Mechanisms for distributed data fusion and reasoning in wireless sensor networks

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Introduction

Despite the impressive progress, several shortcomings still exist which prevent Sensor Networks (SN) from being fully deployed and exploited in everyday life applications.

Resource limitations

Limited amount of energy, short communication range, low bandwidth limited processing and storage capabilities.

***Heterogeneity** of infrastructure*

Different types of devices, protocols and interfaces, encoding schemes and controlled vocabularies, policies and application logic.

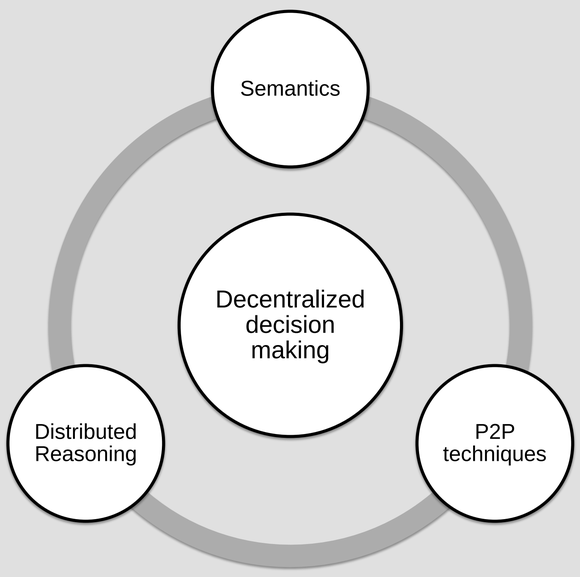
*Requirements for **vast amounts of data** collections.*

By default, sensor data is unstructured, unbounded, continuous and distributed.

Common infrastructure

A different system model is needed, suited for large scale and dynamic environments, in order to support **multiple applications**, **external information sources**, multiple existing and newly deployed **SN infrastructures**, tied together in a integrated infrastructure built upon a common **information space.**

Self-management and decentralized decision making requires a framework for **reliable and decentralized storage and retrieval** of data [1], a set of **ontologies** for the representation of sensor observations and sensor descriptions [2,3] and an efficient **distributed reasoning** and querying mechanism.



Distributed reasoning

Distributed reasoning mechanisms can be classified based on the underlying peer-to-peer network and its **overlay structure**:

The Artificial Intelligence area (read-only access)

✓ **Unstructured** overlays

✓ Presupposed **semantic mappings** between neighbors' ontologies

✓Soundness and completeness depend on the existence of these mappings

The Database Systems area (full access)

✓ **Structured** overlays

✓ Fully Distributed storage – **DHT-based** RDF stores

Hybrid approach

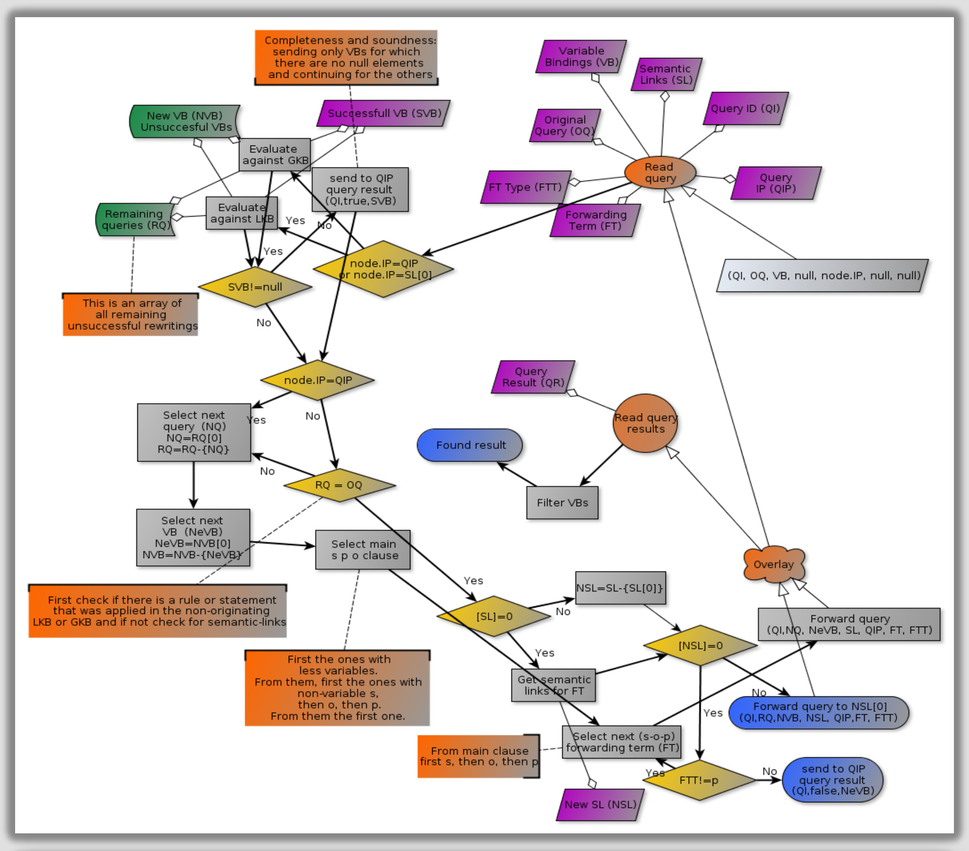
P2P techniques for reliable and efficient storage and retrieval of SN data and RDF model and semantics for the representation and interpretation of SN data.

