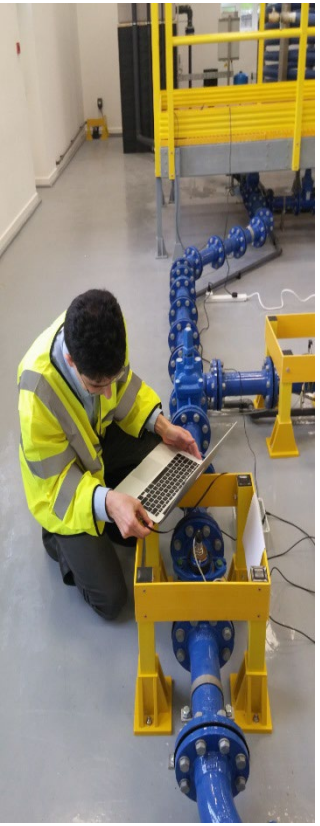
Smart Places

a world of cyber physical interaction



Prof Julie A. McCann

AESE:Adaptive Emergent Systems Engineering Lab
Data Centric Engineering lead for Alan Turing Inst.
Dept. Director UK PeTraS IoT Security Hub

IBM
The Alan Turing Institute
Lloyd's Register Foundation
EPSRC Engineering and Physical Sciences Research Council
NERC Science of the Environment
cisco
intel
PETRAS
National Research Foundation Singapore

Imperial College London Computing | AESE Adaptive Emergent Systems Engineering

Why are Smart Places Interesting to Academia?

- 93 % of urbanization is happening in developing countries
- By 2050, the developing world will have 5.3 million urban dwellers
- 63% of the urban population will reside in Asia alone i.e. 3.3 million

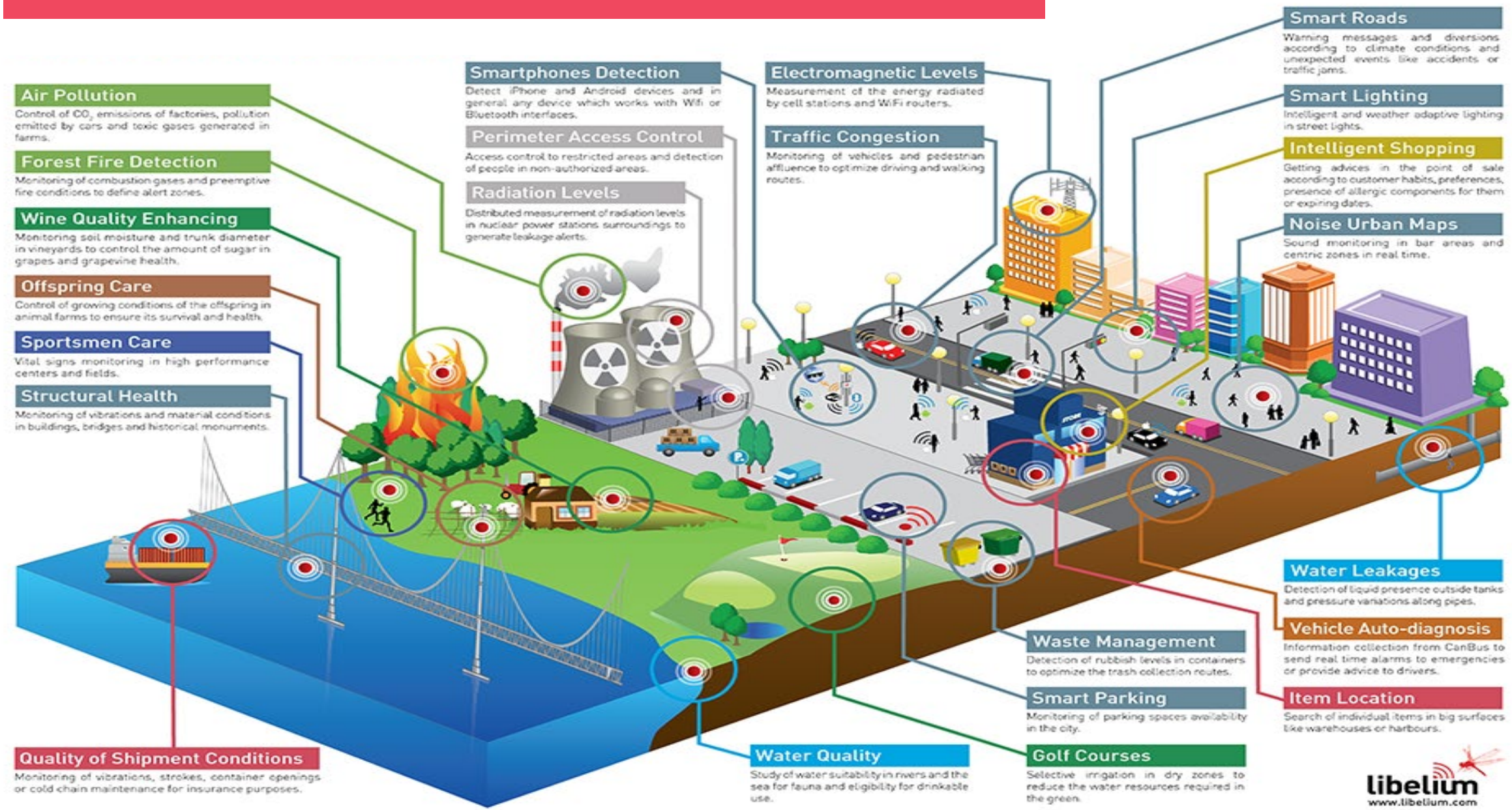
Modern Challenges

- Growth
- Climate Change
  - Resources getting tighter
  - Decisions and ability to adapt slower
  - Therefore Smart/Sustainable Cities

