



The "Smart Ring" Experience in L'Aquila (Italy): Integrating Smart Mobility Public Services with Air Quality Indexes

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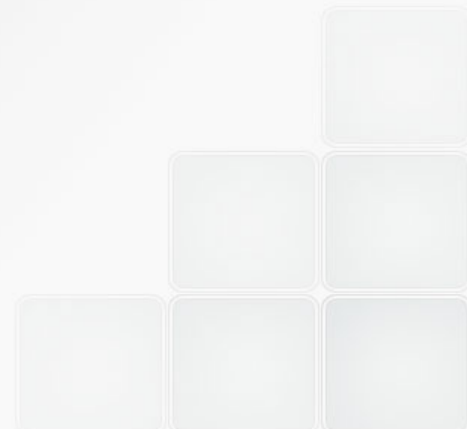
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Smart Ring in L'Aquila (Italy)

- To reconstruct L'Aquila on a Smart City Paradigm (2010)
- Focus on City Dynamics and Smart Environment activities
- “Smart Ring”, 4-5 km circular path around the centre of L'Aquila
- Integration of mobility public service “Smartbus”, with sensor system NASUS IV

AIM:

- Smartbus as a mobile sensor
- Qualitative representations of air status (users)
- Complementary tool to established air quality networks



Smartbus



Experimental public service
(19.05.14-31.10.14)

“On demand” electric bus service (hybrid)

