Smart services for urban environments

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Outline

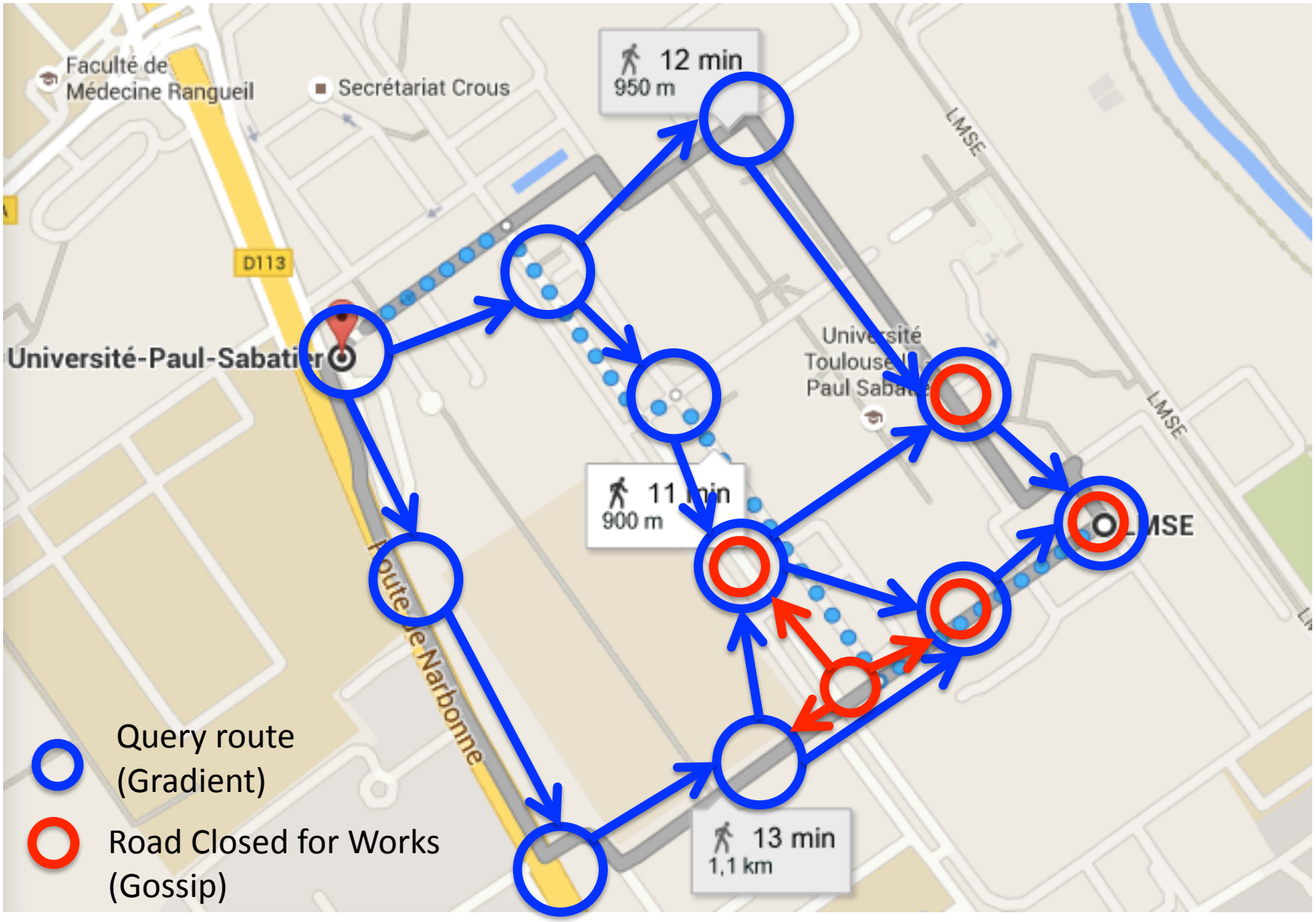
- Motivation
- Bio-inspired design patterns
- Spatial edge services
- Coordination models
- Prototyping platforms
- Actual Applications and Deployments

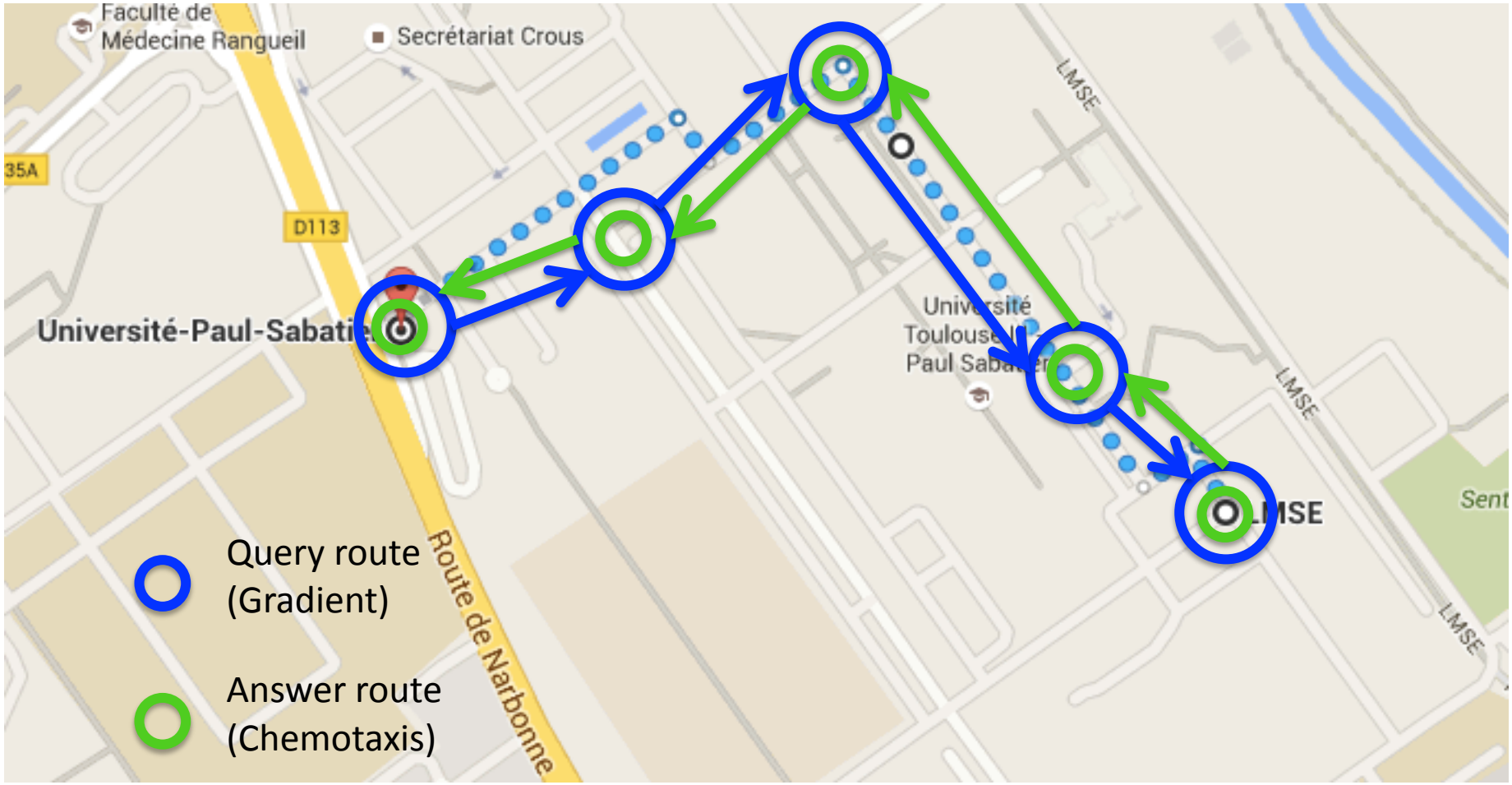
MOTIVATION

Communicating devices
Storing / Computing capabilities
Data propagation
“Things” collaborate to provide service

12 min
950 m
Secrétariat Crous
D113
abatier
Université
Toulouse III -
Paul Sabatier
LMSE
LMSE
LMSE
LMSE
11 min
900 m
LMSE
Sentier Natur
Route de Narbonne
13 min
1,0 km
Rue Malaga

Faculté de Médecine Rangueil
Secrétariat Crous
12 min
950 m
D113
Université-Paul-Sabatier
Université Toulouse III - Paul Sabatier
LMSE
11 min
900 m
Route de Narbonne
13 min
1,1 km
Query route
(Gradient)


Faculté de Médecine Rangueil
Secrétariat Crous
12 min
950 m
D113
Université-Paul-Sabatier
Université Toulouse III Paul Sabatier
LMSE
11 min
900 m
Route de Narbonne
13 min
1,1 km
Query route (Gradient)
Road Closed for Works (Gossip)



Self-organising mechanisms … provided as services
Computing occurs at the "edge"

Time- Space- Related Services

- Time-related: services may last just for a very short time for a specific purpose exploiting current contextual data
- Space-related: services have a meaning because the data they rely on or the data they spread is spatially distributed over a geographic area.
- Geographically distributed data collectively provides a specific meaning (e.g. artificial gradient)

- Services:
  - deposit data at geographic locations,
  - retrieve data, aggregate data,
  - provide information to users,
  - evaporate information, or
  - act on the environment.

Engineering dimension

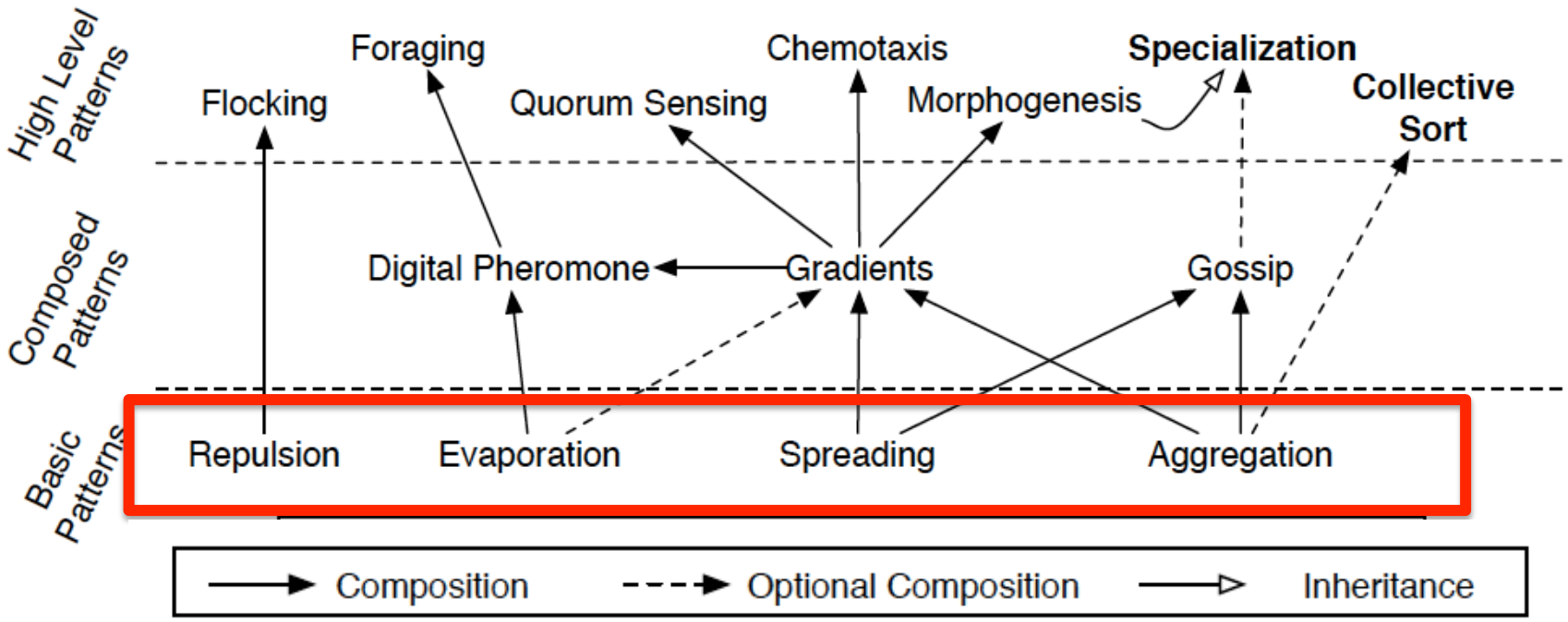
- Ready to use spatial services
- Deployed on-demand over physical environments by higher-level services or applications
- A spatial service is built dynamically through collaboration with other services

Spatial services - ingredients

- Spatial system services
  - Ready to use spatial services supporting other services
  - Based on bio-inspired self-organising mechanisms
  - ➢ Dynamicity, space- time- dimension
  - ➢ Bio-inspired mechanisms provided as services
- Spatial user services
  - Application level
- Chemical-based coordination platform
  - Provides built-in primitives supporting bio-inspired mechanisms