- Resource Optimisation
- Smart Fast Decision Making

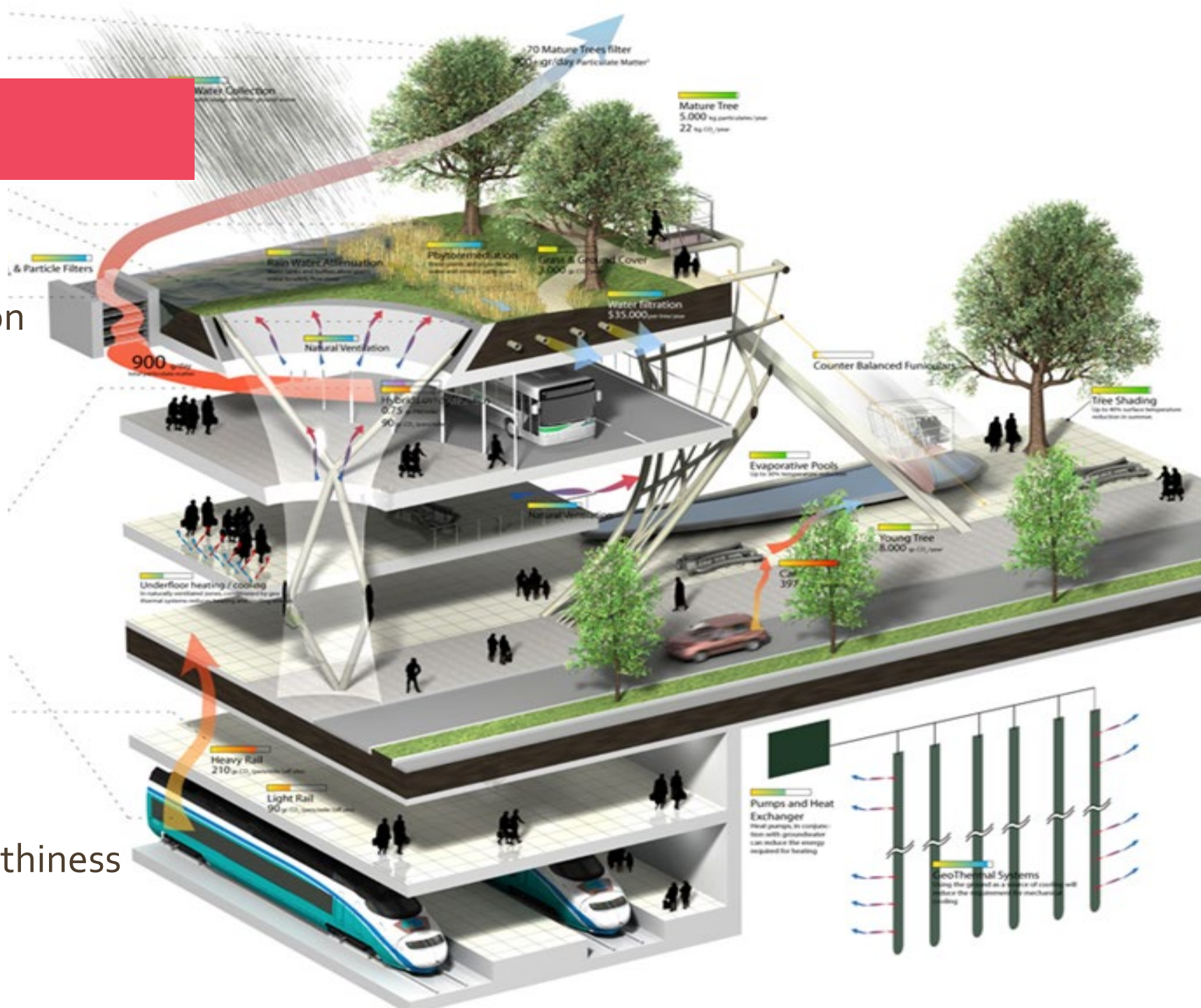
IT can help

Smart Sustainability is Everywhere!



City IT Challenges

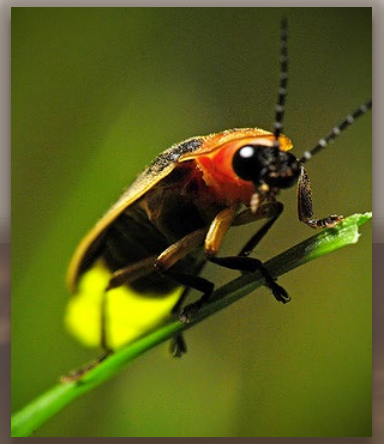
- Costs
  - Frugal systems augmentation
    - Low cost sensing
    - Participatory sensing
- Scale
  - Numbers of Things
  - Interconnections of Things
  - Network capacity
- Trust
  - Data provenance & trustworthiness
  - Agile decentralised systems



Challenge – low resourced and flaky

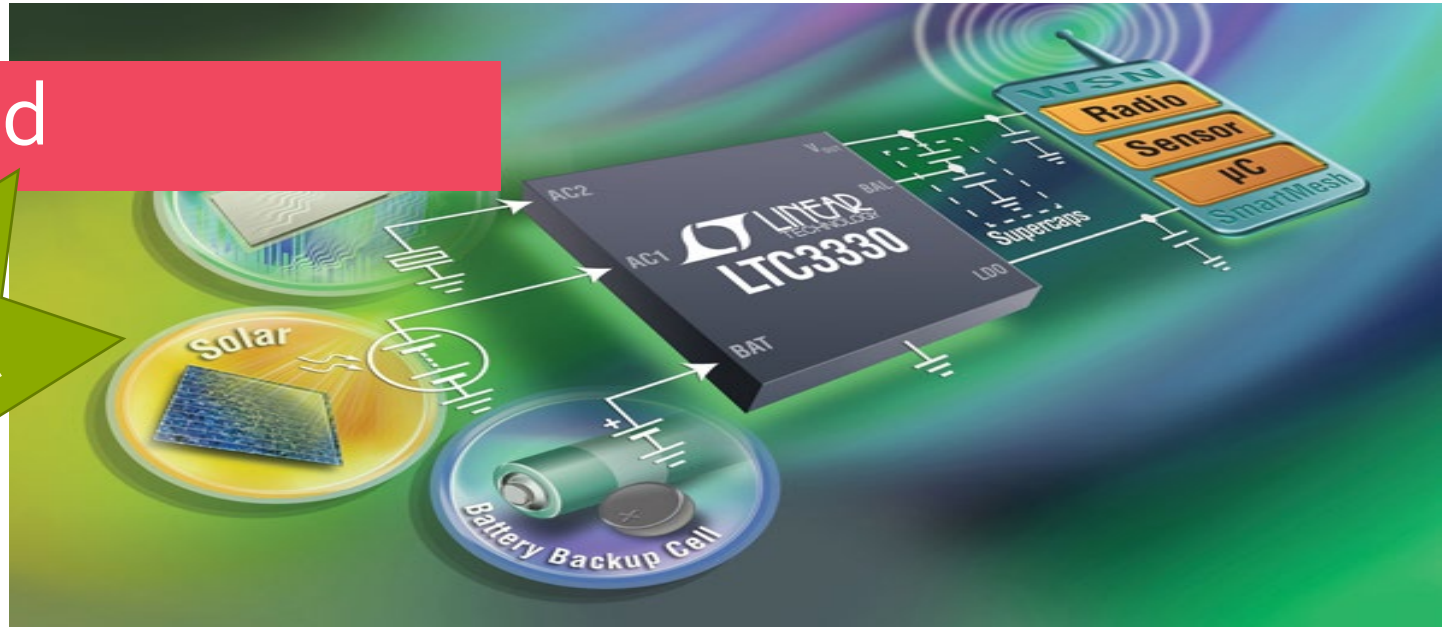
These are:

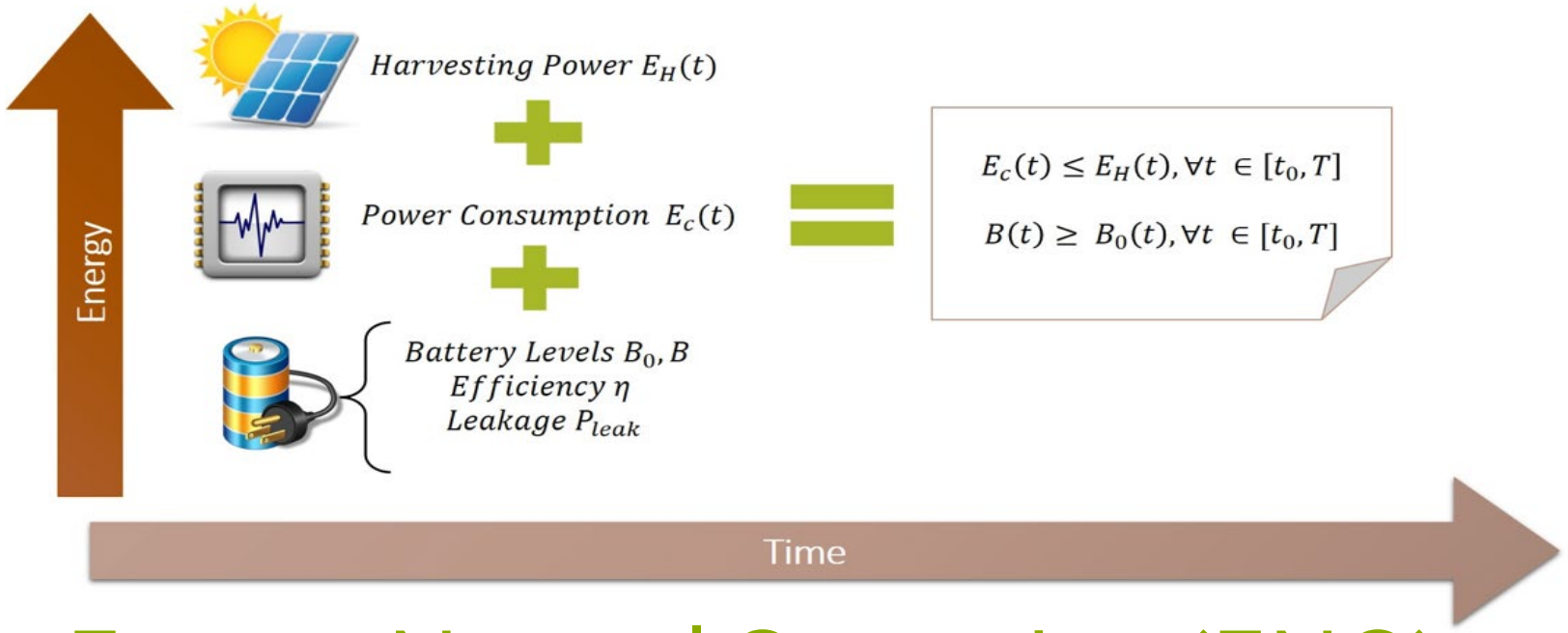
- noisy
- prone to decalibrate,
- may be misplaced,
- moved, compromised, degraded
- both individually and as a collective network.



Challenge – can't eat food

Cyber-physical Interaction





Protocols to : ensure **ENO** + Lengthen the **life-time** of the device (years)

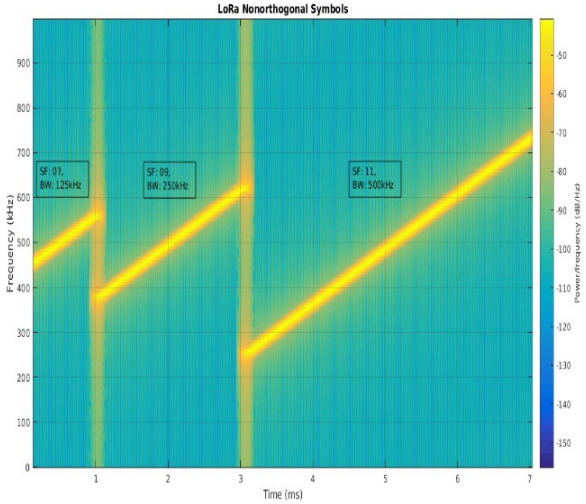
Energy Neutral Operation (ENO)

