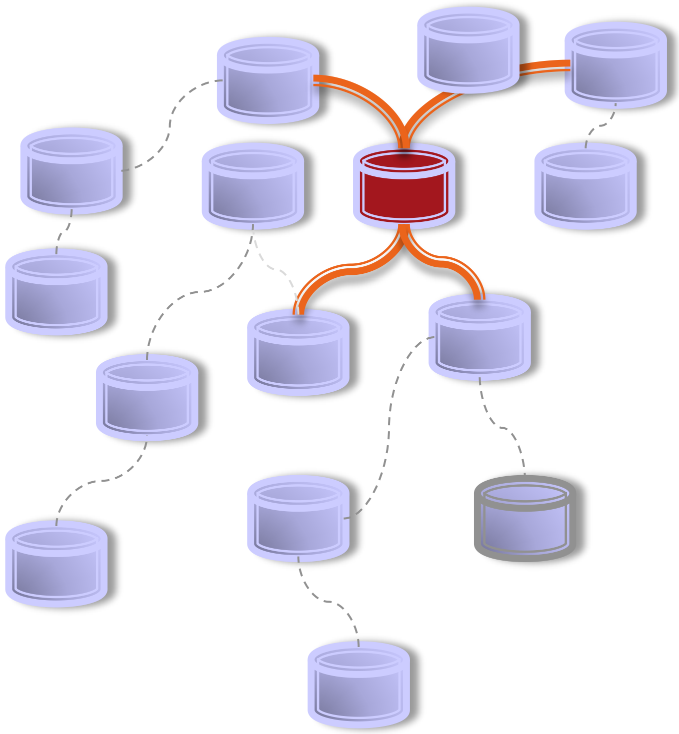




Ad hoc networks of databases

- Characteristics of ad hoc networks:
  - Could be considered as a dynamic graph where nodes are spatial or non spatial databases
  - These nodes can join or leave the network dynamically
  - Dynamic topology (links)
  - No centralised node, each node is an autonomous database
  - The databases contain very heterogeneous data

Ad hoc network



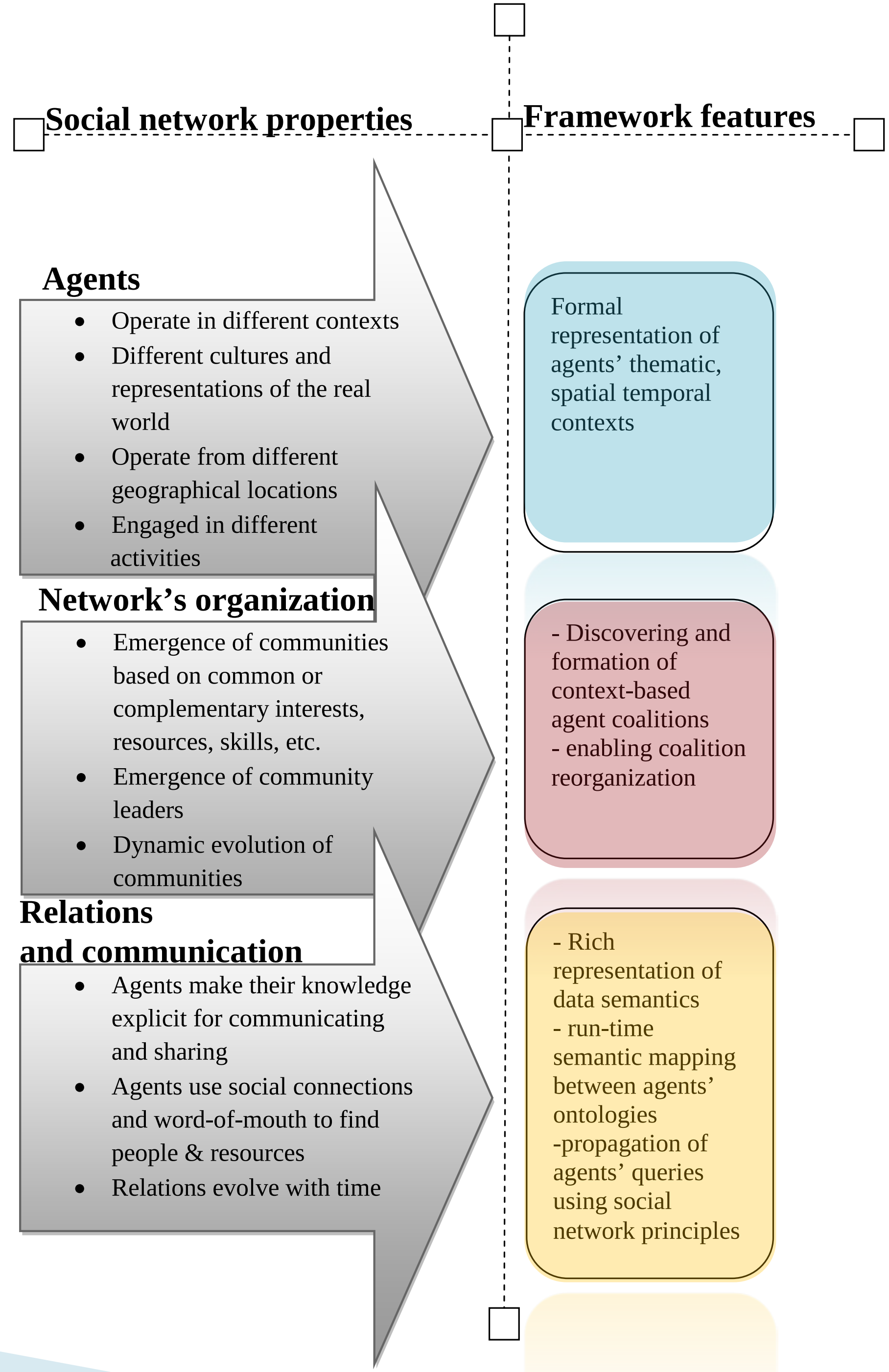
Need for semantic interoperability

- Semantic interoperability is defined as the "*knowledge-level interoperability that provides cooperating databases with the ability to resolve semantic heterogeneities arising from differences in the meaning and representation of concepts*" (Park and Ram 2004).

