UNIVERSITY OF Southampton

LoRaWAN – City Wide Air Quality, A Use Case

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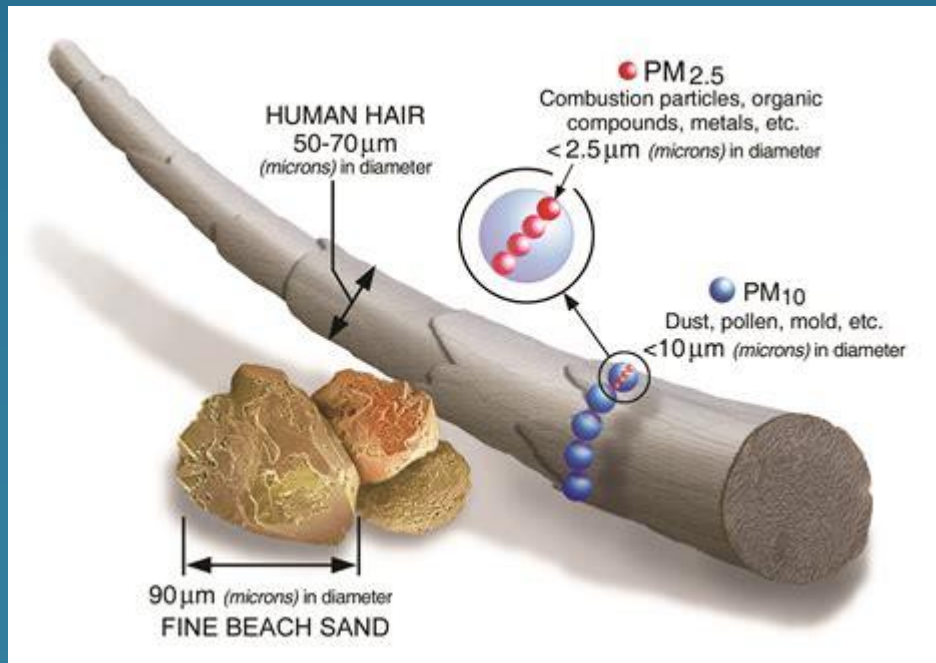
The problem

- Exposure to poor air quality :
  - caused 6.5M premature deaths in 2015 *
  - $PM_{2.5}$ results in 29,000 UK deaths/year
    - with 75% uncertainty
- Personal exposure depends on:
  - Indoor / outdoor
  - Duration / frequency
  - Individual parameters (Health status, age)

What is Particulate Matter (PM)

- PM, is a complex mixture of air-borne particles and liquid droplets composed of acids, ammonium, water, black carbon, organic chemicals, metals, and soil material. – US EPA
- Measured by mass or counting particles.



UK current status

- Automatic Urban Rural Network (ARUN)
  - **Current sites:** 146
  - nitrogen (NO_x), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO) and particles (PM_{10}, $PM_{2.5}$).
  - Public data is 1 hour average

We need more data…

- Need:
  - more sensors
  - (better) sensors

  … better understanding of pollution sources and the impact of exposure

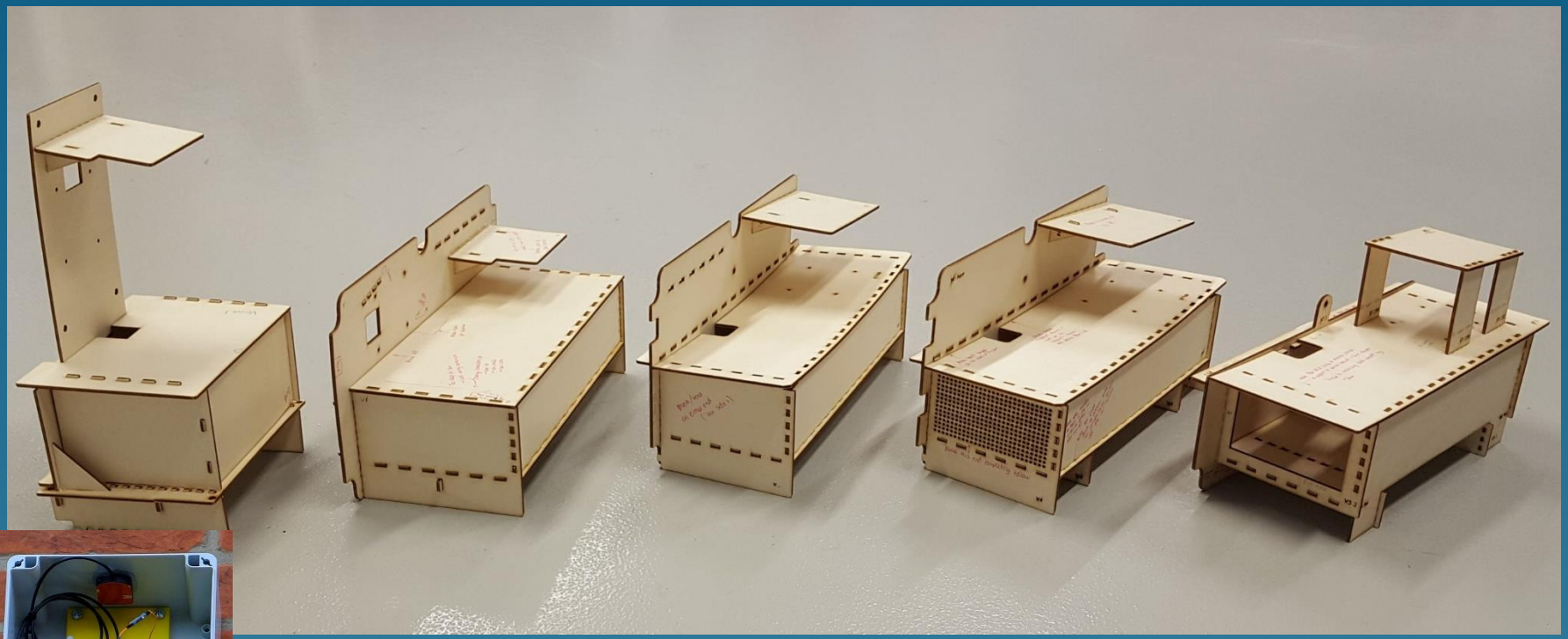
- Cost is an issue… do you trade quality of data for cost?