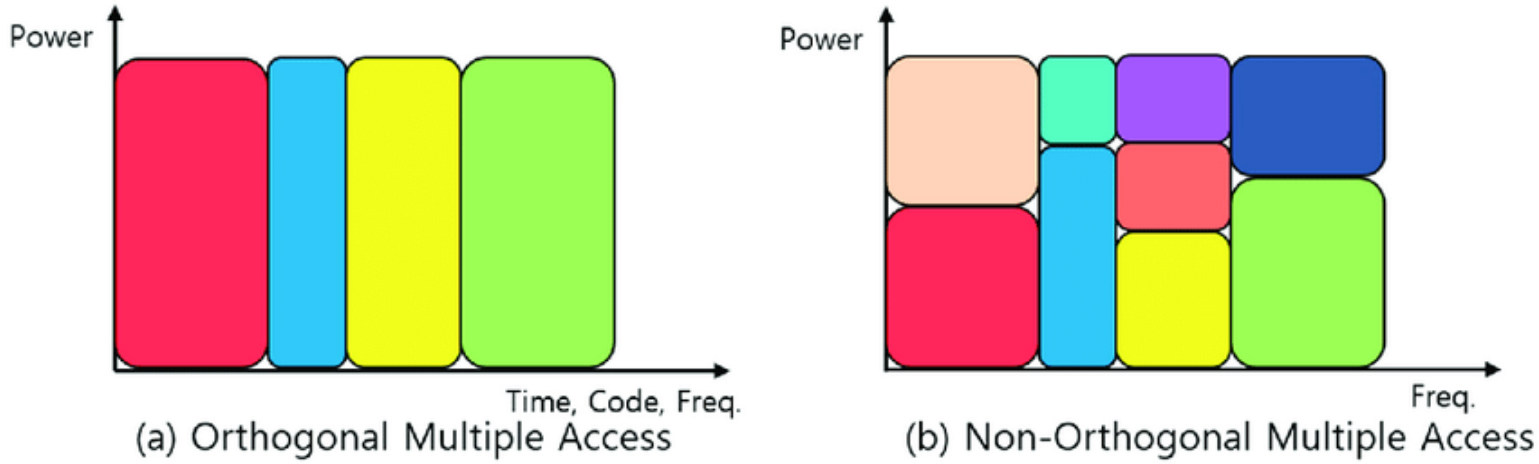
Challenges – Sharing the Air

Challenges – Network Capacity

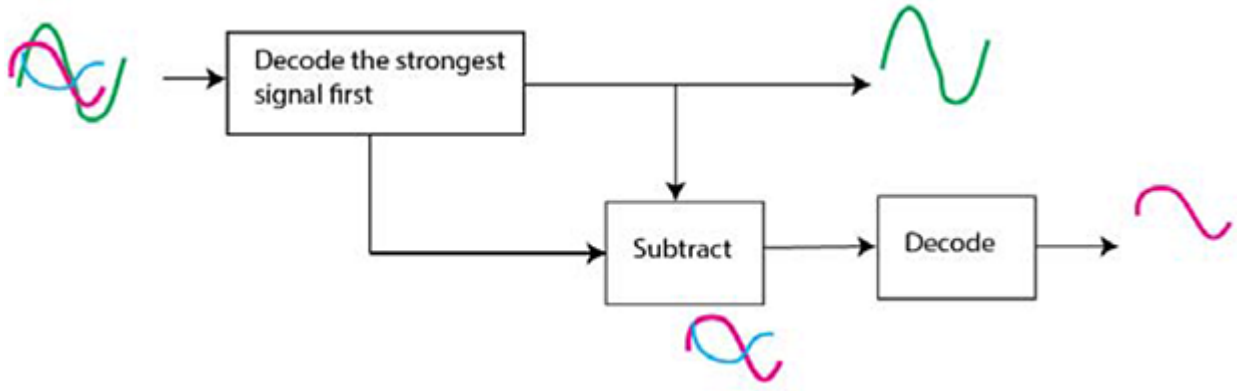
New Communications Technologies brings new ways:

- Low-powered Wide area trades off power/distance with speed e.g. LORA
- Maximising Capacity in Dense Environments





Non-orthogonal multiple access (NOMA)



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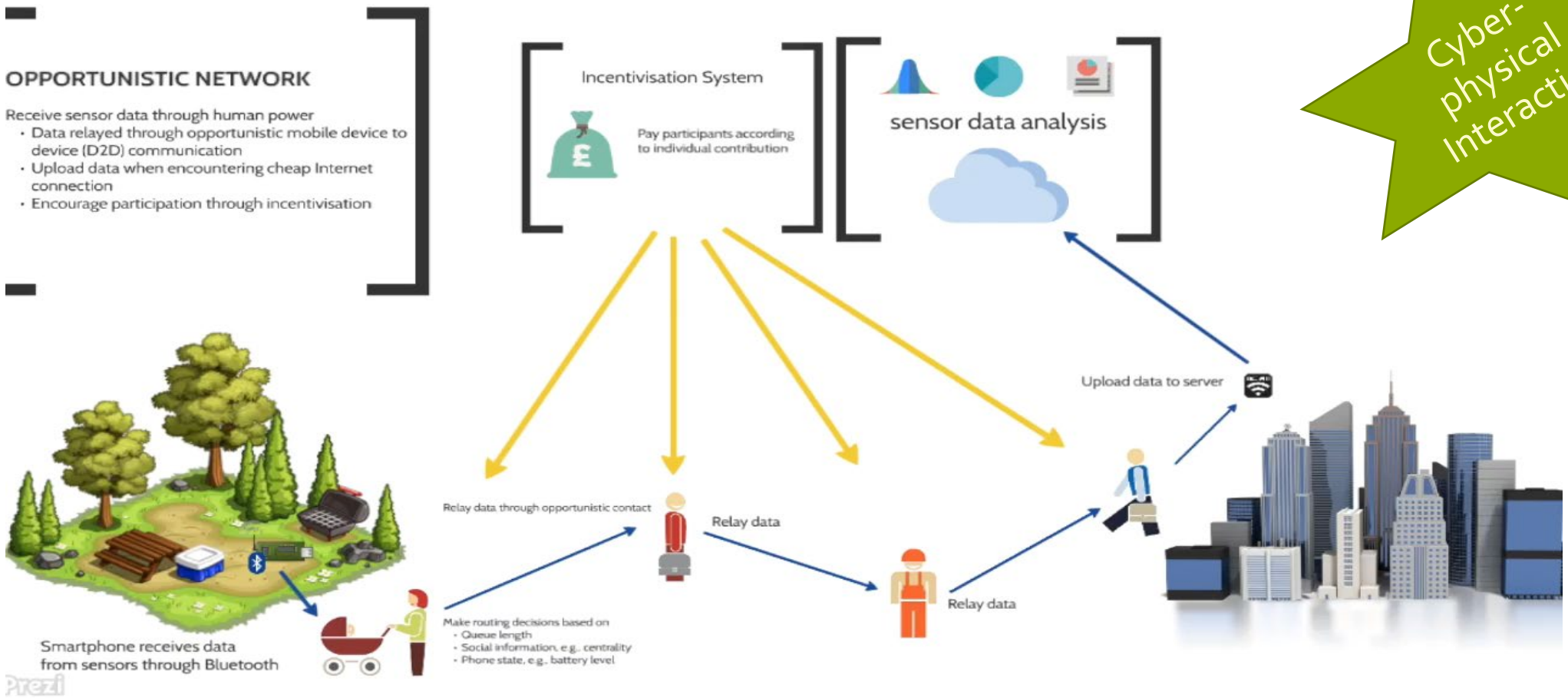
Challenges – Network Capacity