Electric traction by rechargeable batteries

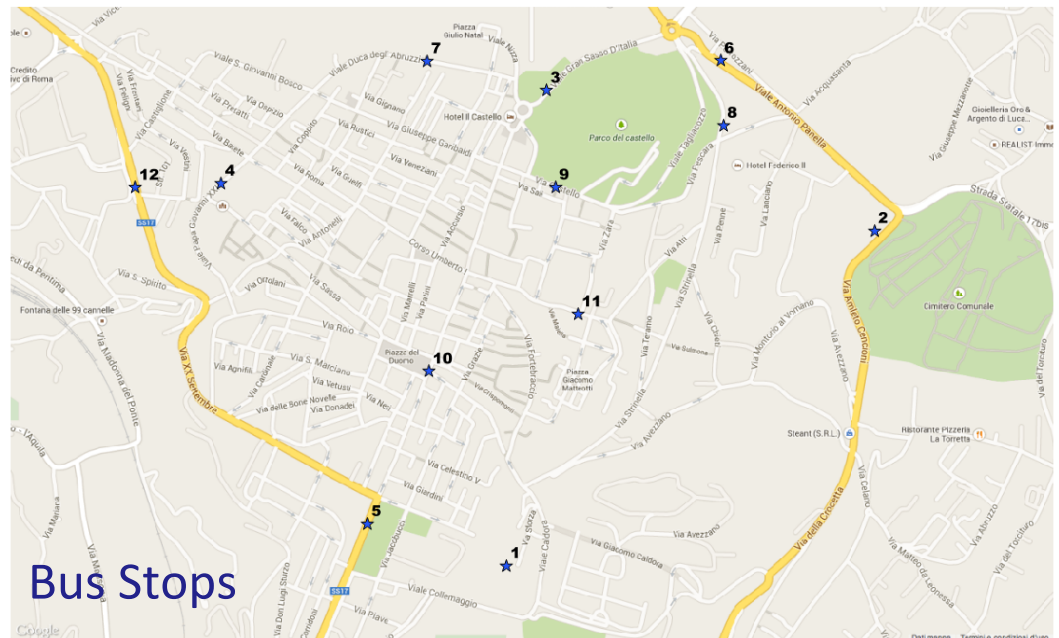
Internal control room

Measurements @ 1 s resolution

Ecological vehicle Iveco Daily

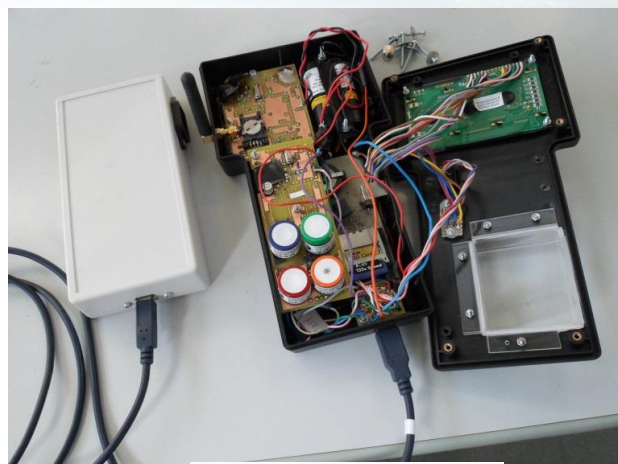
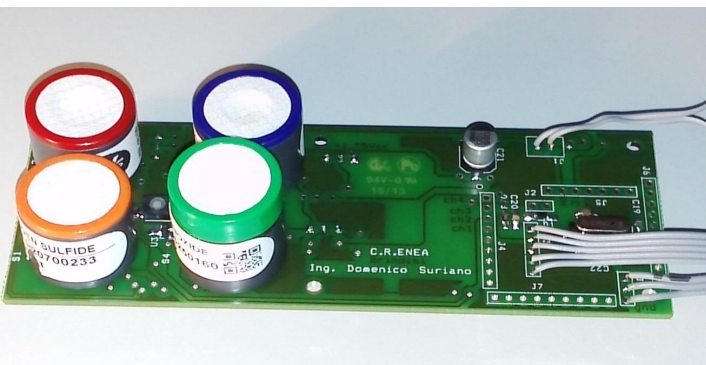
Website to book the service

~ 10 bus stops over the Smart Ring



Bus Stops

NASUS IV



Sensors	Sensors Characteristics	
	Model e factory	Operativity range
NO₂	NO2A1-A3 Alphasense Ltd (UK)	0-20 (ppm)
CO	COCX-A3 Alphasense Ltd (UK)	0-1000 (ppm)
SO₂	SO2AF-A3 Alphasense Ltd (UK)	0-20 (ppm)
H₂S	H2SA1-A3 Alphasense Ltd (UK)	0-20 (ppm)
Temperature	LM35CZ National Semiconductors Co. (USA)	-55°C +150°C
Relative humidity	HIH-3610 Series Honeywell (USA)	0-100% RH

Continuous measurements @ 4 s resolution saved on memory card



Air Quality Index

AQI values	Air quality status	Colours
<33	Excellent	Blue
34-66	Good	Green
67-99	Moderate	Yellow
100-150	Bad	Red
>150	Worse	Violet

Reference levels
(Dgl. 155/2010)

CO: 8 ppm;

NO₂: 100 ppb;

H₂S: 90 ppb;

SO₂: 130 ppb.

$AQI = 100 * (\text{measured concentration}) / (\text{reference concentration})$.

$$AQI_{\max} = \text{MAX}(AQI_{\text{NO}_2}, AQI_{\text{SO}_2}, AQI_{\text{H}_2\text{S}}, AQI_{\text{CO}})$$



Fields Campaign



Parameters

Smartbus & NASUS IV:

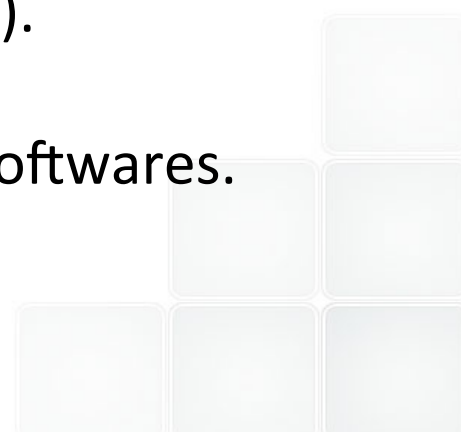
Smartbus	NASUS IV
Datetime (timestamp)	Datetime (timestamp)
Latitude (deg)	NO ₂ (ppm)
Longitude (deg)	SO ₂ (ppm)
Altitude (m)	H ₂ S (ppm)
Speed (km/h)	CO (ppm)
Ambient air Temperature (°C)	Temperature (°C)
	Relative humidity (%)

Five days of measurements (28.08, 29.08, 01.09, 02.09, 03.09.14)

Data generally from 07:00 to 21:00 LT.

