Efficient algorithms, architectures and implementations in internet of things and smart environments

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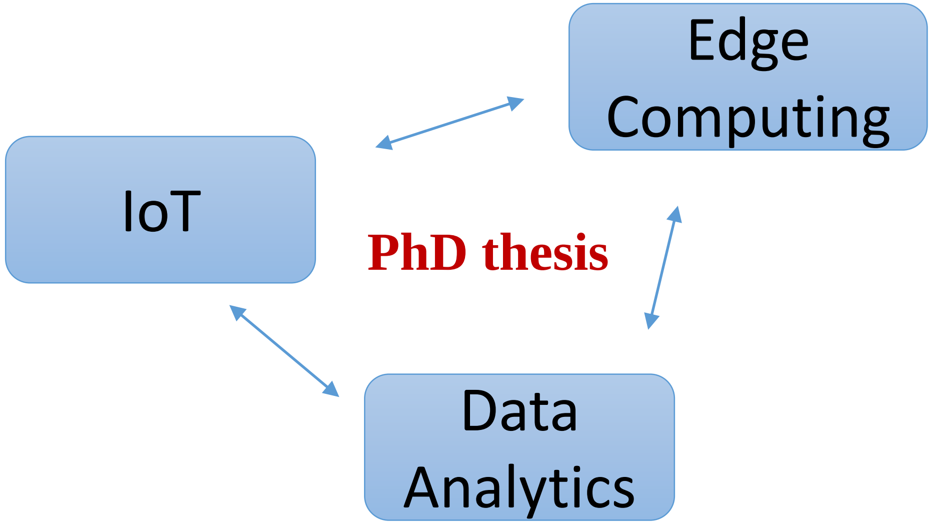
Theoretical Computer Science & Sensor Lab

Presentation Outline



- The Syndesi Testbed
- Modelled Testbeds
- Efficient bidirectional search in large scale networks
- Office automation for Syndesi mobile users
- A Raspberry-Pi cluster for distributed edge computing *(ongoing work)*
- Summary

Syndesi Testbed

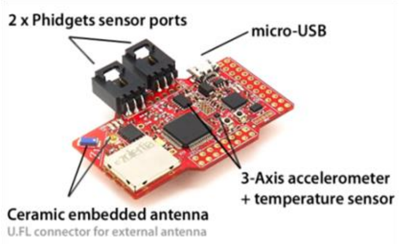
- Syndesi is an IoT framework and testbed located at the University of Geneva

- It includes WSN as well as crowdsensed resources exposing them as a service via a REST-ful architecture

- More than 30 IPv6-enabled sensor motes compose its backbone WSN

MEMSIC TelosB Mote

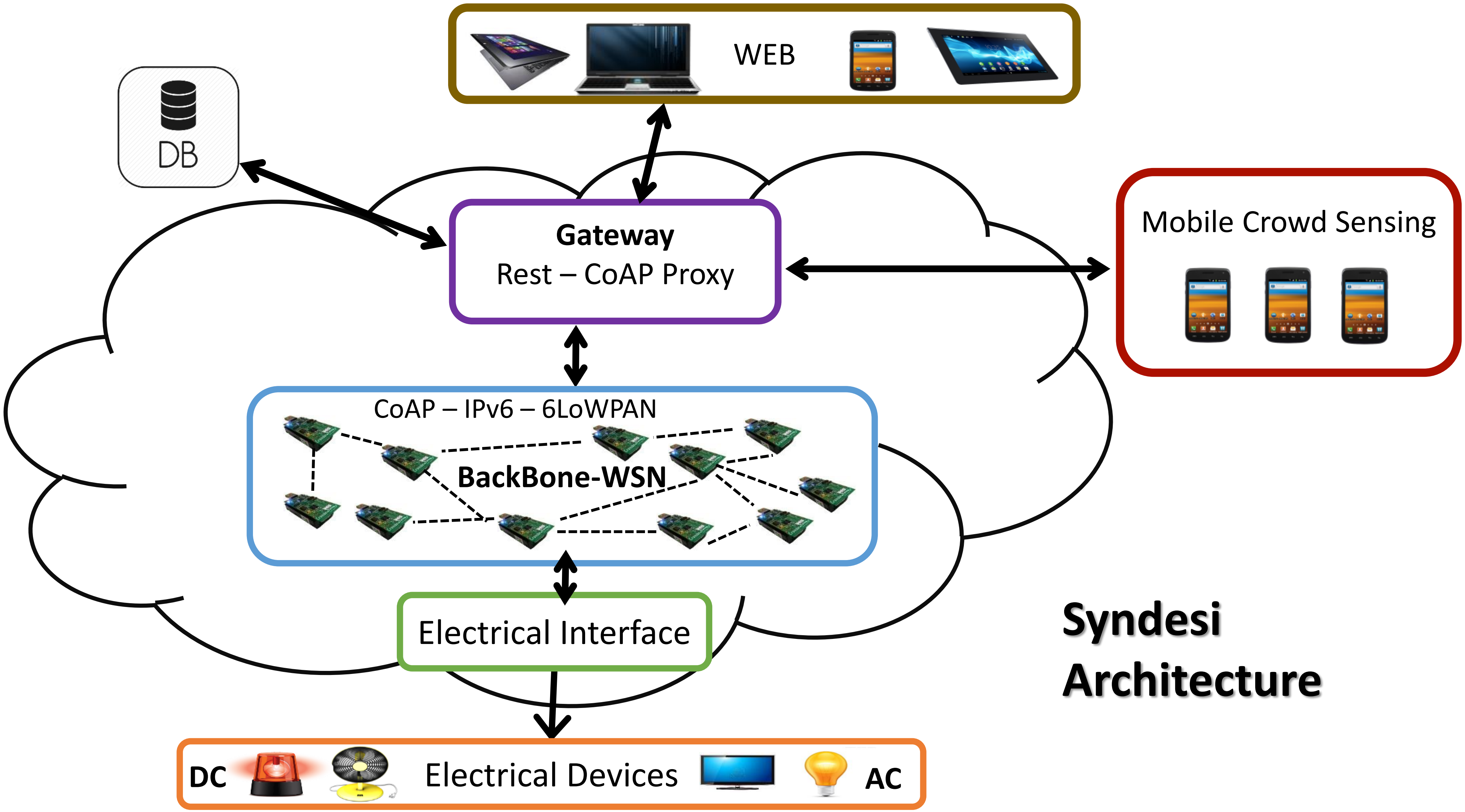
AS-XM1000 802.15.4 Mote



Zolertia's Z1 Mote

O. Evangelatos, K. Samarasinghe and J. Rolim, "Syndesi: A Framework for Creating Personalized Smart Environments Using Wireless Sensor Networks," *2013 IEEE International Conference on Distributed Computing in Sensor Systems*, Cambridge, MA, 2013, pp. 325-330.