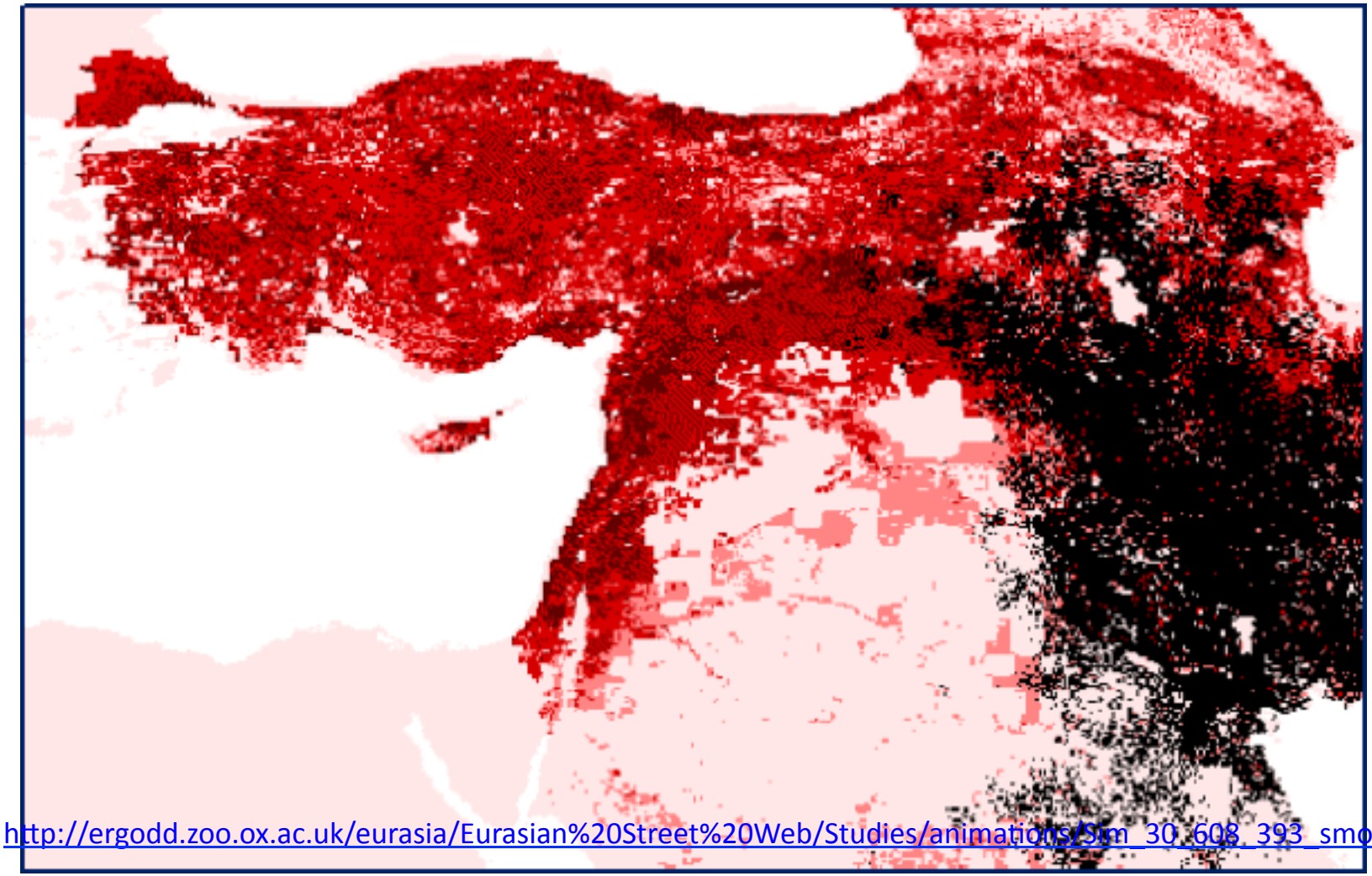
BIO-INSPIRED DESIGN PATTERNS

Self-Organising Design Patterns



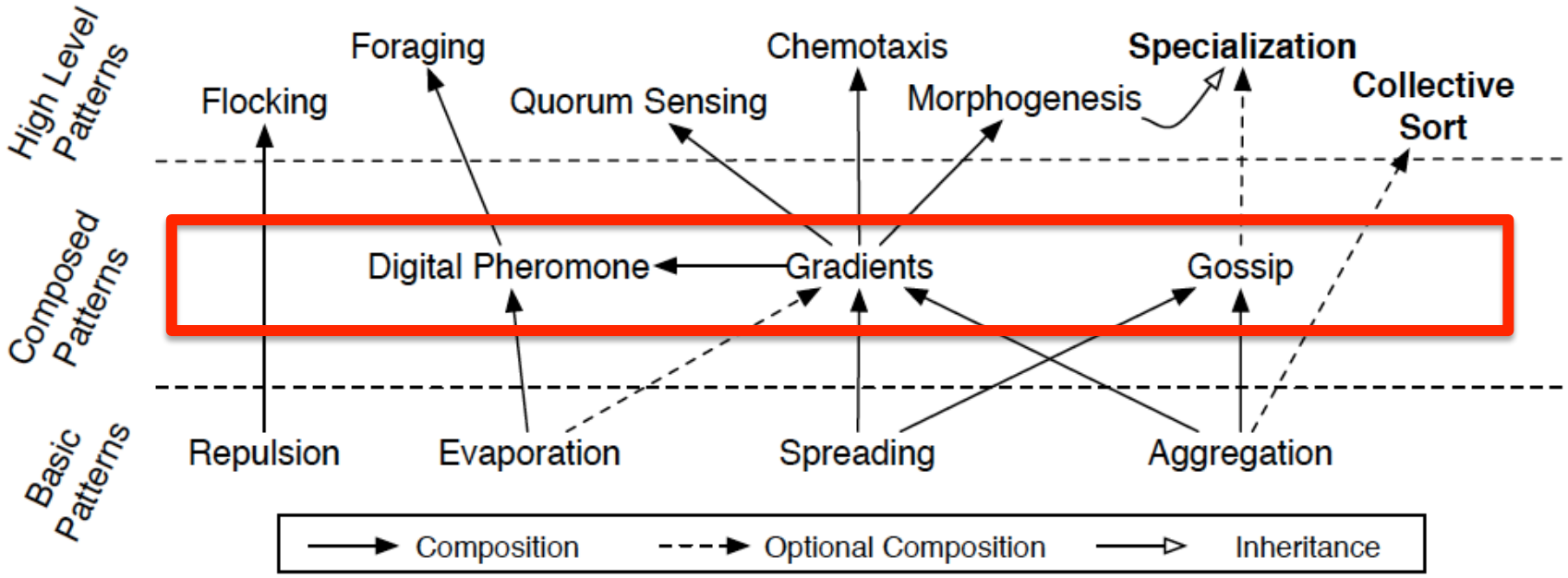
Fernandez-Marquez, J.L., Di Marzo Serugendo, G., Montagna, S., Viroli, M., Arcos, J.L.: Description and composition of bio-inspired design patterns: a complete overview. Natural Computing pp. 1-25 (2012)

Spreading

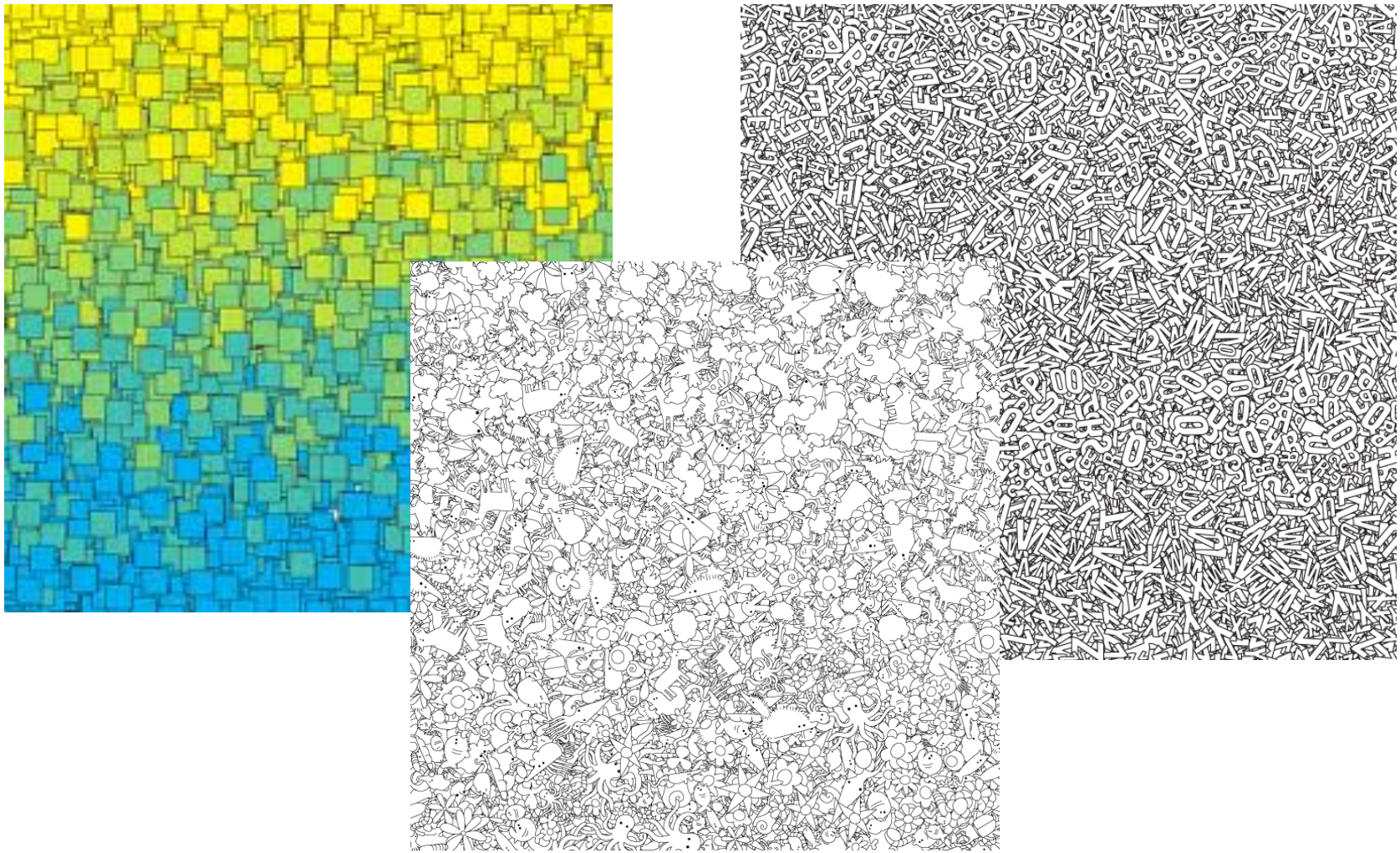


http://ergodd.zoo.ox.ac.uk/eurasia/Eurasian%20Street%20Web/Studies/animations/Sim_30_608_393_smoothed.gif

Self-Organising Design Patterns



Gradient



Gradient

Shortest Path

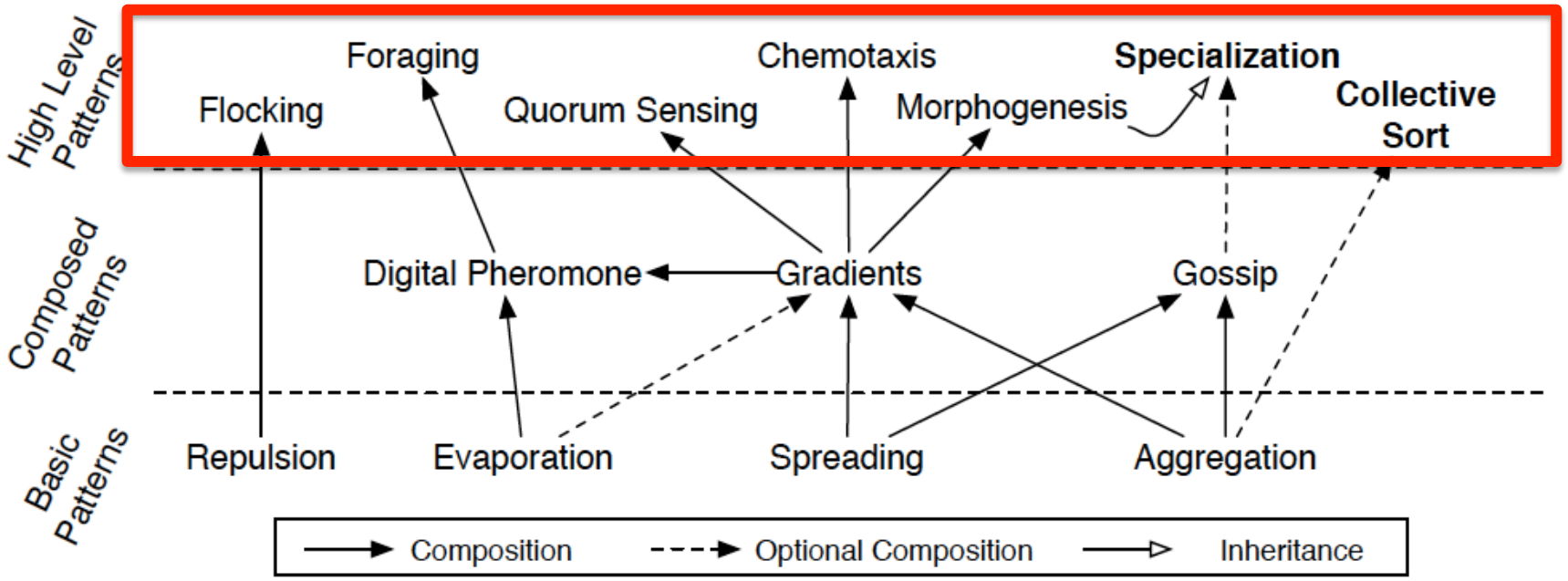
Information
Follows path

Defective
Node

New
Path

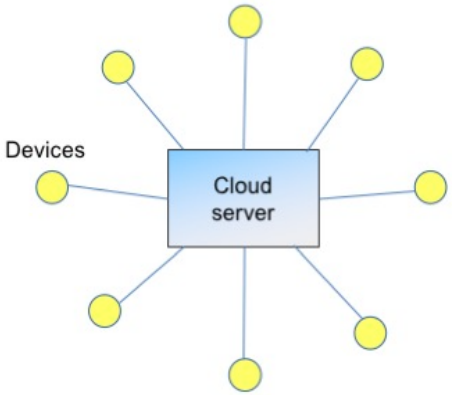
Gradient and Chemotaxis

Self-Organising Design Patterns

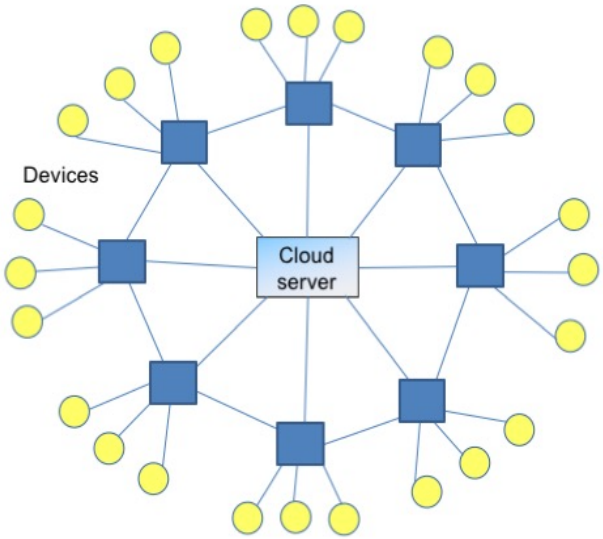


SPATIAL EDGE SERVICES

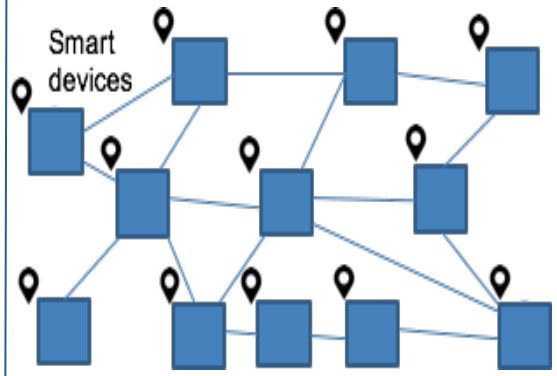
Spatial edge infrastructure



Centralized infrastructure



Edge infrastructure

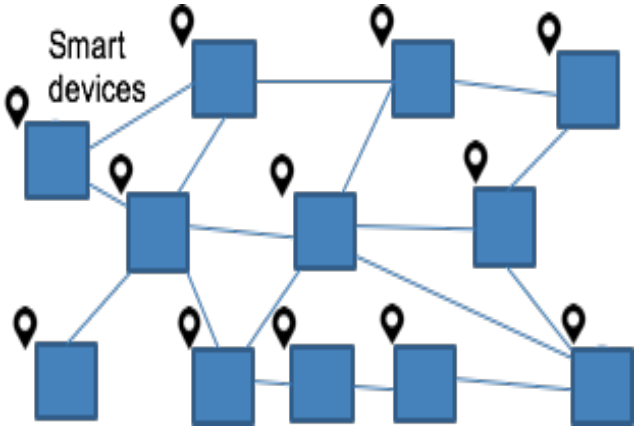


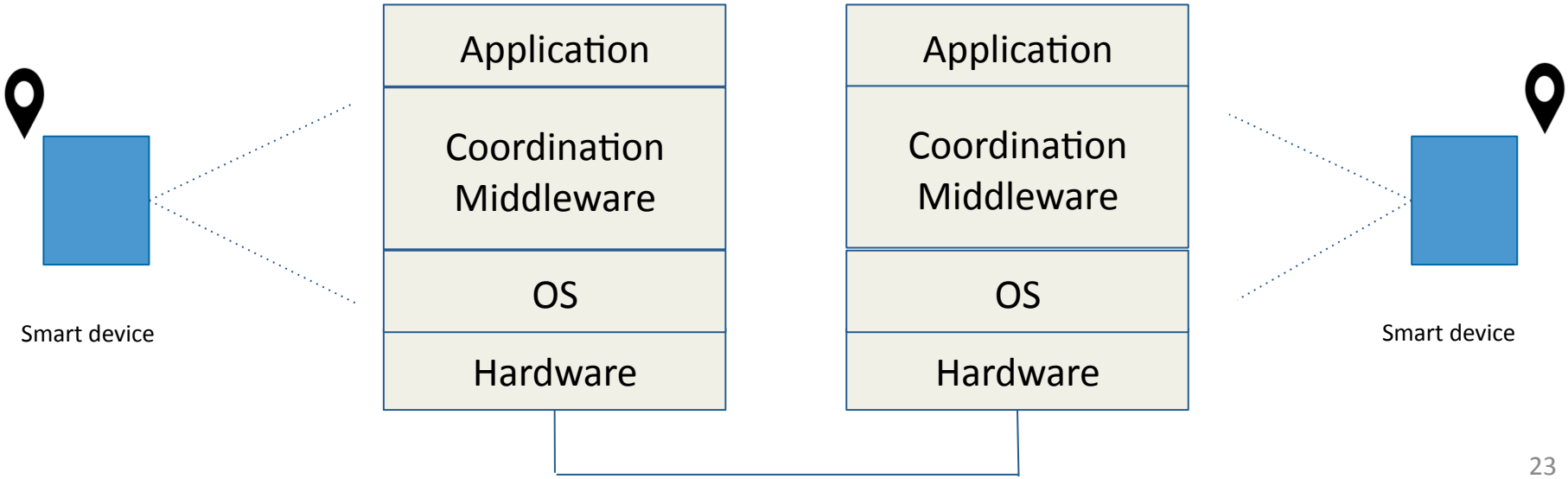
Spatial edge infrastructure

Coordination model

Coordination middleware : (SAPERE)