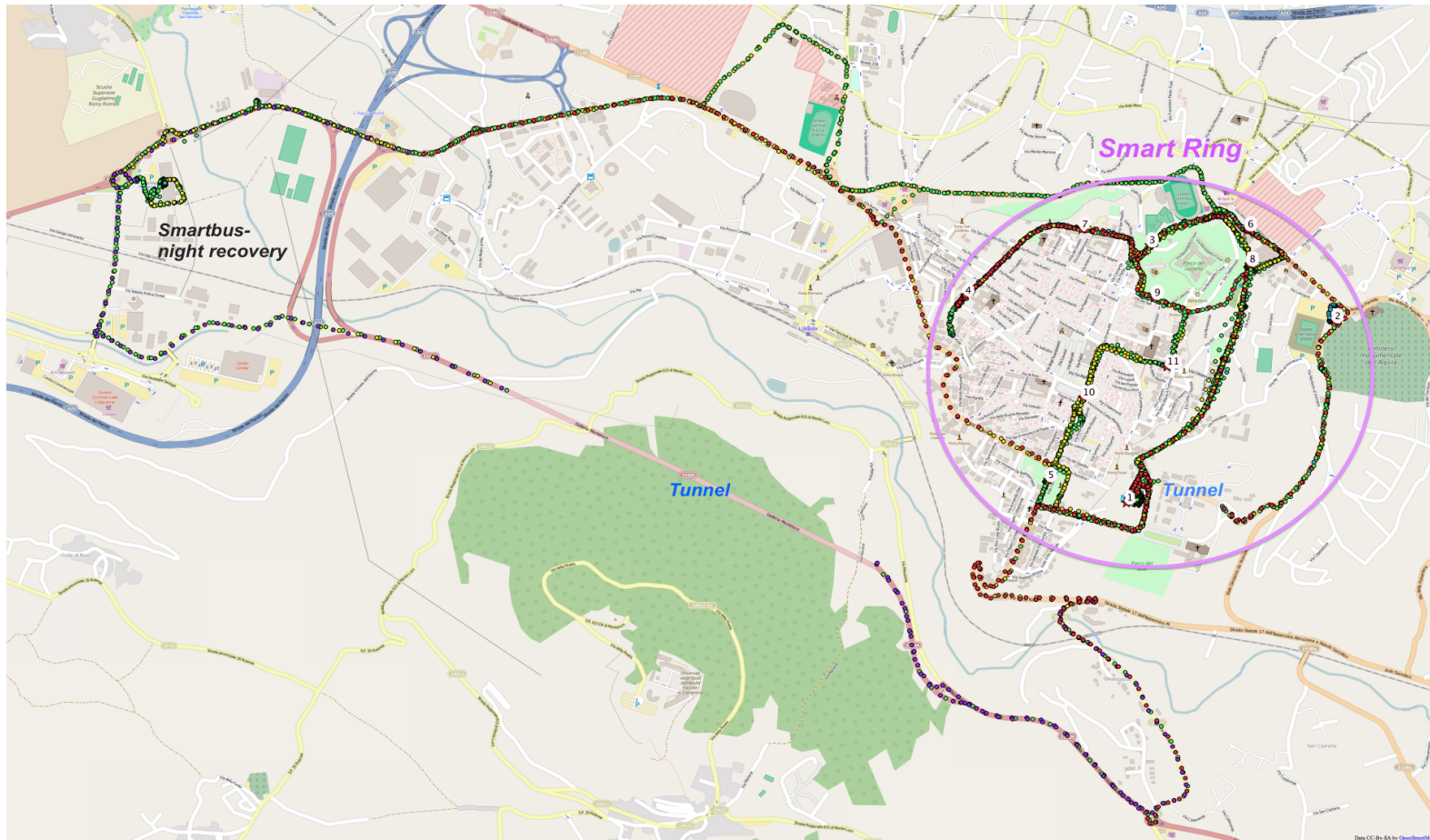
Two independent acquisition systems (timestamp).

USE of PostgreSQL DBs, R-Cran and QuantumGIS softwares.