Syndesi Testbed

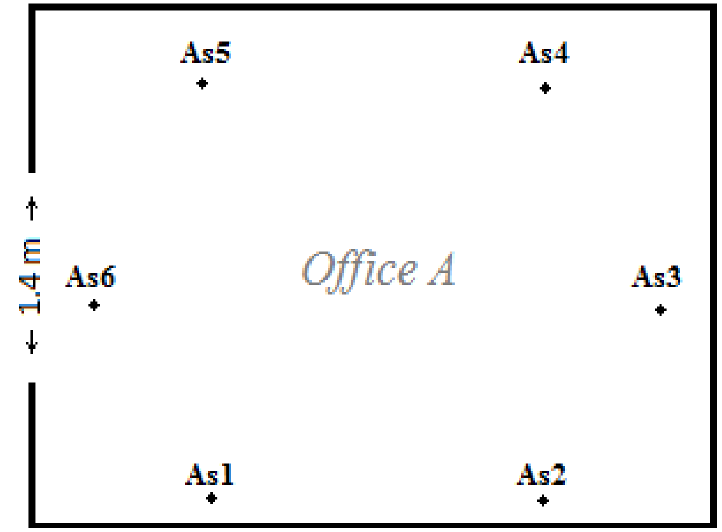


Syndesi Architecture

Creating a dataset

Data Collection

1. Illuminance
2. Temperature
3. Humidity



◆ : Physical Sensor

Automatic query for values every ~20min

	id	node_name	resource_name	value	unit	pos_x	pos_y	pos_z	timestamp
Edit Copy Delete	22040	SGoAs6	illuminance at SGoAs6	270	lux	2.4	9.05	1.45	2016-03-18 11:20:22
Edit Copy Delete	22041	SGoAs5	illuminance at SGoAs5	284	lux	2.4	11.55	3.9	2016-03-18 11:15:38
Edit Copy Delete	22042	SGoAs4	illuminance at SGoAs4	315	lux	2.4	13.55	3.9	2016-03-18 11:20:10
Edit Copy Delete	22043	SGoAs3	illuminance at SGoAs3	331	lux	2.4	17.6	1.45	2016-03-18 11:17:50
Edit Copy Delete	22044	SGoAs2	illuminance at SGoAs2	368	lux	2.4	13.55	0	2016-03-18 11:15:03
Edit Copy Delete	22045	SGoAs1	illuminance at SGoAs1	305	lux	2.4	11.55	0	2016-03-18 11:19:09

DB

~300k measurements so far

Modelled Testbeds

- A modelled testbed (MT) is based on a physical testbed - same 3D space, connected sensors appearing in corresponding positions

- Virtual sensors can be inserted interactively in its GUI

They provide:

-Very large experiment scale

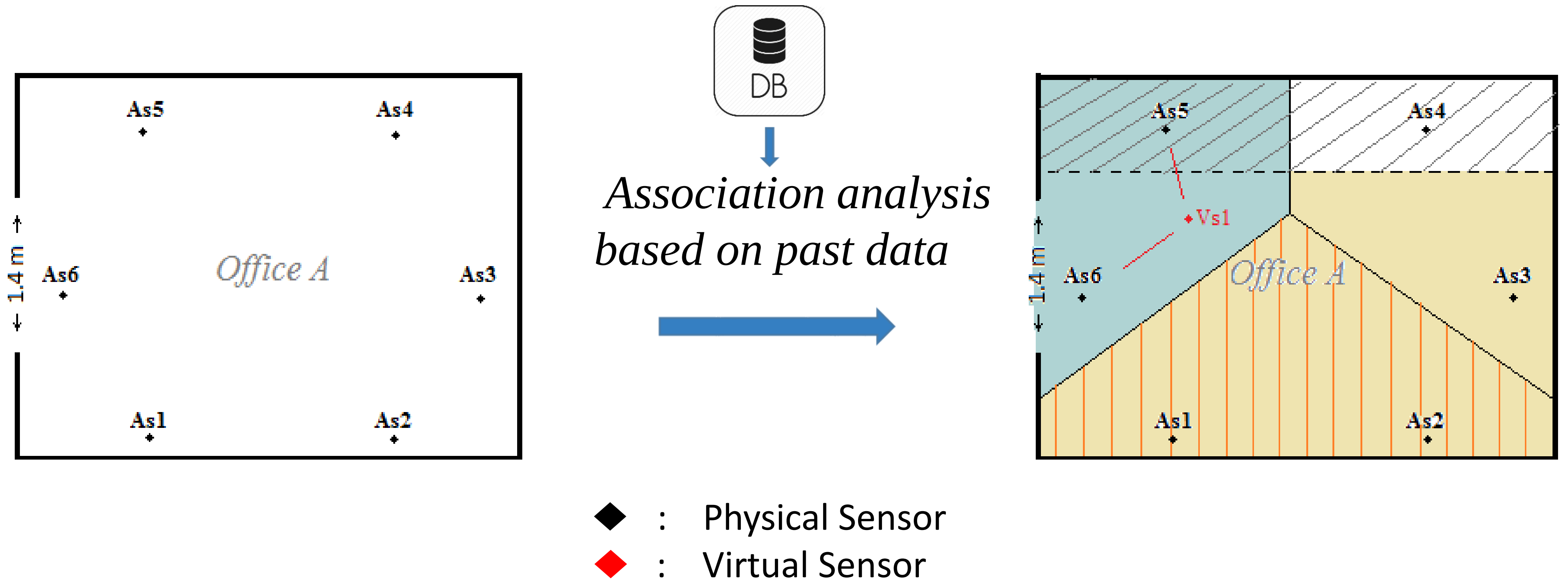
-Unlimited number of simultaneous experiments

Kundig S., Angelopoulos C.M., Rolim J. (2018) “*Modelled Testbeds: Visualizing and Augmenting Physical Testbeds with Virtual Resources*” In: Rocha Á., Guarda T. (eds) Proceedings of the International Conference on Information Technology & Systems (ICITS 2018). ICITS

Experiment accuracy in Modelled Testbeds

- Physical sensors measurement values shown in MTs are close-to-real time.

- Virtual sensors get their values via weighted average on specific physical sensors subsets, derived from association analysis on past data