Low cost PM sensors

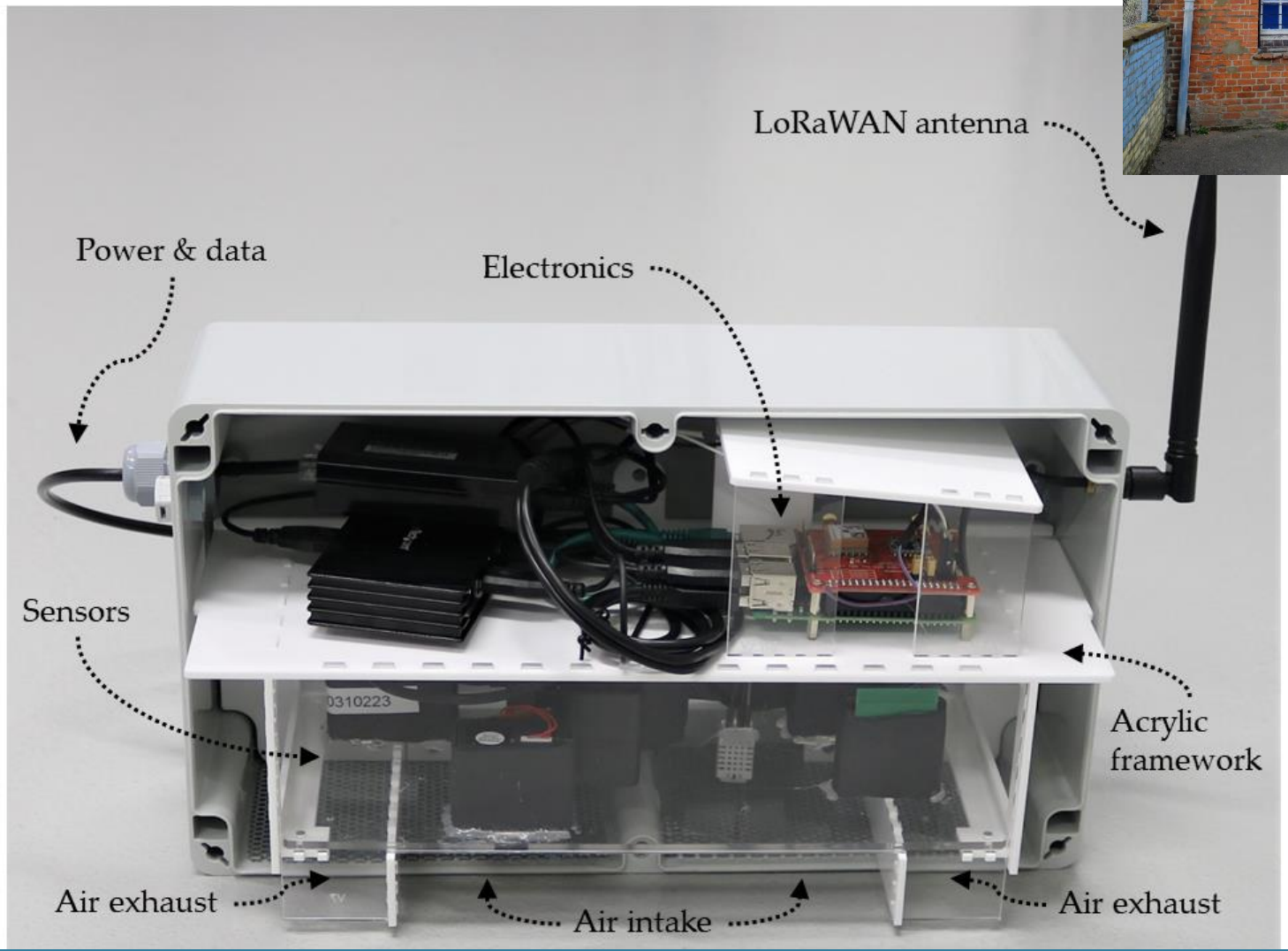
MAIN CHARACTERISTICS OF THE FAN ASSISTED PARTICULATE MATTER (PM) SENSORS USED IN THE DEPLOYMENT

Model	Size (mm) (HxWxD)	Price (USD)	Interface	Current requirement	Detection range (µm)	Concentration range of measurement (µg/m^3)	Raw output
Alphasense OPC-N2[22]	60x64x75	443	SPI	175mA @ 5V DC	0.38 to 17	0.01 to 1,500	Yes
Plantower PMS5003[23]	38x21x50	28	UART	100mA @ 5V DC	0.3 to 10	0 to 500	Yes
Plantower PMS7003[24]	37x12x48	28	UART	100mA @ 5V DC	0.3 to 10	0 to 500	Yes
Honeywell HPMA115S0[25]	36x43x24	33	UART	80mA @ 5V DC	Not known	0 to 1,000	No

A few versions….



