Departament d'Enginyeria de Sistemes,
Automàtica i Informàtica Industrial

Leak Localisation Methodology and Real Applications

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Outline

1. Introduction
2. Leak localisation methodology
3. Results
4. Conclusions

Background and aim

- The stress in water resources
- 30% of the water use (waste)
- Non-Revenue Water (NRW)
- Detection and Localisation methodology

System Input Volume	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	Unbilled Metred Consumption	Non-Revenue Water (NRW)
			Unbilled Unmetered Consumption	
	Water losses	Apparent Losses	Unauthorised Consumption	
			Customer Metering Inaccuracies	
		Real Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer metering	

Milestones

- cs2ac and CETAQUA
- PROFURED

Pérez, R., Puig, V., Pascual, J., Quevedo, J., Landeros, E., & Peralta, A. (2011). Methodology for leakage isolation using pressure sensitivity analysis in water distribution networks. Control Engineering Practice, 19(10), 1157–1167.

- RTNM

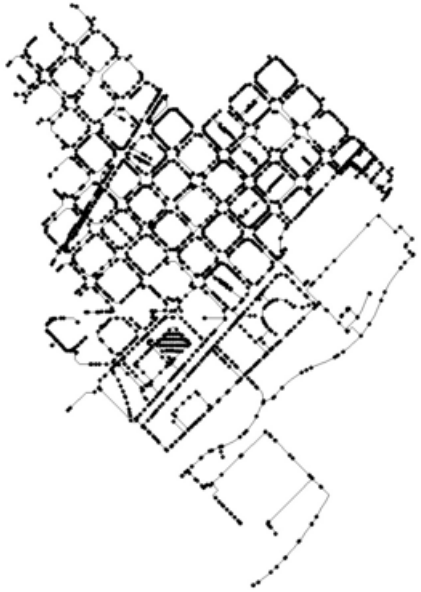
Pérez, R., Sanz, G., Quevedo, J., Nejjari, F., Meseguer, J., Cembrano, G., … Sarrate, R. (2014). Leak Localization in Water Networks. IEEE CONTROL SYSTEMS MAGAZINE, (august), 24–36.

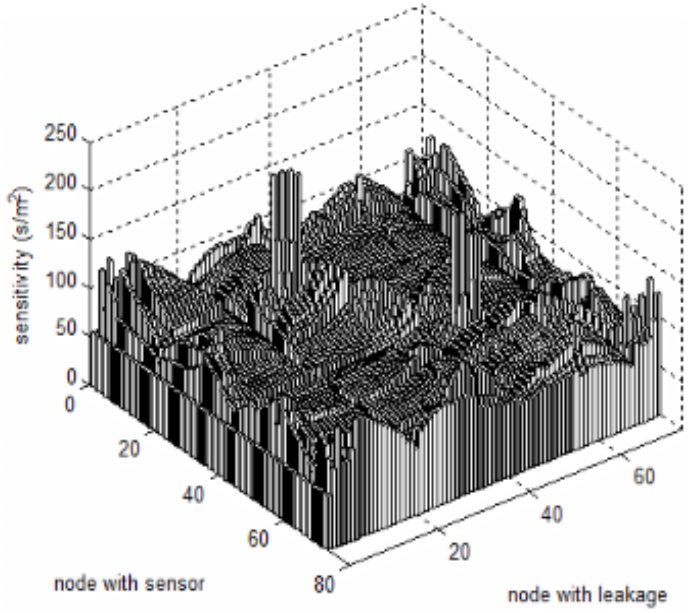
- EFFINET

Sanz, G., Pérez, R., Kapelan, Z., & Savic, D. (2015). Leak Detection and Localization through Demand Components Calibration. Journal of Water Resources Planning and Management.