- Semantic interoperability in add-hoc networks pose new and complex challenges:
  - Need to consider dynamic and evaluative network (dynamic topology),
  - Need for dynamic partition of the network,
  - Need for query propagation strategies,
  - Need for real-time exploration of the network.

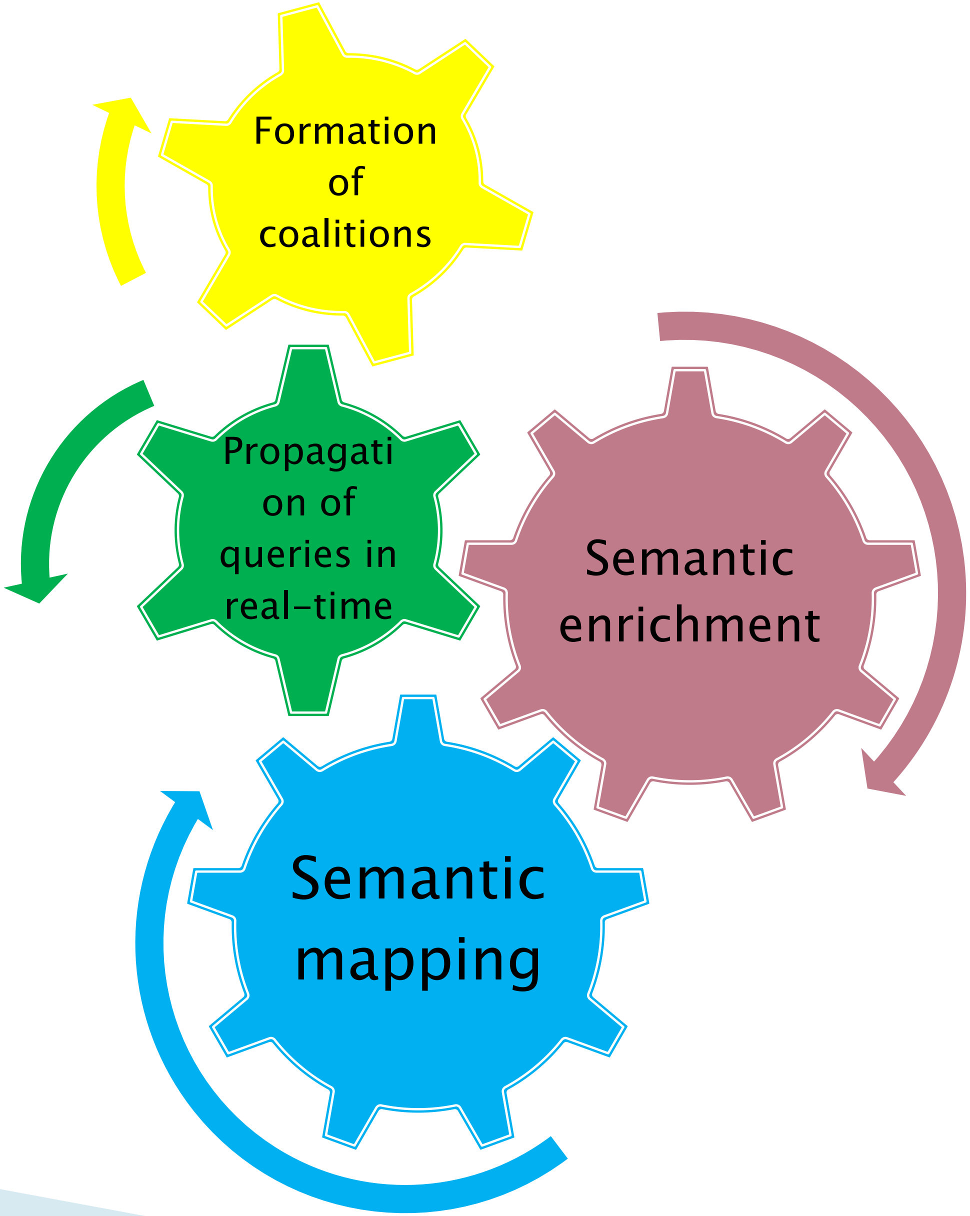
Conceptual framework

- Our proposed frame work for semantic interoperability in ad hoc networks is based on the characteristics and communication strategies in social networks.