Our sensor box



Data connectivity

- Ethernet (PoE)
  - SSH tunnel
  - OpenVPN
- WiFi (Onsite AP)
  - Onsite diagnostics
- LoRAWAN
  - Heartbeat and data averages (one way)

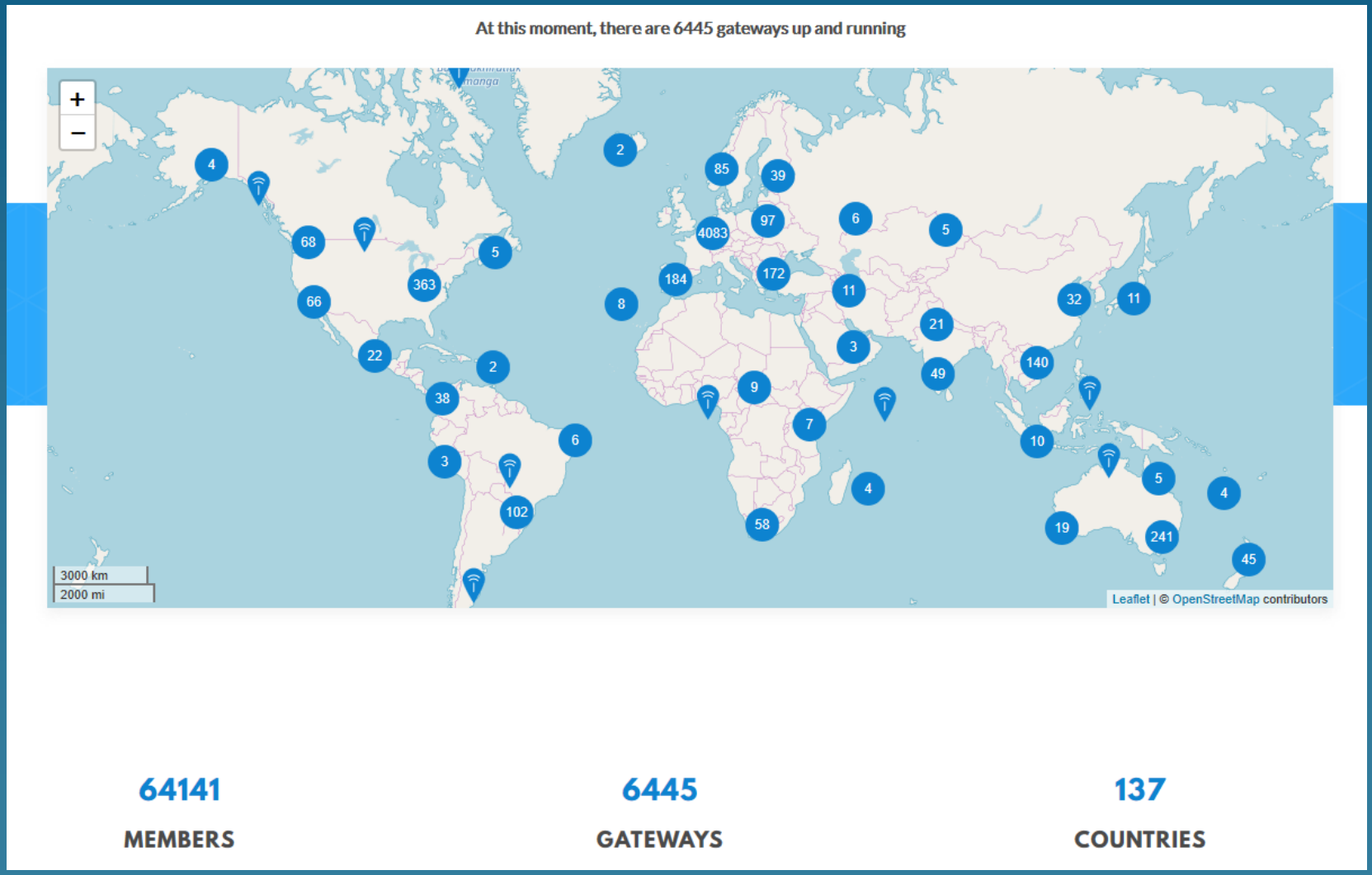
LoRaWAN deployment

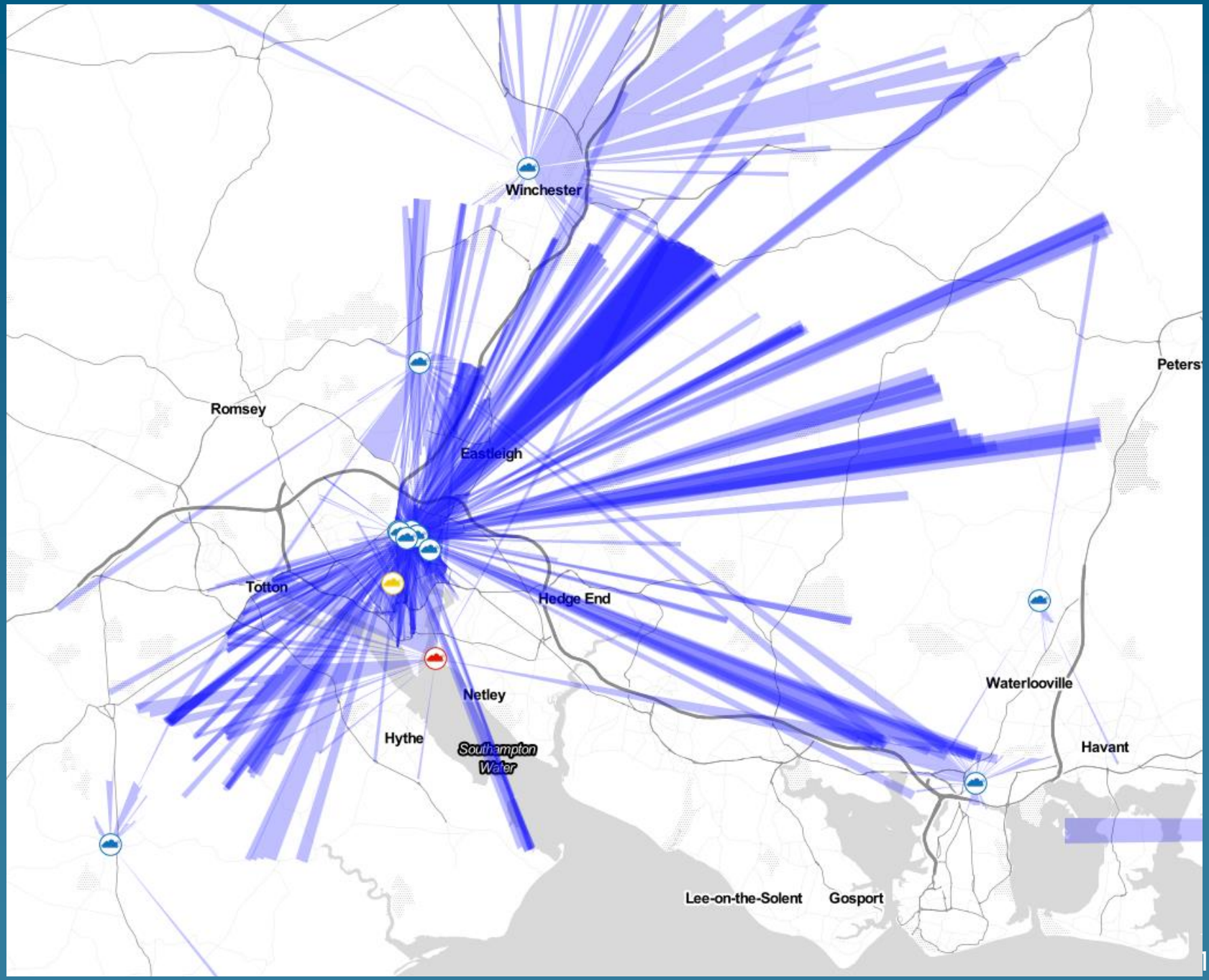
- Data -> The things network
  - Free, open, public
- Mapping coverage -> ttnmapper.org
- LoRA v2 (preview.collos.org)