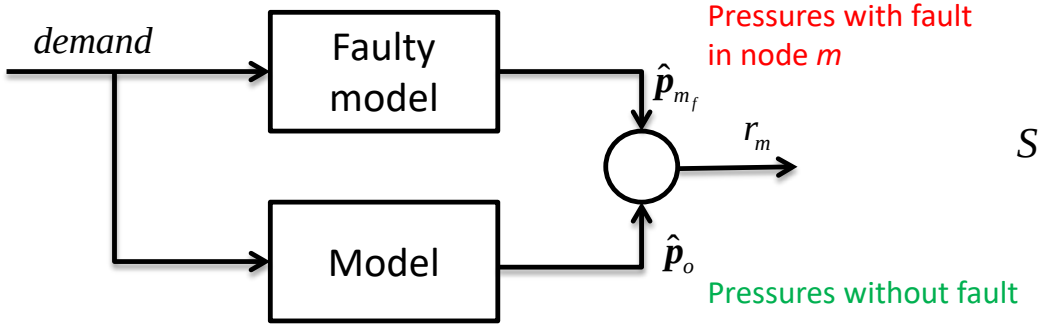
Sensitivity Matrix

$$S = \begin{pmatrix} \frac{\partial p_1}{\partial f_1} & \cdots & \frac{\partial p_1}{\partial f_m} \\ \vdots & \cdots & \vdots \\ \frac{\partial p_m}{\partial f_1} & \cdots & \frac{\partial p_m}{\partial f_m} \end{pmatrix}$$





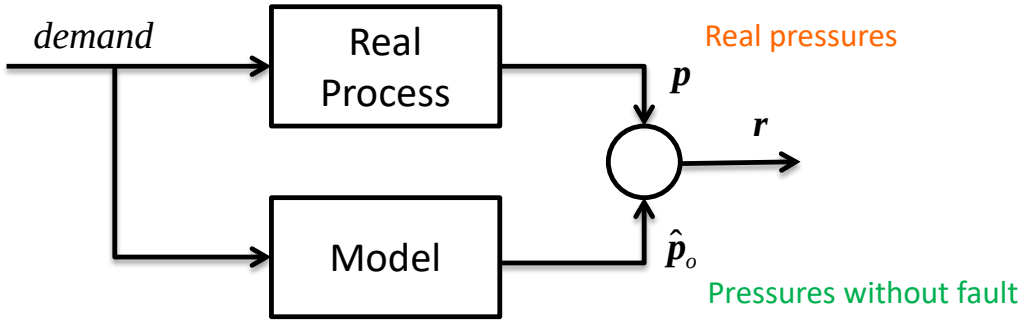
Sensitivity Matrix vs Residuals



m fault signatures

$$S = \begin{pmatrix} \frac{\partial p_1}{\partial f_1} & \cdots & \frac{\partial p_1}{\partial f_m} \\ \cdots & \cdots & \cdots \\ \frac{\partial p_n}{\partial f_1} & \cdots & \frac{\partial p_n}{\partial f_m} \end{pmatrix}$$