- Inspiration from **chemical reactions**
- Spontaneous interactions among services
- Spontaneous aggregation of data
- Context-awareness



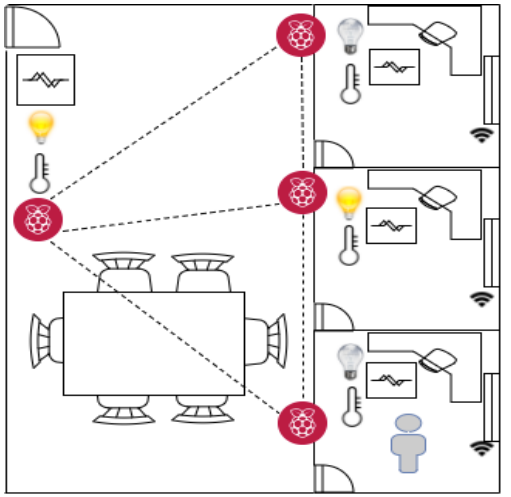


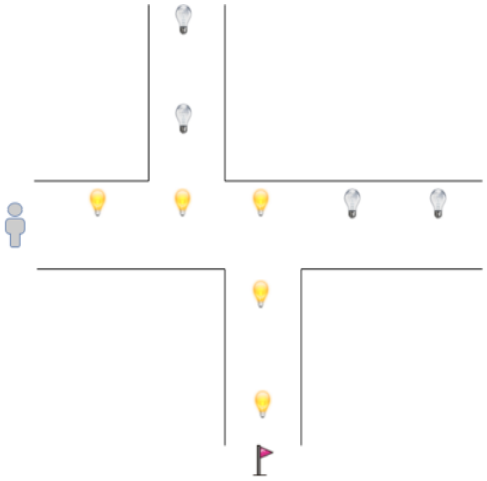
Spatial edge services

Spatial edge services
(Smart lighting, Smart parking, Smart Solar Energy Management, Hazard detection, Smart building)

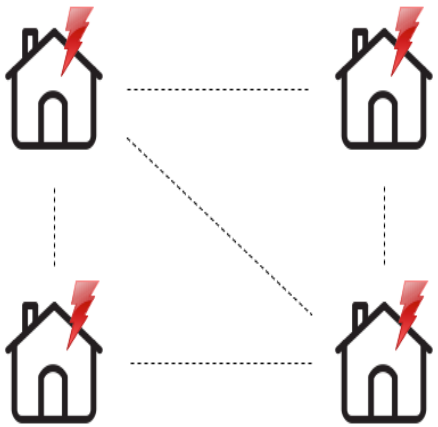
Spatial system services
(bio-inspired mechanisms)

Smart building



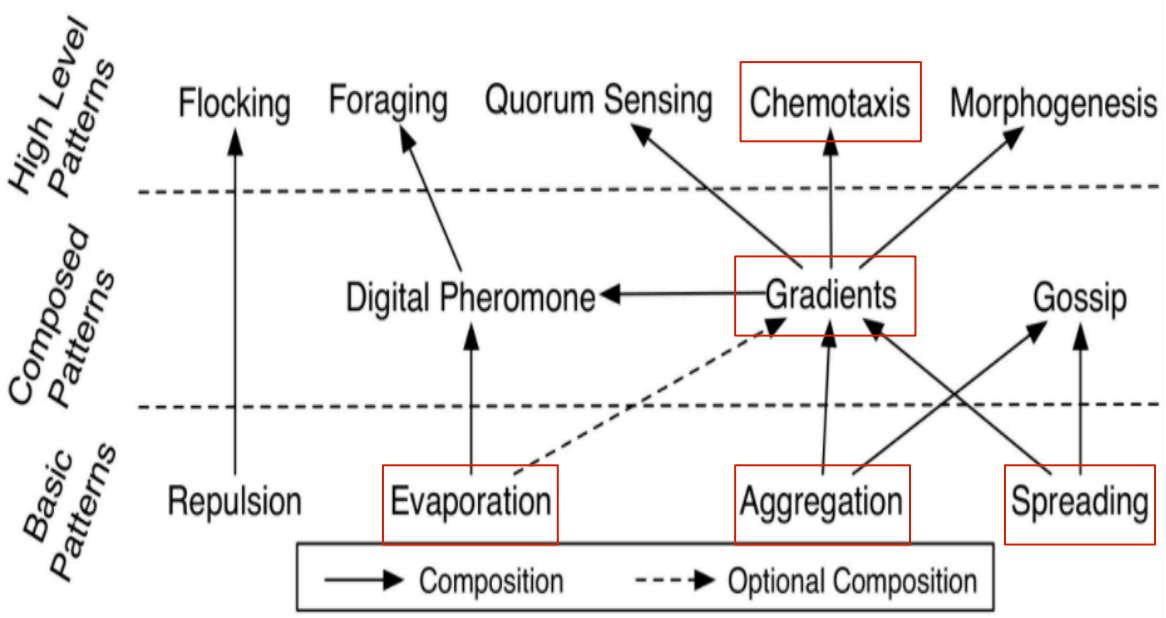


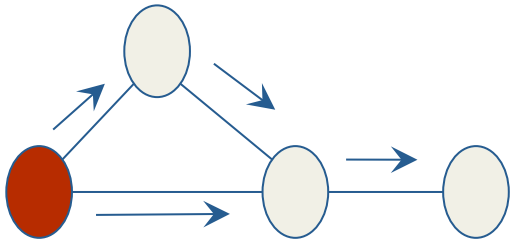
Smart lighting



Smart Solar Energy Management

Bio-inspired - spatial system services





Property
Key:x | Value:y

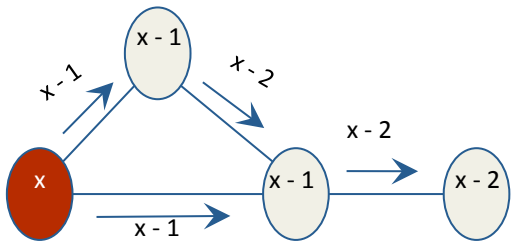
Property
Key:x' | Value:y'

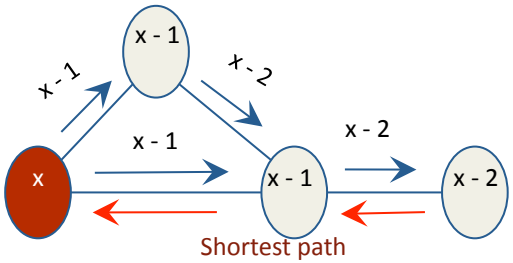
Aggregation operator : *

Property
Key:x | Value:y*y'

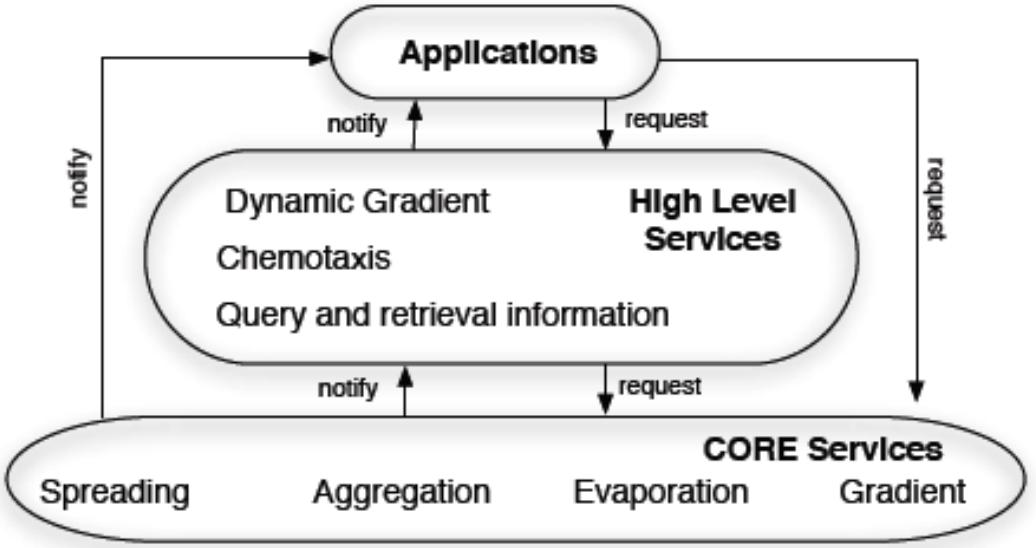
Property
Key:x' | Value:y'