TABLE III
LORAWAN BASE STATIONS FOR SOUTHAMPTON CITY

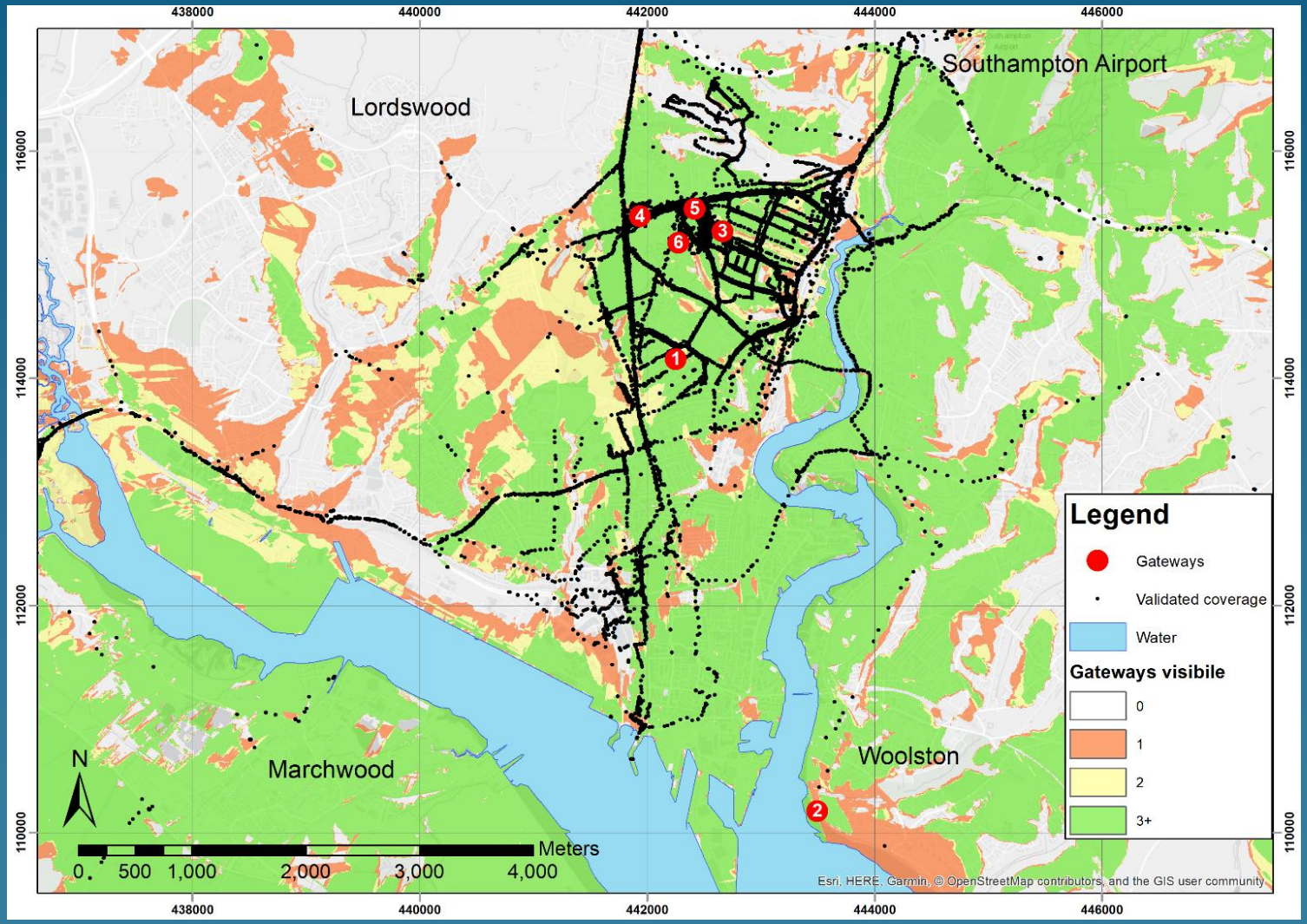
	Name	Altitude(m)	Brand	Model	Antenna	3^{rd} Party
1	7276FFFFFE010292	8	Kerlink	iBTS	Procom CXL 900-3LW-NB (Dual)	No
2	7276FFFFFE0103EC	85	Kerlink	iBTS	Procom CXL 900-3LW/I	No
3	B827EBFFFEE36EF8	85	Raspberry Pi	IMST iC880A	Procom CXL 900-3LW-NB	No
4	7276FFFFFE0103F0	50	Kerlink	iBTS	Procom CXL 900-3LW/I	No
5	B827EBFFFE2D3798	45	Raspberry Pi	IMST iC880A	Taoglas OMB	No
6	B827EBFFFE71AB02	65	Raspberry Pi	IMST iC880A	Taoglas OMB	No
7	B827EBFFFEAC4B12	60	Raspberry Pi	IMST iC880A	RF Solutions FLEXI-SMA90-868	Yes