n sensors

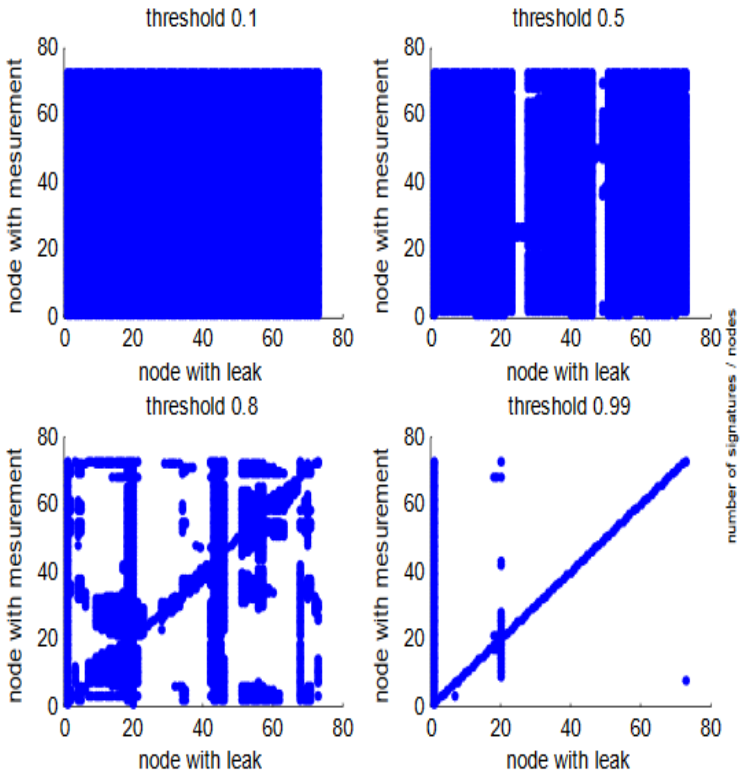


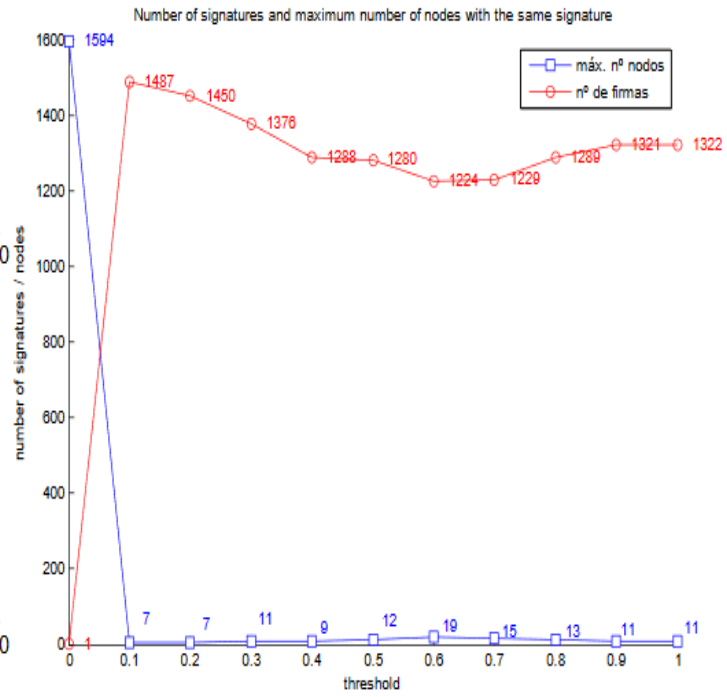
$$\boldsymbol{r} = \begin{pmatrix} p_1 - \hat{p}_o \\ \vdots \\ p_n - \hat{p}_o \end{pmatrix}$$