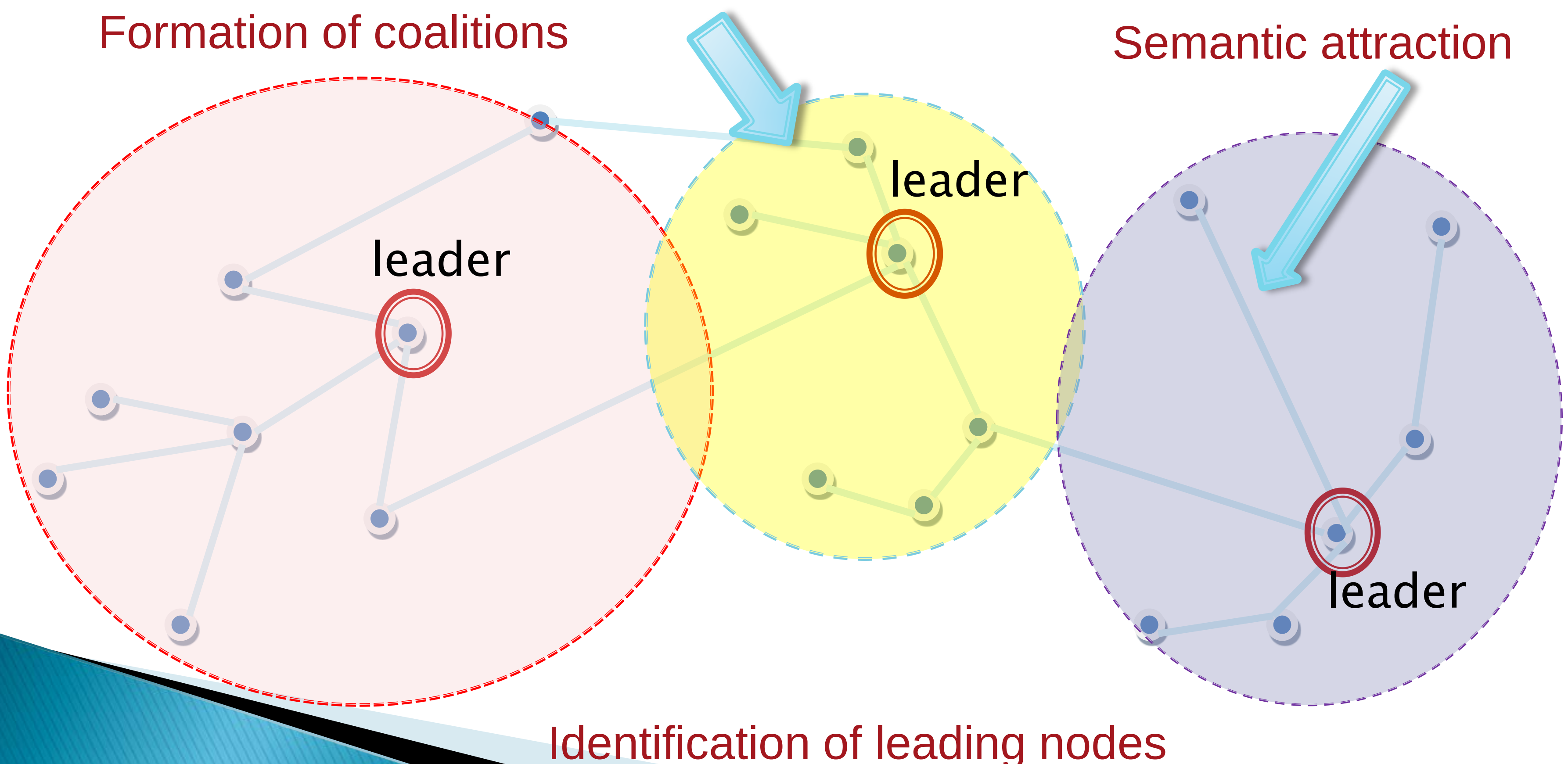
The global approached for interoperability

The Proposed approach consists of 4 main modules that are conceptualised and implemented in java environment