LoRaWAN deployment

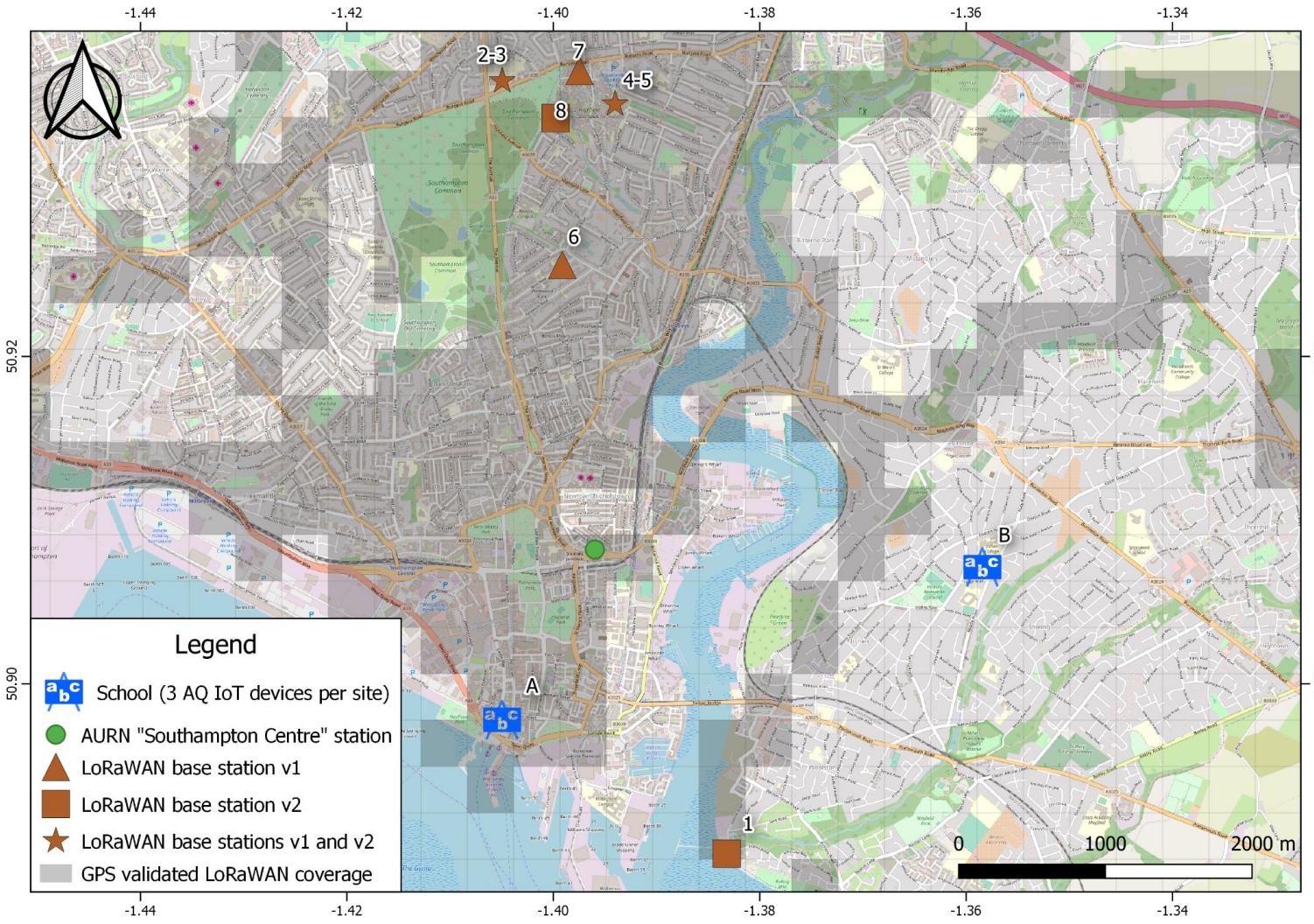



Winchester
Romsey
Eastleigh
Totton
Hedge End
Netley
Hythe
Southampton Water
Waterlooville
Havant
Lee-on-the-Solent
Gosport