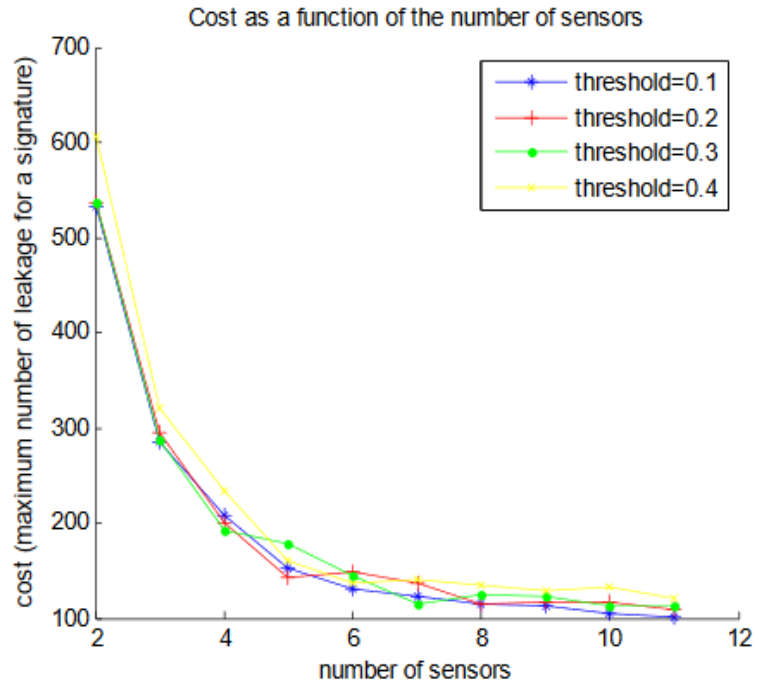
n sensors

2. Leak localisation methodology

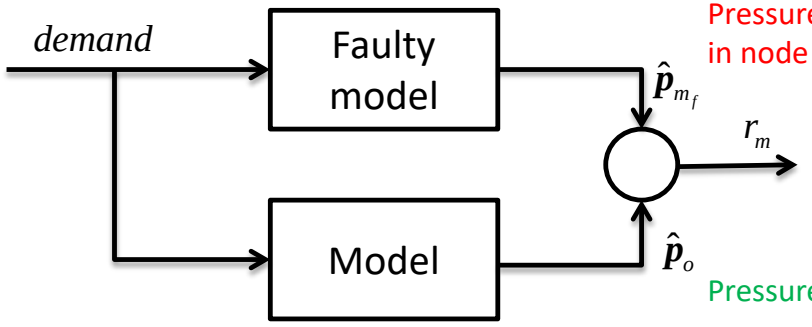
First approach: Binarisation







Second Approach: Correlation



Pressures with fault in node *m*

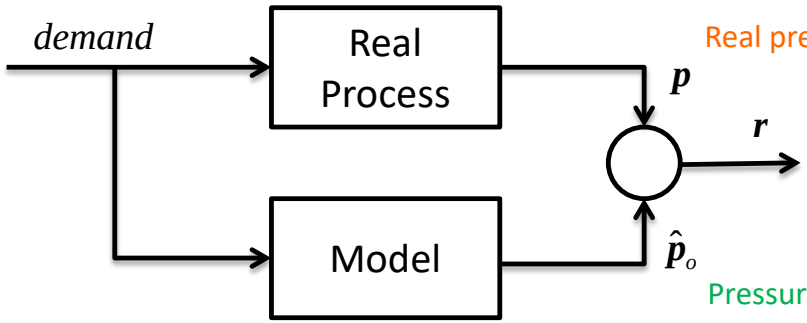
Pressures without fault

m fault signatures

$$S = \begin{pmatrix} \frac{\partial p_1}{\partial f_1} & \cdots & \frac{\partial p_1}{\partial f_m} \\ \cdots & \cdots & \cdots \\ \frac{\partial p_n}{\partial f_1} & \cdots & \frac{\partial p_n}{\partial f_m} \end{pmatrix}$$

