Rule-Based Semantic Sensing

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Introduction

- Sensor Network Middleware (SNM) [1]:

"The main purpose of middleware for sensor networks is to support the development, maintenance, deployment, and execution of sensing-based applications".

- Practical Aims:
  - Allow **non-IT experts** to bring something to the system e.g. specify data fusion logic.
  - Ability to **query** for **high-level facts** about the world not just for raw sensor readings (need for semantics).
  - Query results should be delivered in **easily parseable** format.
  - Use as many available sensors as possible.

Problem

- Popular Sensor Network Middlewares (SNM) such as: GSN, ITA Sensor Fabric, Pachube and SWE-compatibles are rather **low-level**.
  - Simply provide sensor data.
  - Don't make the **application development** easy.
  - Don't meet all **10 challenges** for SNM [2] to satisfactory level.
  - Data Fusion logic **implicit** to the system.

- **High-level** SNM such as Semantic Streams allows to query for real world facts but **lacks** flexibility, interoperability and extensibility (built for purpose).

Research Question

- Can previously stated problems be overcame by using an RBS on the top of existing SNM?

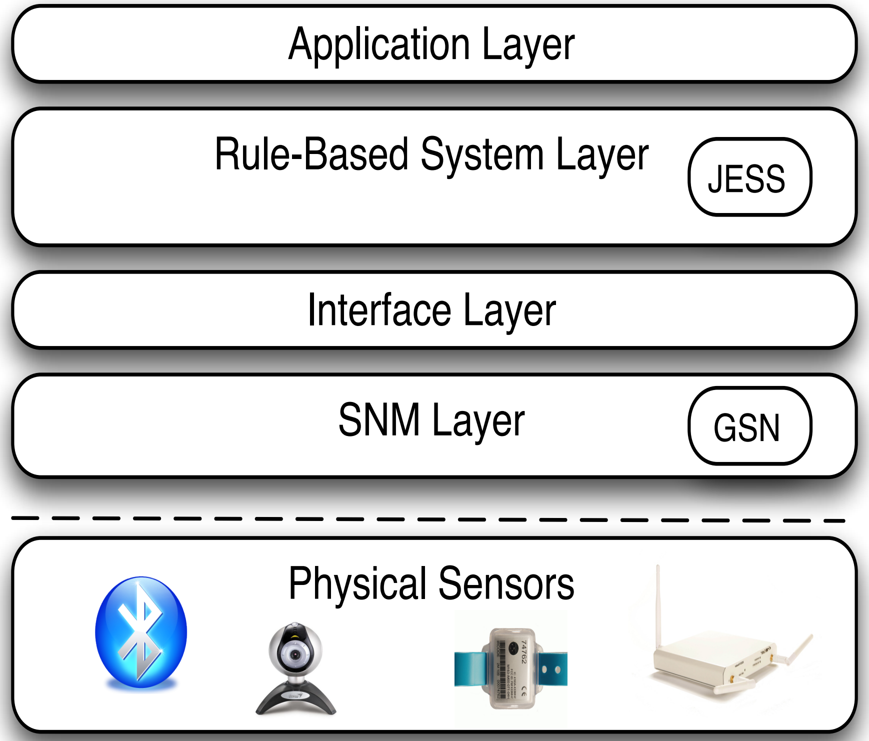
- Rules help to address these problems and can greatly improve the SNM. Such an approach to sensor networks addresses many of the **10** identified **challenges** for SNM (Data Fusion, Application Knowledge, Adaptability, Abstraction Support and QoS).

- Using Rule-Based approach with SNM also gives all the **advantages of RBS** systems: reproducibility, permanence, consistency, timeliness, efficiency, breadth, completeness, documentation, etc [3].