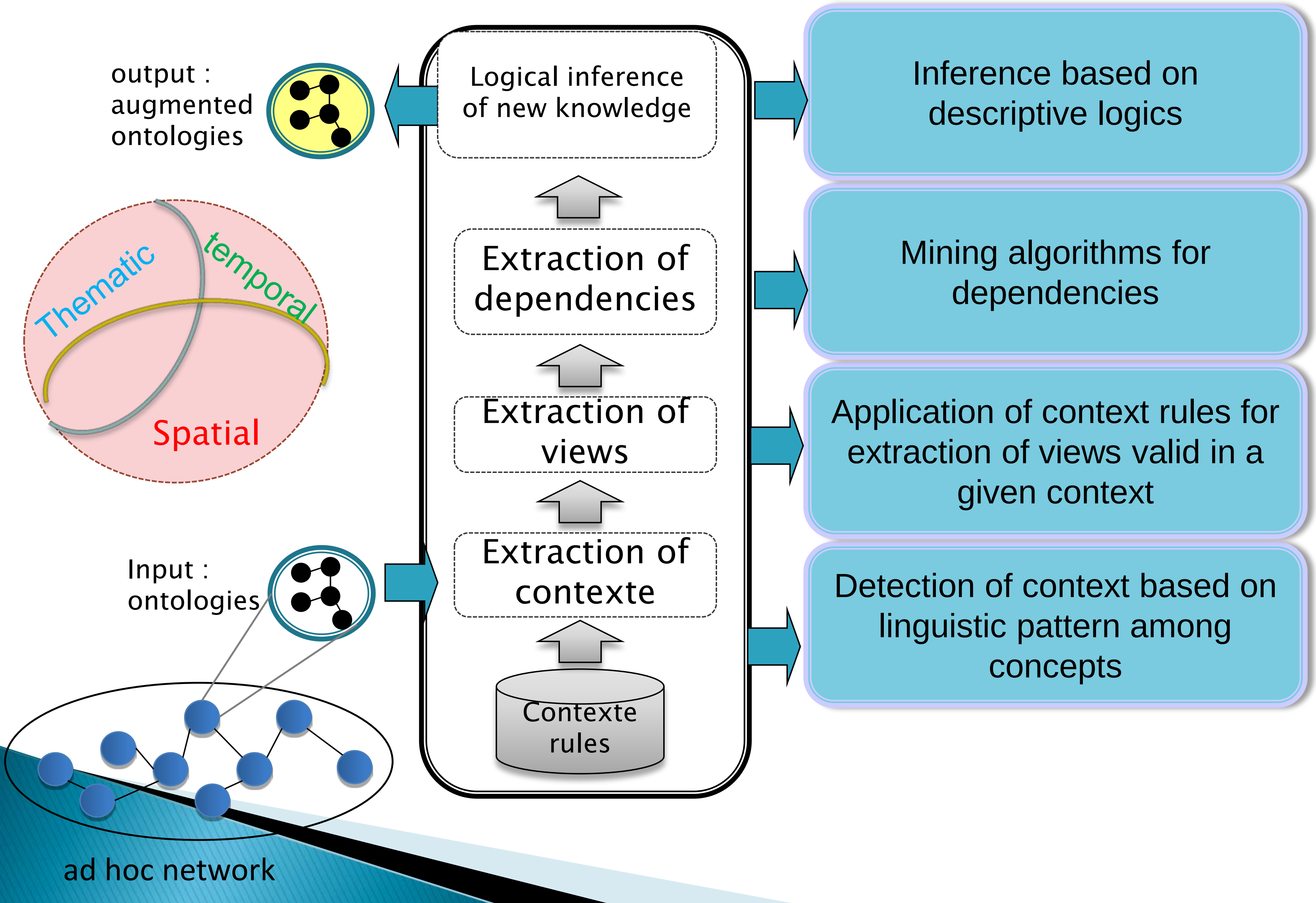


Module 1:Coalition formation based on semantic attraction algorithm

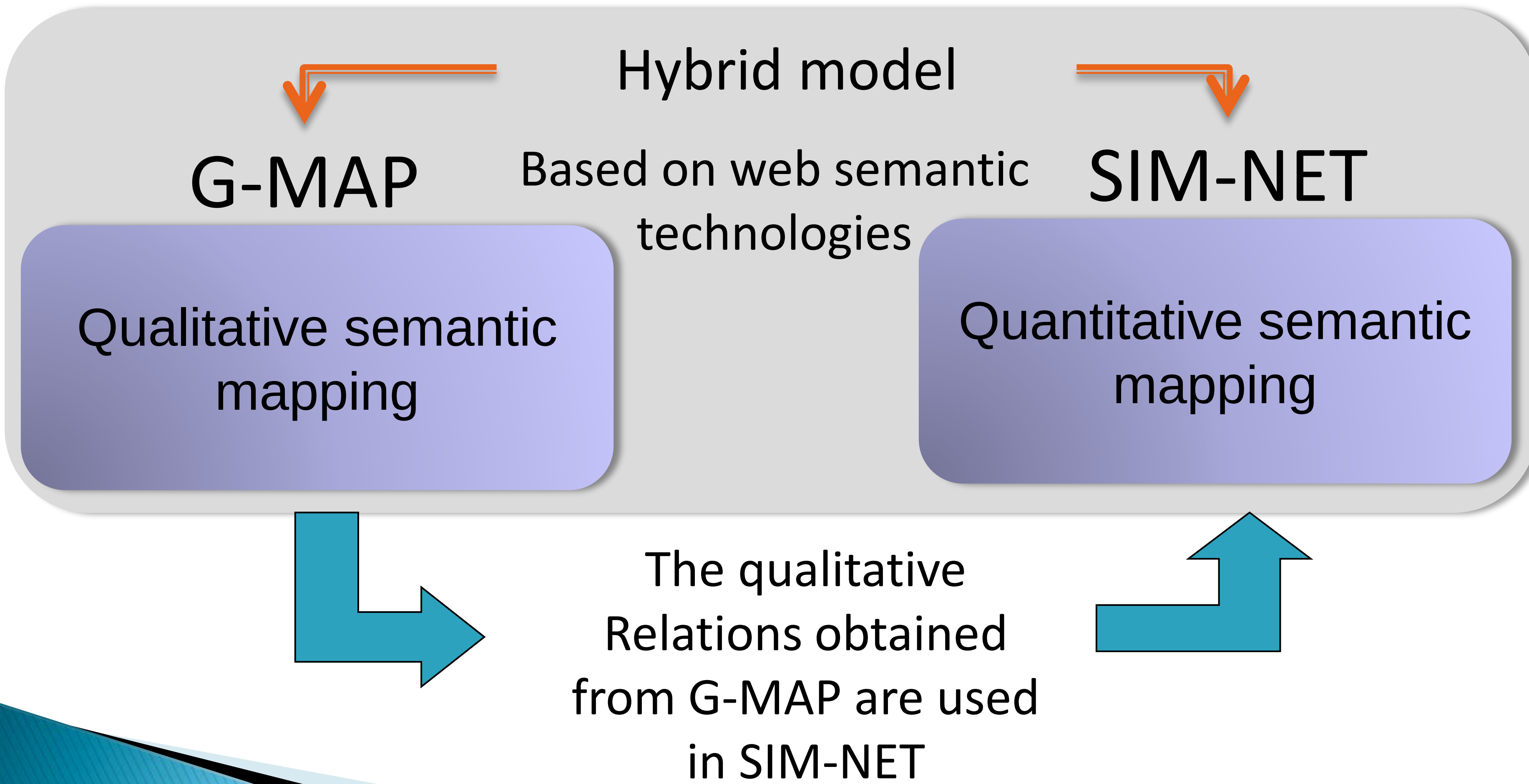
The algorithm is based on network analyses, adjacency matrix which allows formation of coalitions for query propagation



