When Service-oriented Computing Meets the IoT: A Use-case in the Context of Urban Mobile Crowdsensing

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Joint work with G. Bouloukakis, N. Georgantas, F. Sailhan, G. Texier, B. Lefèvre & others…

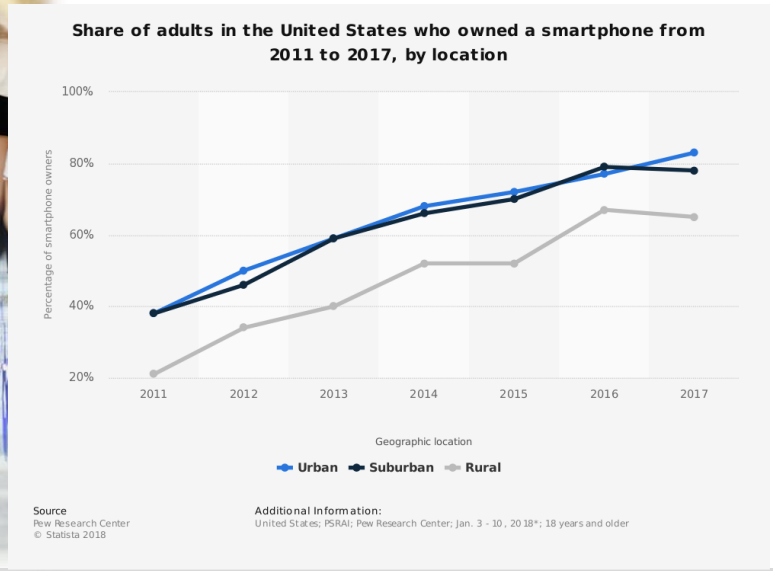
Agenda

01. The promise of mobile crowdsensing but...
02. System architecture for the urban IOT
02. The challenge of sensor accuracy
03. Crowdsensing & The urban IoT networks
04. About the users participation
05. Conclusion

01

The promise of mobile crowdsensing... But

The power of the crowd



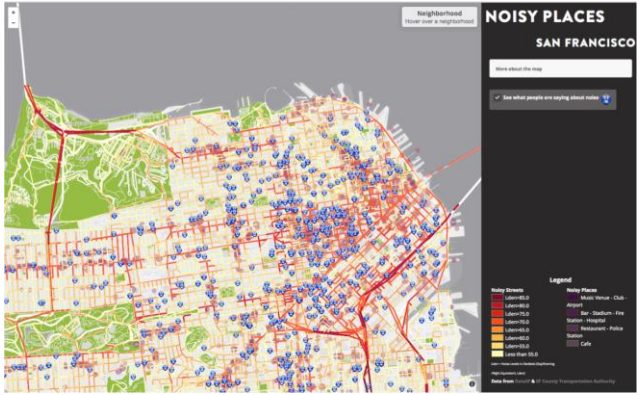
The pollution monitoring use case

Fixed sensing

High cost **but** accurate

Mobile crowdsensing

Many **but** low accuracy & diverse



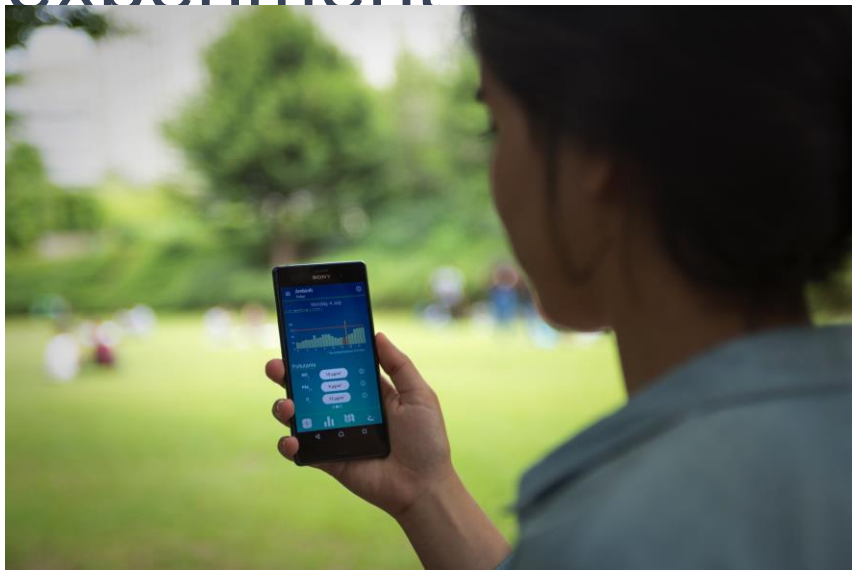
Social sensing

Qualitative **but** subjective

Our initial research question

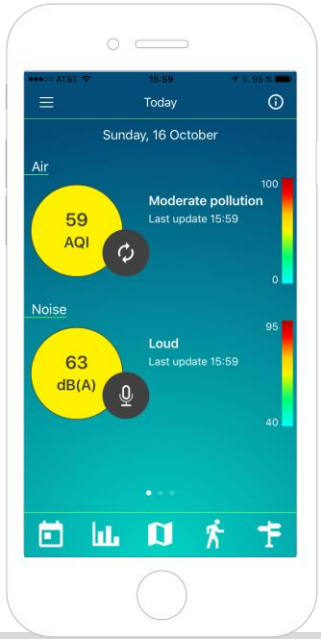
Is mobile phone sensing an effective solution to the aggregation of urban knowledge?

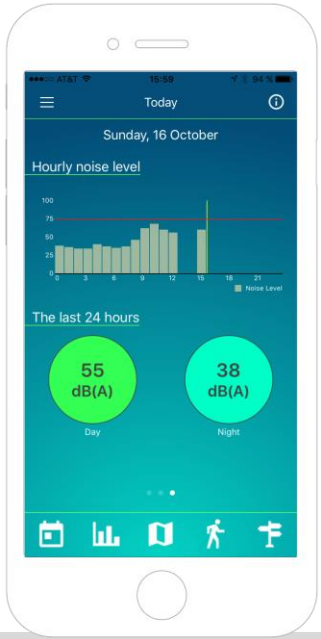
Our approach: Learning from an urban-scale experiment

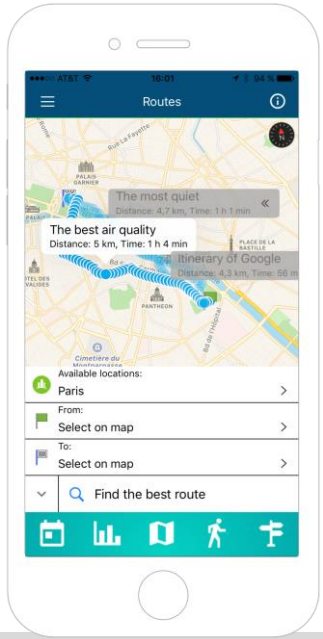


Ambiciti App informing about individual and collective exposure to urban pollution