Addressed Challenges Explained

- **Data Fusion** - Rules fuse simple facts to infer higher-level facts about the real world.
- **Application Knowledge** - Expert's knowledge encoded into an automated system.
- **Adaptability** - Applicable to any domain, non-programmers can write rules.
- **Abstraction Support** - Each fact is an interpretation of data. How the data is interpreted is determined by an expert via rules.
- **QoS Support** - Multiple combinations of rules and facts can often answer the same query. Solution can be explained by retracing the reasoning.
- **Scalability** - To be addressed in my PhD.
- Remaining challenges are addressed by SNM: **Network Heterogeneity, Dynamic Topology, Resource Constraints and Security.**

Proposed System Architecture

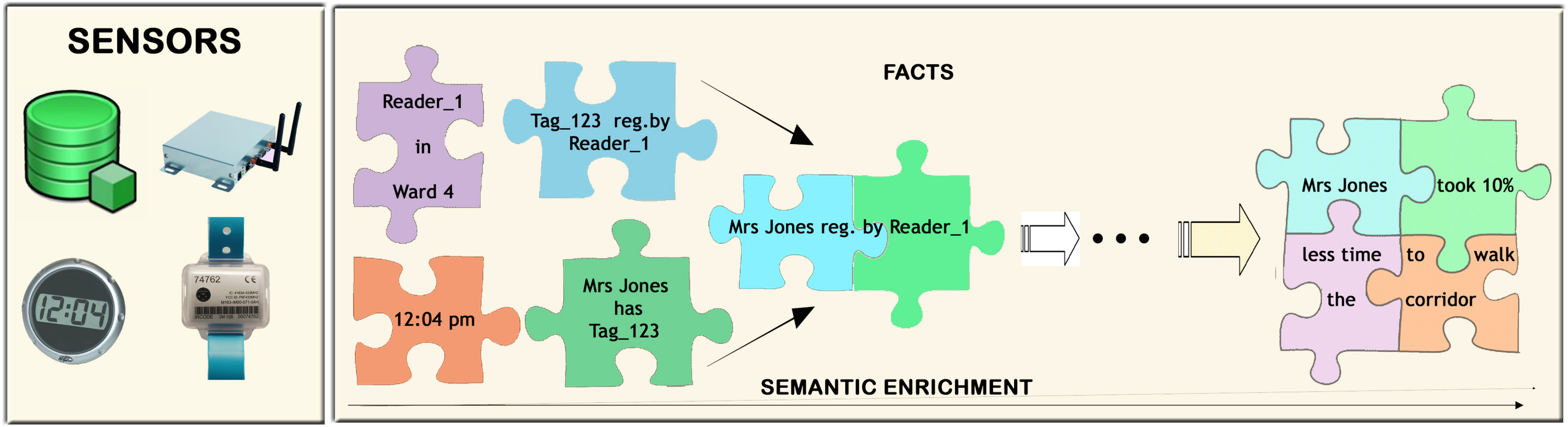


- Bridges UI with the Reasoning Engine layer. Exposes facts and queries to the app. in easily consumable format (JSON).
- Heart of the system. Continuously reasons over stored and incoming sensor data.
- Injects sensor data into the Reasoning Engine in the form of facts.
- Abstracts away network heterogeneity.

Benefits

- Current version:
  - Layered architecture.
  - Query responses delivered in JSON format (parseable in any programming language).
  - All software components are free of charge for non-commercial use.
    - RBS Layer – JESS (CLIPS format)
    - SNM Layer – GSN (Relatively easy to set up and write wrappers for new software/hardware sensors)
  - OS independence.