Evaluation

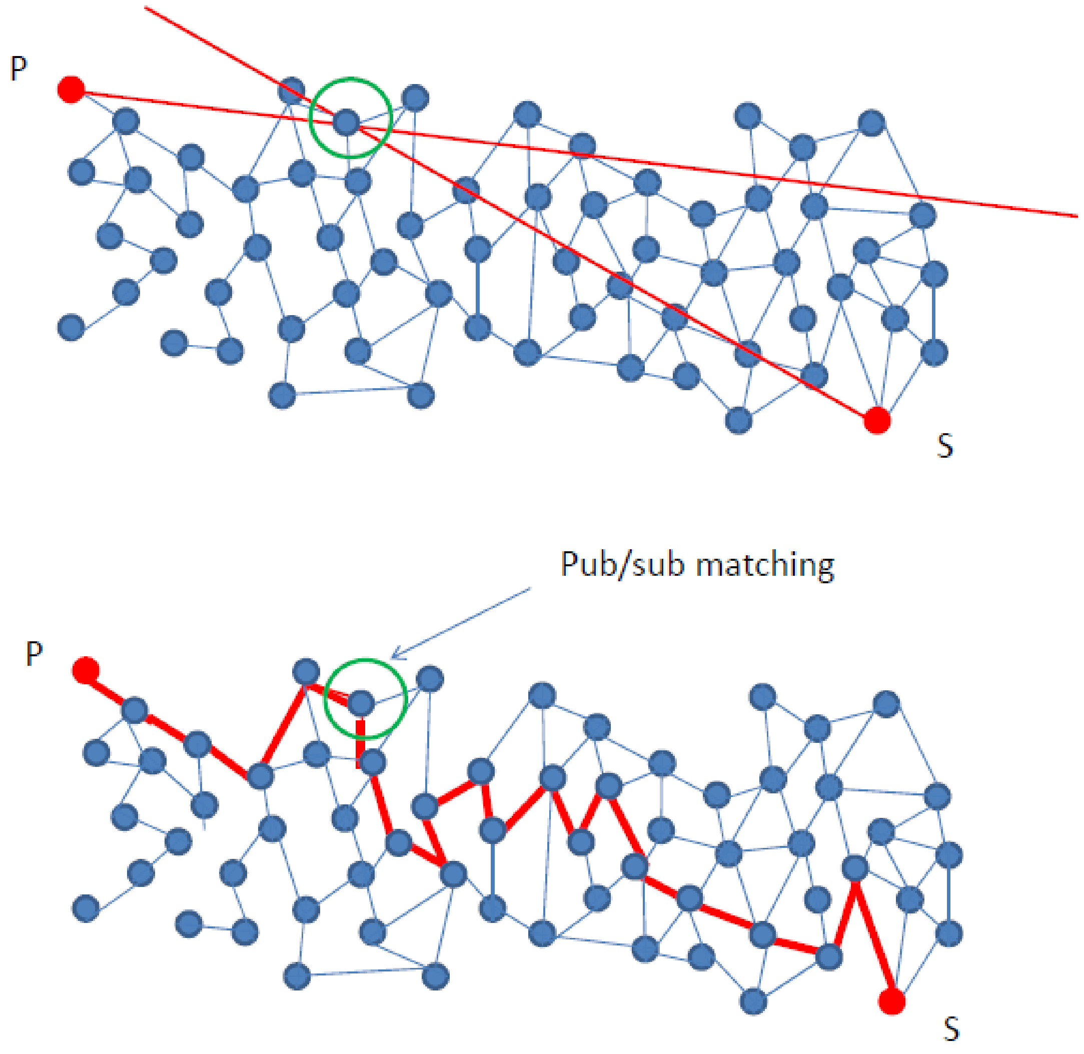
10-fold Cross-validation

Weighted average over inverse distance						
Sensor:	Illuminance(lux)		Temperature(^oC)		Humidity(%)	
Room	Average RMSE	Average MAPE	Average RMSE	Average MAPE	Average RMSE	Average MAPE
Office A	9.22 ± 0.55	3.02 ± 0.12%	0.33 ± 0.01	1.07 ± 0.02%	0.60 ± 0.02	1.50 ± 0.01%
Office B	44.4 ± 3.21	6.58 ± 0.20%	0.60 ± 0.01	1.91 ± 0.03%	1.17 ± 0.10	2.61 ± 0.05%

Weighted average over inverse distance squared						
Sensor:	Illuminance(lux)		Temperature(^oC)		Humidity(%)	
Room	Average RMSE	Average MAPE	Average RMSE	Average MAPE	Average RMSE	Average MAPE
Office A	9.39 ± 0.60	3.20 ± 0.14%	0.30 ± 0.01	0.98 ± 0.01%	0.58 ± 0.01	1.42 ± 0.01%
Office B	43.69 ± 3.41	6.57 ± 0.19%	0.61 ± 0.02	1.88 ± 0.04%	1.18 ± 0.10	2.62 ± 0.06%

Efficient path dissemination

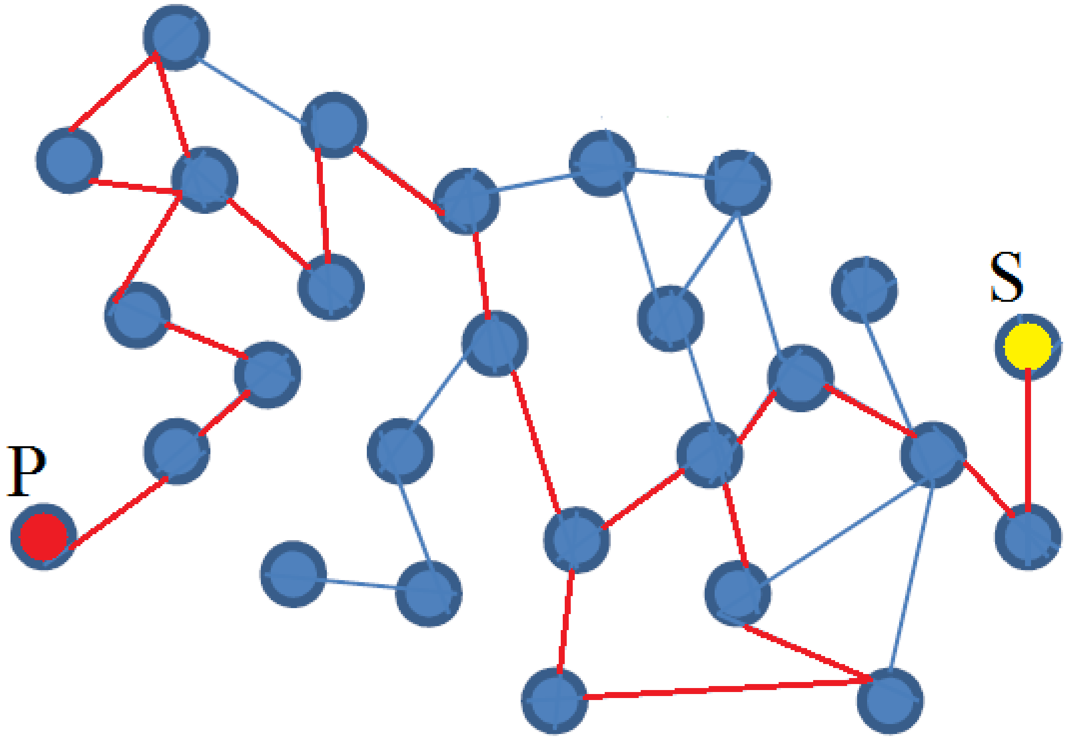
- Publish-Subscribe communication patterns
- No routing layer existence is assumed.
- Fully distributed solution



Stéphane Kundig, Pierre Leone, and José Rolim, 2016, *"A Distributed Algorithm Using Path Dissemination for Publish-Subscribe Communication Patterns",* in Proceedings of the 14th ACM International Symposium on Mobility Management and Wireless Access (MobiWac '16)