Cyber-physical Interaction

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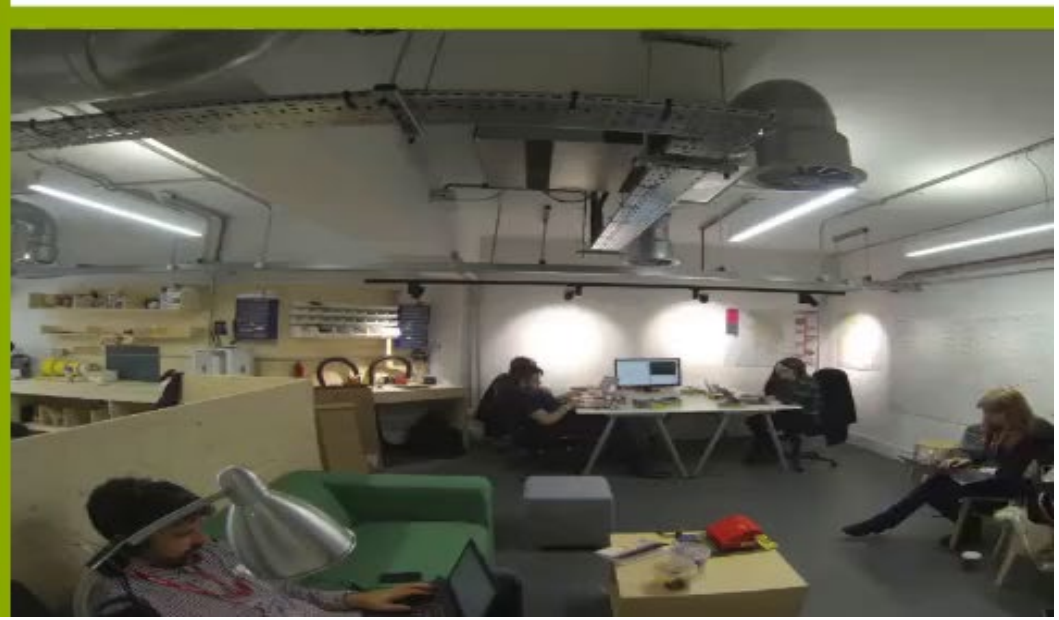
Challenges – Sharing the City's infrastructure

Input: Resource requirements for all the tasks
Set of applications
Set of metrics
Resource capacities for the current time slot

Function: *nextHopNeighbor* (j, t) returns the next-hop neighbour in the multi-hop routing path for task *j*, *Scaffold* (j,t) returns the set of eligible nodes for the task j

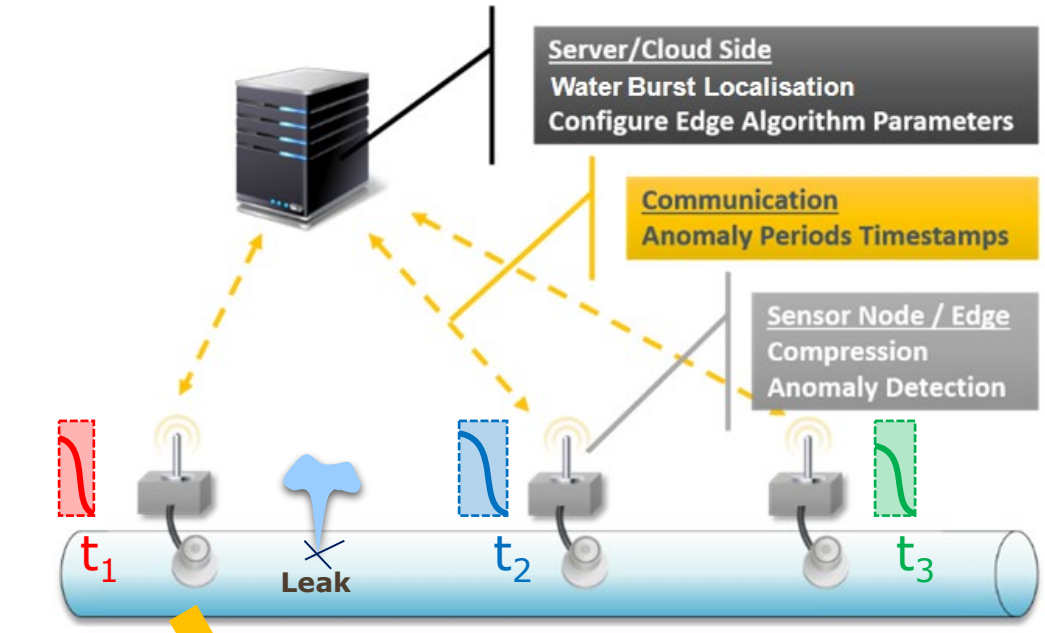
Output: Tasks allocation for all tasks

Implementation: On top of Contiki and its IPv6 stack



So what does this allow us to do?

Water Leak Detection & Localisation

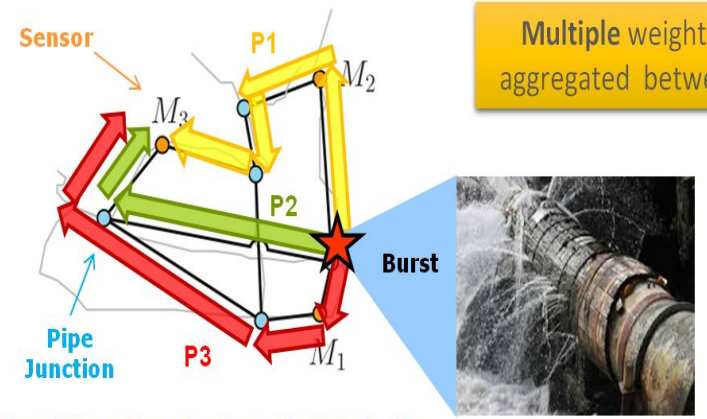


1

Distributed lightweight scheme to extract multiple features

2

Edge decision making for anomaly detection



Multiple weighted paths {P1, P2, P3} are aggregated between Sensor (M3) and Burst