Conceptual Representation



Pilot Application

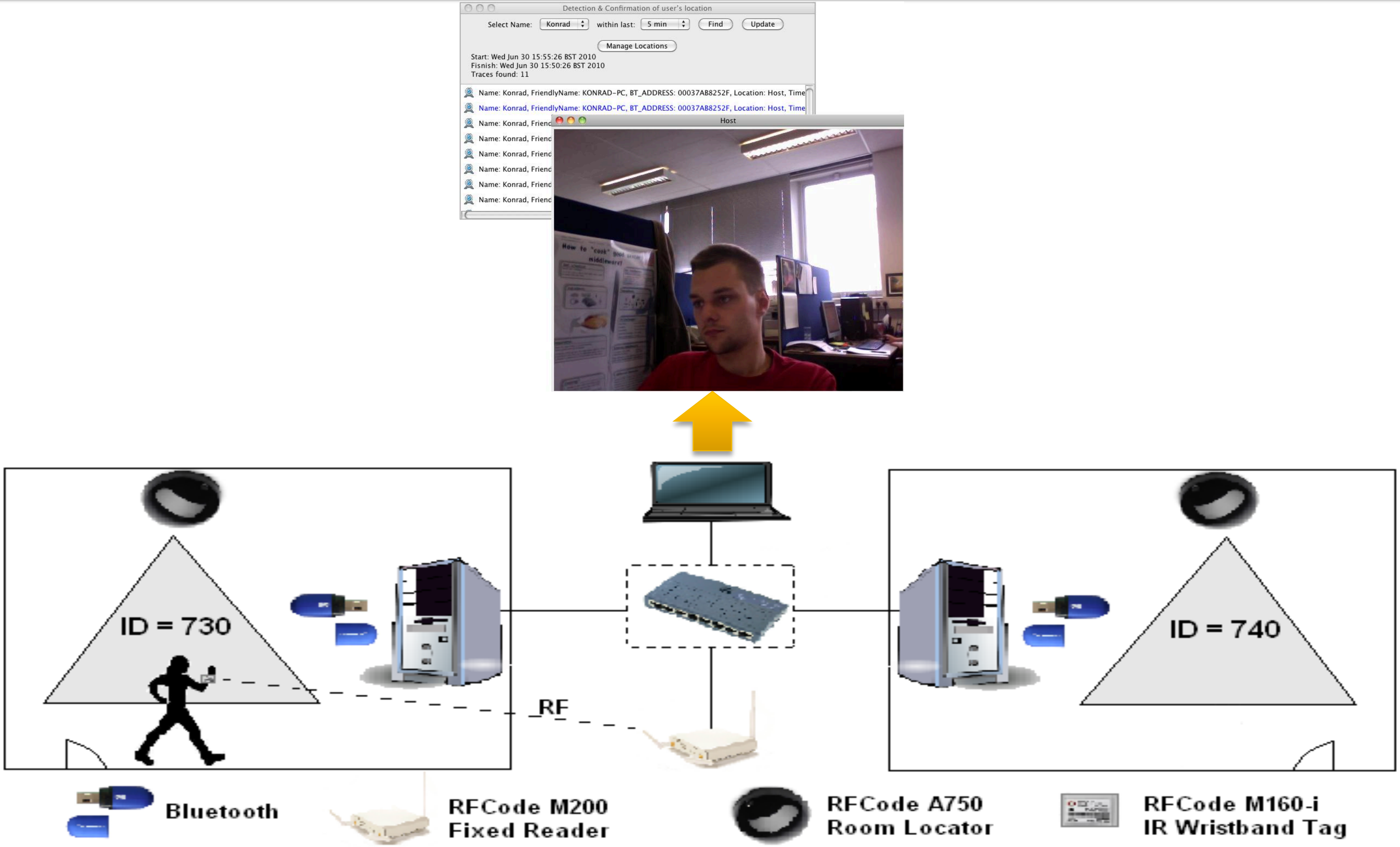
- **Aim:** Provide information on:
  - people's indoor locations,
  - their history of visited locations,
  - and info on walking speed between the locations (corridor test).
- **Prove:**
  - Software suitable for different domains.
  - Rules can be easily specified by the user in order to extend/alter functionality.
  - Proposed architecture is suitable to address SNM challenges.

Use Cases

- **Surveillance**
  - Where is Pete? Tracking users via their Bluetooth/RFID traces in Cardiff University Computer Science Department.
  - Camera picture taken at most recent locations to confirm person's presence (*sensor cueing*).

- **Healthcare**
  - Where is Mrs. Jones? Tracking stroke patients via use of active RFID tag.
  - Doctors can monitor patients' activity outside therapeutic sessions to better assess their condition -> earlier or later discharge.