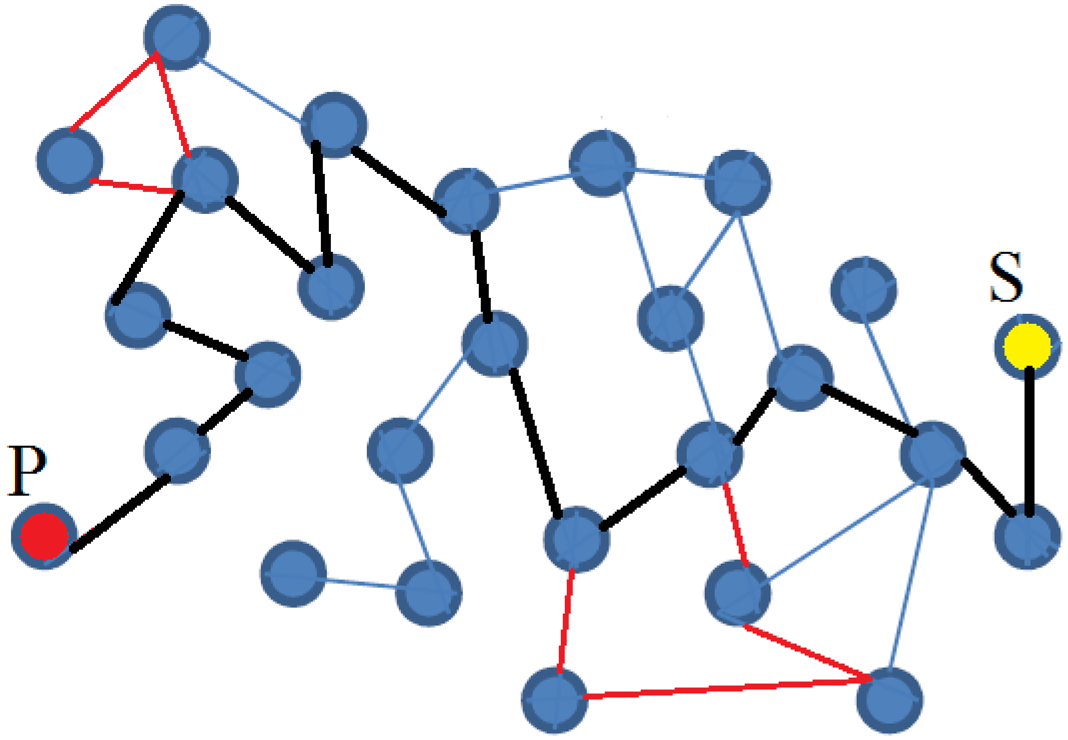
Efficient path dissemination

- A random walk (good at balancing the load)



Efficient path dissemination

- Loop-erased path



Efficient path dissemination

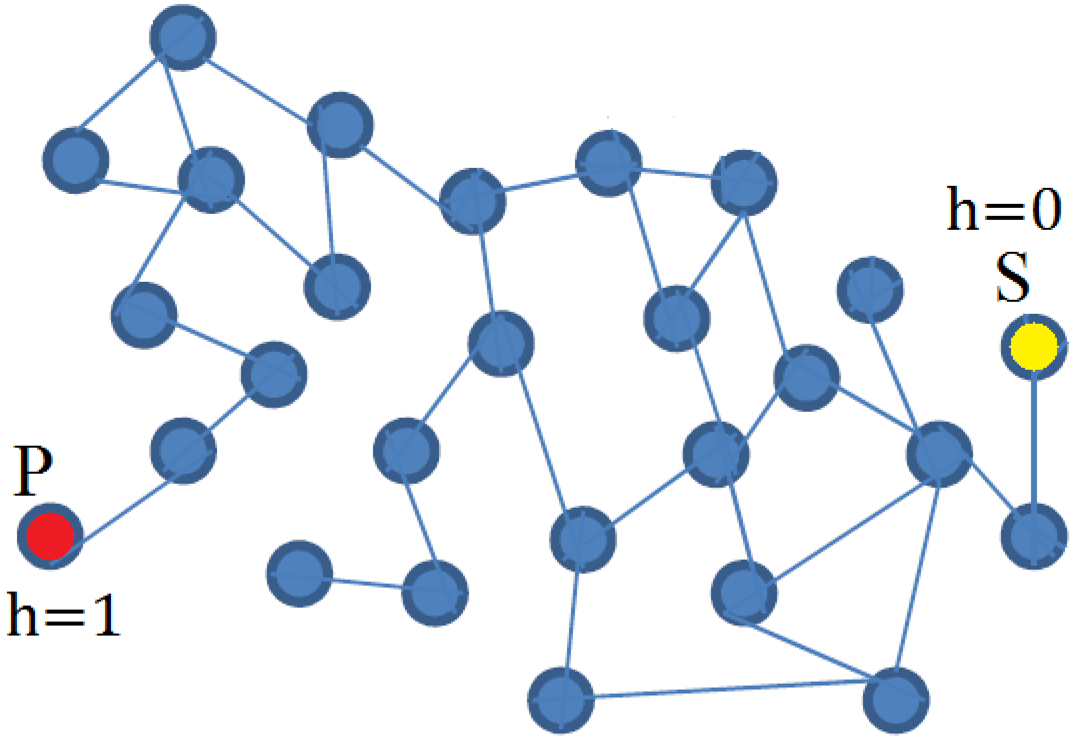
- The Laplacian Random walk

Harmonic function *h:*

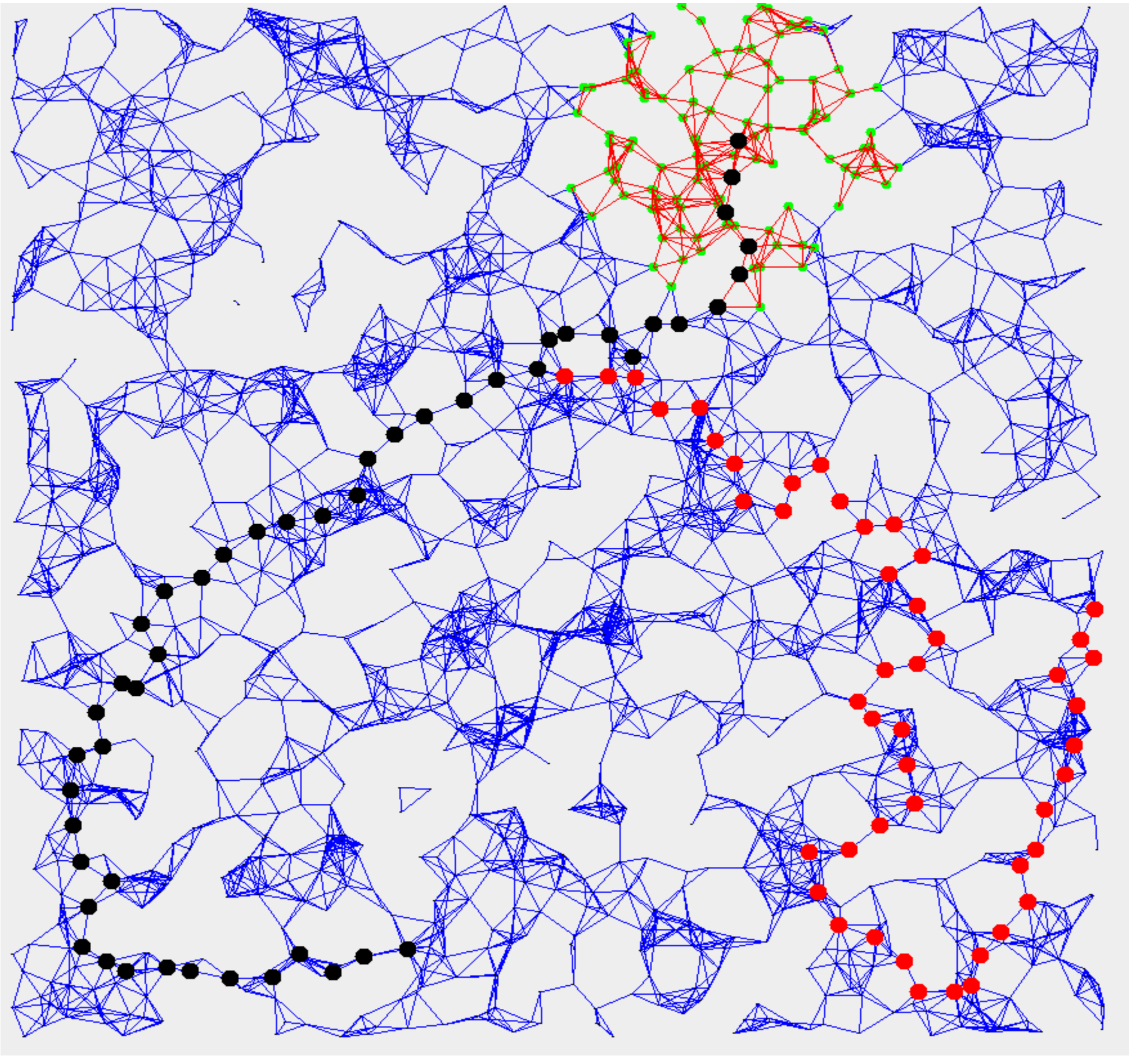
$$h(x_i) = \frac{\sum_{neihgbors} h(x_j)}{\sum neihgbors}$$