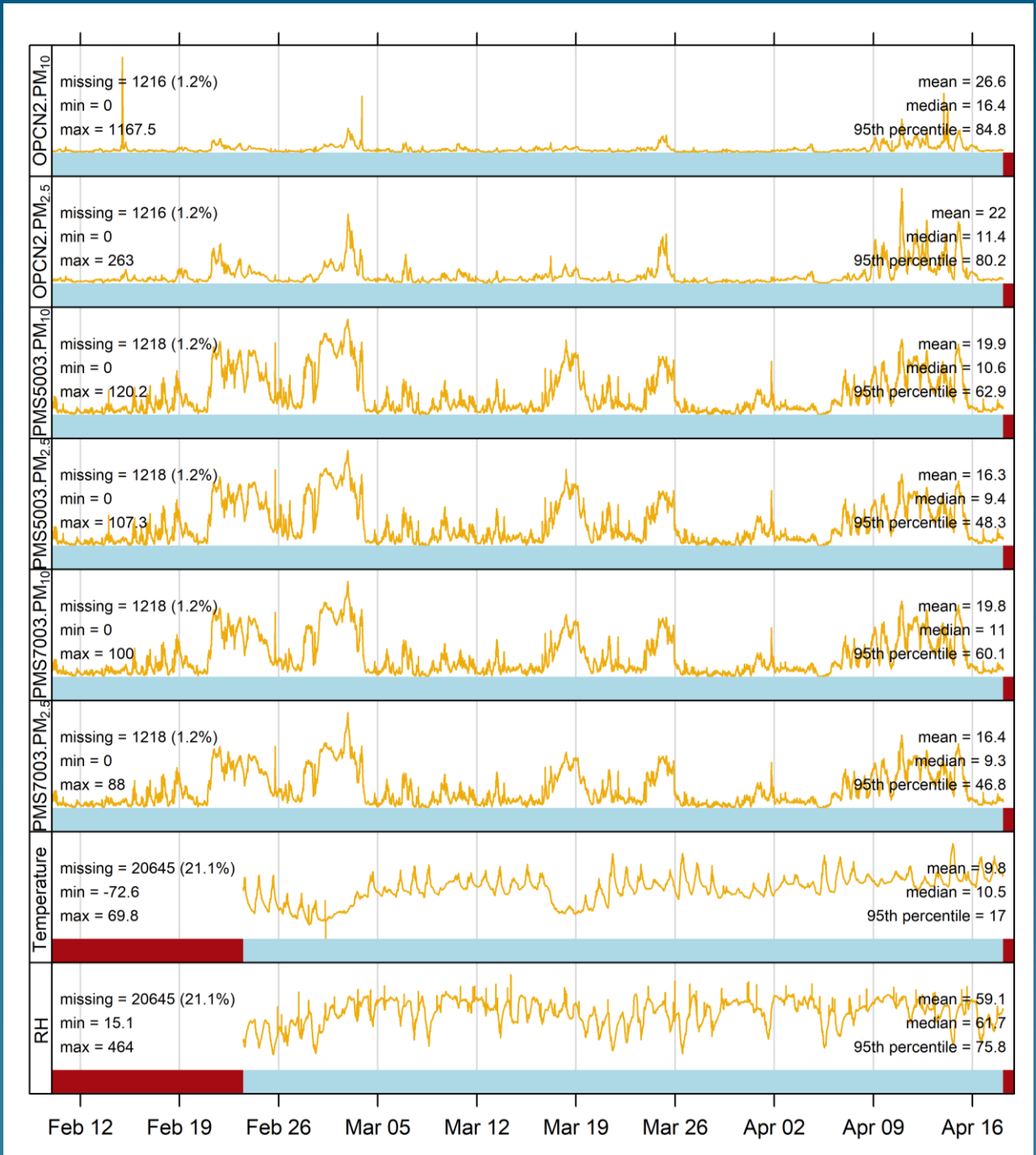
Our use case deployment



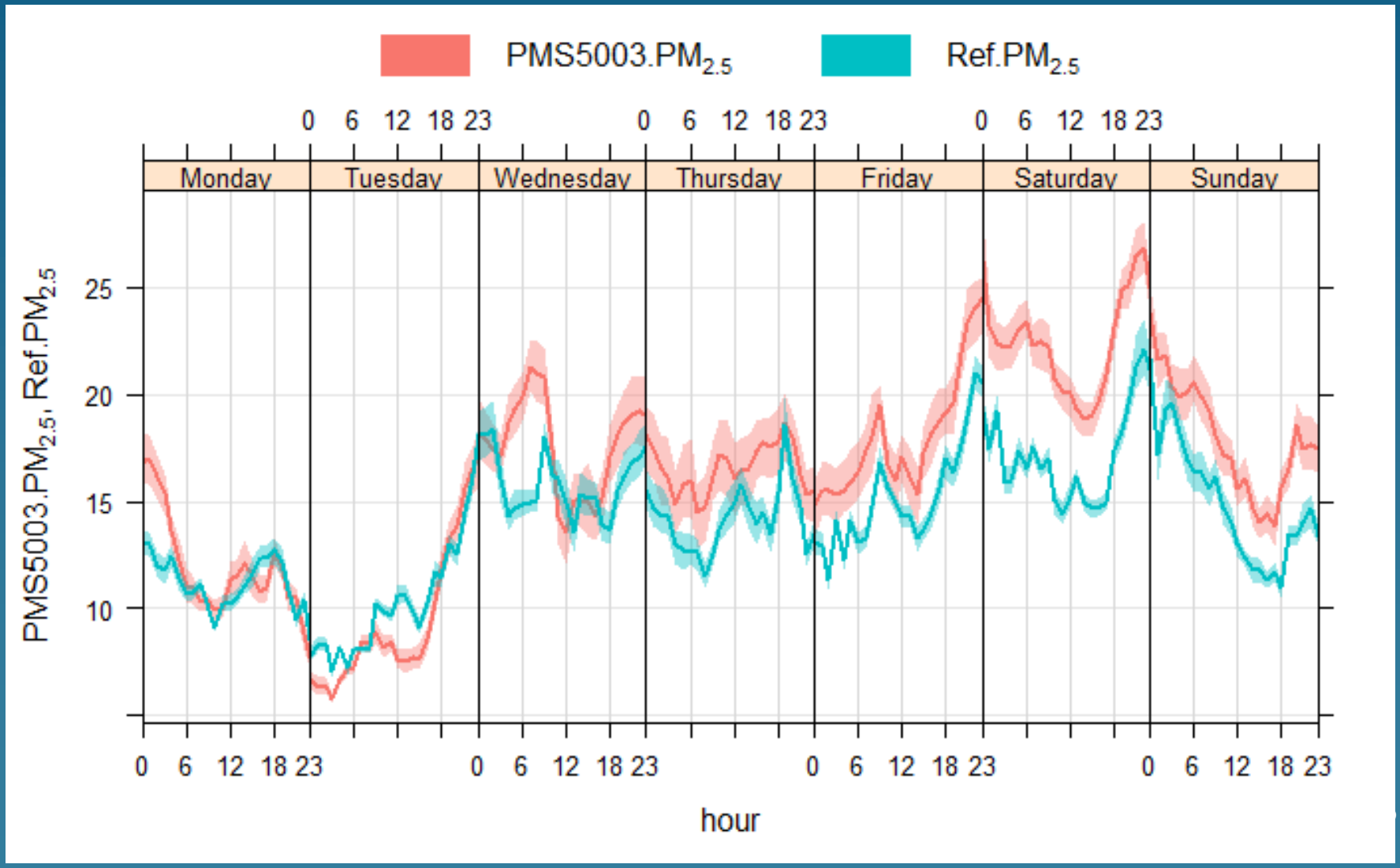
Our use case deployment



Results


OPCN2.PM10
missing = 1216 (1.2%)
min = 0
max = 1167.5
mean = 26.6
median = 16.4
95th percentile = 84.8
OPCN2.PM2.5
missing = 1216 (1.2%)
min = 0
max = 263
mean = 22
median = 11.4
95th percentile = 80.2
PMS5003.PM10
missing = 1218 (1.2%)
min = 0
max = 120.2
mean = 19.9
median = 10.6
95th percentile = 62.9
PMS5003.PM2.5
missing = 1218 (1.2%)
min = 0
max = 107.3
mean = 16.3
median = 9.4
95th percentile = 48.3
PMS7003.PM10
missing = 1218 (1.2%)
min = 0
max = 100
mean = 19.8
median = 11
95th percentile = 60.1
PMS7003.PM2.5
missing = 1218 (1.2%)
min = 0
max = 88
mean = 16.4
median = 9.3
95th percentile = 46.8
Temperature
missing = 20645 (21.1%)
min = -72.6
max = 69.8
mean = 9.8
median = 10.5
95th percentile = 17
RH
missing = 20645 (21.1%)
min = 15.1
max = 464
mean = 59.1
median = 61.7
95th percentile = 75.8
Feb 12
Feb 19
Feb 26
Mar 05
Mar 12
Mar 19
Mar 26
Apr 02
Apr 09
Apr 16

Results


PMS5003.PM2.5
Ref.PM2.5
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
0 6 12 18 23
PMS5003.PM2.5, Ref.PM2.5
10
15
20
25
hour