The many facets of Ambiciti







The many challenges of Ambiciti

Accuracy of the measurements

- Low cost & heterogeneous sensors
- Context of observations

Leveraging the diverse data sources

- Data assimilation
- Integrating with the urban IoT networks

Gathering measurements from a large crowd

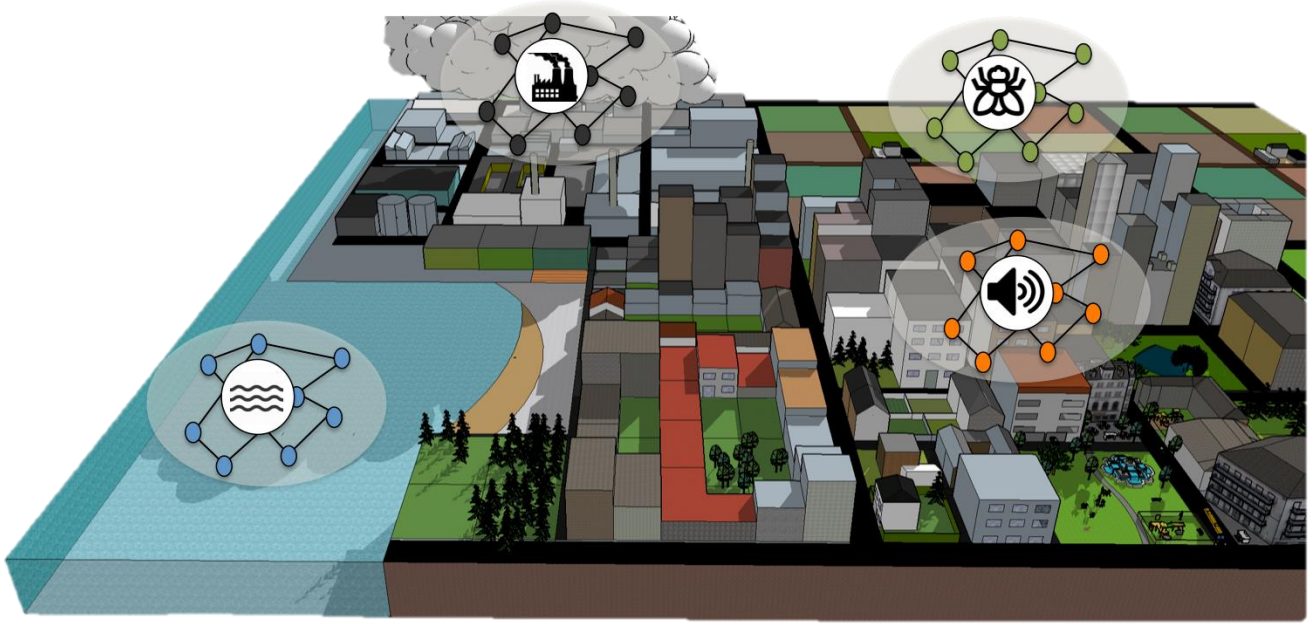
- Matching Technological and societal innovations

And many more….