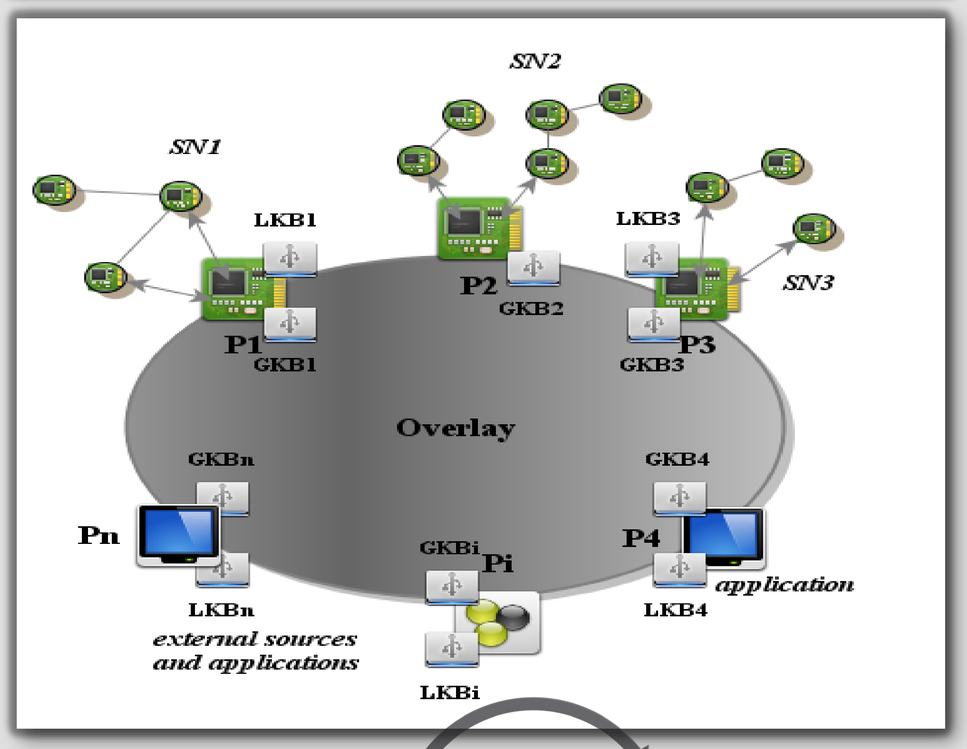
Participating nodes:

✓ Application nodes

✓ External information sources

✓ Hyper nodes from the underlying SNs (gateways, cluster heads, etc)





Semantic overlay

Every peer in the semantic overlay maintains

✓ a **global KB** (**GKB**), where **semantic links** or **distributed statements** from the DHT are stored (required)

✓ a **local KB** (**LKB**), keeping it's own semantically annotated data (optional)

Along with statements, **rules** (ontological axioms or application rules) are also distributed. This ensures that reasoning can be completed without requiring every node to know the ontological axioms needed.

A counterbalance between the full distribution of common ontologies and the creation of links for the rare ones seems a promising approach for large scale and dynamic settings.