n sensors

$$\rho_{s_i r} = {cov(s_i,r)} \Big/ {\sqrt{cov(s_i,s_i)cov(r,r)}}$$



Real pressures

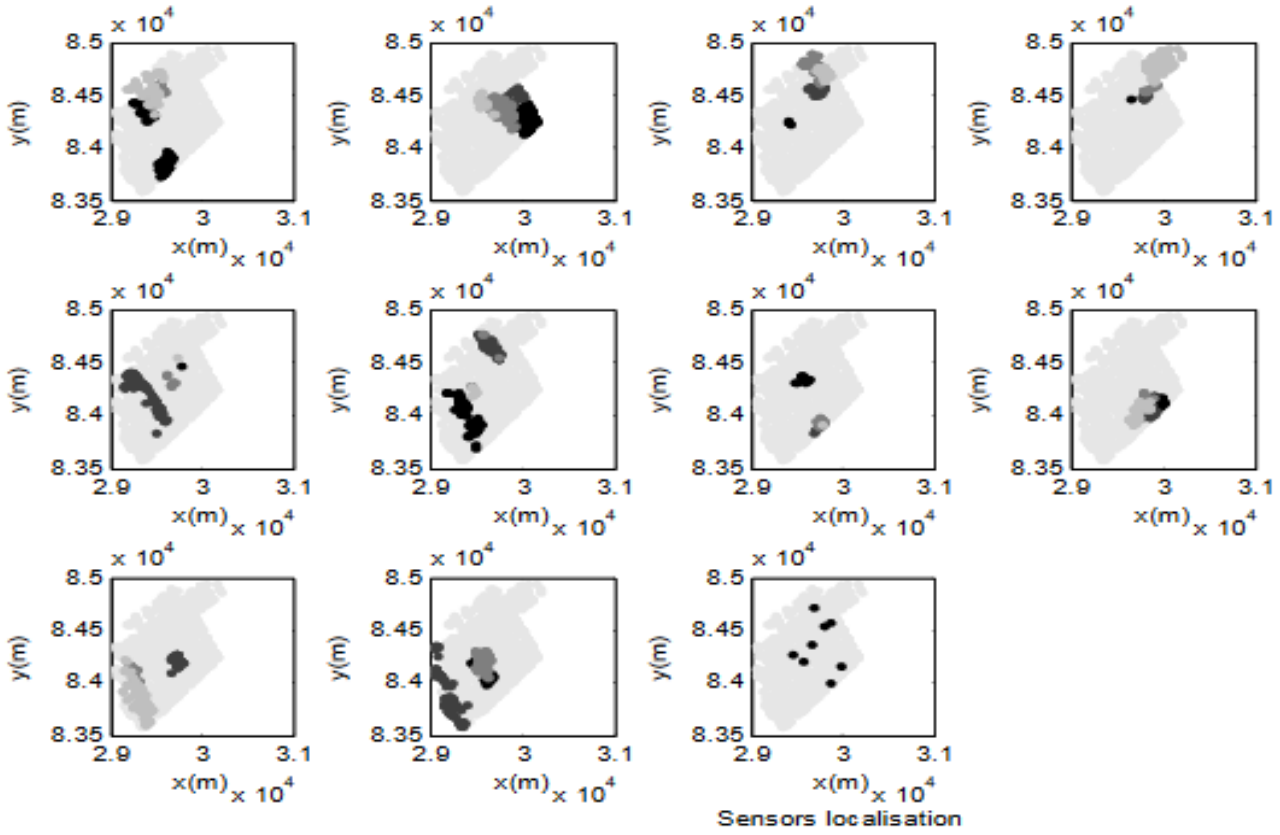
Pressures without fault

$$\boldsymbol{r} = \begin{pmatrix} p_1 - \hat{p}_o \\ \vdots \\ p_n - \hat{p}_o \end{pmatrix}$$