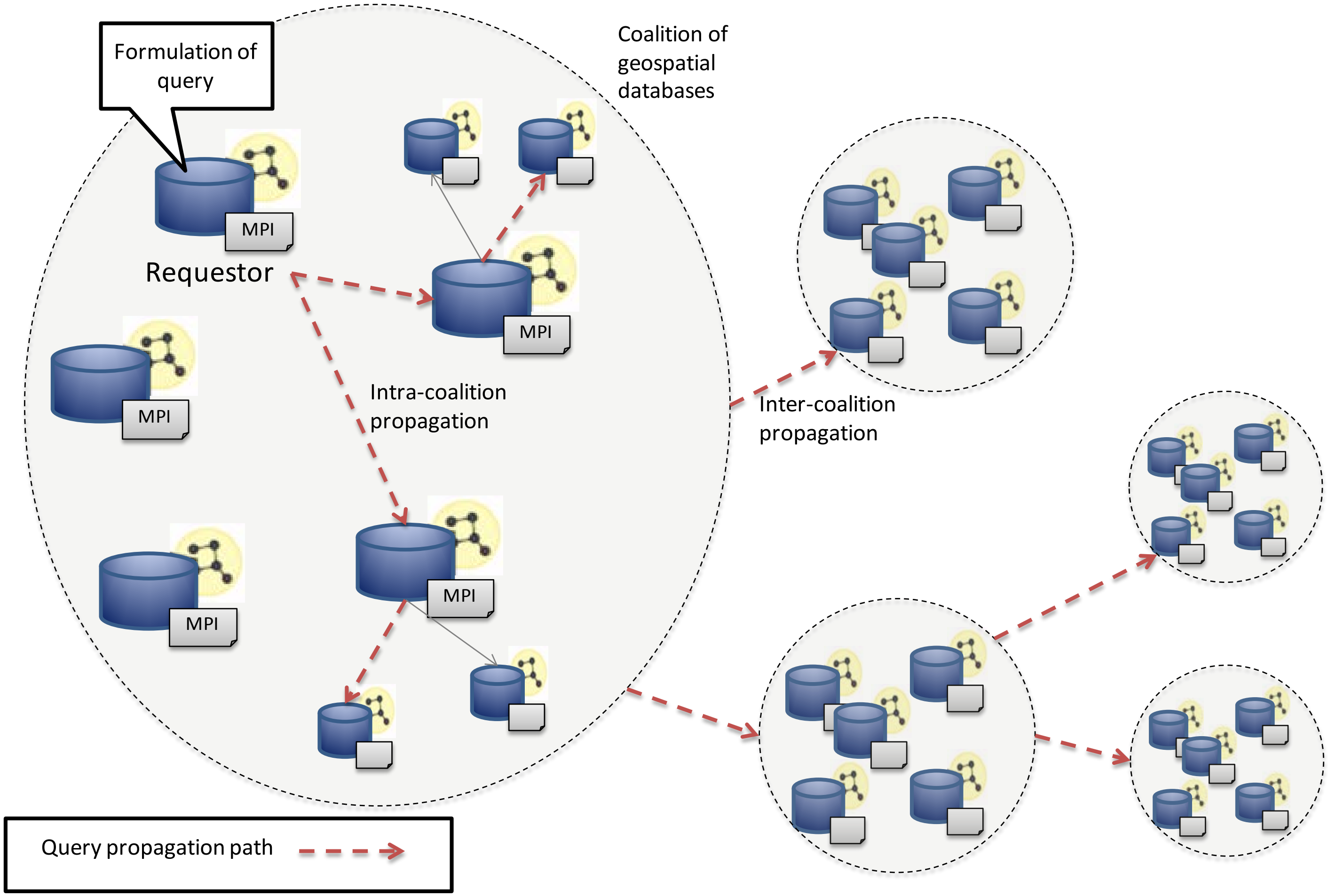
Module 2: MVAC



Module 2 : Semantic mapping between MVACs

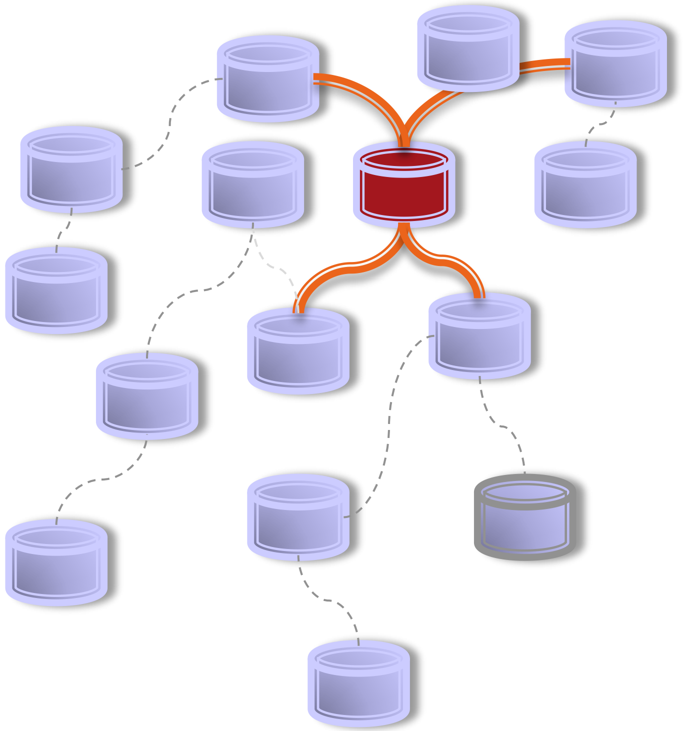


Query propagation strategies



Information Retrieval from Complementary Sources

Ad hoc network



- Complex information retrieval queries
  - queries with several clauses
  - required information coming from various sources

- Most of information retrieval approaches lack of capacity to process complex queries :
  - do not consider cases where data from multiple sources must be combined
  - User has to run several queries and then try to combine the heterogeneous data

Semantic Query-enhanced Web Rule Language (SQWRL)

- SQWRL is built on the Semantic Web Rule Language (SWRL) [O'Connor and Das 2009]
- SWRL rules express a logical implication between an antecedent and a consequent
- Example: Select regions which have specific air particle concentration and temperature :