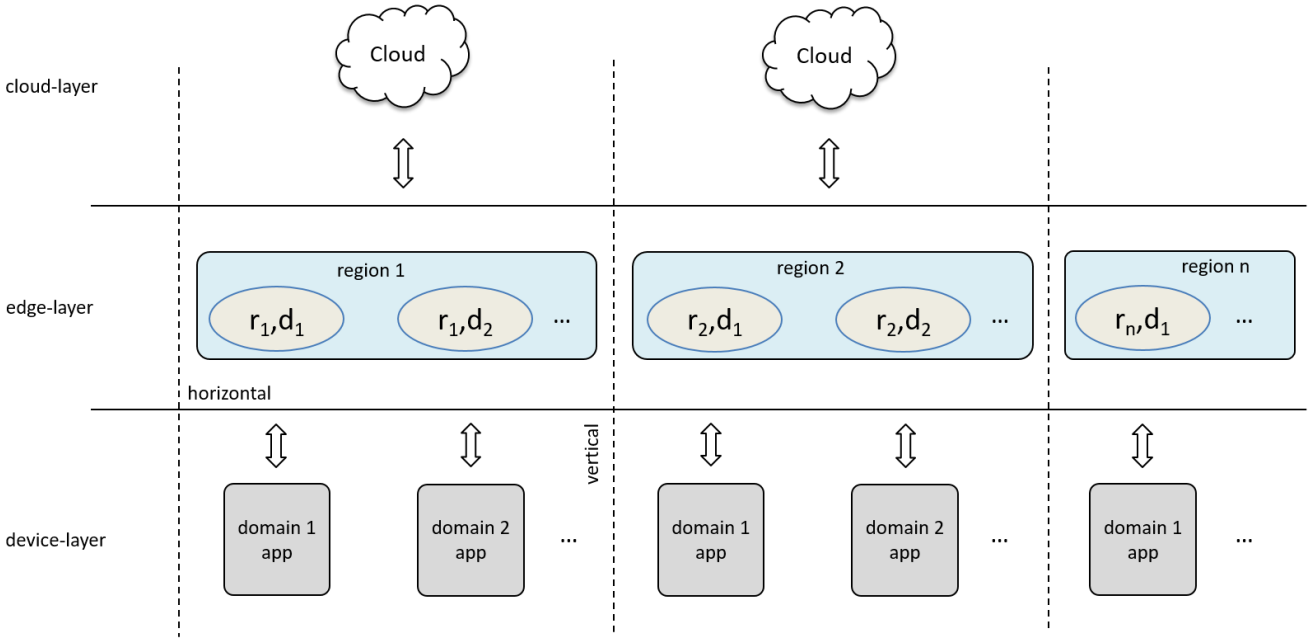
02

System architecture for the urban IoT

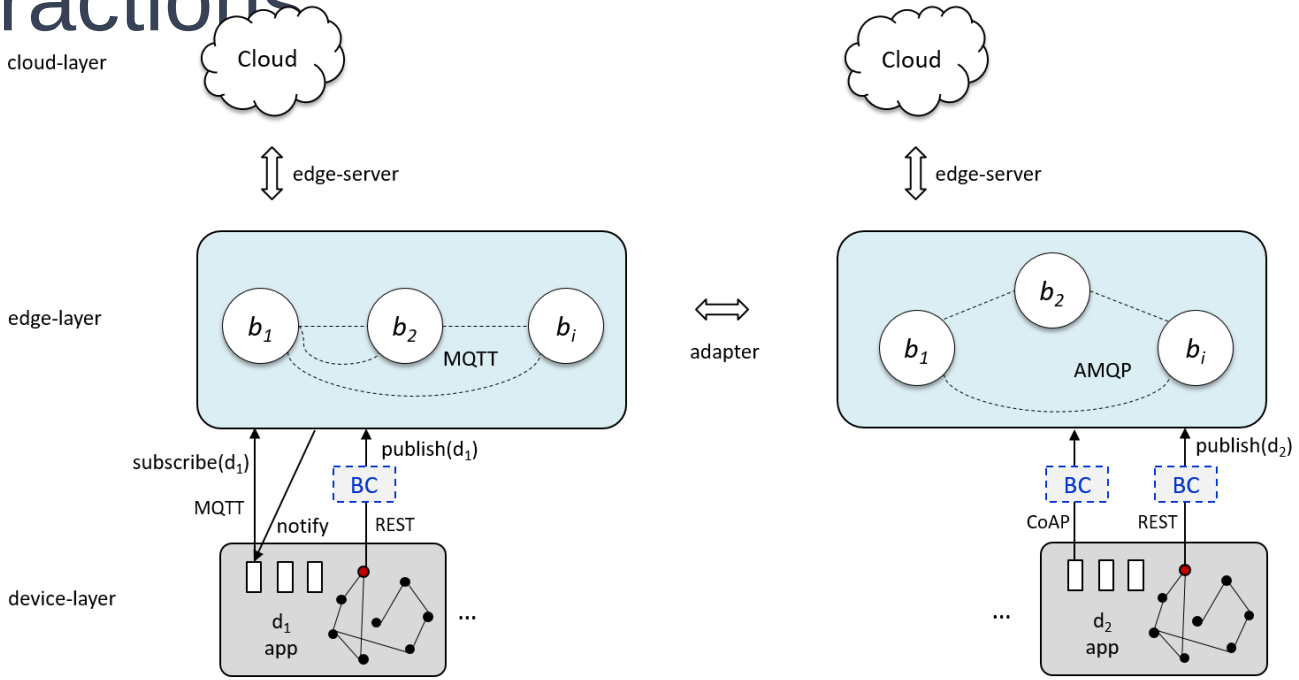
A SOC-based fixed & mobile IoT



Overcoming the scale



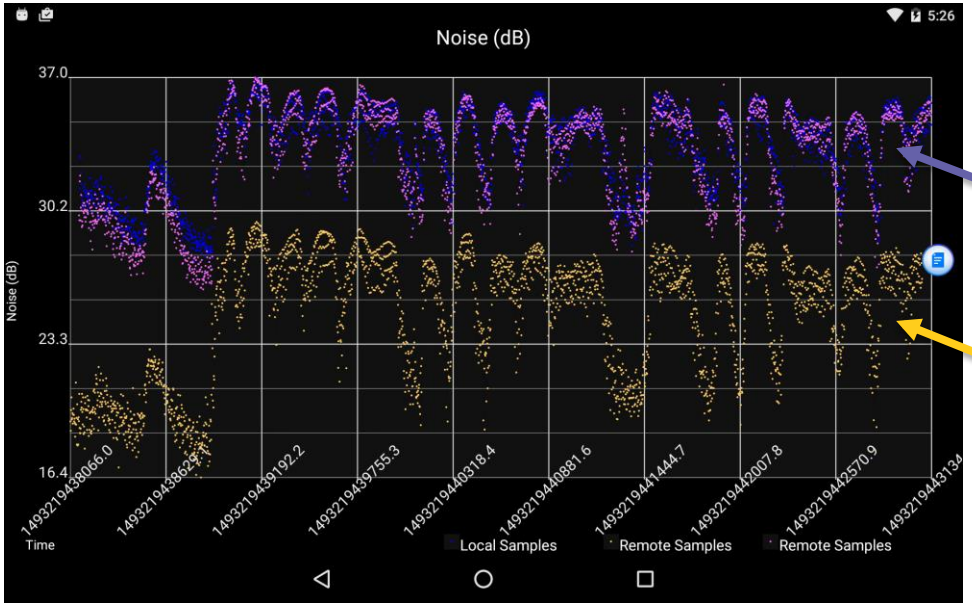
Enabling multi-domain/region interactions



03

The challenge of sensor accuracy

Inaccuracy as the norm



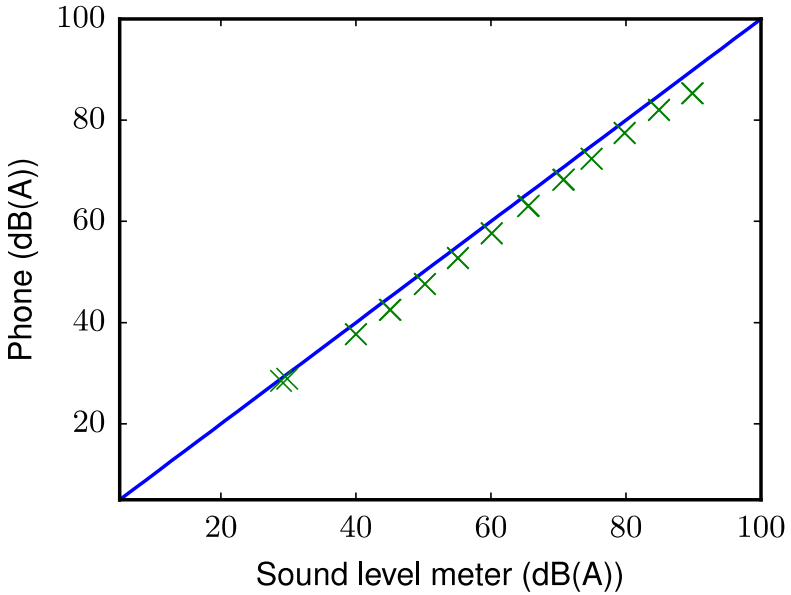
2 calibrated sensors

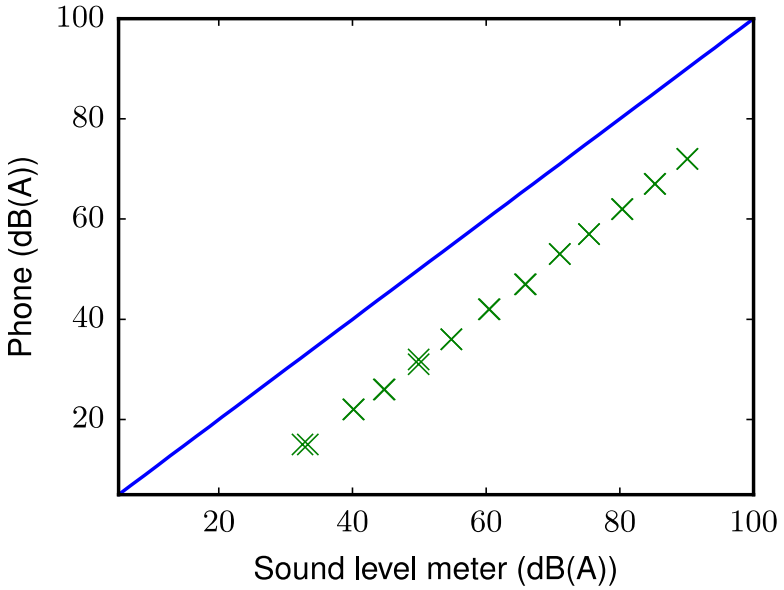
Non-calibrated sensor

[R. Ventura *et al*. JASA 142(5), 2017]