Delete after x iterations



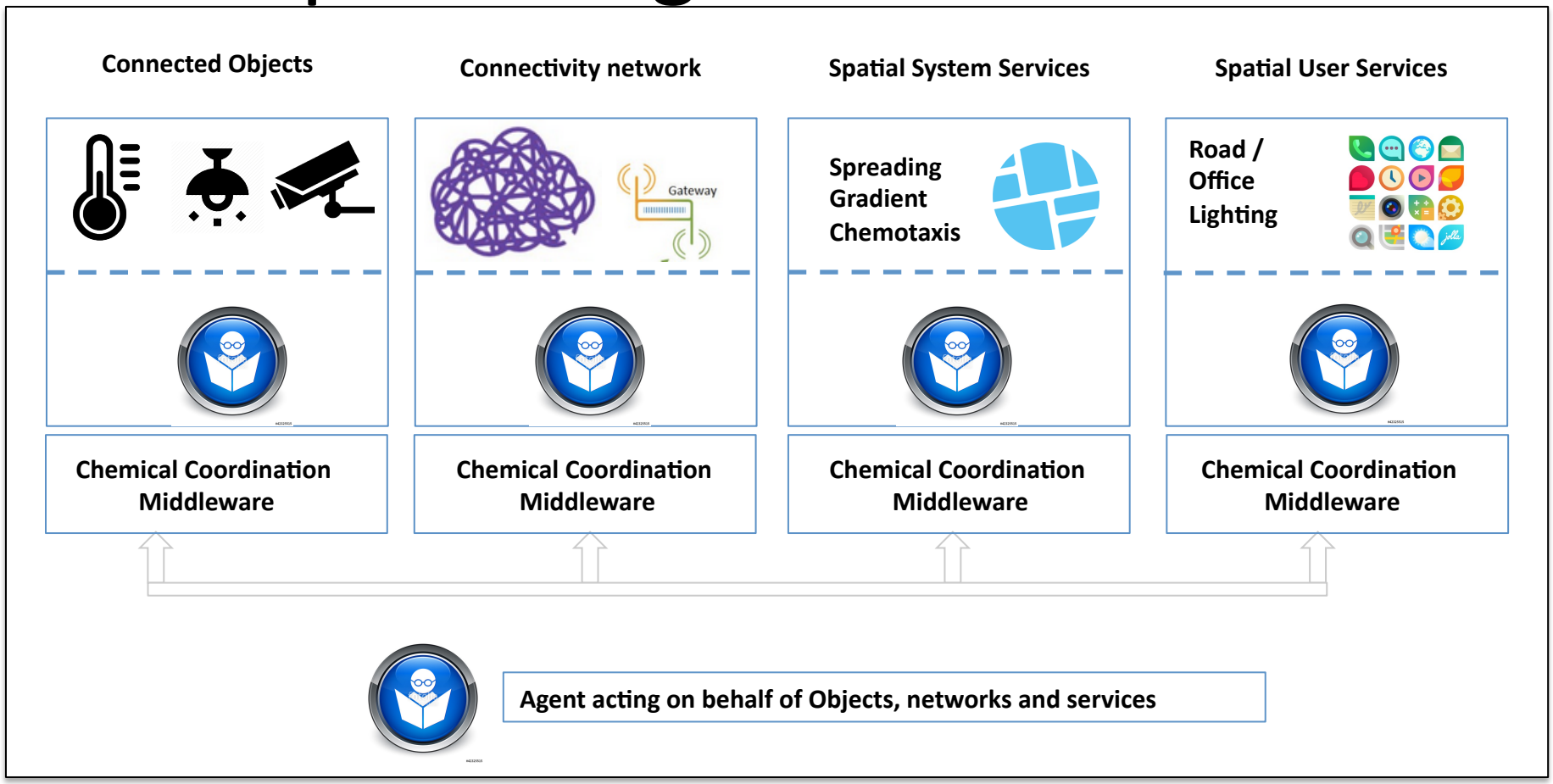


Spatial System / User Services

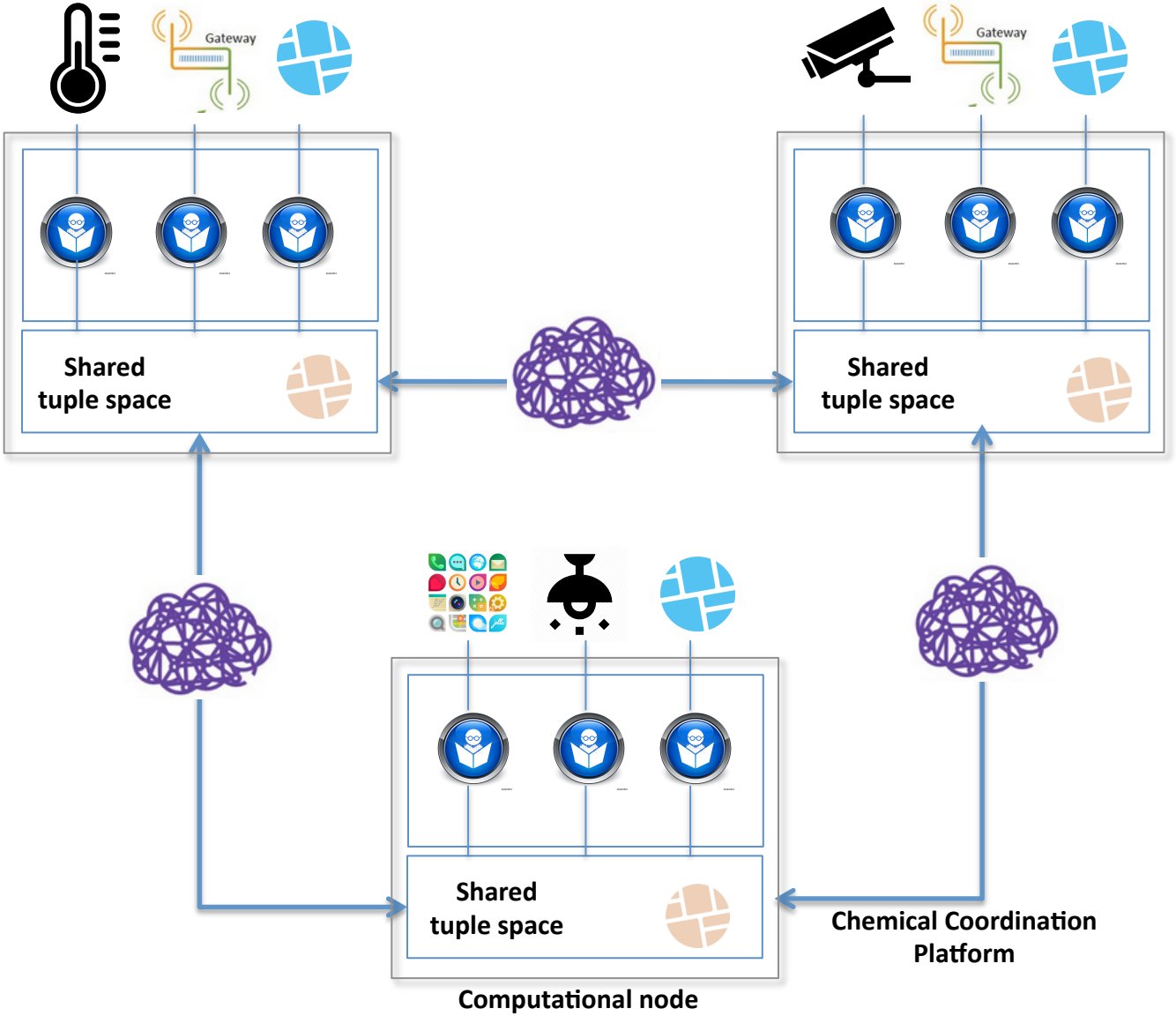


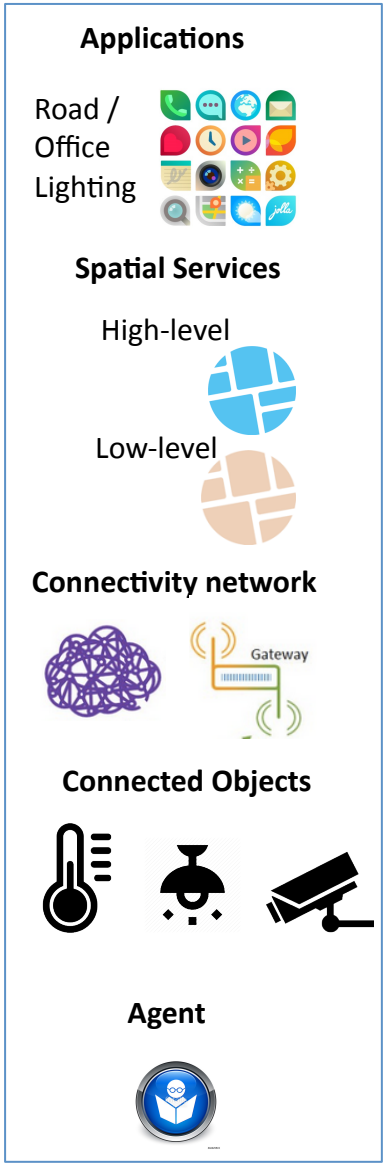
- Engineering
  - Separation of concerns
  - Self-organising mechanisms provided as spatial system services

Spatial edge infrastructure



Spatial edge infrastructure





SAPERE

Logic Fragment Coordination Model

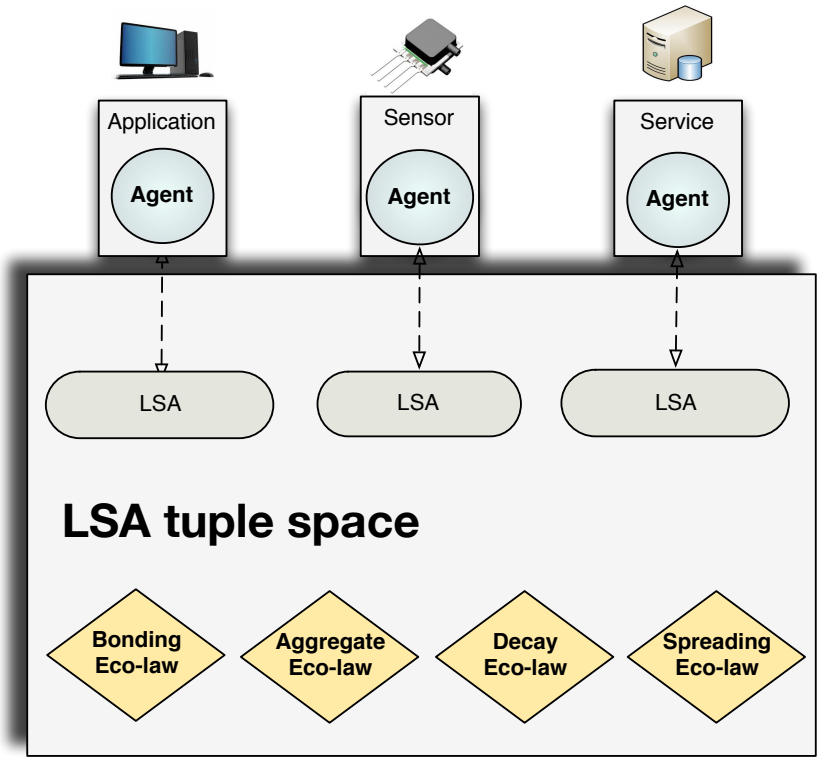
COORDINATION MODELS

SAPERE Chemical-based coordination model

https://www.youtube.com/watch?v=nSIPesWIDx8

SAPERE Chemical-based coordination model

- **Live Semantic Annotation (LSA)** is the virtual representation of a service, data or device (i.e. any SAPERE entity). It ensures a common treatment and manage contextual information.
- **LSA space** is a shared tuple space where SAPERE entities interact through eco-laws.
- **Eco-laws** are virtual chemical reactions that drive the dynamics of the eco-system; built-in primitives for bio-inspired mechanisms
- **Agents** : autonomous entities representing applications, services and sensors



SAPERE Concepts

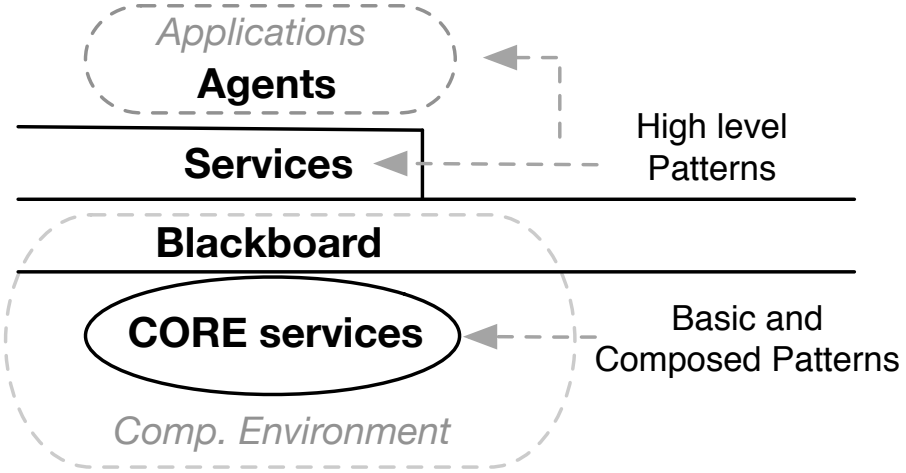
SAPERE Concepts

- Ecosystem of services is ruled by "**eco-laws**"
  - Drive the dynamics of the system
  - Act like Chemical Reactions
  - Trigger when enabled (pattern-matching, rewriting rules)

- Information about services, data, devices: "**Live Semantic Annotations (LSAs)"**
  - Reflect changes in services, data, devices

Zambonelli, F., et al.: Developing pervasive multi-agent systems with nature-inspired coordination. Pervasive and Mobile Computing 17, Part B, 236 - 252 (2015) 10 years of Pervasive Computing' In Honor of Chatschik Bisdikian

SAPERE Structure



Applications

External Libraries

LSA's Space

Eco-laws

Zambonelli, F., et al.: Developing pervasive multi-agent systems with nature-inspired coordination. Pervasive and Mobile Computing 17, Part B, 236 - 252 (2015) 10 years of Pervasive Computing' In Honor of Chatschik Bisdikian

Logic Fragment Coordination Model (LFCM)

Leverage SAPERE with three key advantages:

- Injection of coordination mechanisms at run-time.
- Verification of coordination mechanisms at design-time.
- Evaluation of properties at run-time.

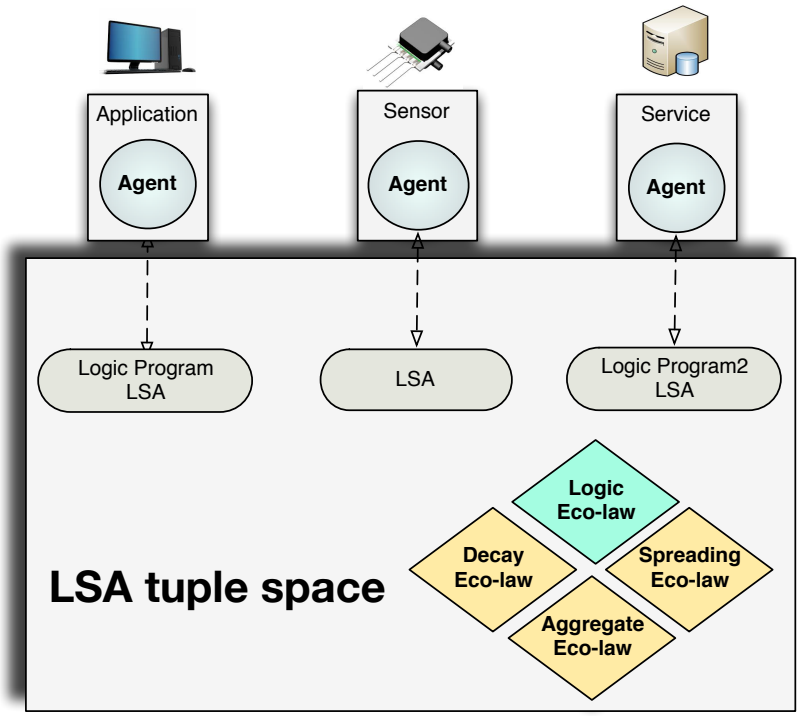
De Angelis, F.L., Di Marzo Serugendo, G.: Coordination Models and Languages: 17th IFIP WG 6.1 International Conference, COORDINATION 2015, chap. Logic Fragments: A Coordination Model Based on Logic Inference, pp. 35-48. Springer International Publishing, Cham (2015)

De Angelis, F.L., Di Marzo Serugendo, G.: A logic language for run time assessment of spatial properties in self-organizing systems. 9th IEEE Conference on Self-Adaptive and Self-Organizing Systems Workshops (SASOW), Springer (2015)

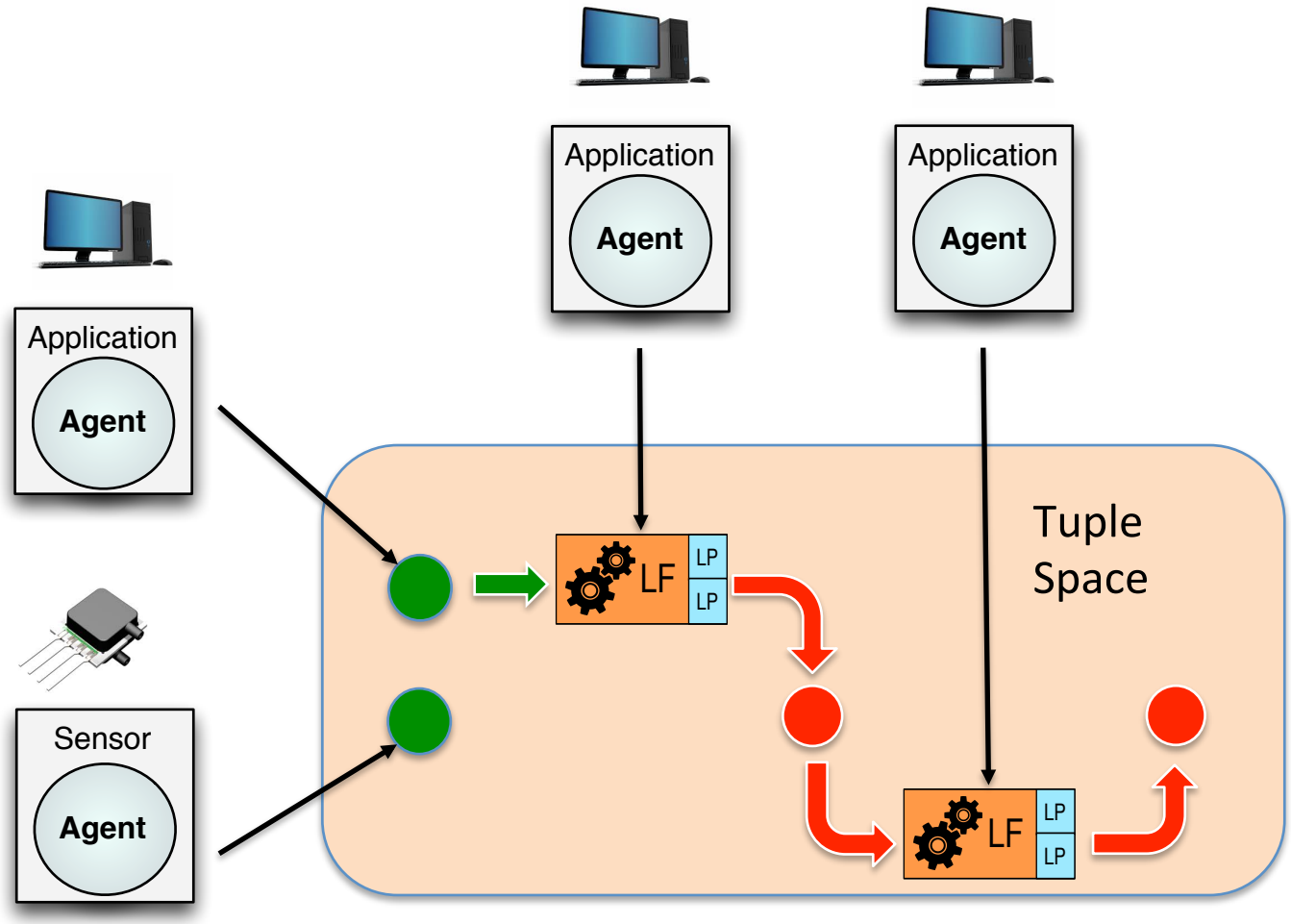
De Angelis, F.L., Di Marzo Serugendo, G.: Logic fragments: coordinating entities with logic programs. In: 7th International Symposium On Leveraging Applications of Formal Methods Verification and Validation (ISOLA), (2016)

Logic Fragment Coordination Model (LFCM)

- **Logic Fragment LSA:** logical formula - defines new eco-law, new interactions among agents or properties to verify.
- **LSA space:** is a shared tuple space with LSA and Logic Fragment LSA
- **Logic Eco-law:** interprets logic fragment LSA
- **Agents** : autonomous entities representing applications, services and sensors



LFCM


Application
Agent
Application
Agent
Application
Agent
Sensor
Agent
LF
LP
LP
LF
LP
LP
Tuple
Space

SAPERE Middleware / TheONE-SAPERE

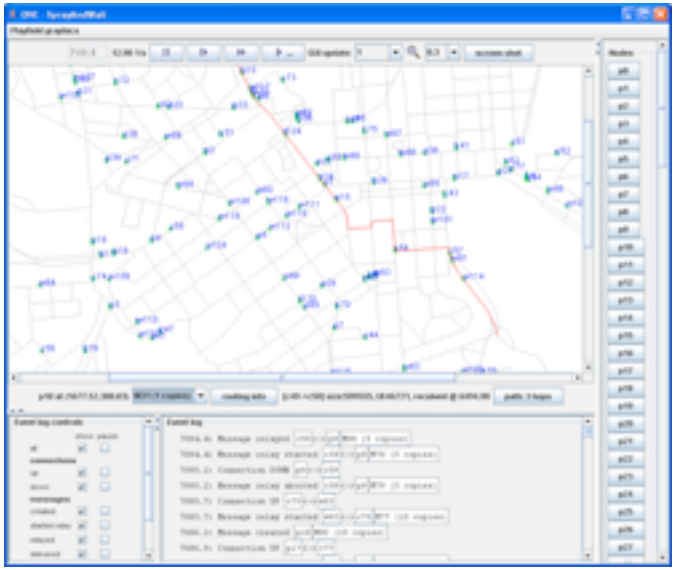
LFCM Middleware / LFCM-TheONE

PROTOTYPING PLATFORMS

The ONE - simulation

The Opportunistic Network Environment Simulator

- The ONE is a simulation environment that is capable of:
  - Generating node movement using different movement models
  - Using real Google maps
  - Importing mobility data from real traces
  - Creating simulations with different types of nodes (e.g. people, cars, public displays,etc..)
  - Assigning more than one communication interface per each device (e.g. Bluetooth, wi-fi, etc..)
  - Networking metrics
  - Reporting quality of the network (e.g. Message delivered, dropped, etc..)