Surveillance



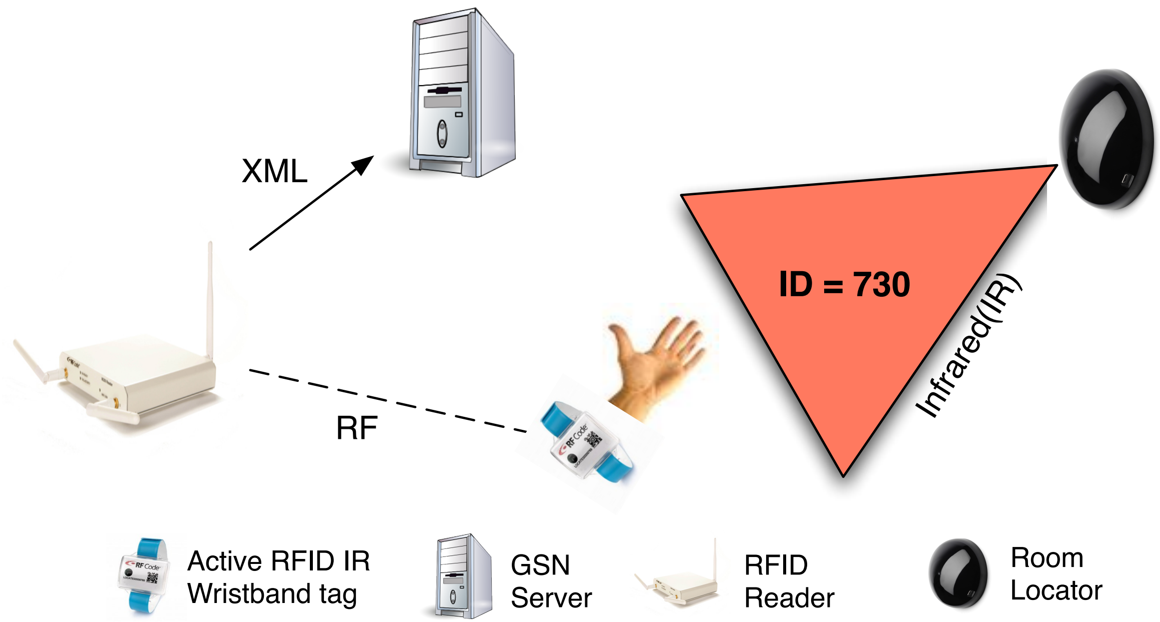
Healthcare (RSU)

Purpose/Aims of the project

The aim of the project is to provide information on patients' activity and location within controlled environment equipped with RFID technology. In this environment patients, recovering after a serious medical condition (e.g. stroke), are monitored without human assistance in order to assess their fitness/mobility.

Healthcare: Sensors Explained

- Active RFID tags (IR enabled, with motion sensors).
- Readers.
- Room Locator concept.



Facts

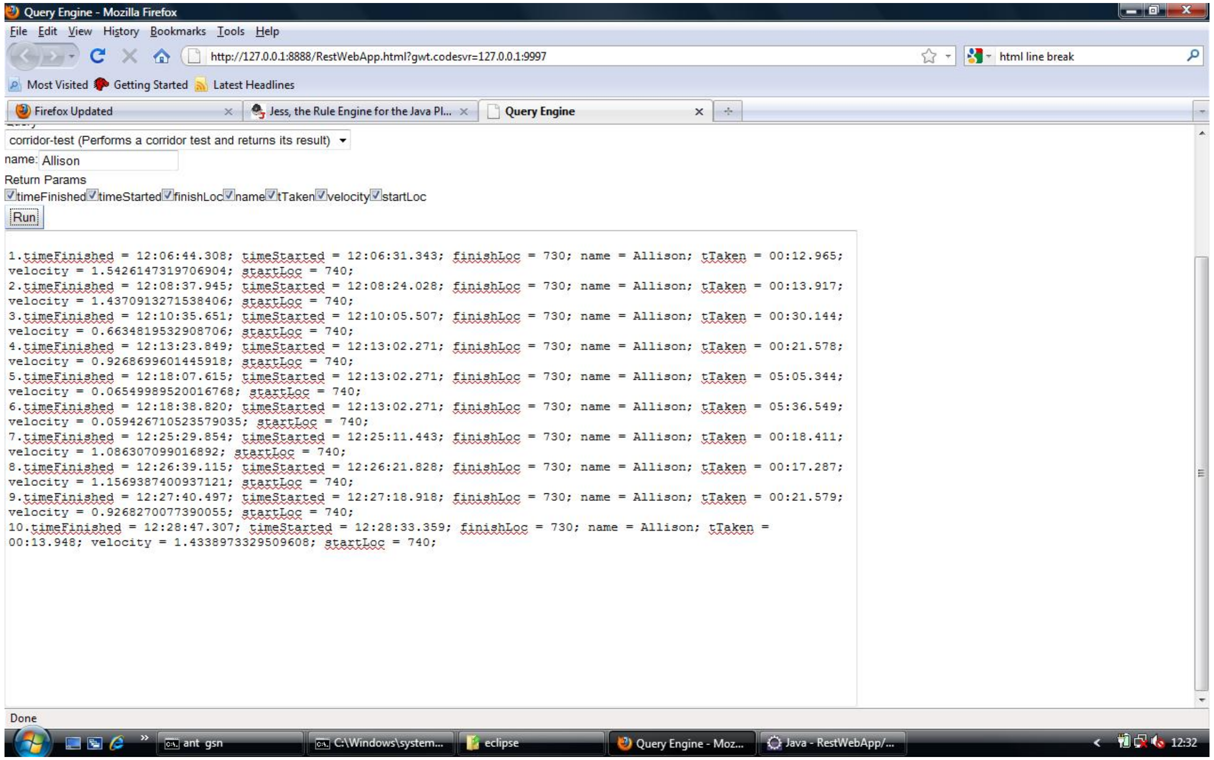
- From sensors:
  - **MobileTrace** – RFID (or BT trace in case of Surveillance app) with slots: location, address and time.
  - **Person** – simple mapping service (name -> deviceAddress).
  - **Corridor** – static data. Slots: endA, endB, length.