-choose min *h(x)*

-generates loop-erased path!



Simulation-Evaluation

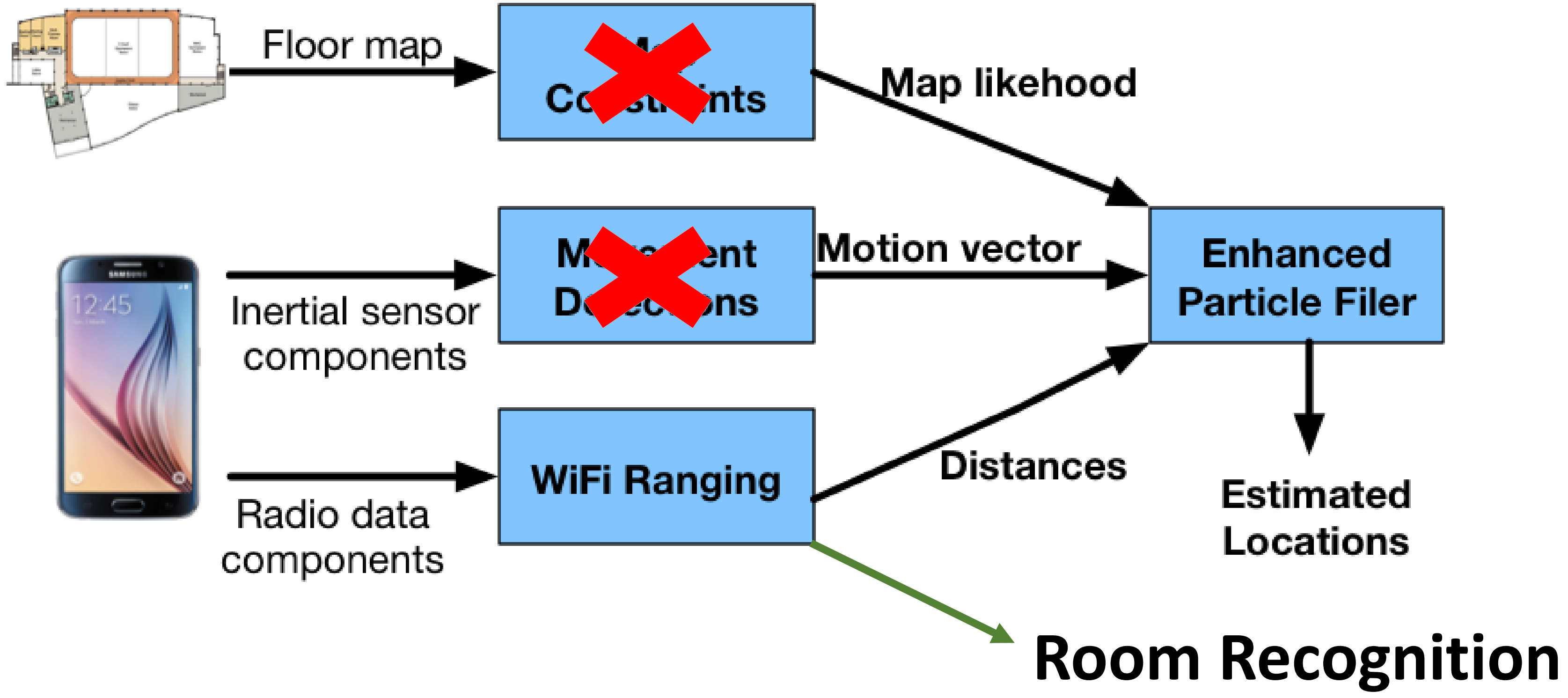


Key results:

- A minimal local knowledge of the network suffices. (d = 3 → 95% success)
- Optimal local values are observed (d = 3, St_b = 200, C_b = 200).