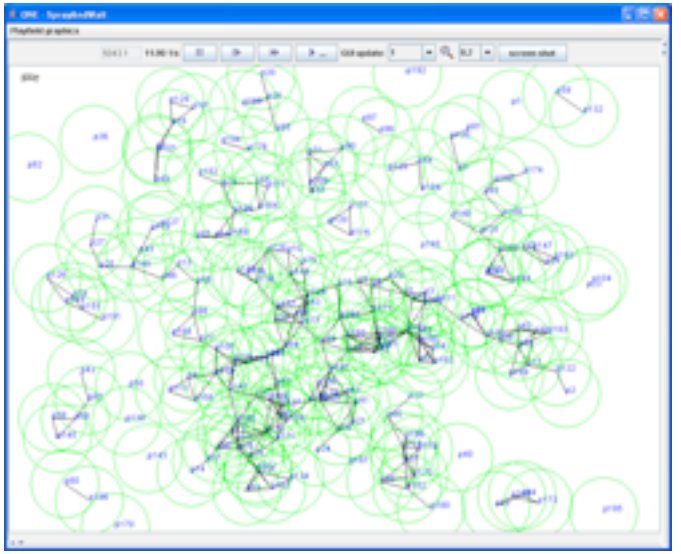


https://akeranen.github.io/the-one/

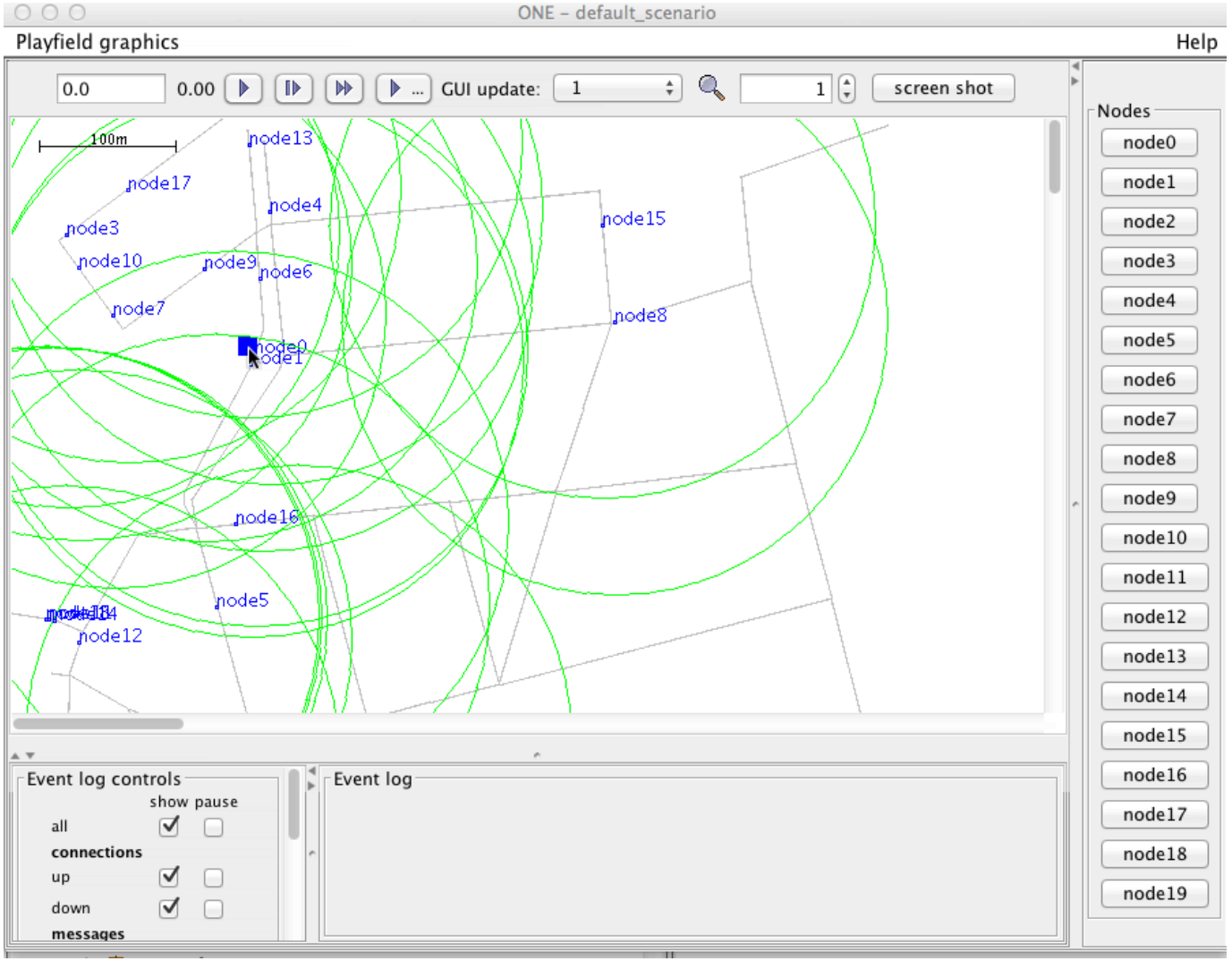
The ONE-Sapere - Prototyping

SAPERE middleware on top of The One simulation, helps us to:

- Validate the current actual version of the middleware in large scale system.
- Get easily performance metrics (e.g. analysing the number of LSAs in the system, and the bandwidth consumption).
- Validate external libraries before their real implementation in the SAPERE middleware.
- Evaluate the feasibility of the SAPERE middleware running on a large scale distributed environment composed of many types of devices. (i.e. to simulate real case scenario, in a very accurate way)

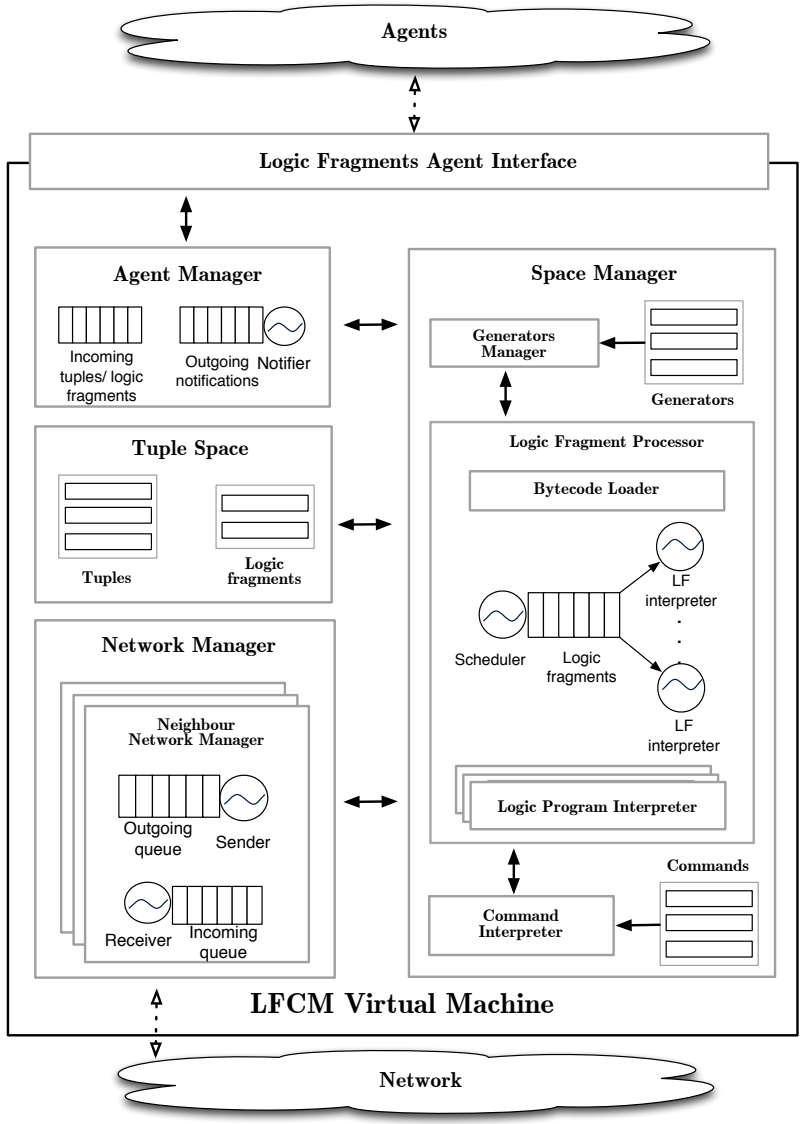


The ONE-SAPERE



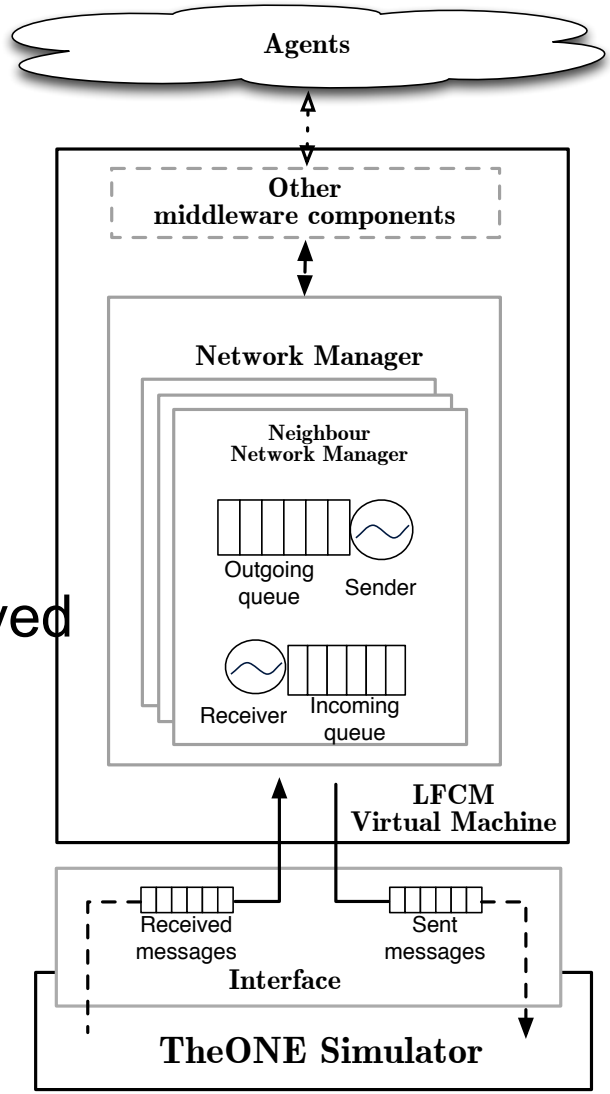
LFCM middleware

- Java implementation:
  - Workstations, tablets, embedded systems.
- Full implementation of RL^N interpreter.
- Extensible:
  - Logic programming languages.
  - Network technologies.



LFCM + The ONE

- TheOne simulator: network simulator.
- LFCMTheOne:
  - One LFCM Virtual Machine per virtual node.
  - Fast prototyping.
  - Logic fragments can be directly deployed on physical devices.



Road runners –
Actual P2P deployment using SAPERE for tracking mobile objects

Smart Lighting – IoT P2P deployment using SAPERE

Hazard Factory – Prototyping with LFCM

APPLICATIONS – ACTUAL DEPLOYMENTS

Road runners

Problem :

- Hard follow favourite runner in a race due to crowd, velocity, position, …

Goal :

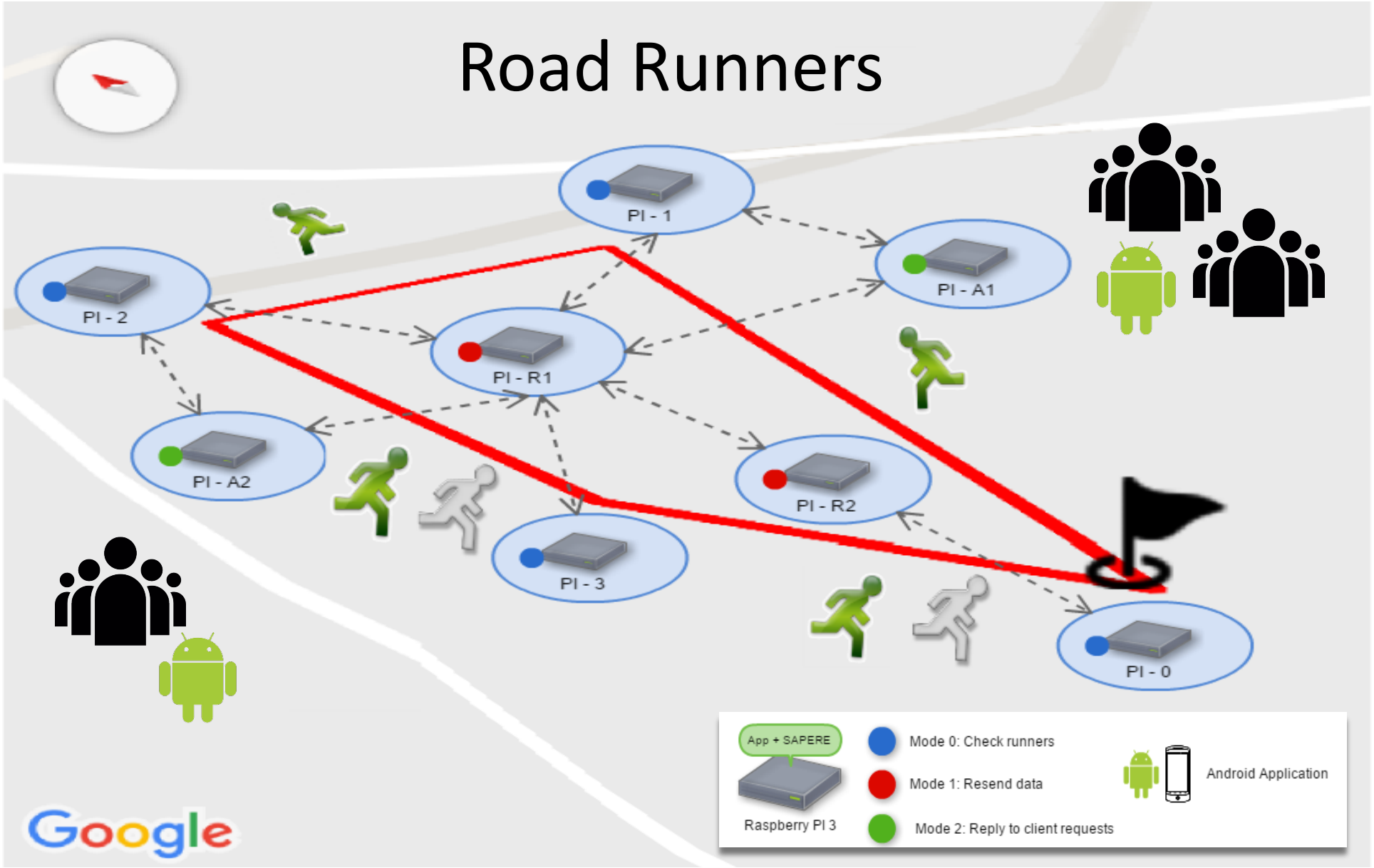
- Tracking mobile objects in real-time in a P2P fashion