- Inferred by rules:
  - **is-seen-at** – slots: name, location and time.
  - **is-currently-at** – slots: name, location, tStart and tFinish.
  - **was-at** – slots: name, location, tStart and tFinish.
  - **was-tracked** – slots: name, endA, endB, tStart, tFinish, distance, tTaken and velocity.

Rules

- **seen_at** : MobileTrace observed at some location + RFID device registered with some user -> retract RFID trace, assert is-seen-at some location.
- **was_at** : is-seen-at at some location and is-currently-at different location -> retract both facts, assert was-at fact for old location, assert is-currently-at some new location.
- **update_current_loc** : is-currently-at some location and is-seen-at the same location -> retract is-seen-at, update is-currently-at with new finish time.
- **find_corridor_events** : was-at location_1, is-currently-at location_2, corridor instance with location_1 and location_2 as ends of corridor - > assert was-tracked.

Results



Recorded by the system			Recorded by hand		
tStart	tFinish	tTaken	tStart	tFinish	tTaken
13:30:44	13:31:26	42	13:30:43	13:31:21	38
13:36:21	13:37:00	39	13:36:18	13:36:56	38
13:59:25	14:00:08	43	13:59:22	14:00:03	41
14:13:41	14:14:16	35	14:13:38	14:14:08	30

- **Conclusion:** Never an underestimate but an overestimate.
- **Reason:** RFID tag report its status every 2 seconds.
- **Lesson learned:** promising results, only couple of rules specified and already 3 queries can be answered.

Way Forward (RSU)

- Introduce more sensors (tags) to the environment in order to infer the amount of movement each patient does (assisted/unassisted).
- Not quite closed-world assumption
  - Everything is tagged – tags with a built-in motion sensor attached to chairs, beds and walking aids.
  - Staff also tagged.
  - Visitors are not tagged (opportunity to include schedule info into the system e.g. visiting hours, linen changing, etc. to account for this).
- Events of interest (assisted/unassisted):
  - Bed to chair transfers.
  - Wheelchair ambulation to the day room.
  - Walking using walking aid.
  - + other activities.

Future Work (System Implementation)

- **Wrappers** to interface with other popular SNM such as Pachube, ITA Sensor Fabric, SWE-compatible middleware.
- Interface Layer needs modification to replace parsing XML to JavaBeans with **RDF** data **serialised in JSON**, so that the Reasoning Engine processes and exposes semantically rich data.
- Consider **backward-chaining** in conjunction with forward-chaining.
- **Choice** at the Application Layer to receive the data either in JSON or RDF format.
- Extensive **scalability** and **reliability** tests.

Questions

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References

1. K.Romer, O.Kasten, and F.Mattern, "Middleware challenges for wireless sensor networks," ACM SIGMOBILE Mobile Computing and Communications Review, vol.6, pp.59–61, Oct. 2002.
2. M.Molla and S.Ahamed, "A survey of middleware for sensor network and chal- lenges," in Parallel Processing Workshops, 2006. ICPP 2006 Workshops. 2006 International Conference on Parallel Processing Workshops, p.6, 2006.
3. C. E. Brown and D. E. O'Leary, "Introduction to Artificial Intelligence and Expert Systems." available at http://www.carfield.com.hk/document/ai/Expert+Systems.html.