Results

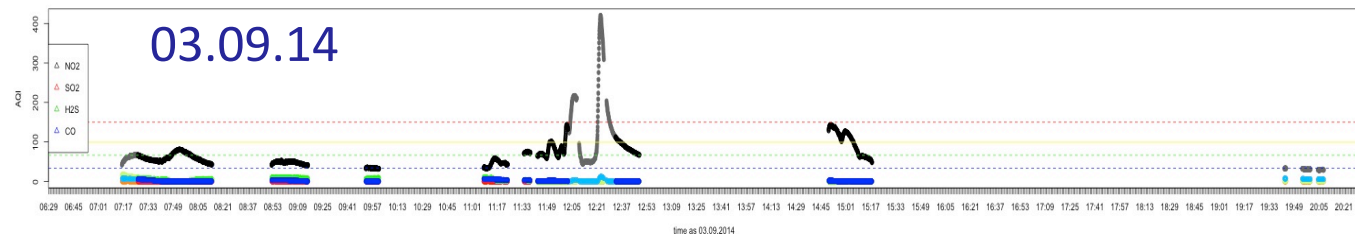
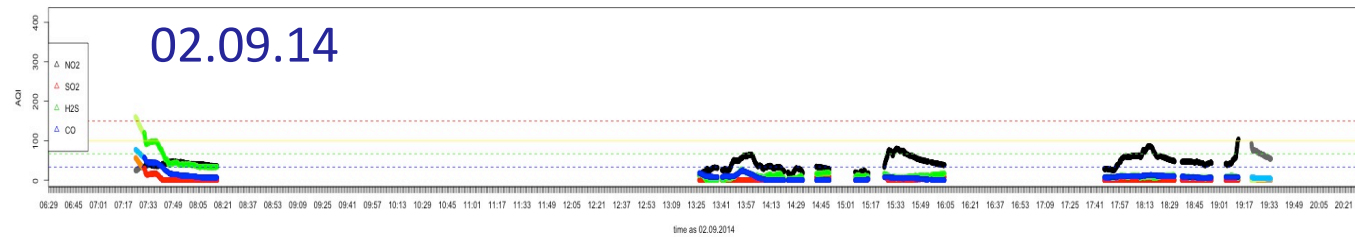
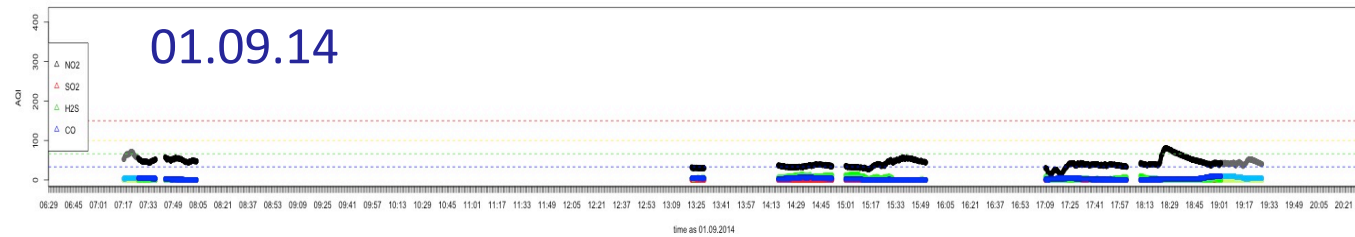
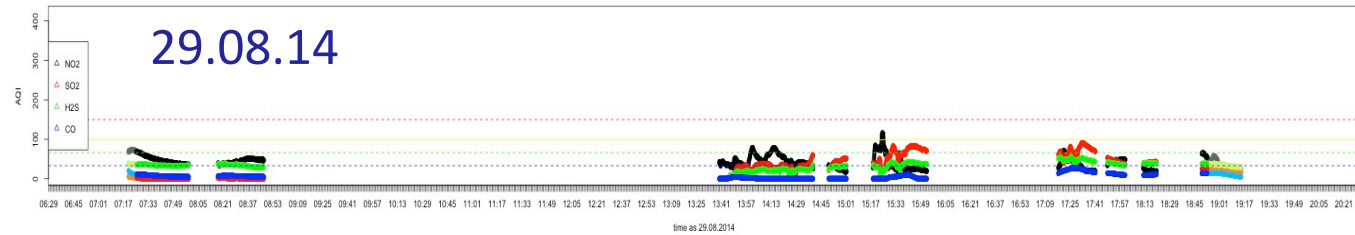
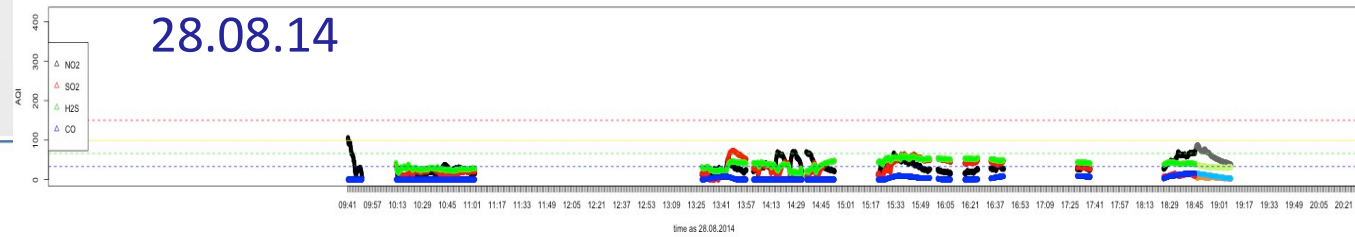
From the movie: five days of measurement campaign