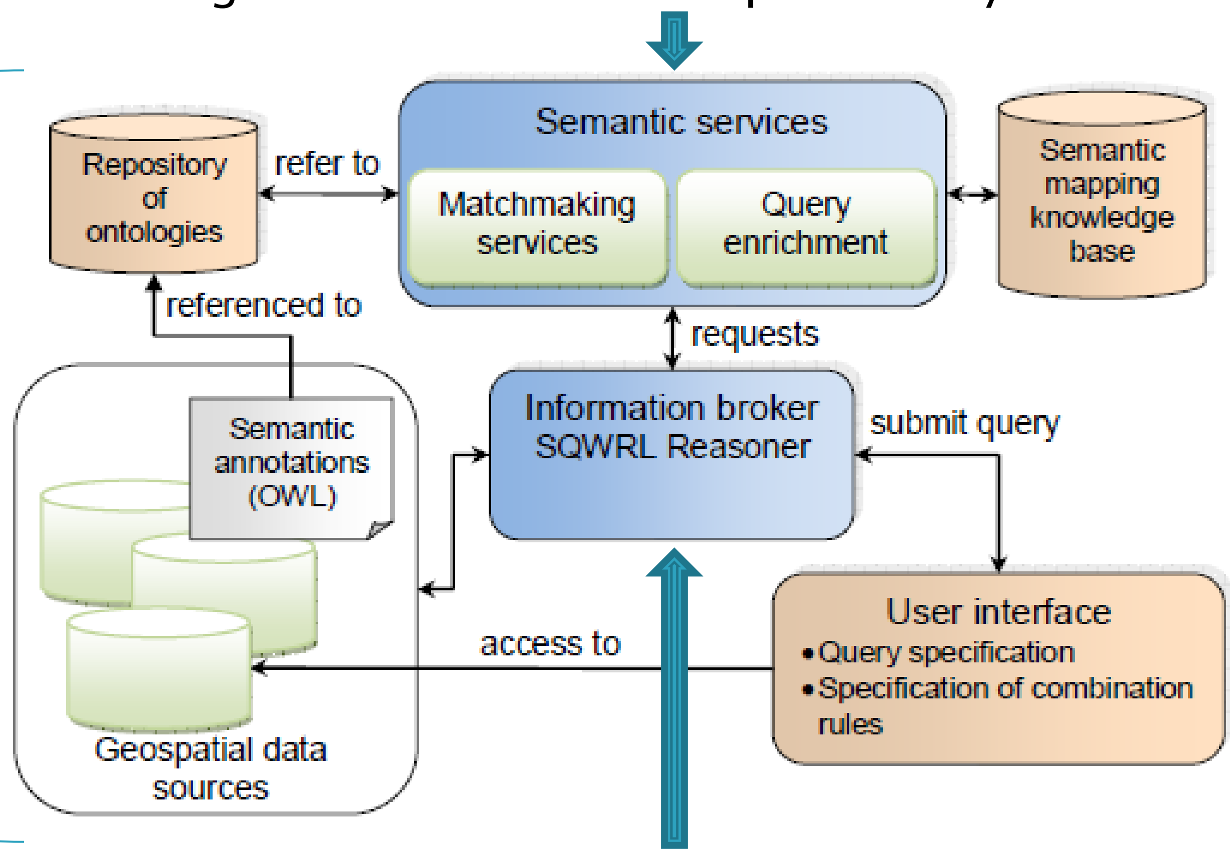
$$Region(?R) \wedge HasAirParticleConcentration(?R, C) \wedge HasTemperature(?R, T) \\ \rightarrow sqwrl{:}select(?R)$$

- SQWRL can be used to express queries that relate elements (classes and properties) from different sources in a same statement.

SQWRL Approach for Retrieval of Complementary Data

3. Semantic services are used to resolve semantic heterogeneities between complementary sources

1. Geospatial data sources are annotated to application ontologies



2. SQWRL-based information broker bridges the user's query and sources

Semantic annotation

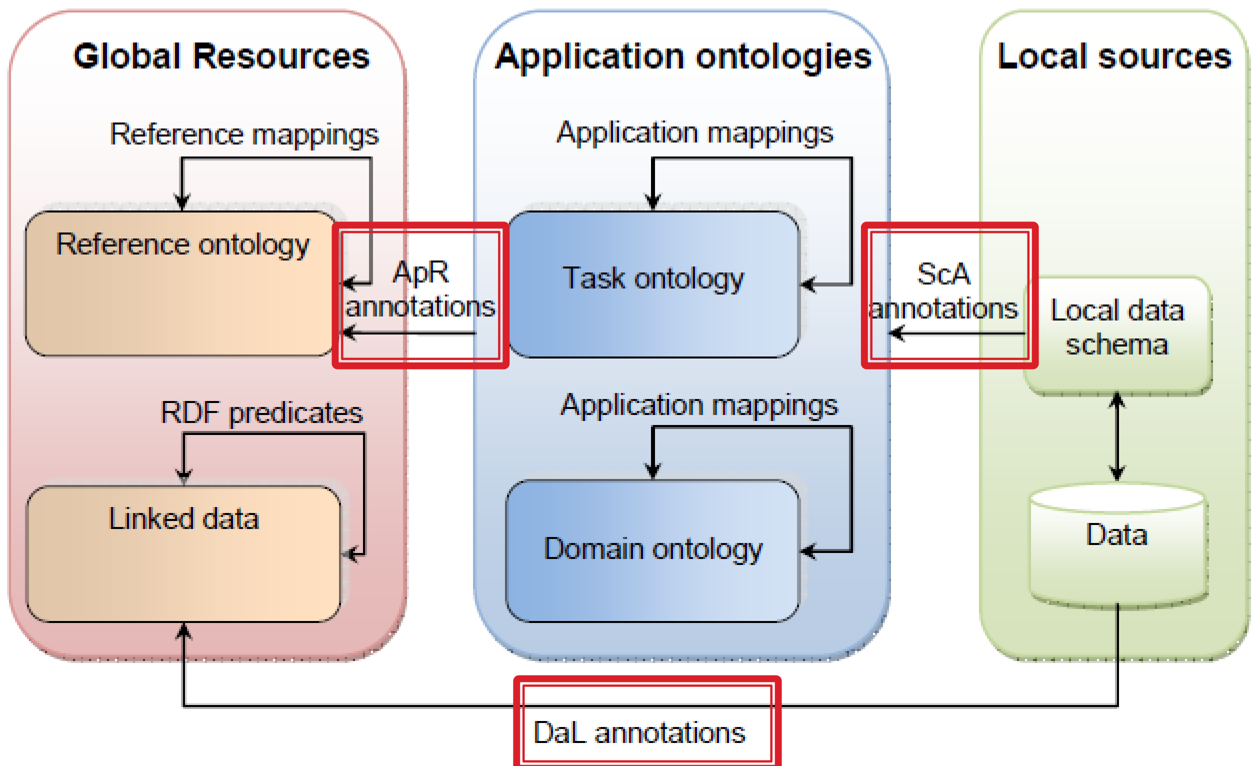
- Semantic annotations are defined by Klien [2007] as explicit correspondences (mappings) between the components (classes, attributes, relations, values, etc.) of the schema of a data source and the components (classes, properties, etc.) of an ontology.
- Semantic annotations formalize the semantics of a component by assigning a formalized meaning to it (e.g. expressed by OWL)
- Semantic annotations enable reasoning process without altering the local data schemas