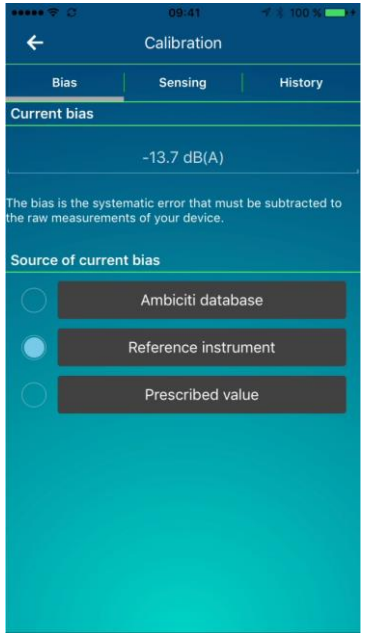
Assessing the sensors performance

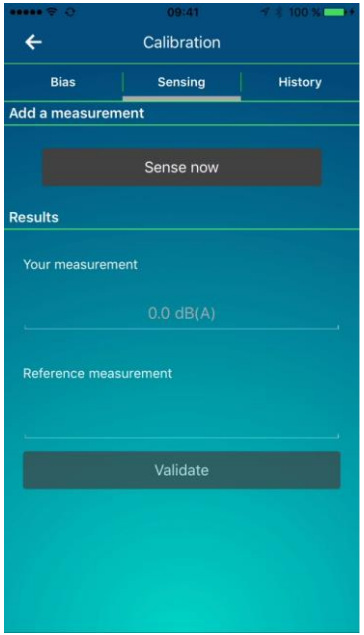
Phone SPL vs Reference SPL

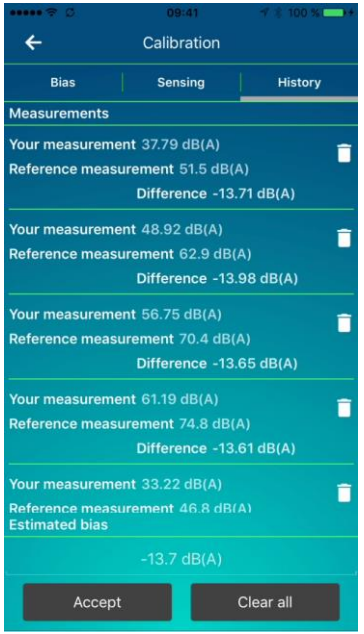




User-initiated calibration



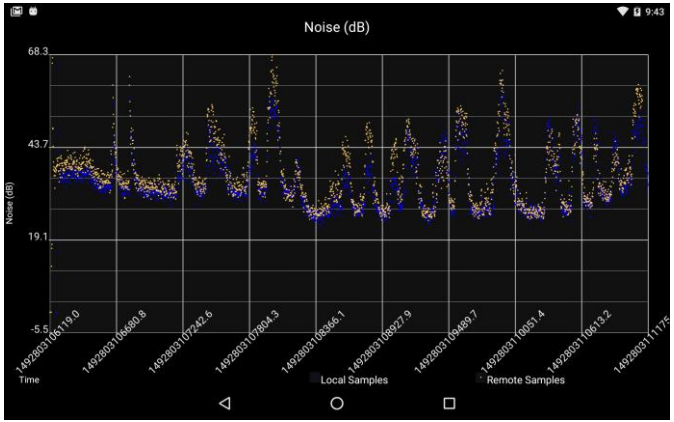


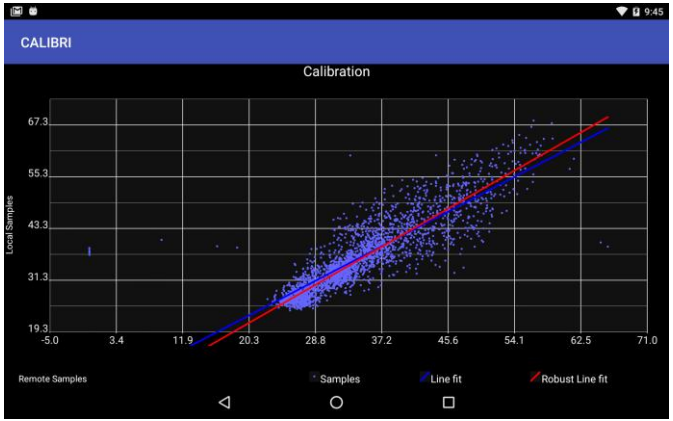


Automated collaborative calibration

Calibrate Y through collaboration with X as they meet

- The measurements by Y & calibrated X, at time t, can be related as: $y(t) = B_0 + B_1 x(t)$





Multi-party regression

$$\hat{y}_i(t) = \beta_0 + x_1(t)\ \beta_1 + x_2(t)\beta_2 + \cdots + x_K(t)\beta_K + e_i(t) \quad (1)$$

$$\hat{Y}_i(t) = X\beta + E \quad (2)$$

We want to estimate the $\hat{B}$ that minimise $\sum_{t=t_1}^{t_p}[y_i(t) - \hat{y}_i(t)]^2$ Formally,

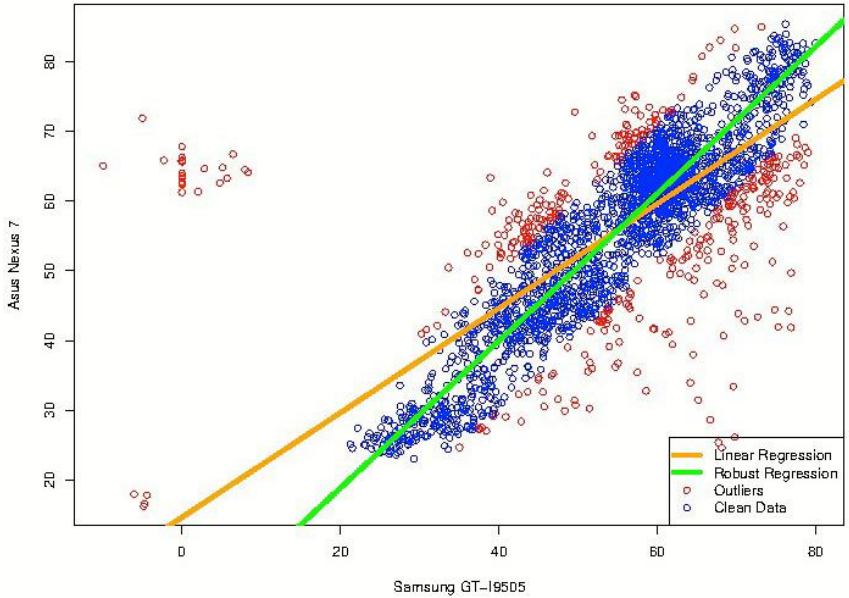
$$\hat{B} = (X^T X)^{-1} X^T Y \quad (3)$$