n sensors

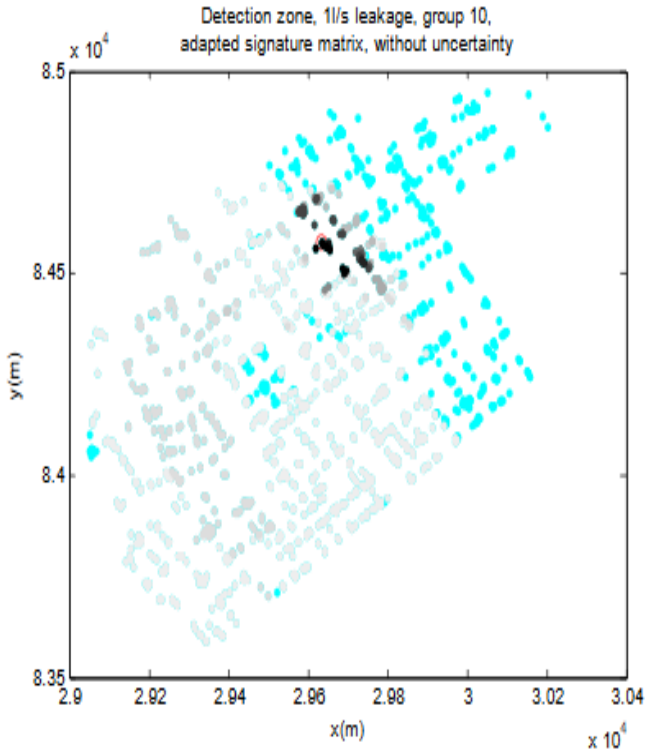
Binarisation: Simulation

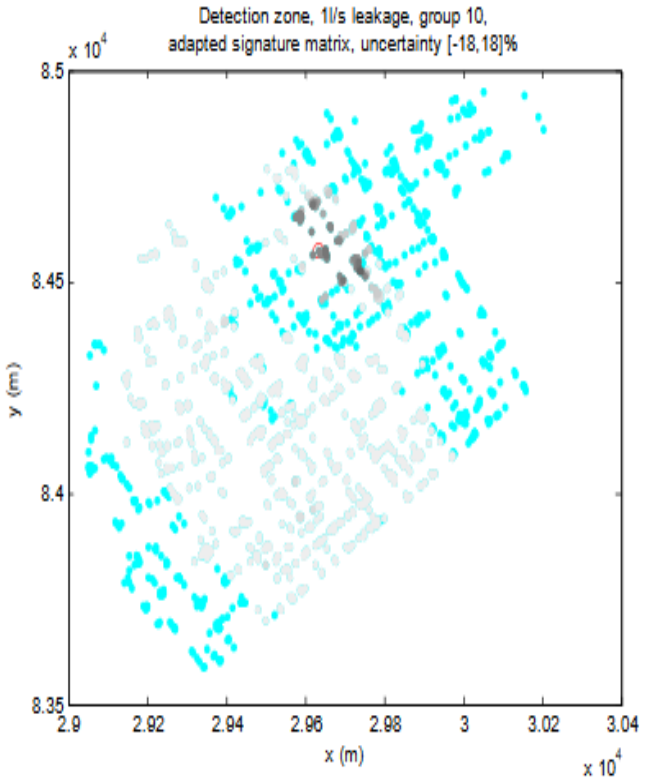
- 1600 nodes
- 41.153m
- Simulated leaks 1 l/s
- 3% of the total demand of the sector (in the night time)



Binarisation: Simulation

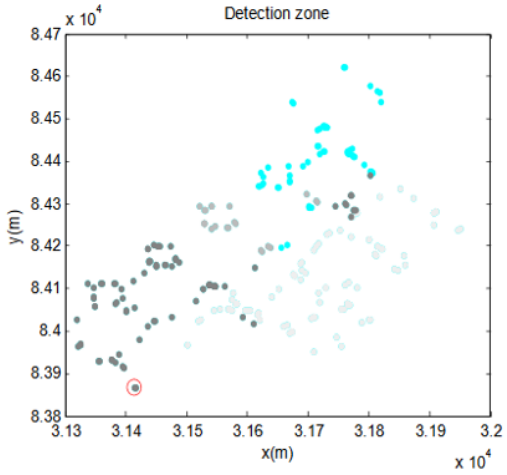
- voting result for 15 samples horizon is presented.
- Exact model
- With 18% of uncertainty in the demand distribution:
  - Some leaks are not in the most voted group but even so the most voted group is in the neighbourhood of the real leak.