Feature :

- Continuous spreading and aggregation

Tomaylla, R.: Bio-Inspired approach for tracking mobile entities in a Peer to Peer MANET. An application of The SAPERE Project in Road Running events . Master's thesis, Centre Universitaire d'Informatique, University of Geneva, Geneva, Switzerland (2016)

Road Runners

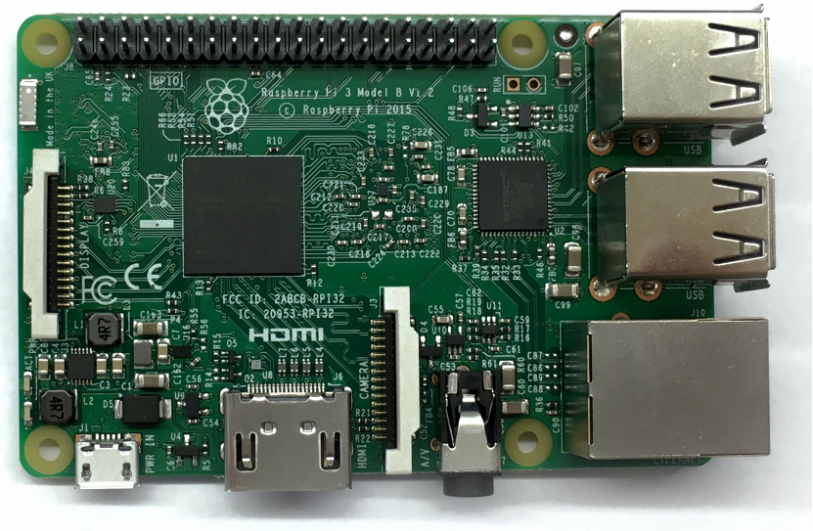


Wireless Protocol and Devices

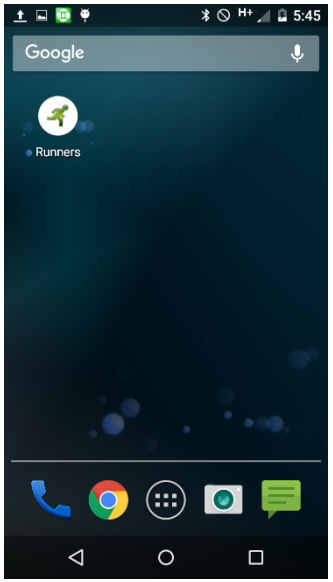
Bluetooth™ 4.0

Low Energy

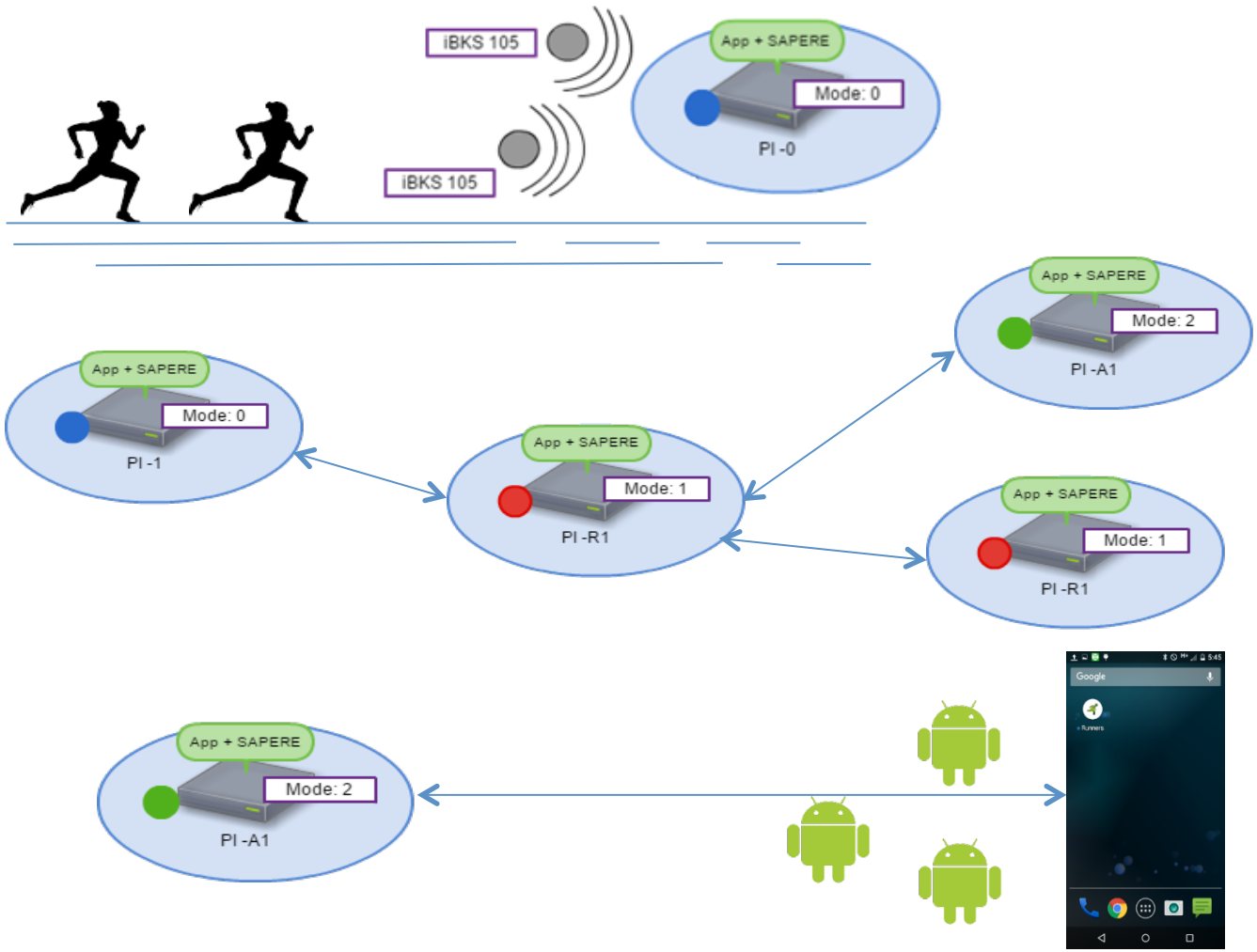
iBKS 105



RaspberryPi



Nodes along the path