$$\hat{Y} = X\hat{B} = X(X^T X)^{-1} X^T Y \quad (4)$$

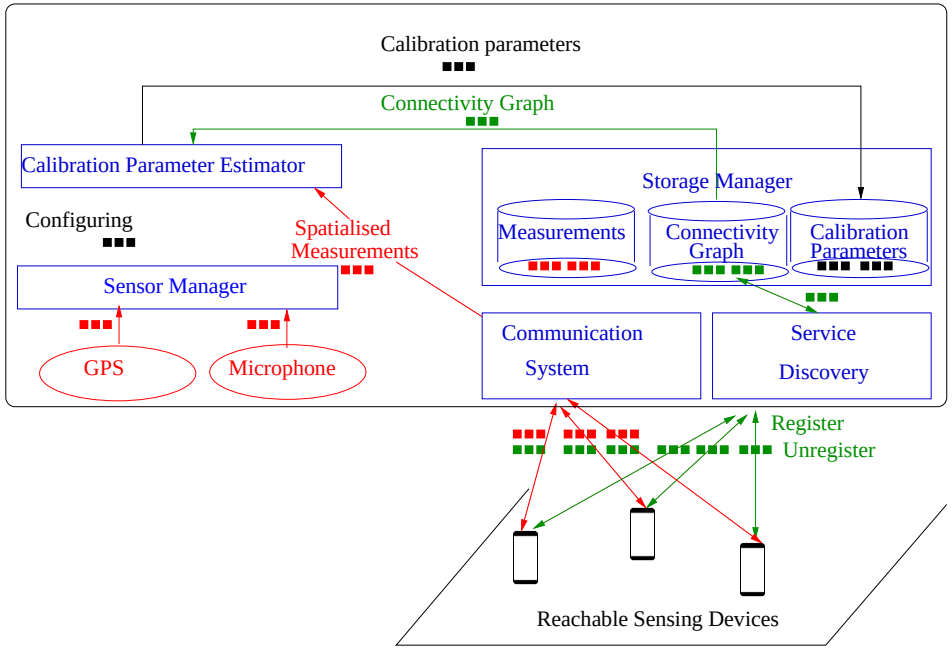
Residual Error is given by:

$$\hat{E} = Y - \hat{Y} = (I - X(X^T X)^{-1} X^T) Y \quad (5)$$

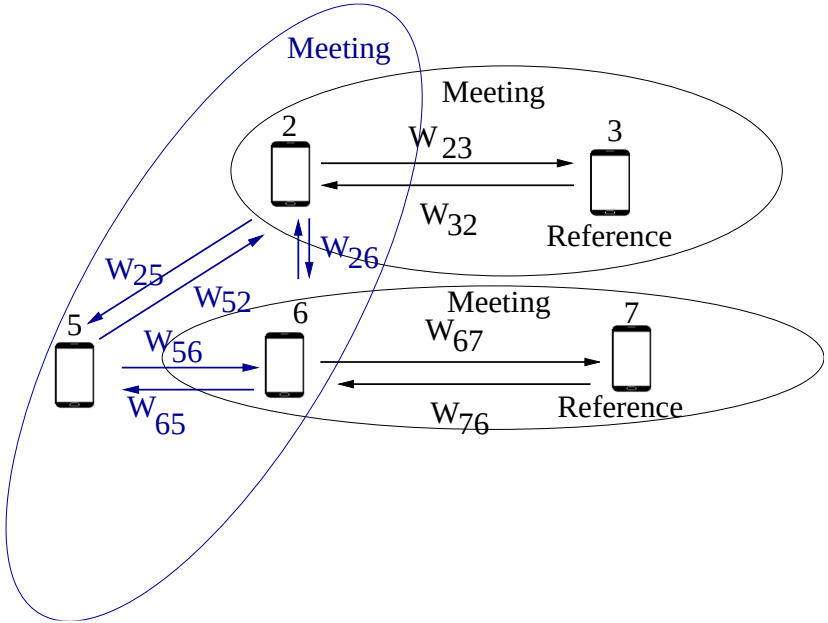
Robust regression filtering outliers



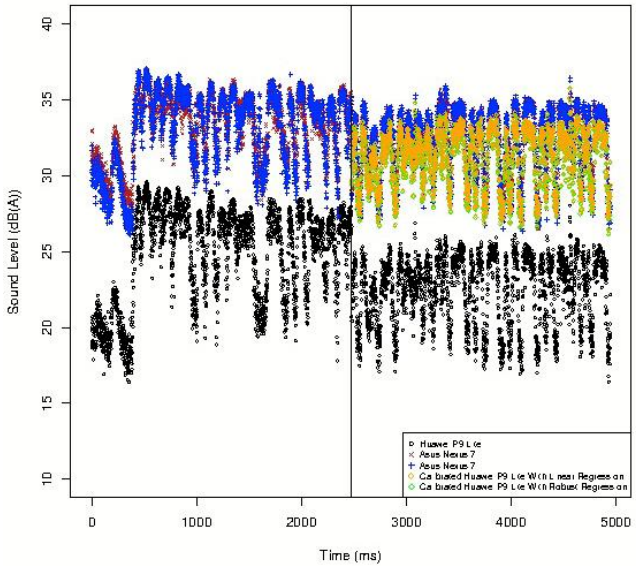
Collaborative calibration



Assessing the relevance of a rendez-vous



Evaluation



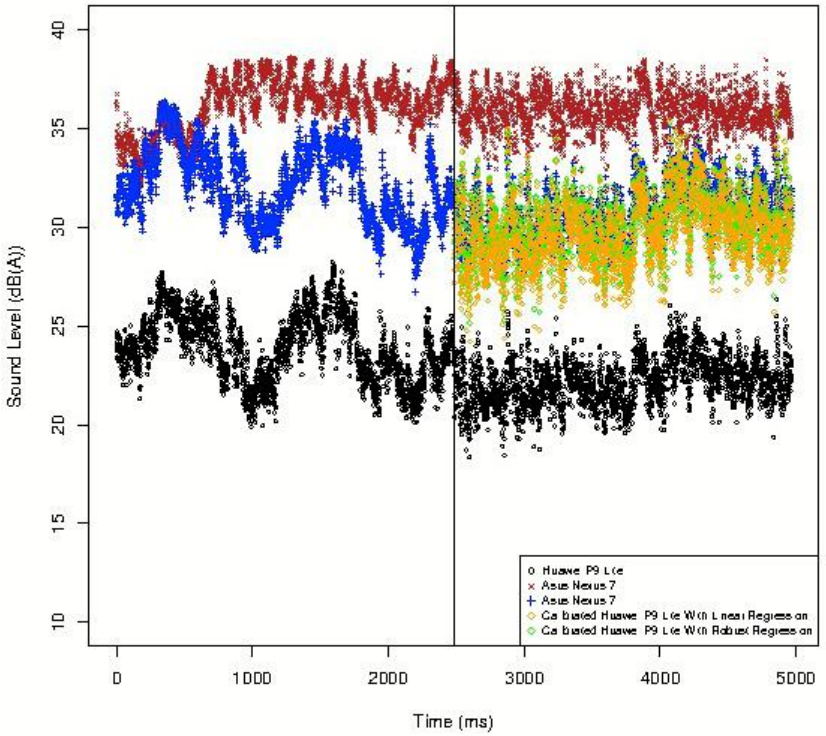
$\mathbb{E}$(uncalibrated reading - calibrated ones)	8.34 dB(A)	
$\mathbb{E}$(adjusted reading - calibrated ones)	0.78 dB(A)	0.64 dB(A)
Adjusted R^2	0.84	0.92
$\mathbb{E}(residualerror)$	$-7.27.10^{-15}$	-2.35.10−15
σ(residual error)	1.23	0.85

Evaluation

Encouraging results in a controlled environment.