Results

TABLE IV
ROOT MEAN SQUARE ERROR AND PEARSON COEFFICIENT OF ONE IOT DEVICE AT EACH SCHOOL

	School A		School B	
Sensor	RMSE	R^2	RMSE	R^2
Alphasense OPC-N2	0.052	0.276	0.045	0.259
Plantower PMS5003	0.030	0.694	0.024	0.577
Plantower PMS7003	0.027	0.669	0.024	0.566
Honeywell HPMA115S0	0.044	0	0.038	0

Findings

- Low-cost sensor are viable *
- LoRaWAN can transmit PM data*
- Cost ≠ accuracy
  - Sensor sensitivity range
- We need a better OS / Management

Future

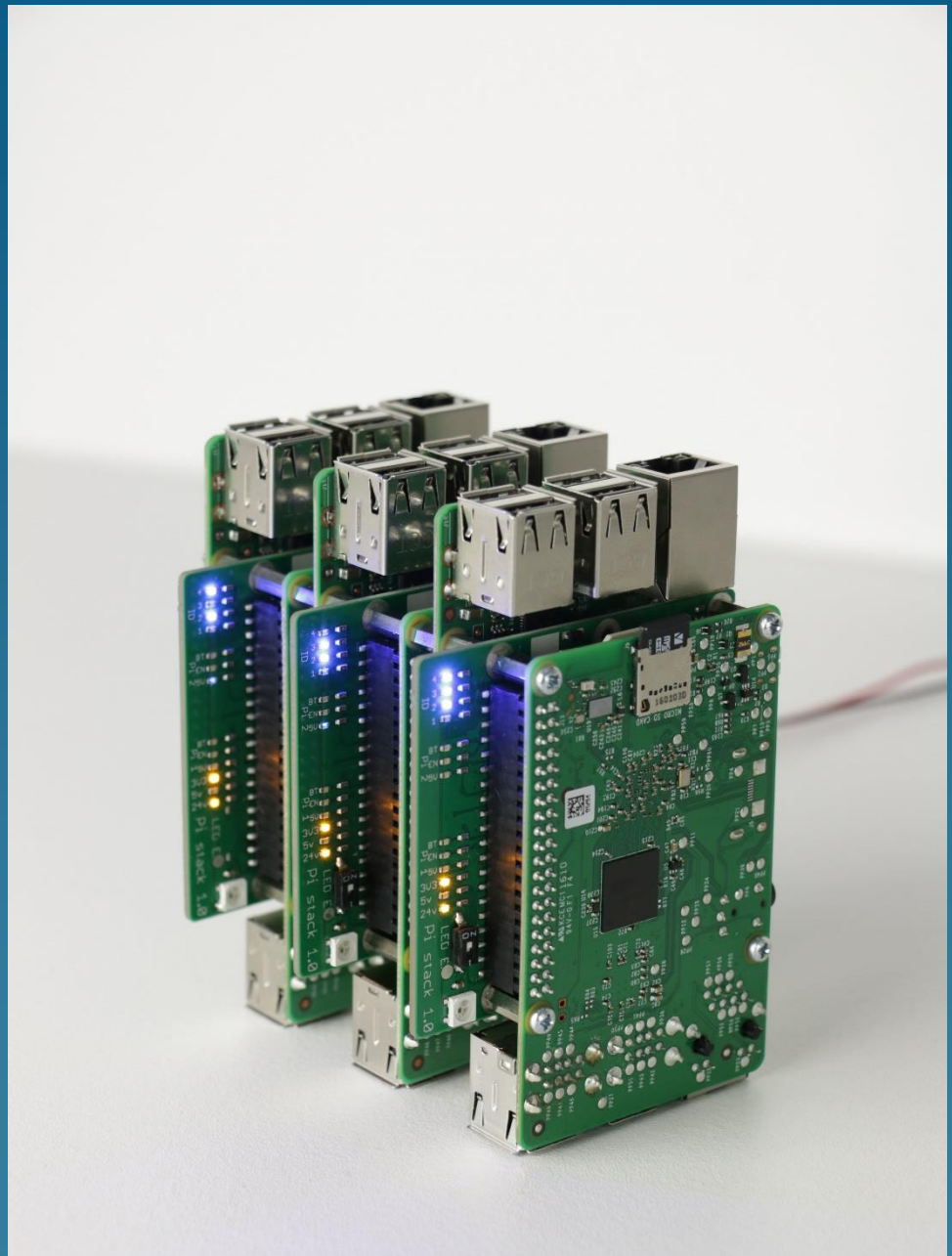
- LoRAWAN
  - 2 way coms
  - Out of band reset
  - All sensor data via LoRAWAN

Future

- Custom OS
  - Yocto custom build
  - Dual partitions (reliability)
  - OSTree (Over the Air Updates)
  - Containers
    - Docker
    - Singularity
  - More hardware
    - Raspberry Pi, Odroid, UP-Core, ++

Future

- Edge Compute Cluster
  - Spare energy
  - Low cost
    - Disposable?
  - Transmission costs
  - FOG/EDGE ??



Future

- New Sensors
  - DEFRA
- Co-localisation
  - ARUN
  - AQ-Mesh

Future

- Delay tolerant networking (DTN)
  - No network coverage
- Lower power
  - PoE (15/30w MAX) – current usage 5w
  - Photovoltaic

Questions?

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- University of Southampton, UK.
- Philip J. Basford, Florentin M. J. Bulot, Mihaela Apetroaie-Cristea, Gavin L Foster, Matthew Loxham, Simon J. Cox