Dealing with semantic heterogeneity using semantic annotation and mapping system

Three levels of annotations :

- From local source schema to application ontology (ScA annotations)
- From application ontologies to reference ontology (ApR annotations)
- From data to linked data (DaL annotations)

Annotations enable to specify semantics according to common resources while not altering local schemas or ontologies

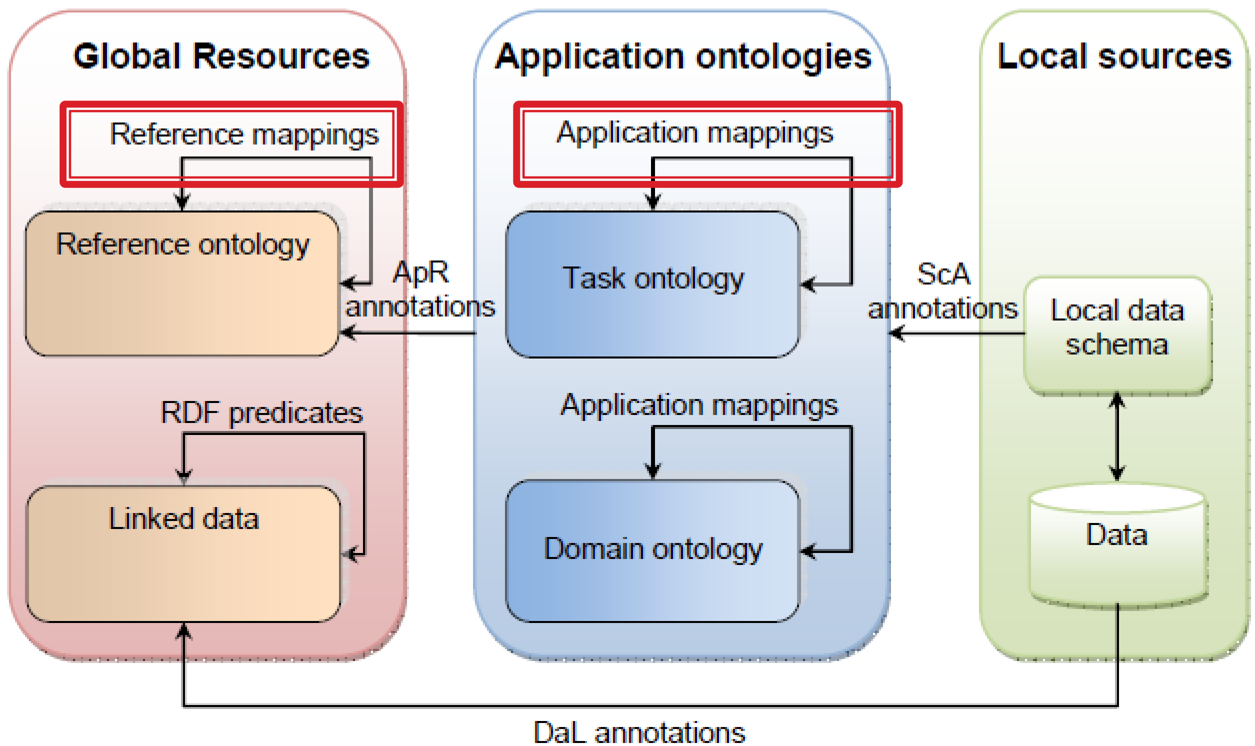


Dealing with semantic heterogeneity using semantic annotation and mapping system

Two types of mappings:

- Mapping between two application ontologies
- Mapping between two reference ontologies

Mappings relates ontologies from the same level (application or reference) and can be established with the help of annotations



Semantic Query Enrichment

- query enrichment = expand the query with additional elements from other ontologies or linked data elements

SQWRL Query

Composed of two types of elements:

Application ontology elements (classes and properties)