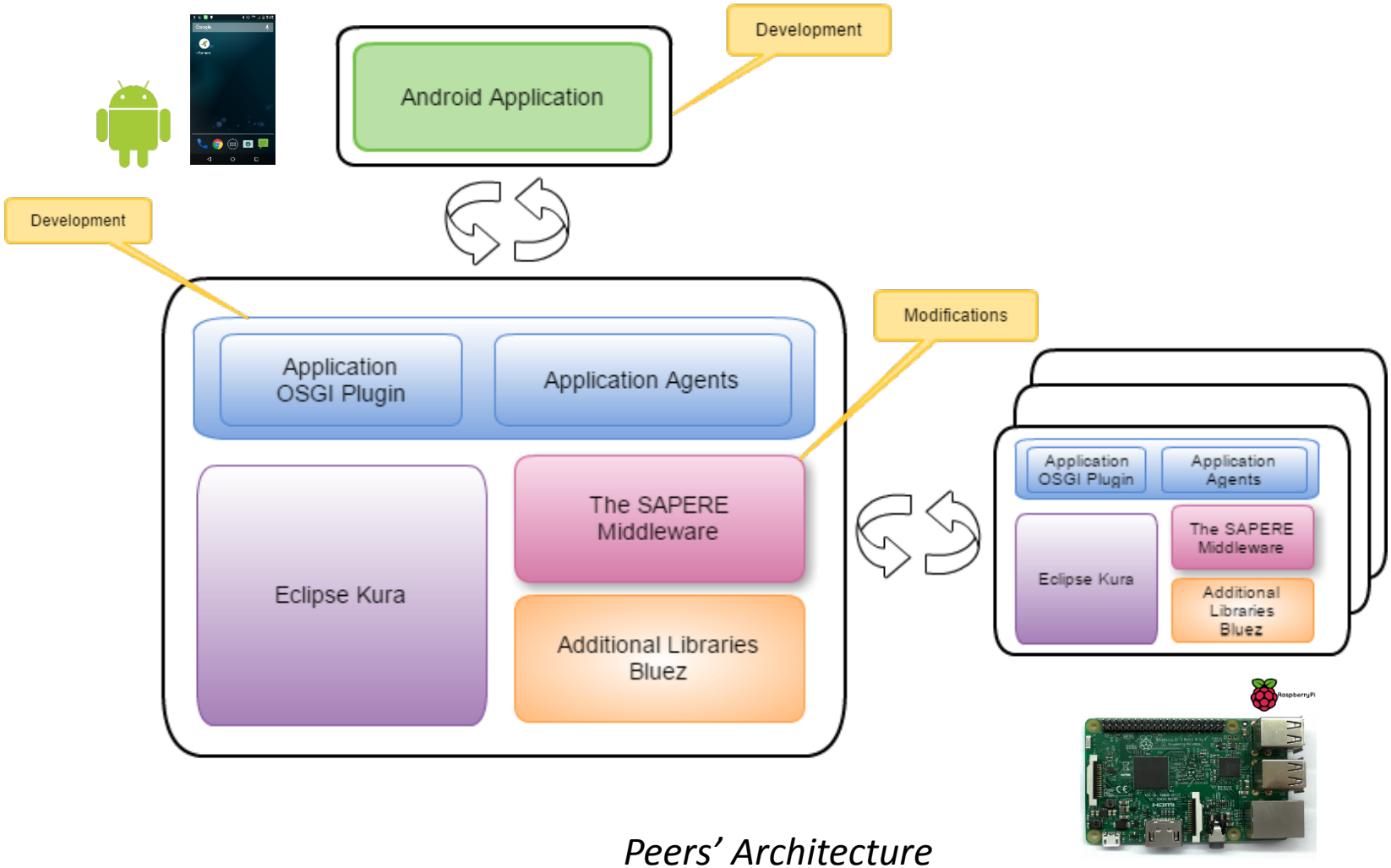


Checkpoint Nodes

Relay Nodes

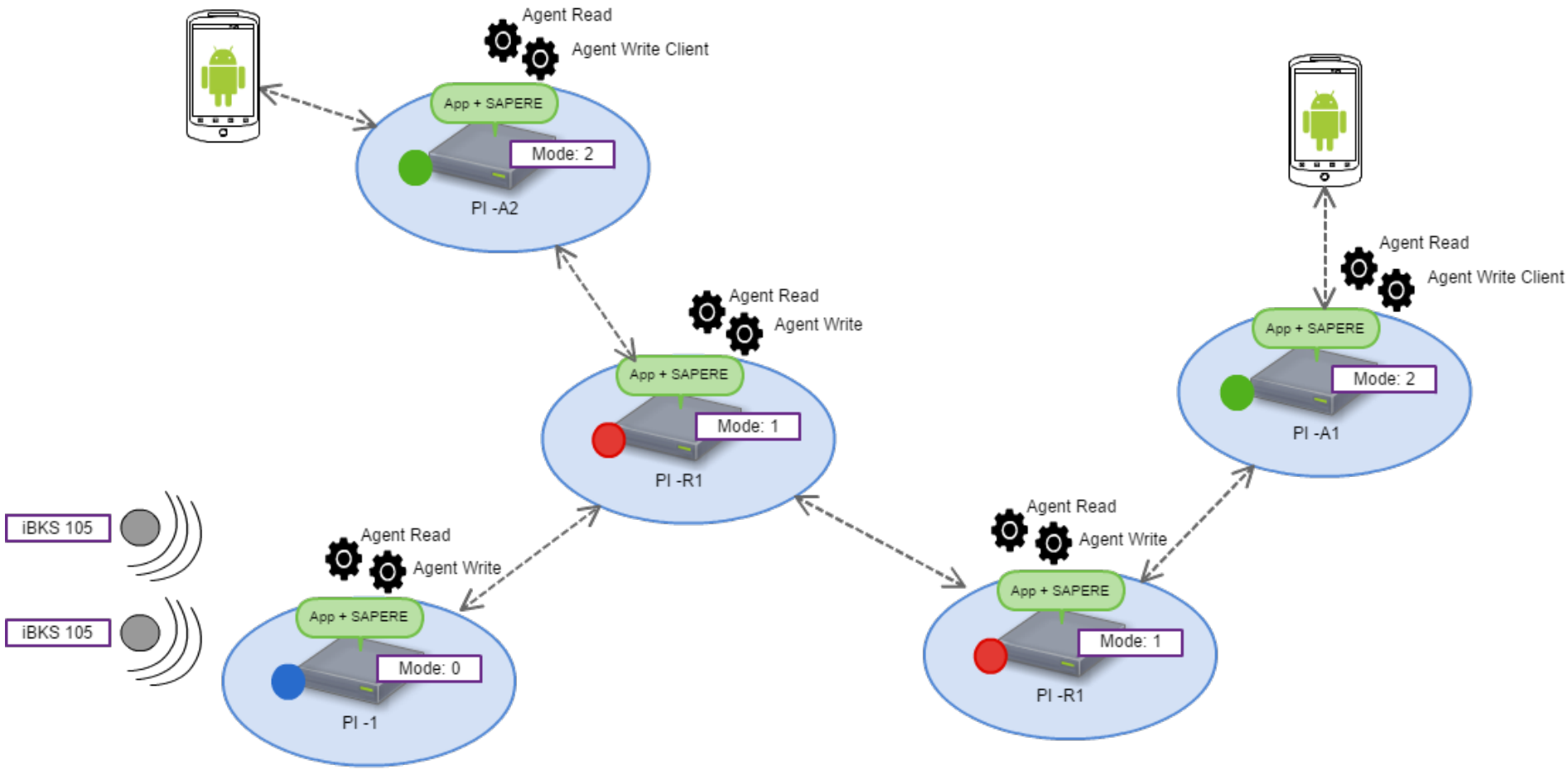
Client Advertiser Nodes

System Architecture

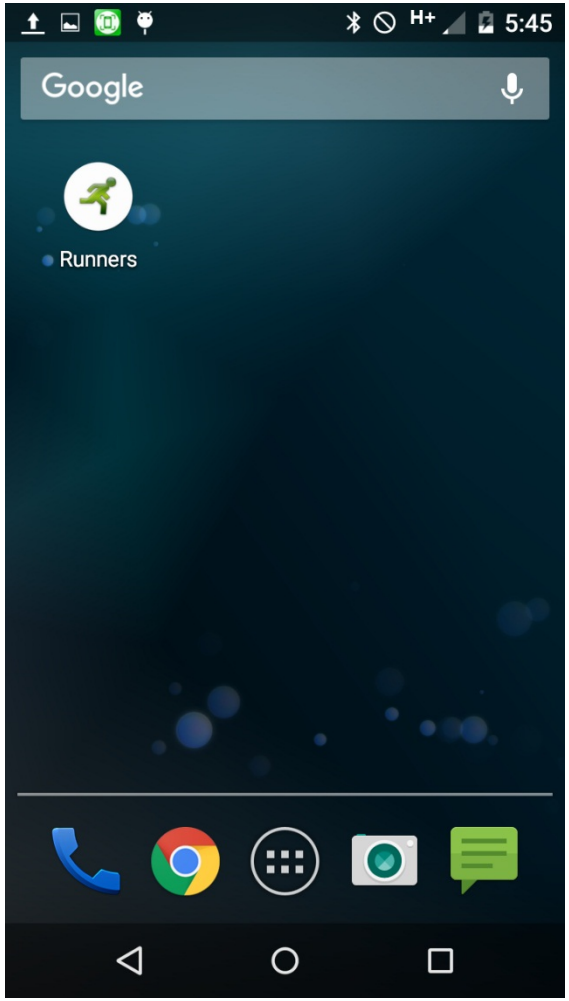


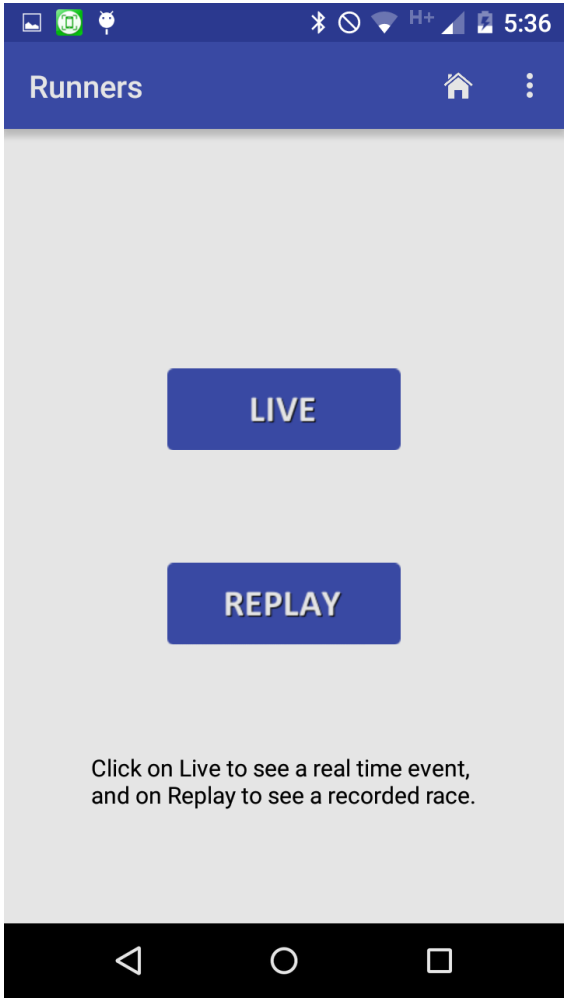
Peers' Architecture

SAPERE Application - LIVE Scenario

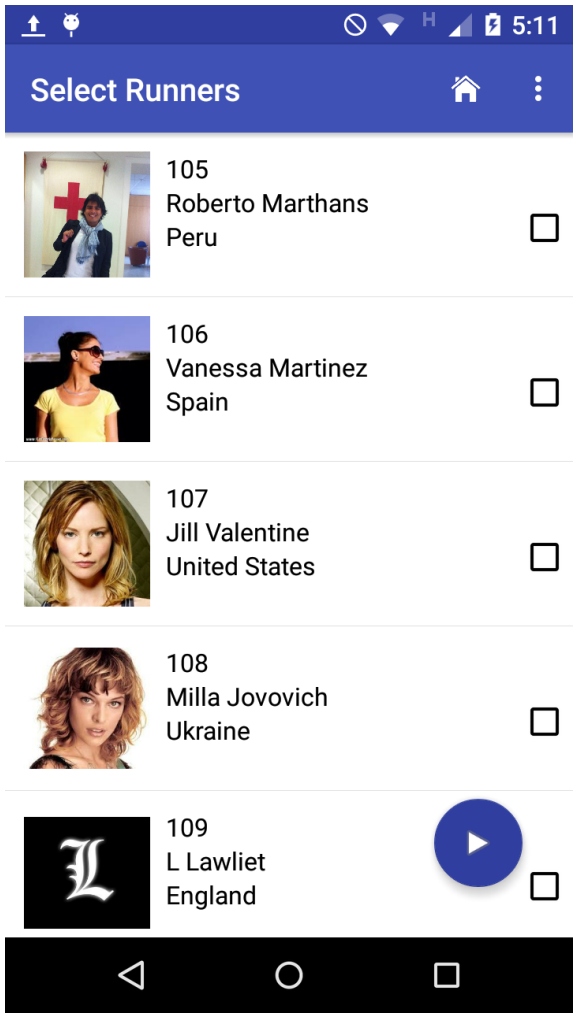


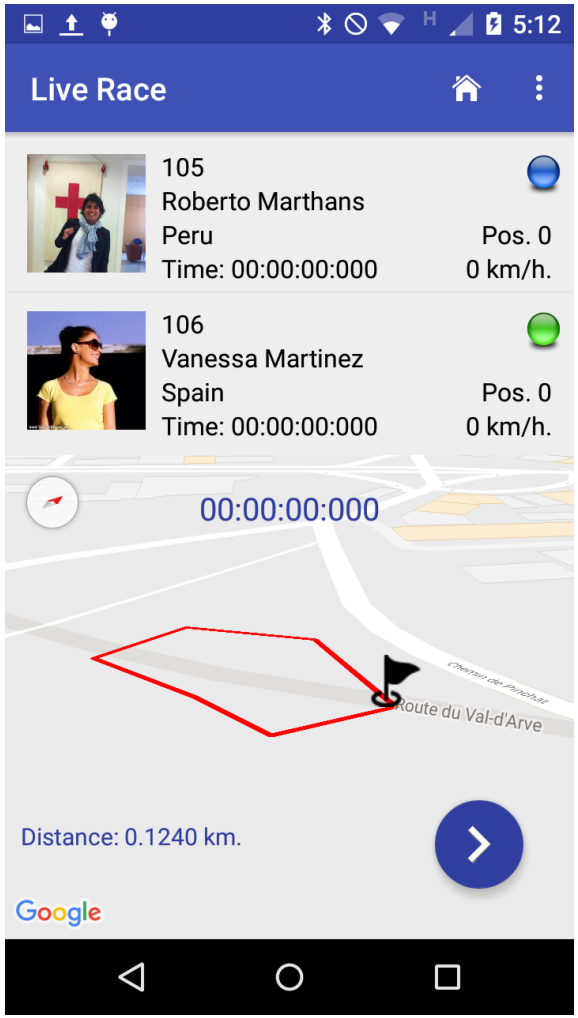
Mobile Android Application

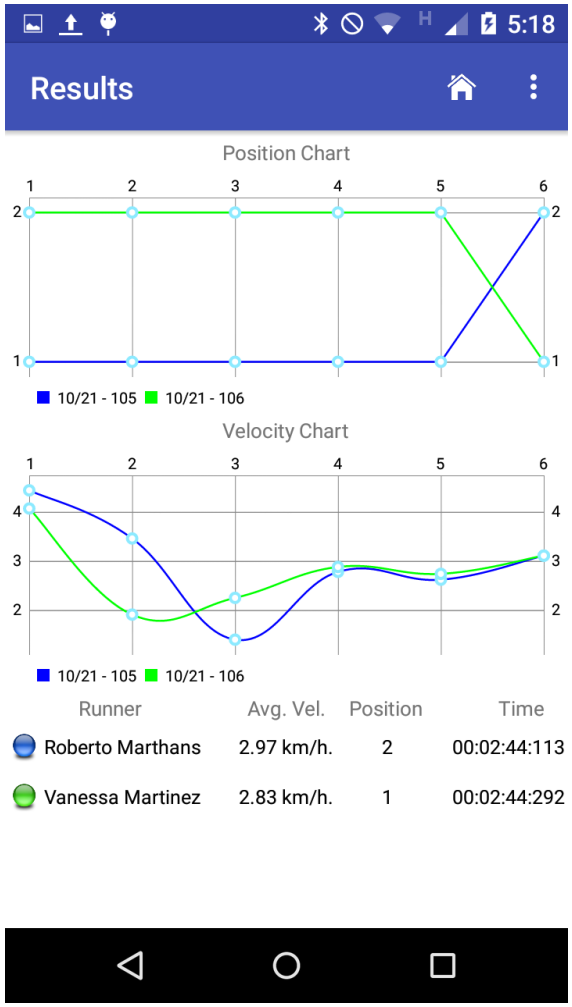




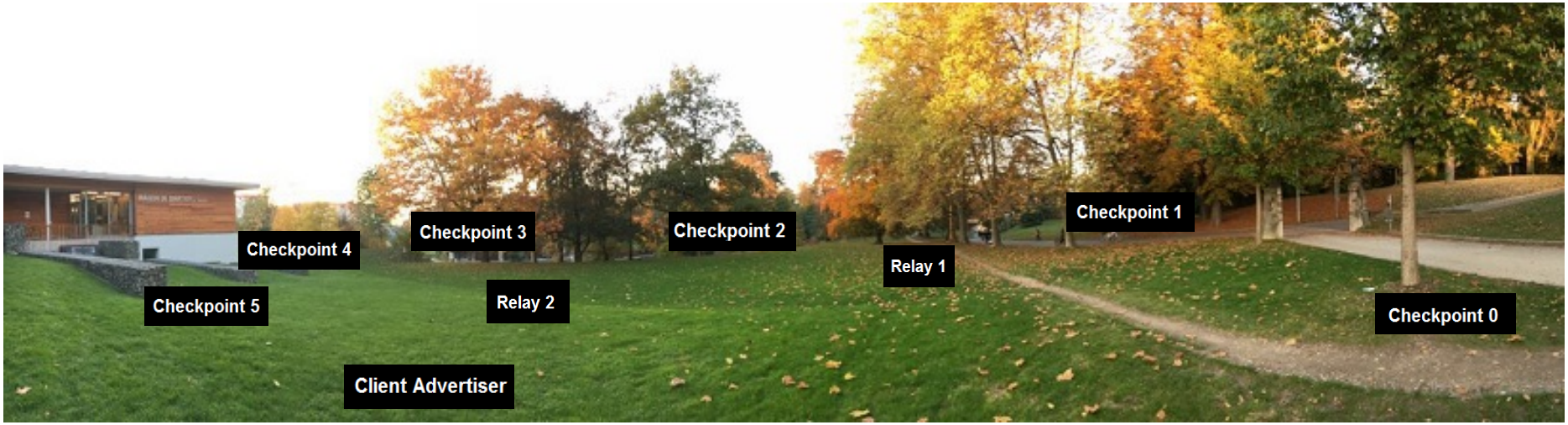
Mobile Android Application - LIVE Navigation