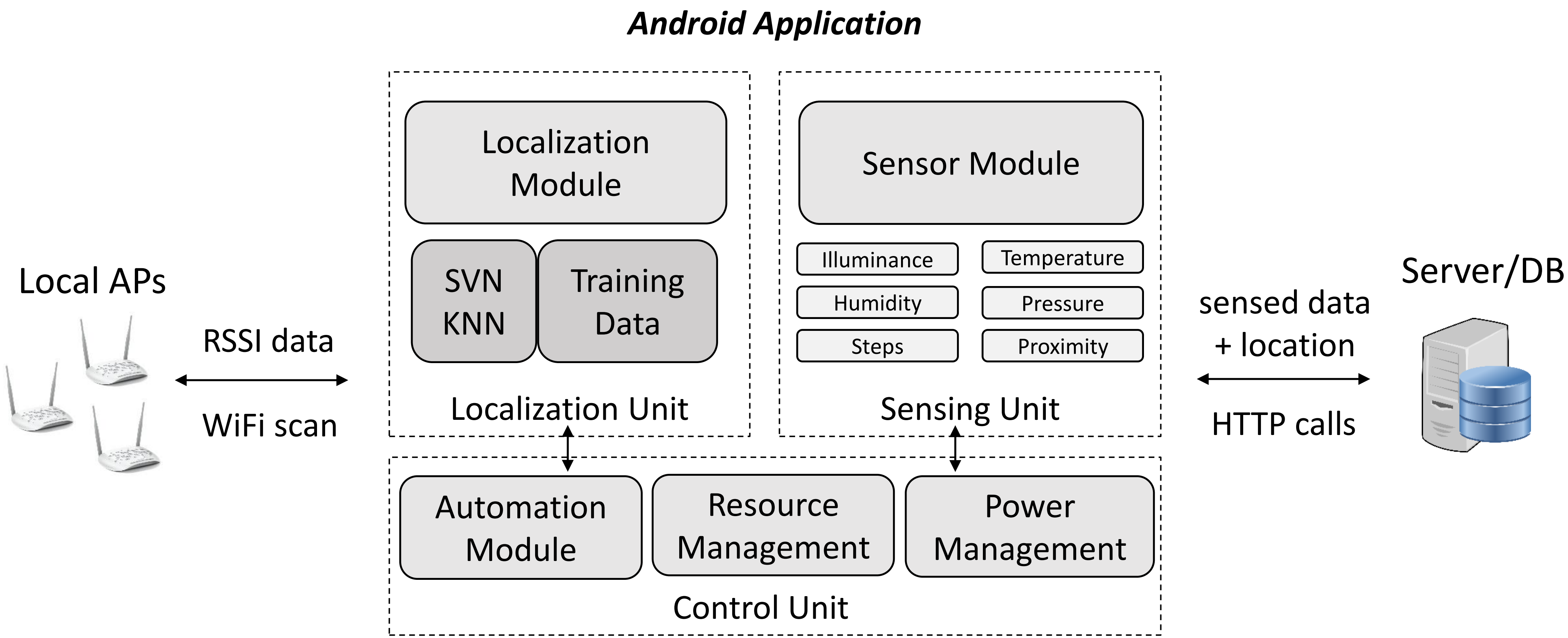
Stéphane Kundig, Pierre Leone, and José Rolim, 2016, *"A Distributed Algorithm Using Path Dissemination for Publish-Subscribe Communication Patterns",* in Proceedings of the 14th ACM International Symposium on Mobility Management and Wireless Access (MobiWac '16)

Office Automation – Indoor Location



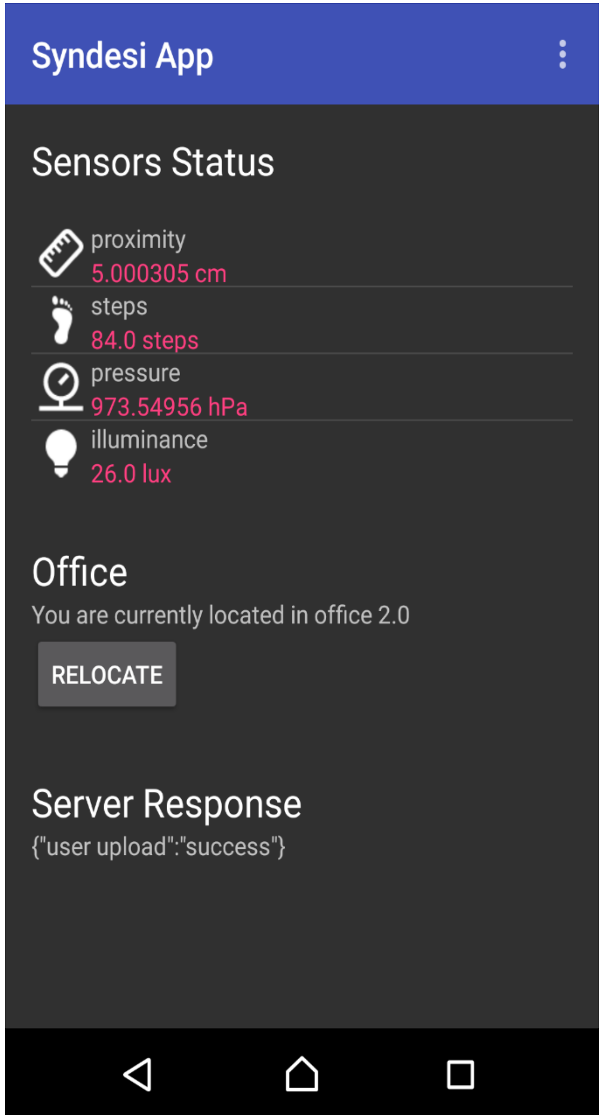
too expensive!