Burst Wave Travels along Multiple Paths

Weighted Average Distance Within L Hops

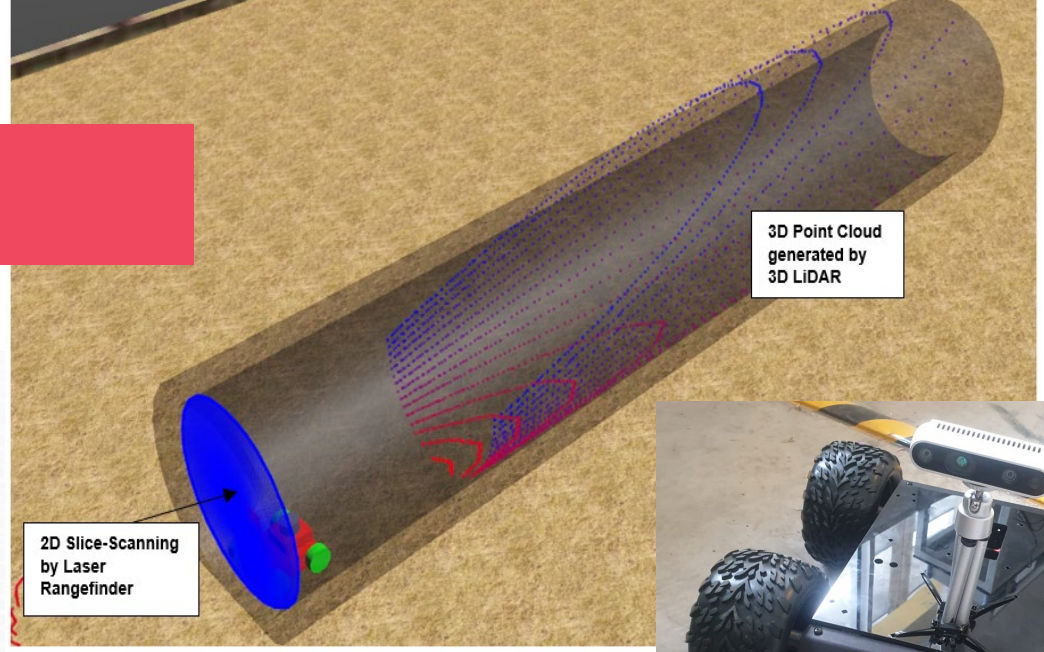
$$[\mathbf{S}^{(L)}]_{(u,v)} = \begin{cases} \frac{1}{\beta}\left[\lambda \mathbf{D} + \lambda^2 \mathbf{W}^{(2)} + \cdots + \lambda^L \mathbf{W}^{(L)}\right]_{(u,v)}, & (u \neq v); \\ 0, & (u = v). \end{cases}$$

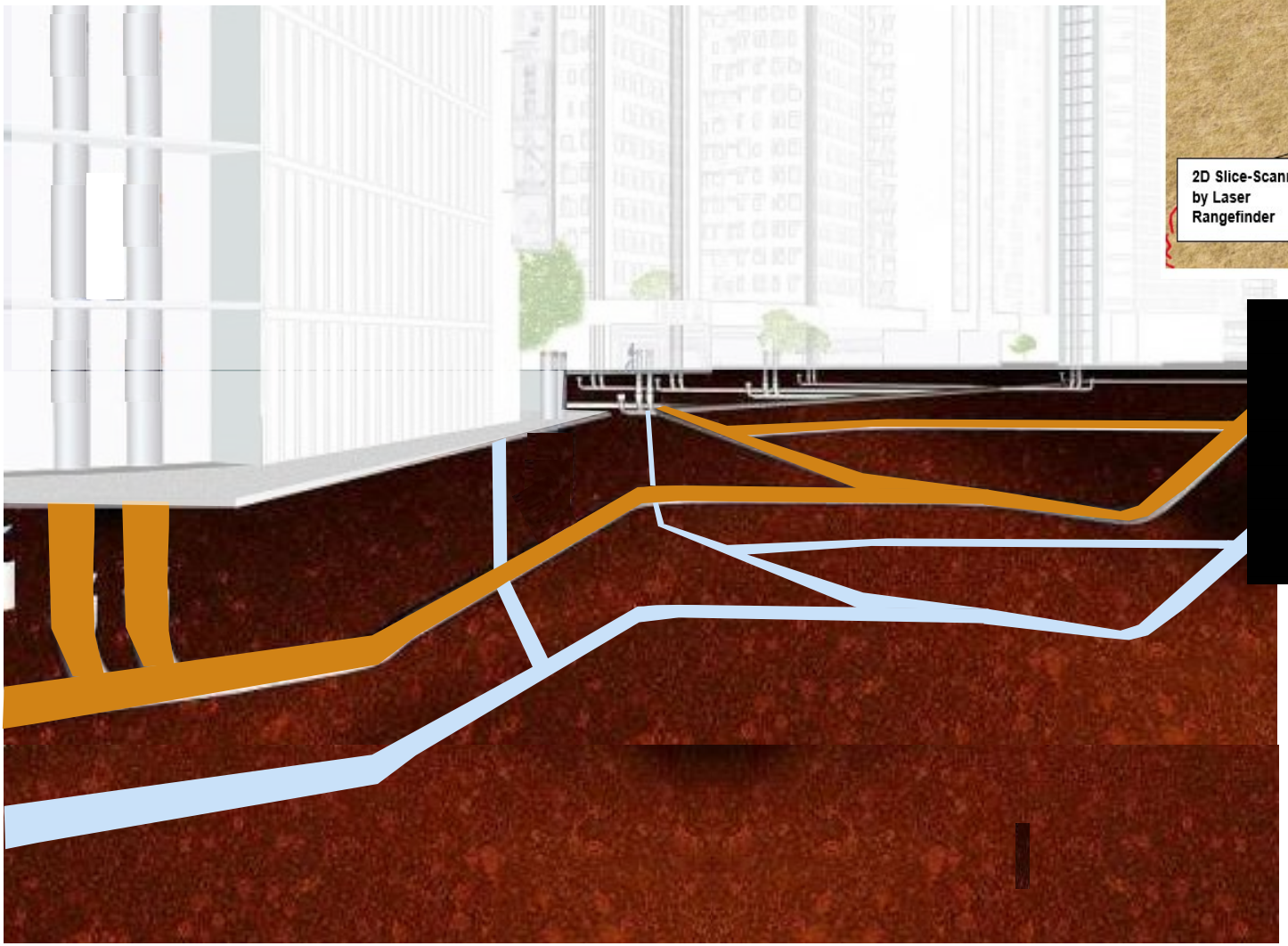
$\lambda \in (0,1)$ a decay factor

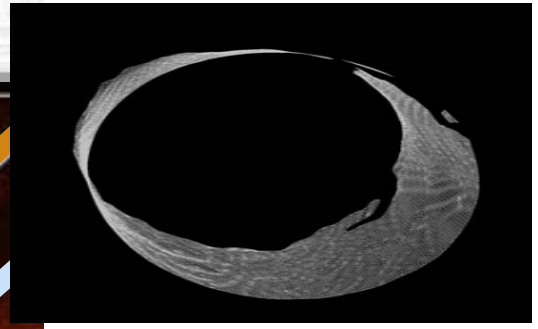
$$\beta = \sum_{i=1}^{L} \lambda^i \cdot \mathbf{1}_{\{[\mathbf{W}^{(i)}]_{(u,v)} \neq 0\}}$$