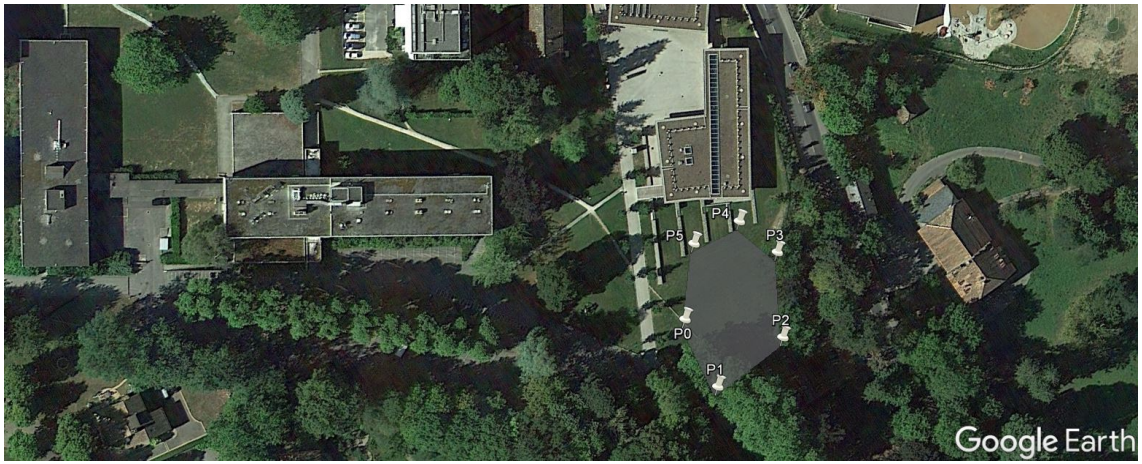






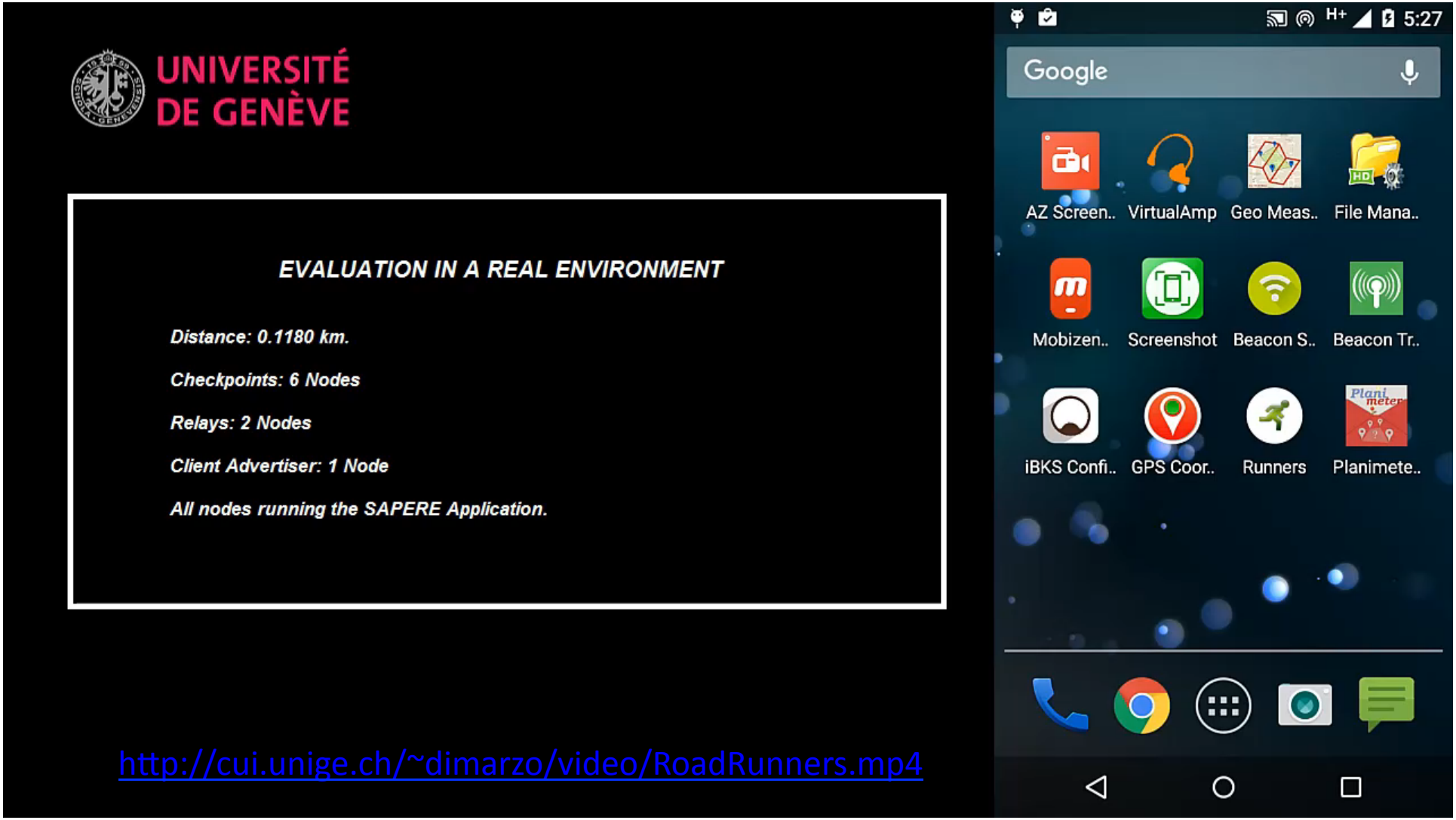
System Deployment - Outdoor Experiment



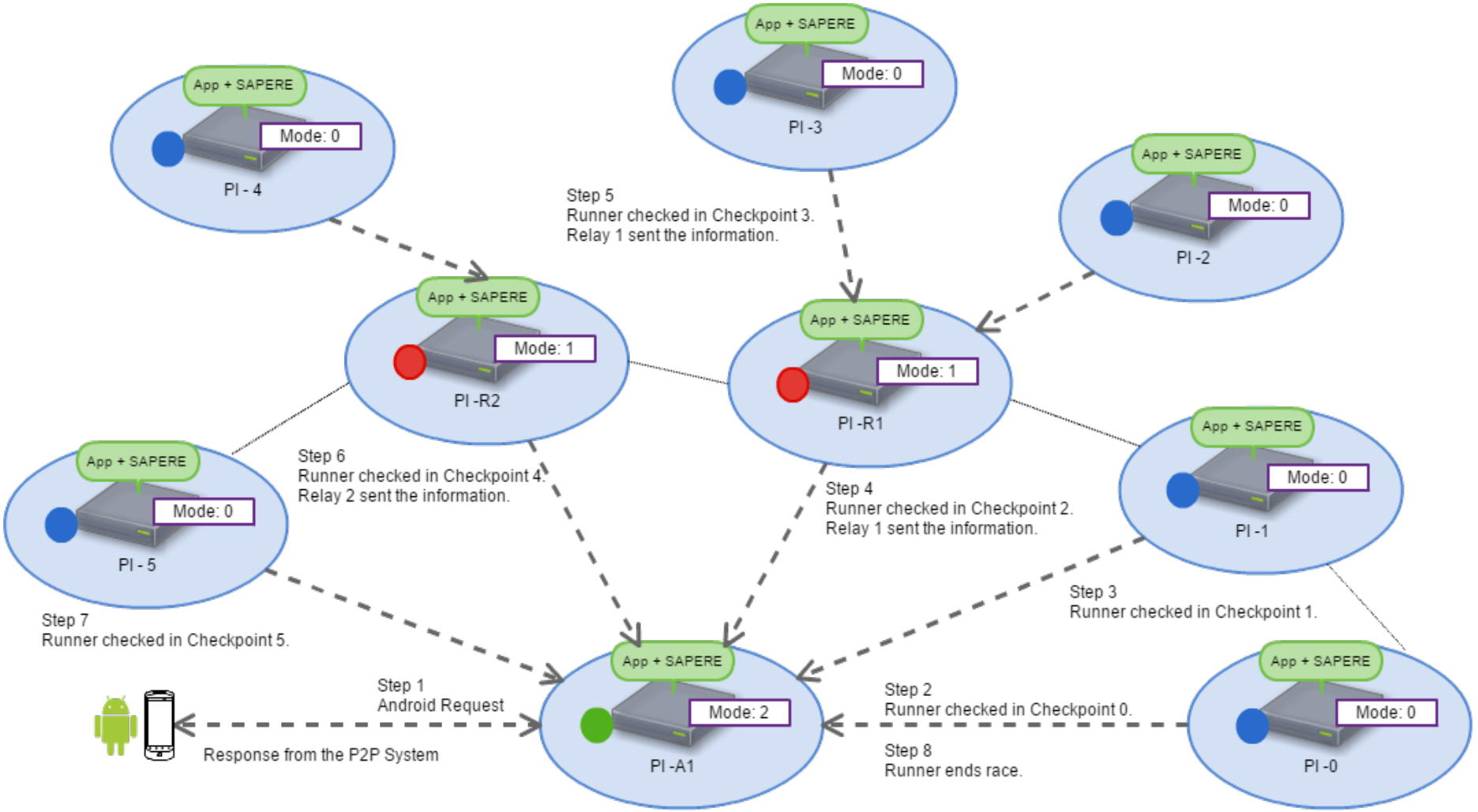


Perimeter: 118 m.
Area: 917 m2

System Deployment Video - Outdoor Experiment



Outdoor experiment - Message Routing



Smart Lighting

Problem :

- Hard to find some places in a big building

Goal :

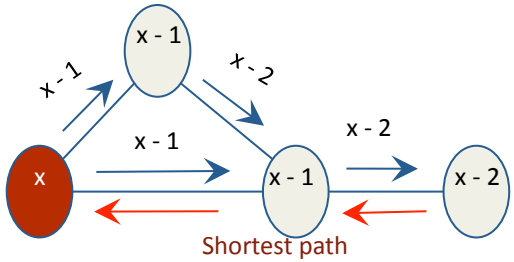
- Find the shortest path to a destination

Feature :

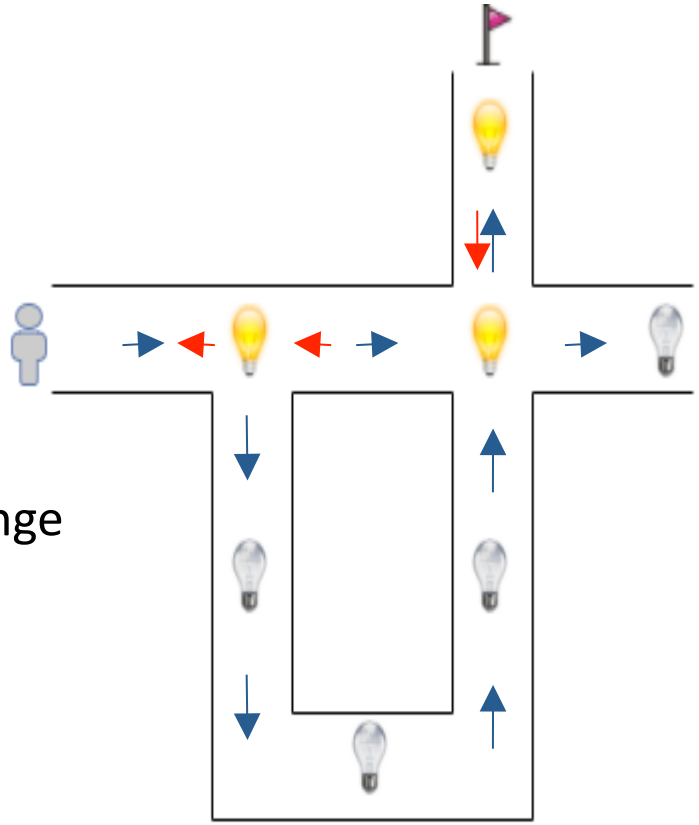
- Self-adaptation at run-time in response to any perturbation or environmental change

IoT Implementation:

- Actual deployment on sensors / actuators



Chemotaxis



Smart lighting

https://www.youtube.com/watch?v=nSOJHKM95lg

Hazard Factory - LFCM

Problem:

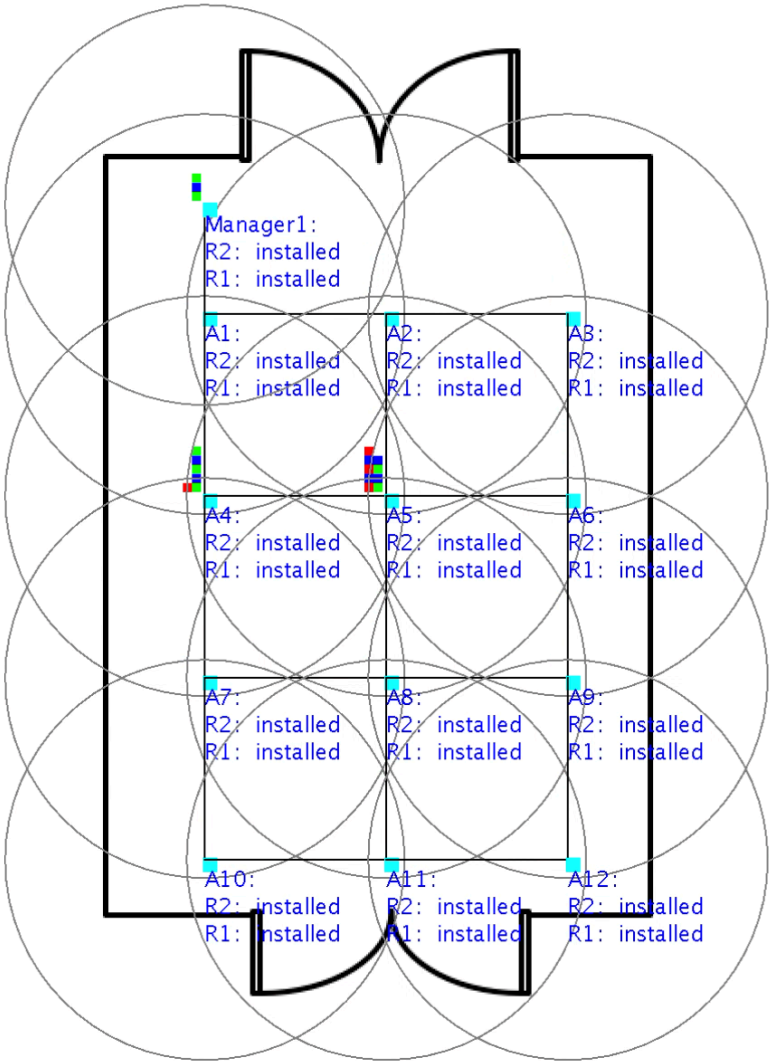
- Chemical warehousing

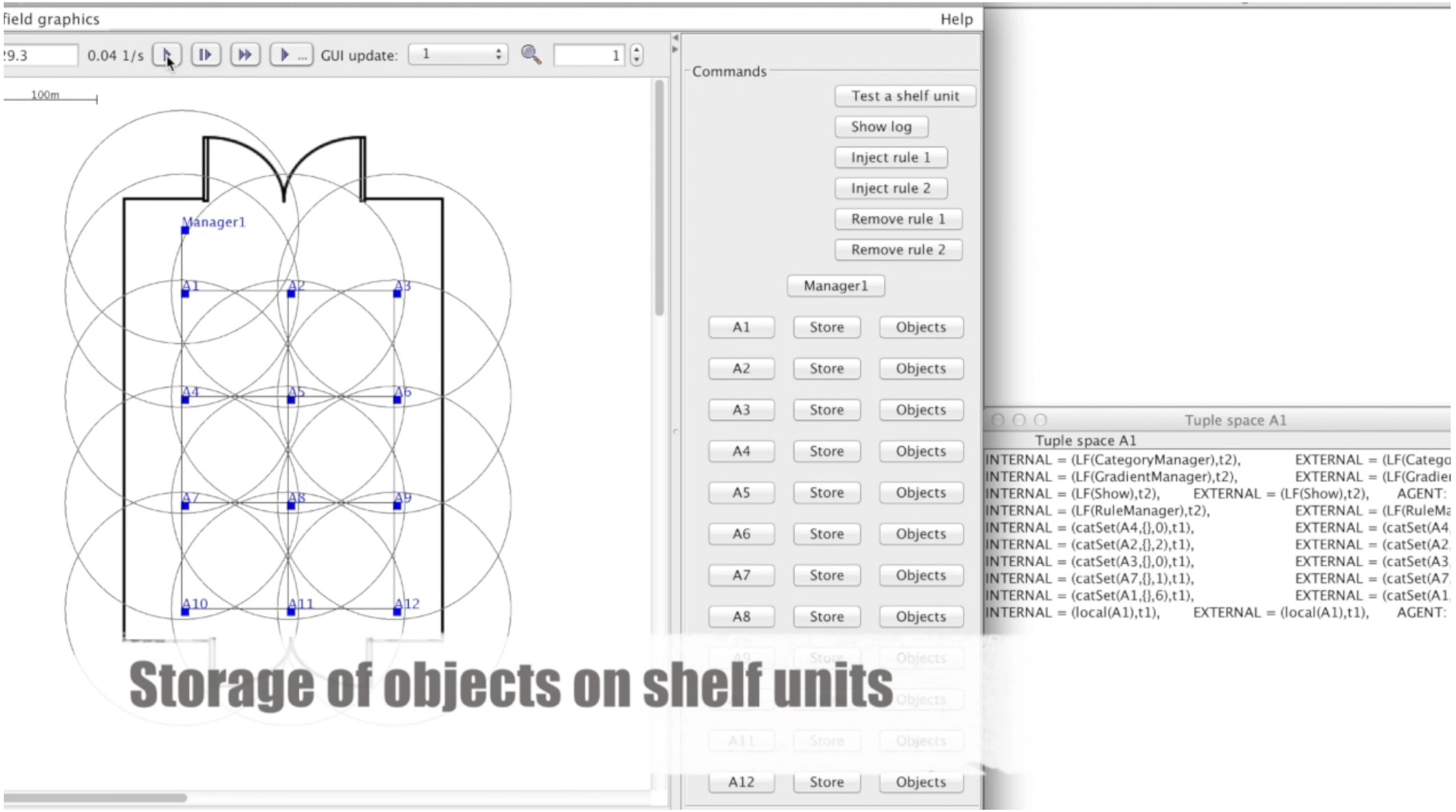
Goal :

- Avoid hazards arising from potential interactions among chemical compounds

Feature :

- Injecting safety policy at run-time, assessing properties at run-time





http://cui.unige.ch/~dimarzo/video/HazardFactory.mov

Evaluation / Performances

- ✘ Delay within a large mesh network
- ✘ Communication protocol limitations
- ✘ Unification of variables

- ✔ Coordination middleware implementations
- ✔ Prototyping
- ✔ Actual deployments on mobile / IoT infrastructures

Conclusion

Spatial edge services :

- Based on bio-inspired mechanisms
- Chemical coordination model
- Prototyping tool available
- Uses logic formulae
- Decentralized solution
- Suited for IoT
- Deployed on actual scenarios

Future works :

- Security and privacy
- On the fly services
- Self adaptation of parameters
- Learning
- Communication protocol

Thanks to …

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- Matteo Risoldi (Post-doc)
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- Jose Luis Fernandez-Marquez (Post-doc)
- Francesco Luca De Angelis (PhD)
- Houssem Ben Mahfoudh (PhD)
- Roberto Tomaylla (MSc)

SAPERE

Self-Aware Pervasive Service Ecosystems
EU STREP Project
FP7-ICT-2009.8.5: Self-awareness in Autonomic Systems

Thank you

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http://www.sapere-project.eu

http://cas.unige.ch (coming soon)