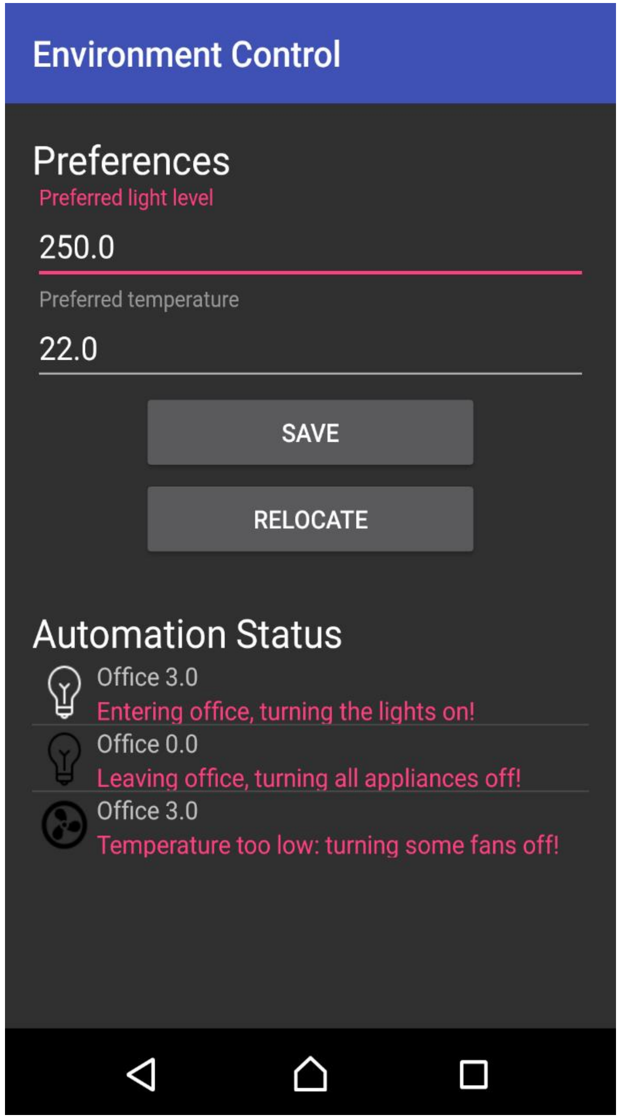
Office Automation – Indoor Location

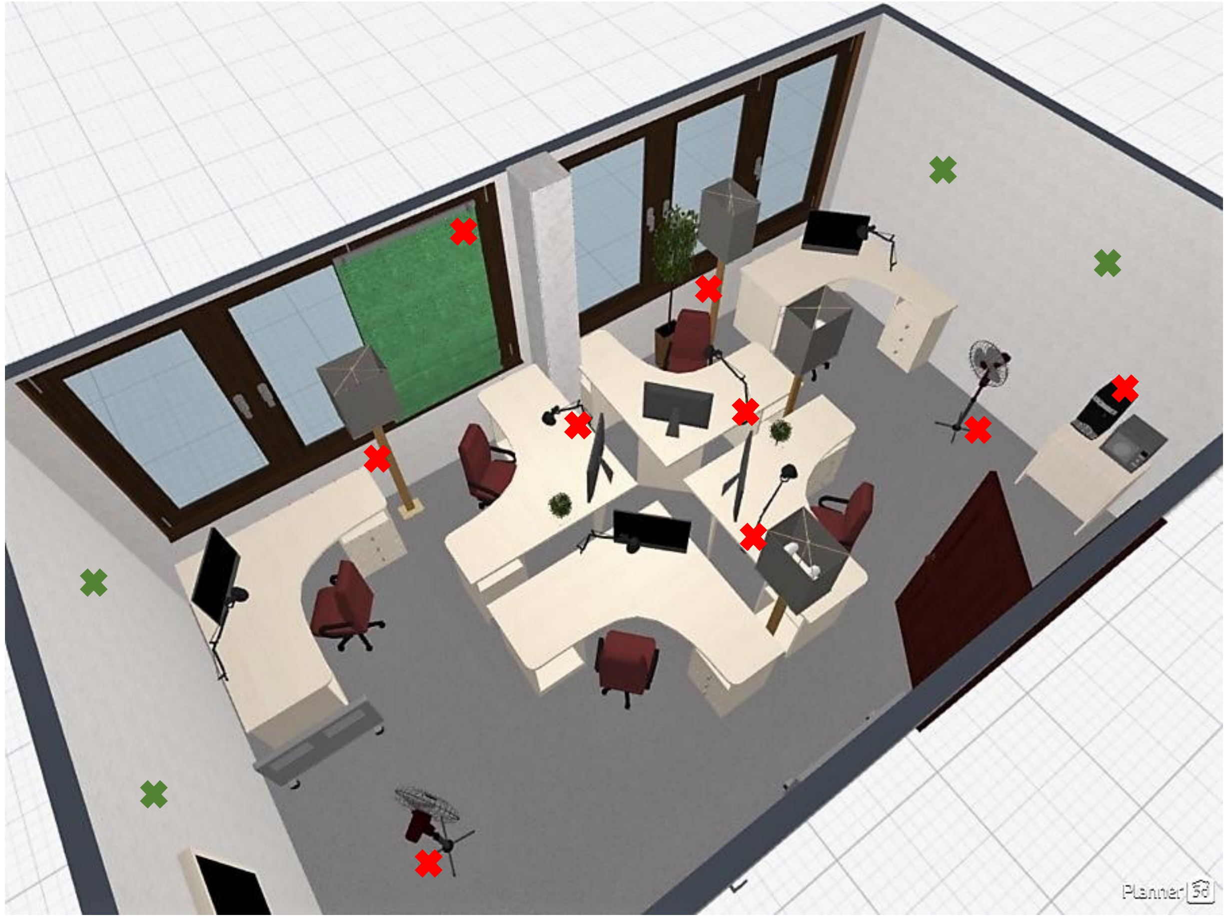


S. Kundig, Z. Zhao, B. Carron, J. Carrera, T. Braun and J. Rolim, "Indoor Location for Smart Environments with Wireless Sensor and Actuator Networks," *2017 IEEE 42nd Conference on Local Computer Networks (LCN)*, Singapore, 2017, pp. 535-538.