Longer paths will have lower weights than shorter paths

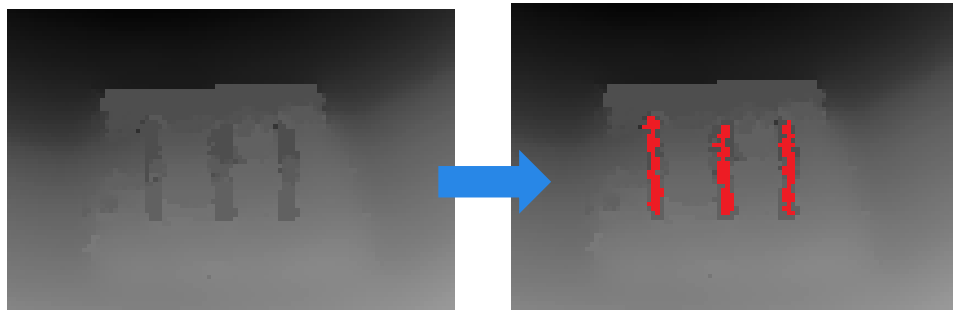
Waste Pipes (in Singapore)







DIFFERENT DEPTH VALUES IN A PIPELINE BY DEPTH CAMERA



Machine learning helping control

use case: fine-grained rainfall nowcasting based on collaborative meta learning

Adaptive learning in dynamic environments

- Data-driven understanding of real-world systems
- Multi-sourced big data support
- Portability and labor-saving
- **Challenge: learning efficiency & adaptability**
  - Sample insufficiency
  - Sample untimeliness
  - Model inadaptability
- **Solution: collaborative distributed learning**
  - Few-shot learning
  - On-line learning
  - Cross-task meta learning

Essential block services such as water tanks and lift motor rooms were strategically located to optimise available space for installation of solar panels on the roofs, with access routes planned for easy maintenance

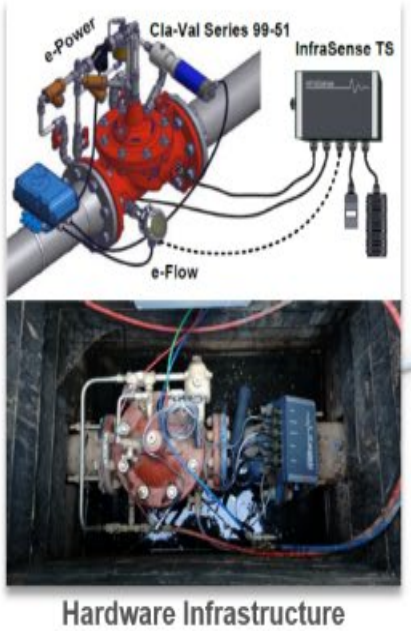
Challenges- Security

Recall – low resourced and flaky

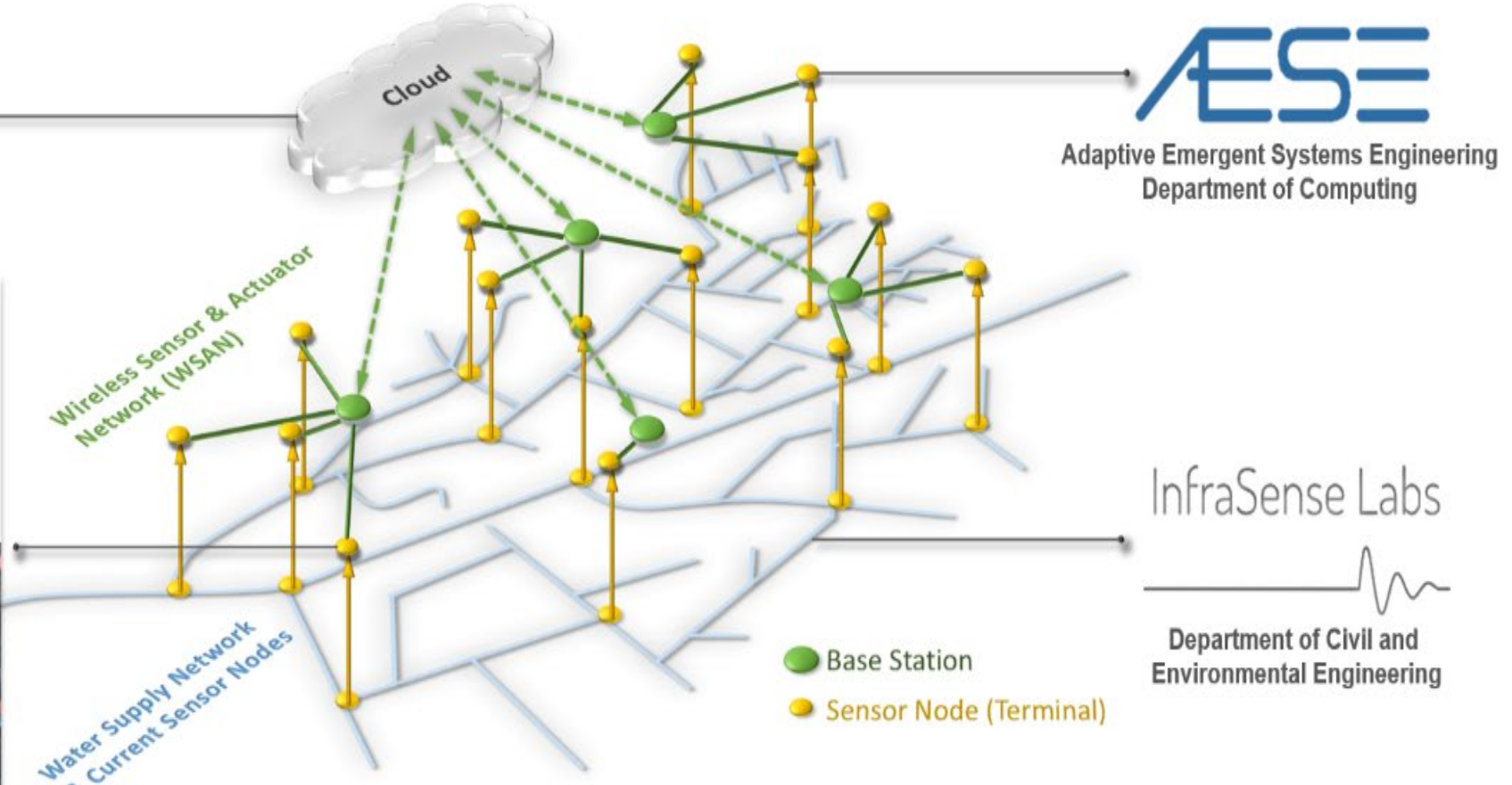
We used self-adaptive Techniques to make the System resilient?