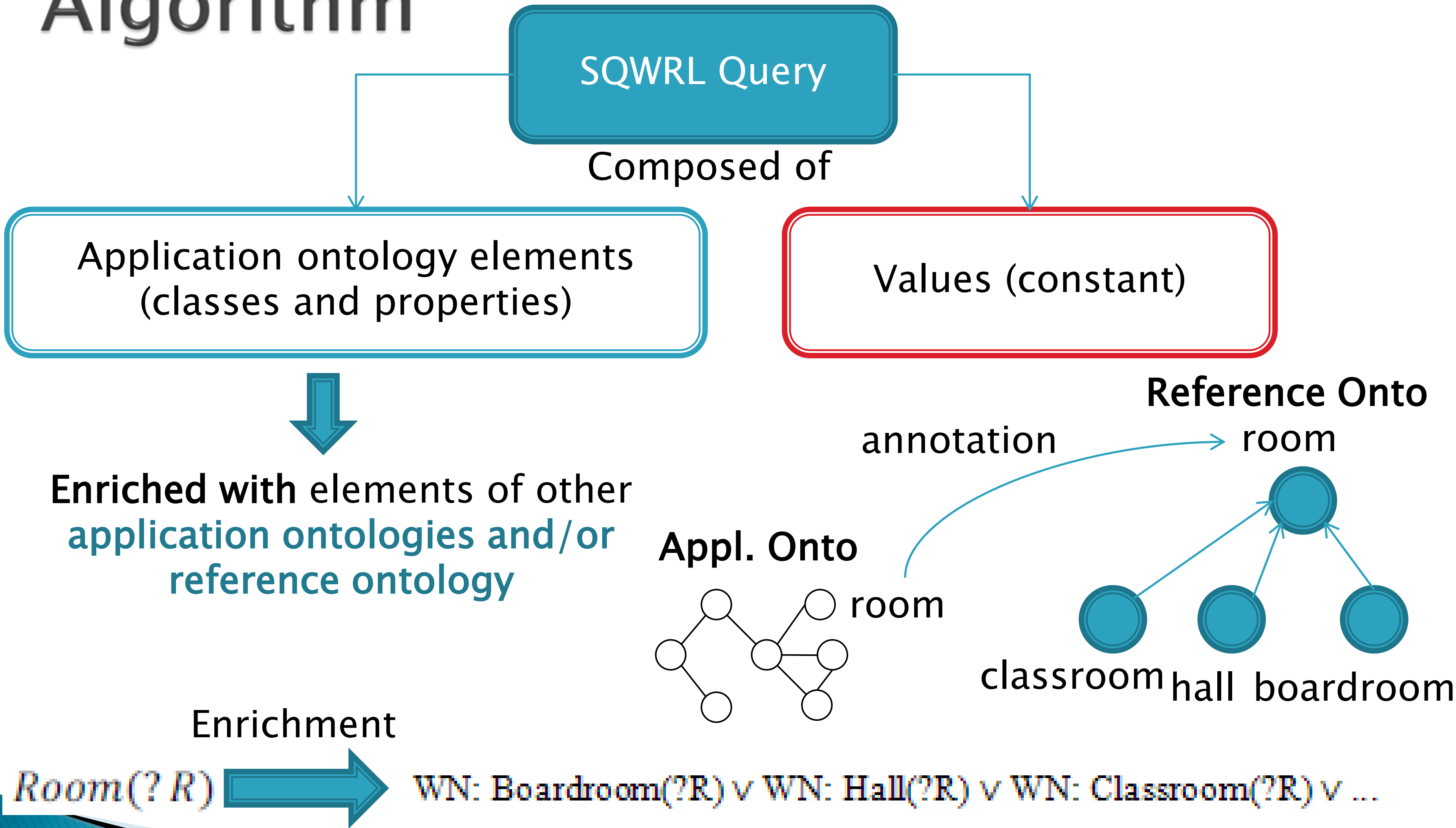
Values (constant)

Example

Example

$$\boxed{Building}(?B) \land Near(?B, \boxed{University\ of\ Calgary}) \land Room(?R) \land PartOf(?R, ?B) \land HasCapacity(?R, 100) \rightarrow sqwrl{:}select(?B)$$

SQWRL Query Enrichment Algorithm



SQWRL Query Enrichment Algorithm

SQWRL Query

Composed of

Application ontology elements (classes and properties)

Values (constant)

Enriched with elements of
Linked Data
For example, GeoNames

University of Calgary

UofC

...

Enrichment with unique URI in GeoNames

http://www.geonames.org/7626260/university-of-calgary.html

Example of query enrichment

$$Building(?B) \wedge Near(?B, University\ of\ Calgary) \wedge Room(?R) \wedge PartOf(?R, ?B) \wedge HasCapacity(?R, 100) \rightarrow sqwrl{:}select(?B)$$

- All elements of the query are enriched with additional elements:

Original query statement	Enriched query statement excerpt
Building(?B)	BNDT:Building(?B) ∨ BNDT:Arena(?B) ∨... ∨ BNDT:CommunityCentre(?B) ...
Near(?B, UniversityOf-Calgary)	Cyc: Touches(?B, UniversityOfCalgary) ∨ Cyc: AdjacentTo(?B, UniversityOfCalgary) ∨ Cyc: CloseTo(?B, UniversityOfCalgary) ...
Room(?R)	WN: Boardroom(?R) ∨ WN: Hall(?R) ∨ WN: Classroom(?R) ∨ ...
PartOf(?R, ?B)	Cyc: PhysicalPart(?R, ?B) ∨ Cyc: PhysicalPortion(?R, ?B) ∨ Cyc: InternalPart(?R, ?B) ∨ Cyc: ExternalPart(?R, ?B)…
(UniversityOfCalgary)	(http://www.geonames.org/7626260/university-of-calgary.html)

Conclusions:

- Improved semantic interoperability in ad hoc networks of geospatial databases.

- For retrieval of spatial information:
  - We have coupled the SQWRL approach with a query enrichment approach based on a framework of semantic mappings and annotations between multiple resources
  - SQWRL allows to express queries that relate elements from different sources
  - SQWRL queries can be semantically enriched to deal with semantic heterogeneity

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