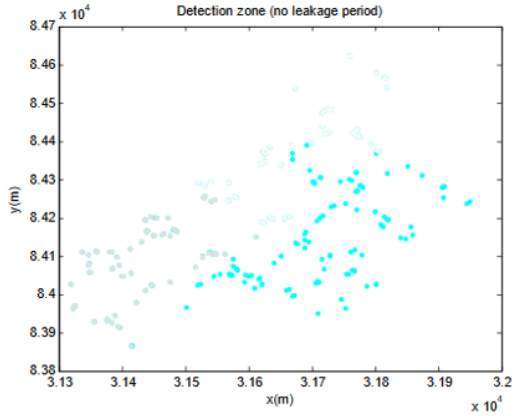




Binarisation: Real leak

- 260 nodes
- 2 water input points
- 3 installed pressure sensors

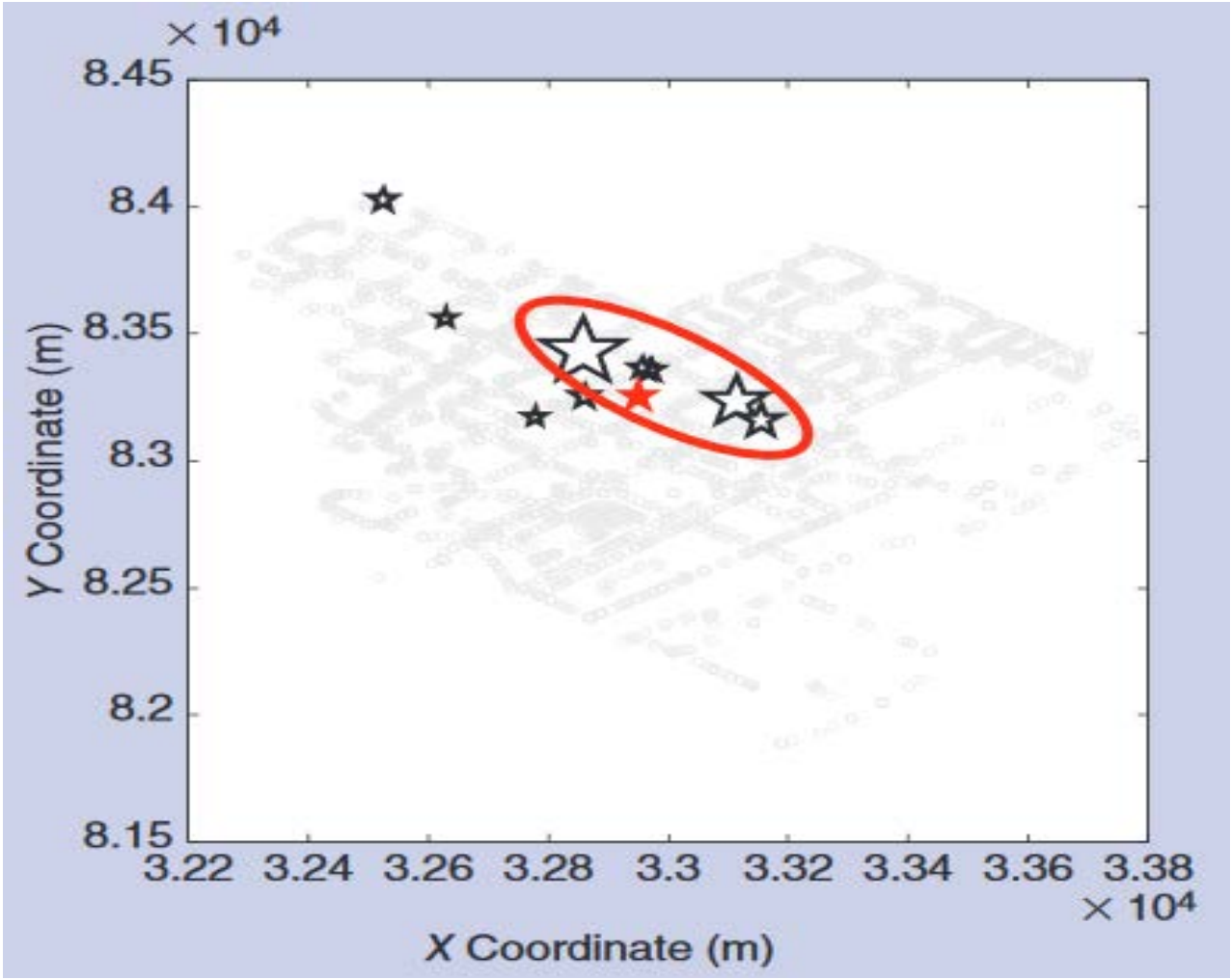




Signature				
Sensor 1	Sensor 2	Sensor 3	Nº of nodes	Nº of detections
0	0	0	55	0
1	0	0	23	17
1	1	0	88	31
1	1	1	94	4
Total (max = 64)				52

Correlation: Real leak

- 3377 nodes
- 3442 pipes
- The real leak was of 5.6l/s
- The mean night consumption is around 30l/s. ç
- Five pressure sensors with a 0.1 m of precision
- Search distance below 200m



4. Conclusions

- Model-based methodology for leak localization in DMA using pressure measurements.
- Leak isolation relies on correlating the observed residuals with the theoretical fault sensitivity.
- Has been implemented in a software tool that interfaces with a geographic information system
- Quantify the effect of uncertainty in demands, sensors and leak magnitude estimation on the methodology and accuracy of the leak localization procedure.