Ongoing work focused on use in the wild

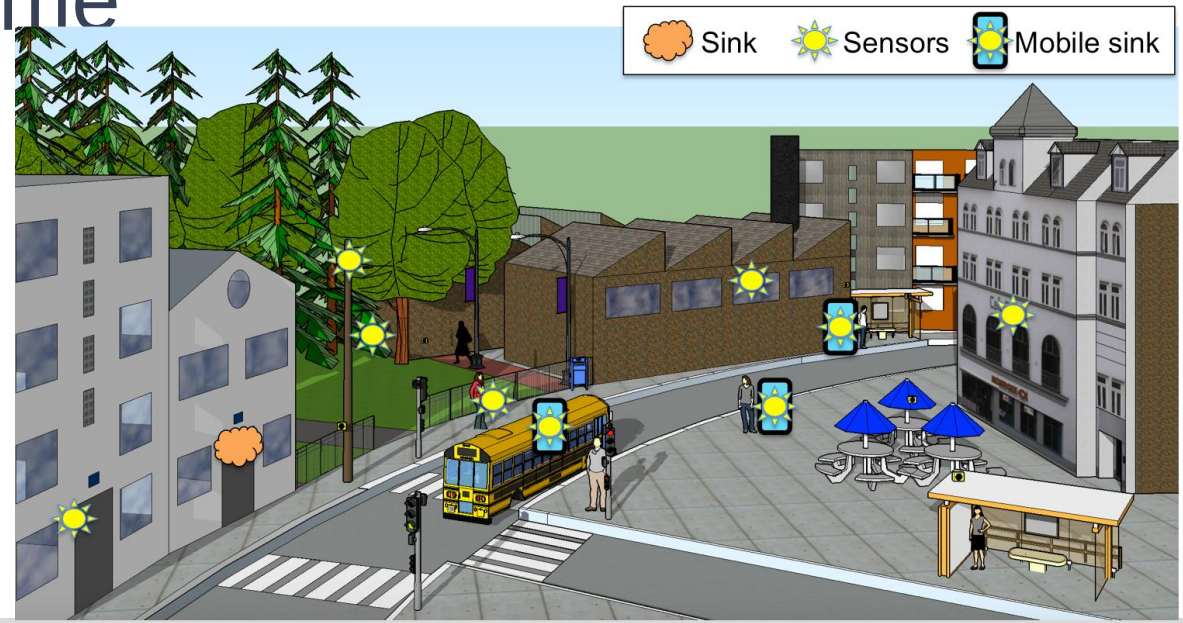
Context-aware collaborative sensing



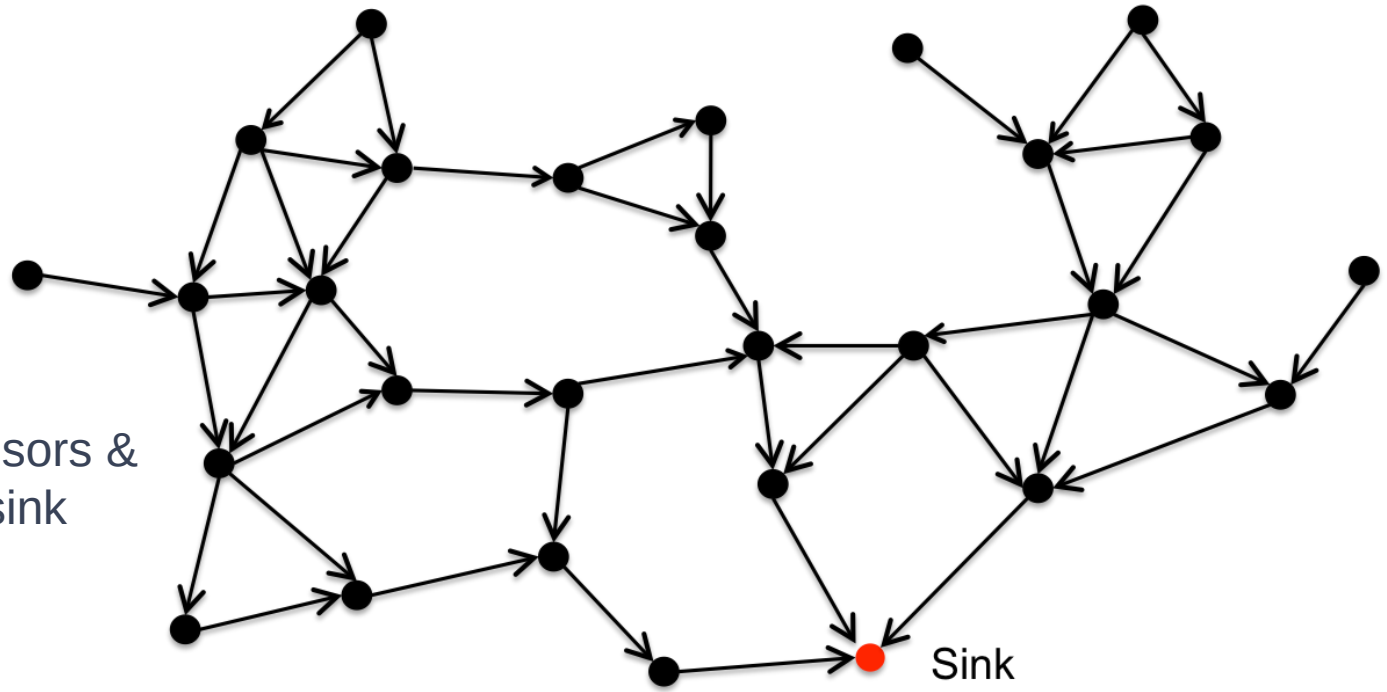
04

Crowdsensing &
The urban IoT networks

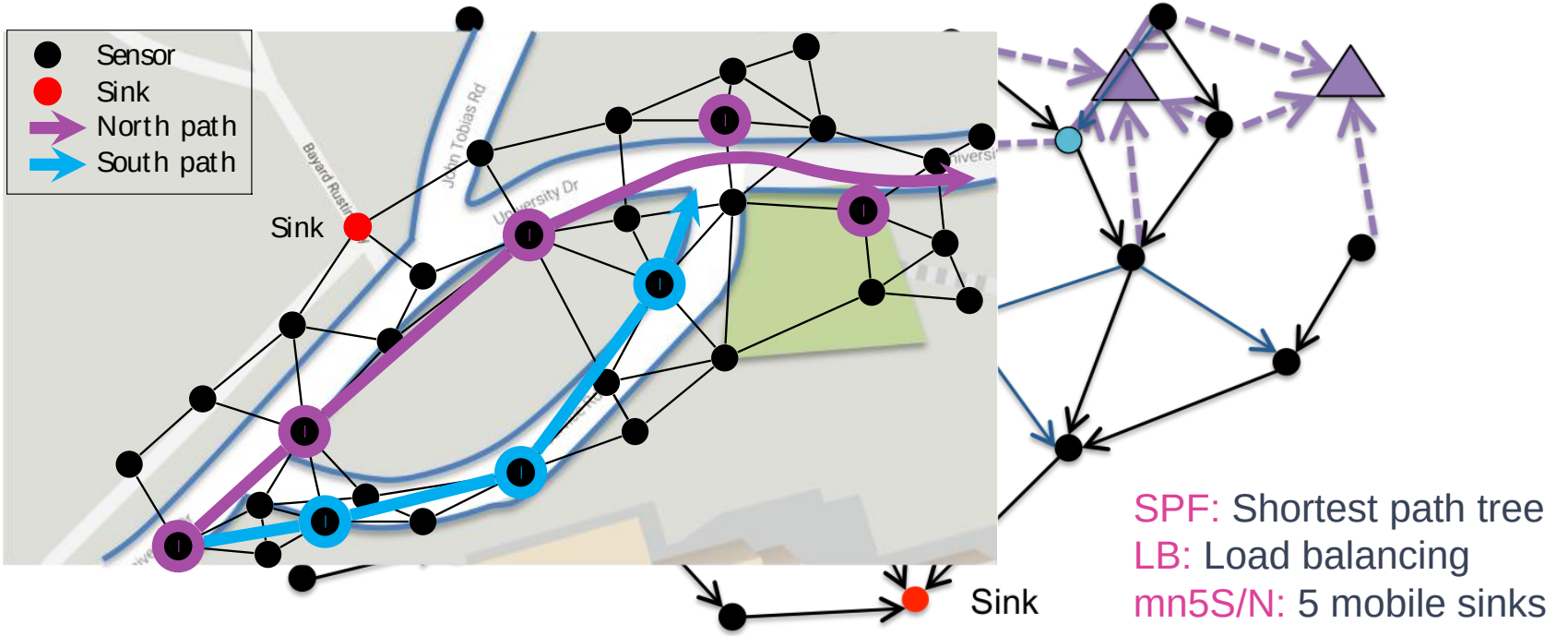
Combining the IoT infrastructure and crowdsensing to extend the WSN lifetime



The WSN



The WSN leveraging mobile sinks



SPF: Shortest path tree
LB: Load balancing
mn5S/N: 5 mobile sinks

The LP formulation

$$\max \quad min(l_d)$$

subject to

$$\sum_{j \in \mathcal{N}_{out}(i)} \varphi_{dij} - \sum_{j \in \mathcal{N}_{in}(i)} \varphi_{dji} = 0, \quad \forall d \in \mathcal{D}, \forall i \in \mathcal{N}_{\mathcal{I}} \tag{1a}$$

Flow conservation

$$\sum_{j \in \mathcal{N}_{out}(i)} \varphi_{dij} = 0, \quad \forall d \in \mathcal{D}, \forall i \in \mathcal{S} \cup \mathcal{M} \tag{1b}$$

Exit at a sink

$$\sum_{j \in \mathcal{N}_{out}(s_d)} \varphi_{dij} \geq l_d * Q \tag{1c}$$

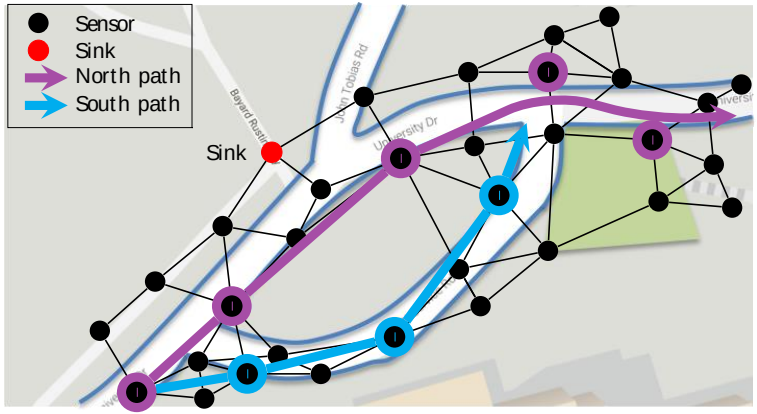
$$e_t * \sum_{d \in \mathcal{D}} \Big(\sum_{j \in \mathcal{N}_{out}(i)} \varphi_{dij} + \sum_{j \in \mathcal{N}_{in}(i)} \varphi_{dji} \Big) + \sum_{k \in \mathcal{N}_{out}(i)} (e_m * \varphi_{dik} + e_c) \leq E, \quad \forall j \in \mathcal{N}_{\mathcal{I}}, \forall k \in \mathcal{M} \tag{1d}$$