Results

Time series for AQIs

Black: NO₂
Red: SO₂
Green: H₂S
Blue: CO



Results: over the Smart Ring

AQI		Date					
		28.08.14	29.08.14	01.09.14	02.09.14	03.09.14	5-days
		(3427)	(3266)	(3463)	(3492)	(2393)	(16041)
NO₂	Mean	32.0	43.0	41.9	44.0	67.0	44.0
	(Std)	(17.0)	(16.0)	(11.5)	(16.0)	(26.0)	(20.0)
	90%	61.1	64.0	55.1	64.4	106.5	69.0
	(Min-max)	(0-106.0)	(16.0-116.0)	(12.4-81.1)	(7.0-99.0)	(31.-143.0)	(0-143.)
SO₂	Mean	27.	32.	0	1.3	0	13.
	(Std)	(19.)	(27.)	(0)	(3.3)	(0)	(18.)
	90%	53.4	74.1		6.4		45.6
	(Min-max)	(0-73.)	(0-91.)		(0-17.8)		(0-91.)
H₂S	Mean	36.0	31.0	3.3	18.0	3.2	19.0
	(Std)	(14.0)	(11.)	(4.1)	(20.0)	(3.6)	(18.0)
	90%	52.3	43.4	10.1	39.4	8.8	43.7
	(Min-max)	(0-61.)	(0-56.)	(0-15.2)	(0-99.)	(0-11.)	(0-99.)
CO	Mean	2.7	6.4	2.4	8.9	1.3	5.
	(Std)	(4.1)	(6.9)	(2.2)	(9.1)	(1.7)	(6.)
	90%	8.6	16.6	4.9	16.5	3.8	10.7
	(Min-max)	(0-15.7)	(0-27.2)	(0-9.4)	(0-47.0)	(0-6.2)	(0-47.)
MAX	Mean	44.0	54.0	41.9	46.6	68.0	50.0
	(Std)	(15.0)	(16.0)	(11.5)	(18.6)	(26.0)	(19.0)
	90%	63.5	77.3	55.1	73.1	143.3	143.3
	(Min-max)	(2.0-106.)	(27.-116.)	(12.4-81.1)	(7.4-99.3)	(31.-143.)	(2.-143.)

Results: Main Features



“On-demand” service: Smartbus path followed did change (over five days).
Measurements were be too limited for data analyses over specific tracks.

Data were discontinuously distributed over time, with several missing data
(Smartbus was at rest)

Most frequented bus stops were identified.

Over Smart Ring (85% of data): good air quality status, mean $AQI_{\max} < 68$.

On peripheral roads (15% of data): AQI_{\max} was higher (major traffic, tunnels,
Smartbus function mode set to gasoline).

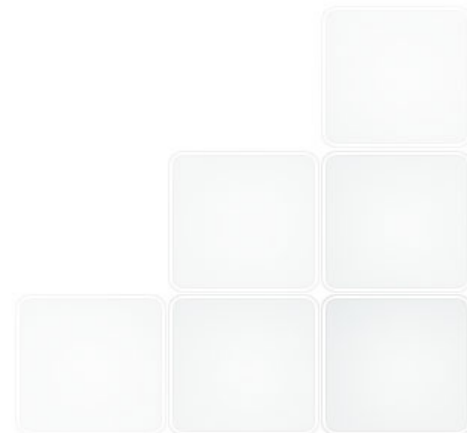
Over the Smart Ring (five days): NO_2 (AQI mean value of 44), H_2S (AQI mean
value of 19), SO_2 (AQI mean value of 13), and CO (AQI mean value of 5).

Our system can provide data at high temporal and spatial resolutions

A larger number of data is required for better identifying spatial and temporal trends

Further developments of the Smart Ring experience:

- Improve the NASUS IV system
- Only one acquisition system infrastructure
- Calibration procedure to better characterise air quality sensors data with referenced values
- Comparisons between air inside the vehicle and outdoor ambient air



Thank you !

Authors' contribution:

Cignini Fabio & Ortenzi Fernando: **Smartbus**

Suriano Domenico & Mario Prato: **NASUS IV sensor system**

Villani Maria Gabriella: **Data analyses**