Cyber-physical Interaction

NEC



Hardware Infrastructure



AESE

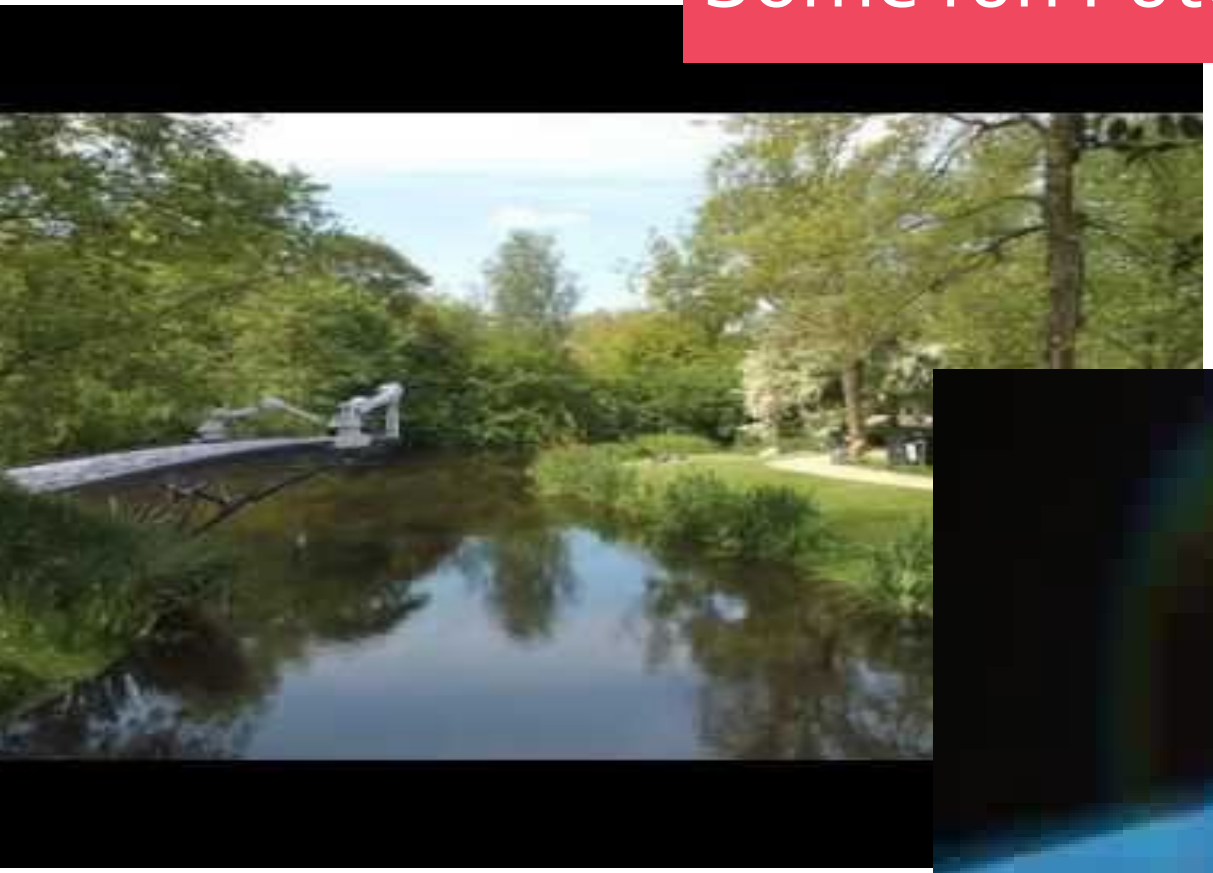
Adaptive Emergent Systems Engineering
Department of Computing

InfraSense Labs

Department of Civil and Environmental Engineering

Internet of Water

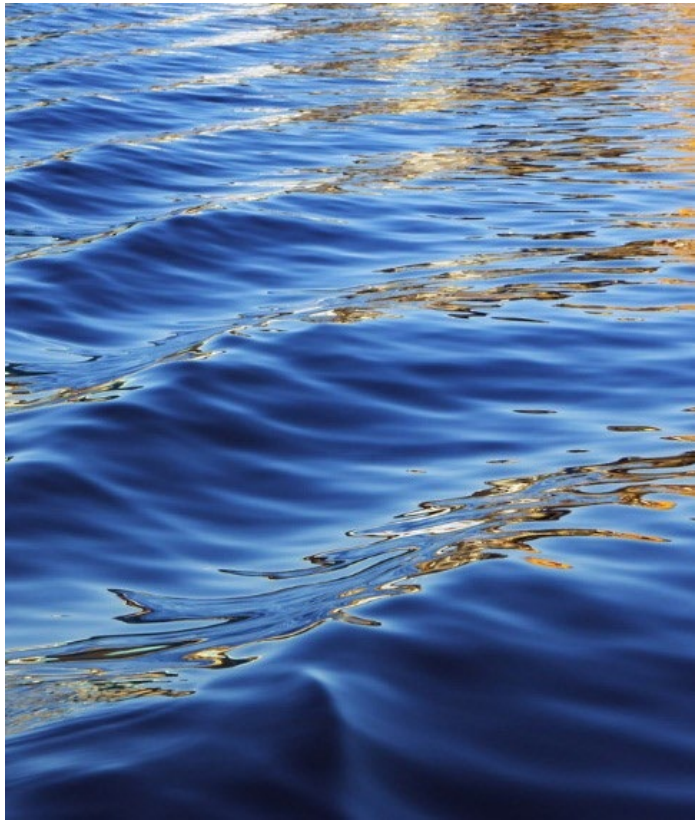
Some fun Futures



Sensors/Actuators printed in Situ

thanks

Julie A. McCann
jamm@imperial.ac.uk
www.smart-dust.co.uk



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