Office Automation





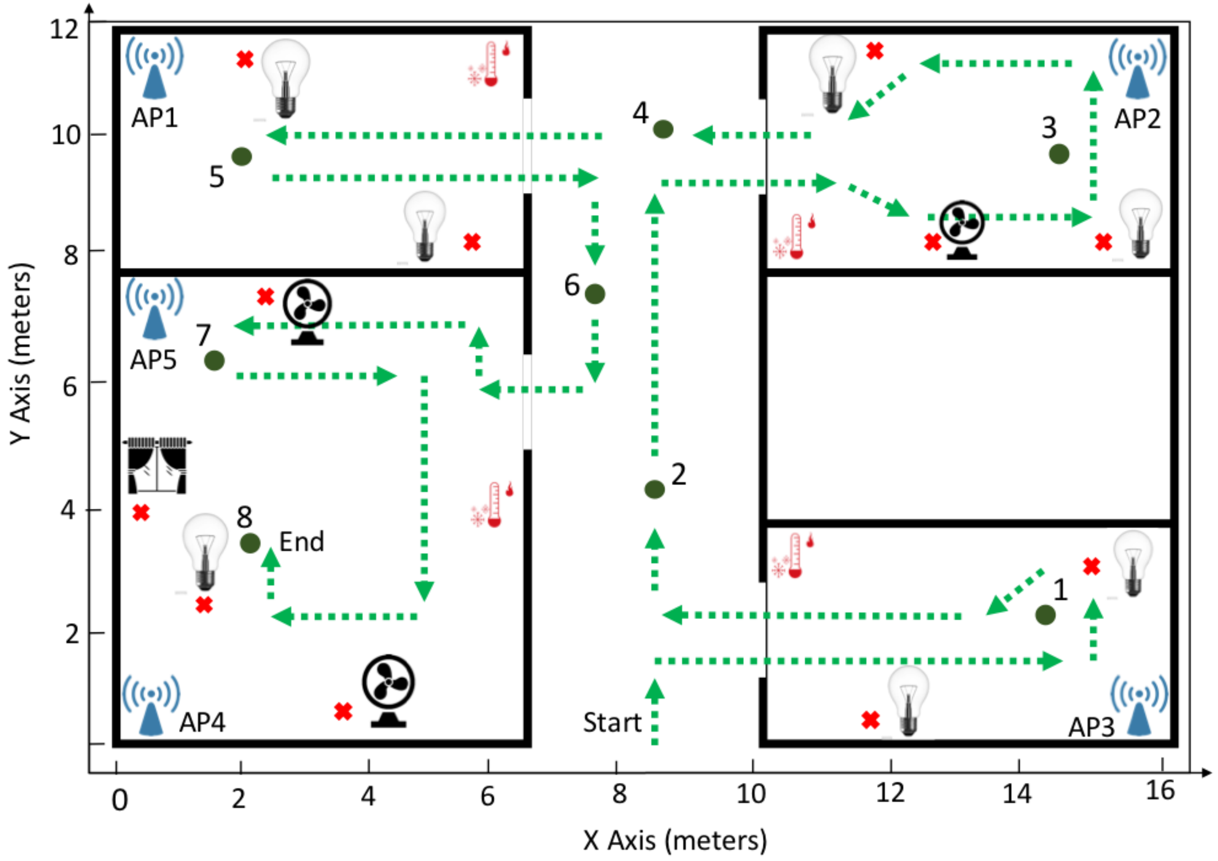


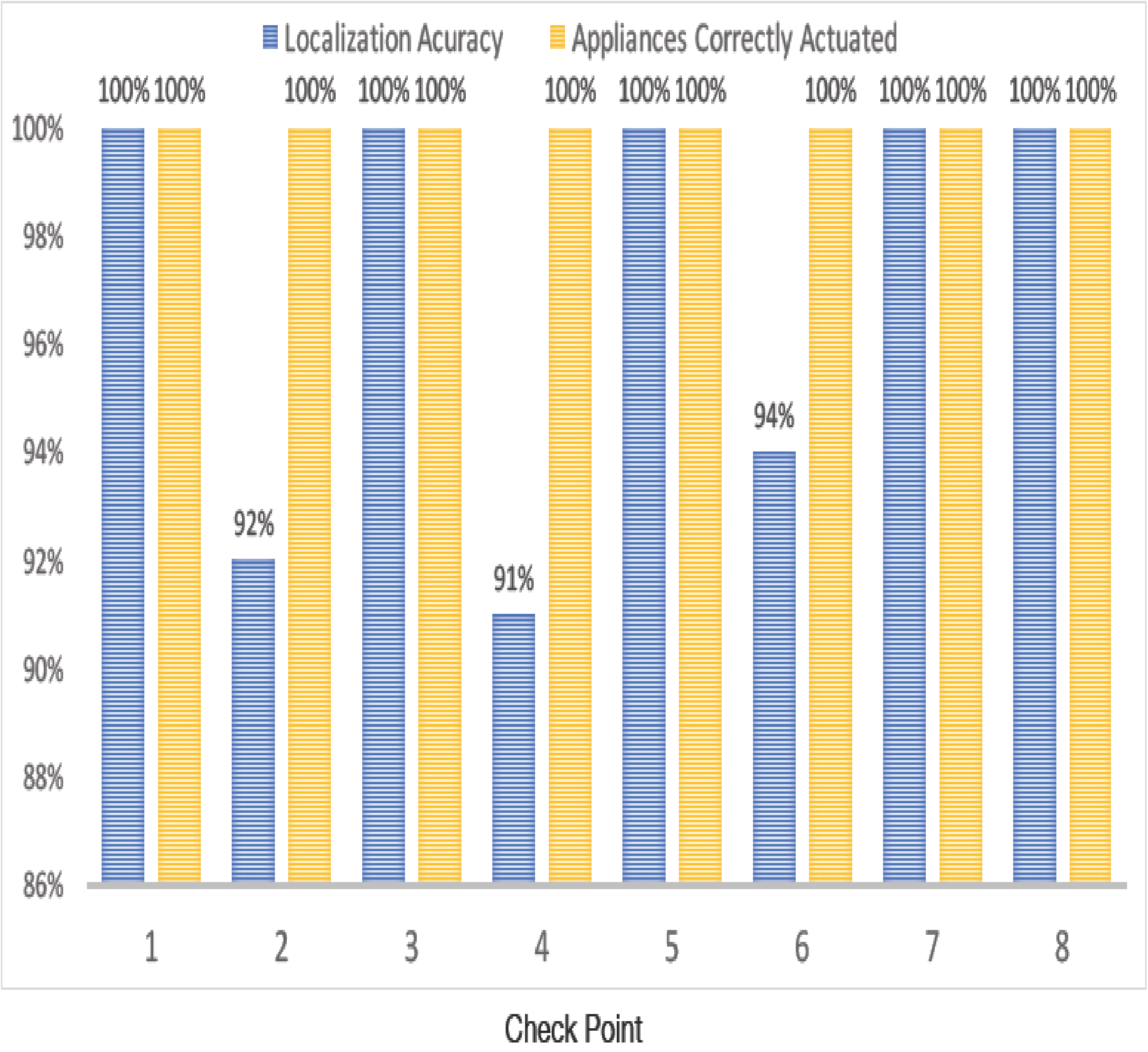
✖ Sensor
✖ Sensor-Actuator

Location-based automation

Evaluation

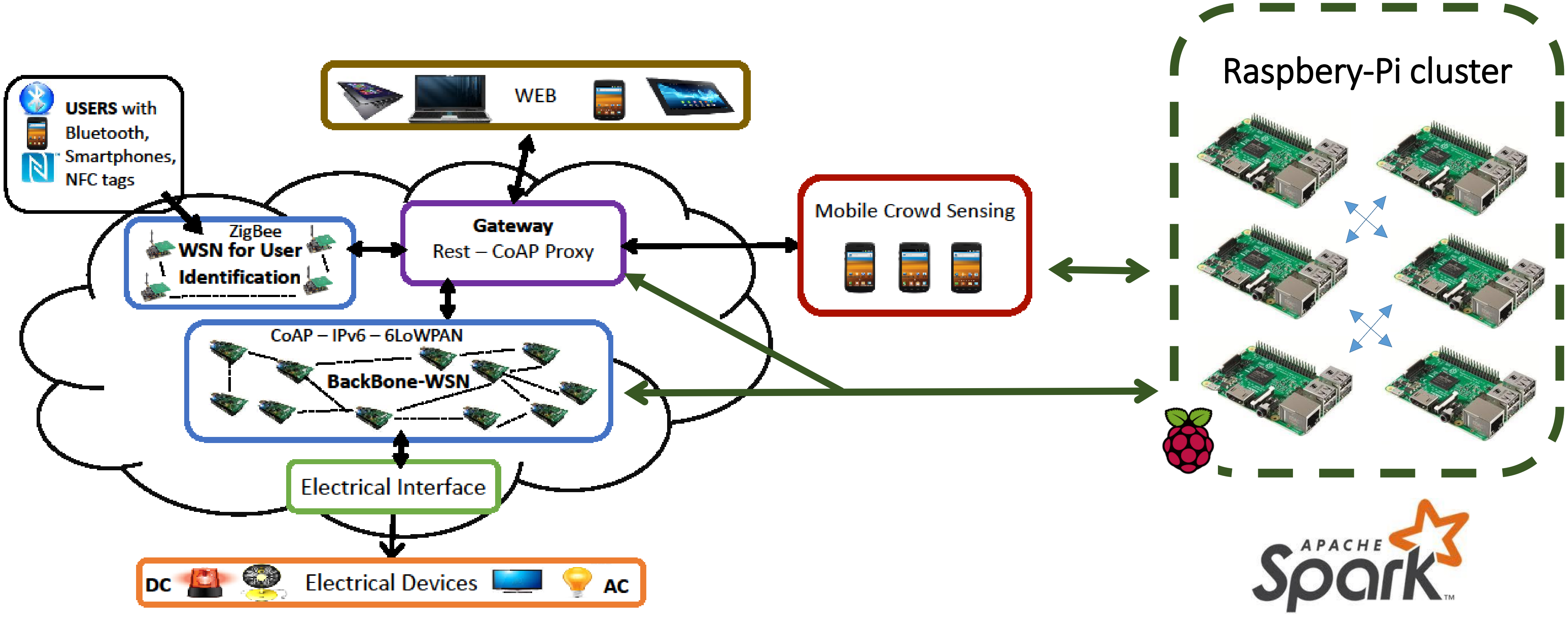
Experiment scenario





A distributed computing cluster on the edge

-Computationally demanding applications
-Low-latency demanding applications



Summary/Future work

- A WSN-based framework with diverse modules/utilities:
  -Environmental monitoring/crowdsensing
  -Location-based automation
  -Its modelled 3D-version with virtual resources of realistic values

- A distributed algorithm for bidirectional search in large scale networks

<u>Future work:</u>

-Benchmark the Raspberry-Pi cluster
-Test it in some application!

Q&A

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