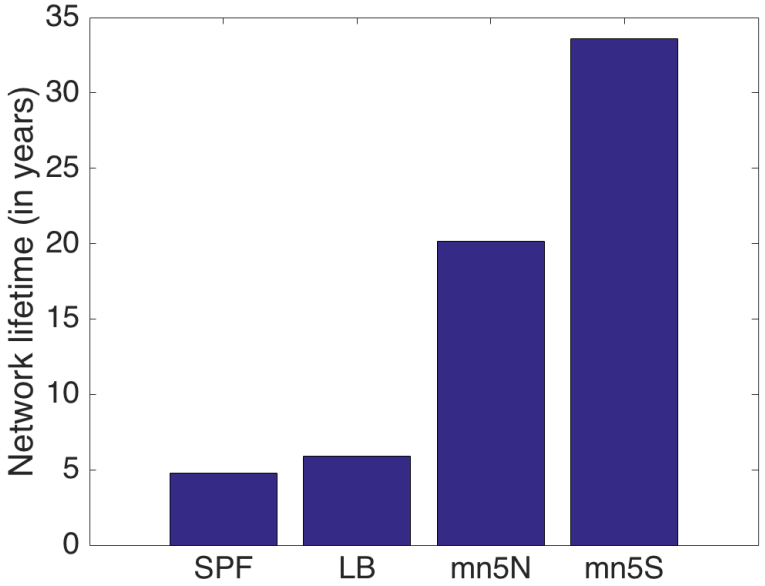
Energy cost incl. routing

$$\sum_{d \in \mathcal{D}} \nu_d \geq 0 \tag{1e}$$

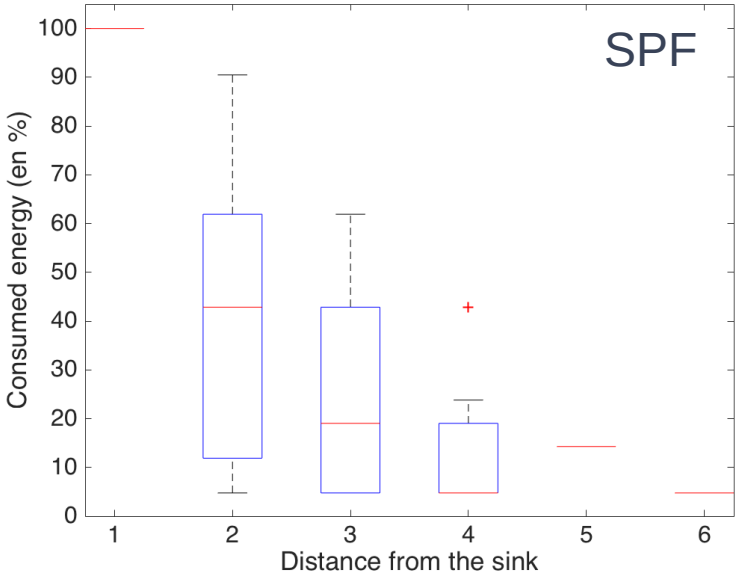
$$\varphi_{dij} \geq 0, \quad \forall d \in \mathcal{D}, \forall i, j \in \mathcal{N} \tag{1f}$$

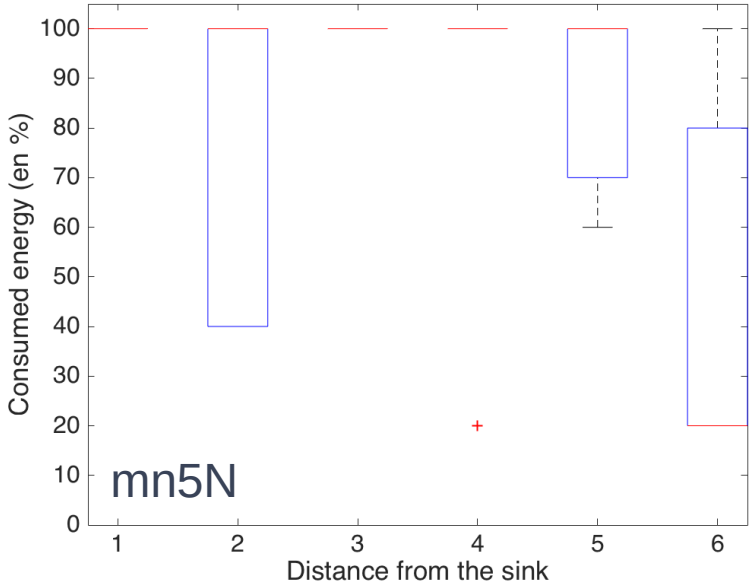
The network lifetime





Sensor lifetime analysis





05

About the users participation

A look at contributed observations (10 months)

Filtering		Observations		Known Bias
Criteria	Value	#	%	
-	-	18,047,413	1279.0	
Paris	Loc accuracy < 100 meters	1,411,174	100.0	
Location acc.	<30 meters	896,917	63.5	293,253
Noise level	<25 & >95	555,377	39.3	260,221
Outdoor	Clustering	73,841	5.2	34,351
Speed	< 7km/h	62,290	4.4	26,830
Proximity	No	36,768	2.6	14,503

The diverse user perspectives

Why ?	What for ?	Registre	Usage	Design	Interface
(What are the reasons why I expect to use it ?)	*(And after ? How should I exploit these data in a more global project ?)*	*(How do I consider noise levels data?)*	*(How do I socially expect to use these data?)*	*(What kind of design would be convenient to me?)*	*(What the interface should provide me first?)*
Out of curiosity	No a piori project. One shot.	Social, geek	Network	Trendy, High tech	Original graphism and Data vizualisation
To know more about my personal noise exposure	An individual noise tracking	Health, Quality of life	Personal	A simple and efficient tool	Streamlined and reliable
To reduce my personal noise exposure	I get valuable tips to reduce my exposure and check it is positively changing	Health. Mobility.	Personal.	An accurate partner and adviser.	Indicators about the danger levels related to my exposure. Help services.
To get new kind of information for a better health protection	Evaluating my personal exposure regards to standard levels and inherent risks	Health	Personal, Network	Relate measurements and information and notifications	Indicators that contextualize and give meanings to my measurements
To produce new knowledge about the place I live or work	To mobilize my neighbors or colleagues to collectively minimize excessive noise exposure	Health, Quality of life, Citizenship	Network, Policies	Relation to perceived noise, to territorial visualization, to social comments	Space and time contextualized measurements, global information about pollutants. Social network
To contribute to producing new knowledge for urban action	I share my measurements. I expect a collective action.	Citizenship, Environment, Urbanism.	Network, Collaborative	A customizable multi-features tool. Connected to others.	Easily customizable interface, responsive. Maps and social network
To make choices including noise pollution	For many cases (mobility, choice of a living area, militant action), I need opportunistic measurements.	Citizenship, Environment, Expert.	Personal, Network, Collaborative	A multi-resource tool	A functional tool, customizable, qualified data. Maps and social network

Take away & next step

User-centered plastic interfaces

Must allow the adaptation of the user interface
by and for the user

Effective usage environment & subjective aims

Privacy

Guaranteeing privacy remains an open research question

06

Conclusion

Back to our initial research question

Is mobile phone sensing an effective solution to the aggregation of urban knowledge?

Yes but…

Thank you!!

To know more

valerie-issarny.me

project.inria.fr/siliconvalley

mimove.inria.fr

ambiciti.io