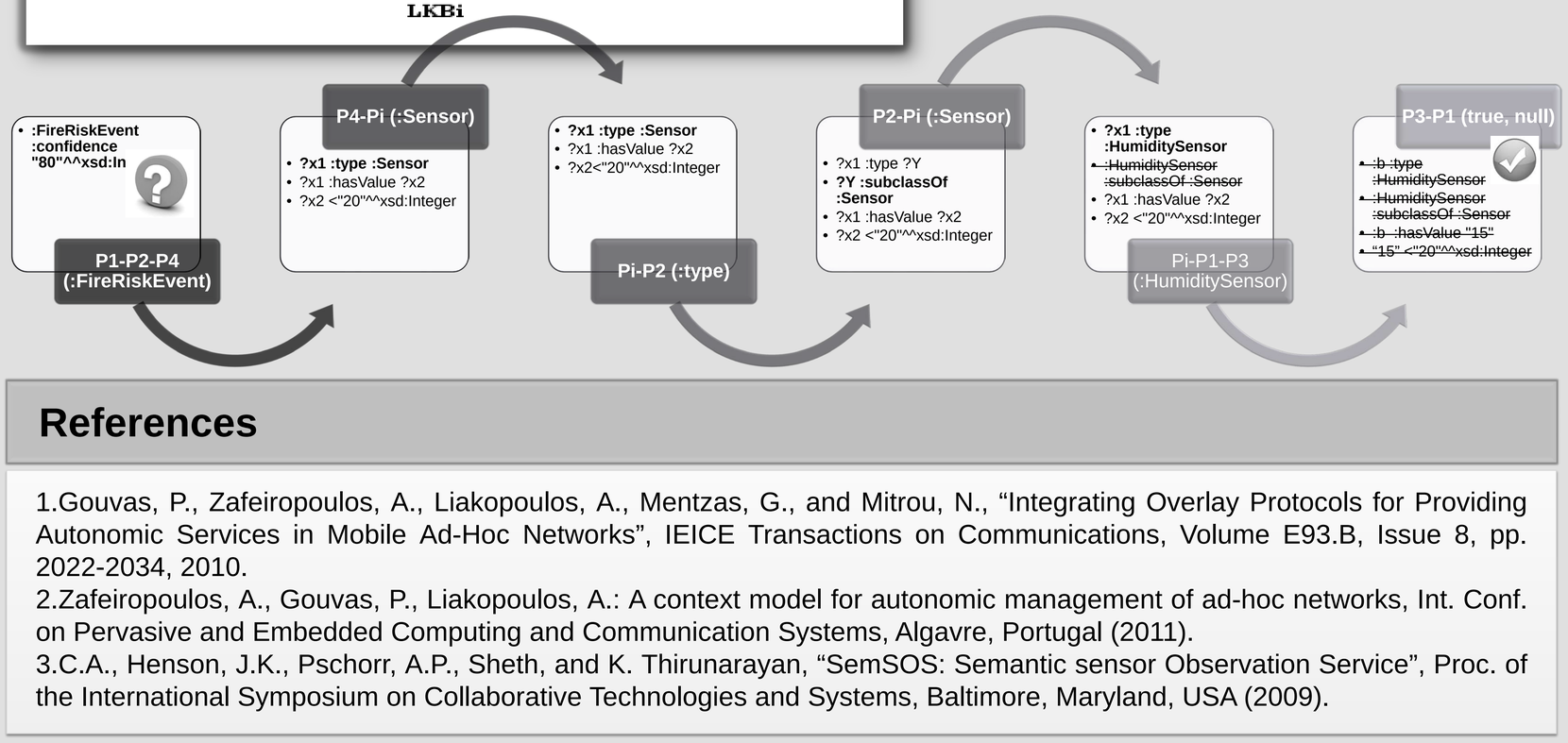
P1 (10.1.1.1)
- **GKB1**
- (hash(:HumiditySensor), 10.1.1.3)
- (hash(:HumiditySensor), <:HumiditySensor, :subclassOf, :Sensor>)
- ...
- **LKB1**
- <:a, :type, :TempSensor>
- <:a, :hasValue, "45"^^xsd:integer>
- ...

P2 (10.1.1.2)
- **GKB2**
- (hash(:FireRiskEvent), 10.1.1.4)
- (hash(:type), ?x :type ?Z :- ?x :type ?Y & ?Y :subclassOf ?Z)
- ...
- **LKB2**
- ...

P3 (10.1.1.3)
- **GKB3**
- (hash(:TempSensor), 10.1.1.1)
- (hash(:subclassOf), <:HumiditySensor, :subclassOf, :Sensor>)
- ...
- **LKB3**
- <:b, :type, :HumiditySensor>
- <:b, :hasValue, "15"^^xsd:integer>
- ...

P4 (10.1.1.4)
- **GKB4**
- ...
- **LKB4**
- :FireRiskEvent :confidence "80"^^xsd:Integer :- ?x1 :type :Sensor & ?x1 :hasValue ?x2 & ?x2 < "20"^^xsd:Integer
- ...

Pi (10.1.1.100)
- **GKBi**
- (hash(:b),10.1.1.3)
- (hash(:Sensor), <:HumiditySensor, :subclassOf, :Sensor>)
- ...
- **LKBi**
- <:HumiditySensor, :subclassOf, :Sensor>
- …



References

1.Gouvas, P., Zafeiropoulos, A., Liakopoulos, A., Mentzas, G., and Mitrou, N., "Integrating Overlay Protocols for Providing Autonomic Services in Mobile Ad-Hoc Networks", IEICE Transactions on Communications, Volume E93.B, Issue 8, pp. 2022-2034, 2010.
2.Zafeiropoulos, A., Gouvas, P., Liakopoulos, A.: A context model for autonomic management of ad-hoc networks, Int. Conf. on Pervasive and Embedded Computing and Communication Systems, Algavre, Portugal (2011).
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