# A Reputation and Trust Based Multi-Modal Sensor Network for Environmental Monitoring

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# Presentation Outline

- Issues with in-situ WSNs.
- Multi-modal sensor networks.
- Data aggregation.
- Pilot studies:
  - River Lee water depth study.
  - Water level prediction for adaptive sampling.
- Trust and reputation framework.

# Water Management

- Water management is an important part of the monitoring of the natural environment.
- For many years water managers relied on field measurements for coastal monitoring and water quality evaluation.
- However this process is being revolutionised through the introduction of new technologies such as sensor networks.

Image: John Cleary

# Issues

- Current state of the art in **chemo/bio-sensor networks** not at a stage for reliable long-term large scale deployment.
- Even without the complexity of chemo-bio sensing, still considerable issues
  - Sensors subject to **harsh conditions**
  - **Bio-fouling**
  - Limited **spatial resolution**
  - Difficult to **monitor large areas** over long periods of time
  - **Unsuitable for certain environments** and the immediate detection of certain events
  - Developments in sensor research **pushing towards ever cheaper systems**
  - Huge **information overload** – user requires reliable event detection.

Image: www.ferrybox.eu/imperia/md/images/ferryboxuse

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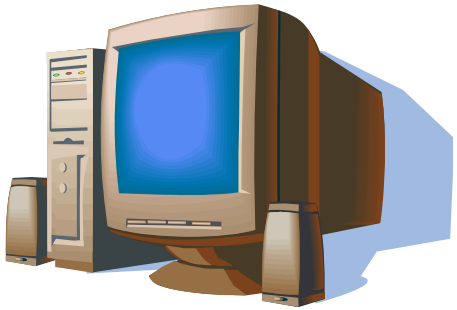
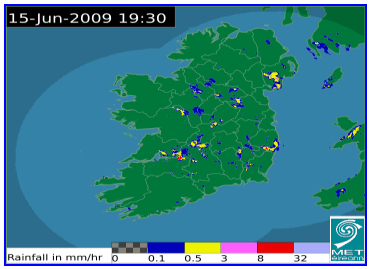
# Multi-modal sensor networks

- The incorporation of alternative sensing modalities such as visual sensors, alongside an in-situ WSN can help to overcome some of these problems.





# Test Sites

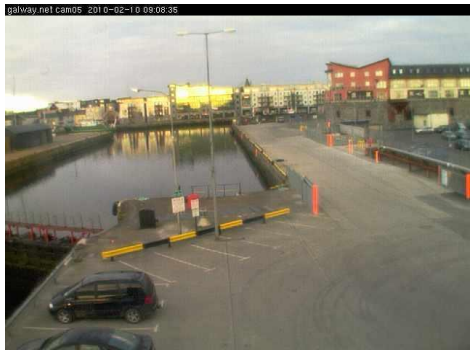
| Requirements | River Lee | Galway Bay | River Tolka |
|---|---|---|---|
| Network | x | x | |
| Power | x | x | |
| Security | x | x | |
| Multiple sensing modalities | x | x | |
| Interesting from marine perspective | x | x | x |

# Data Aggregation – Camera data

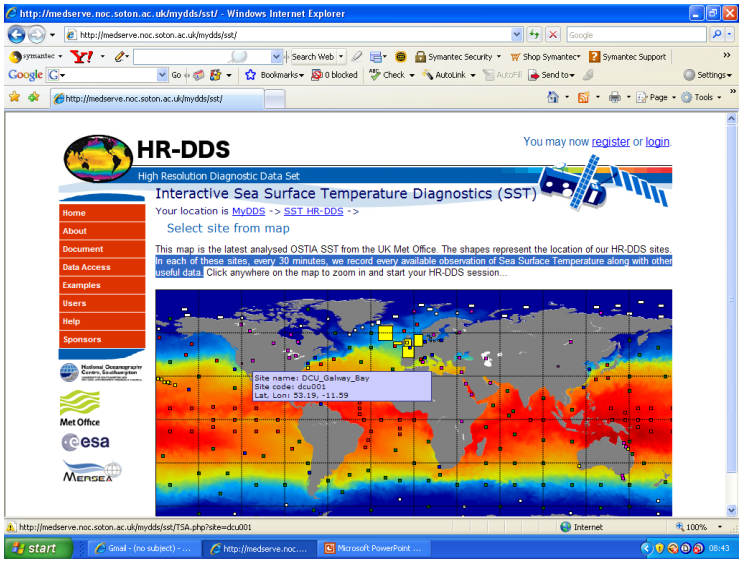


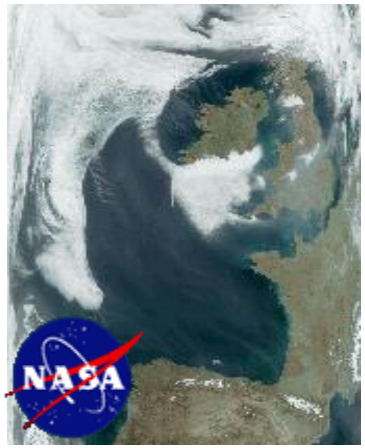


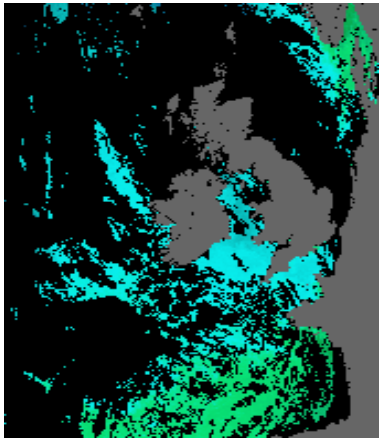


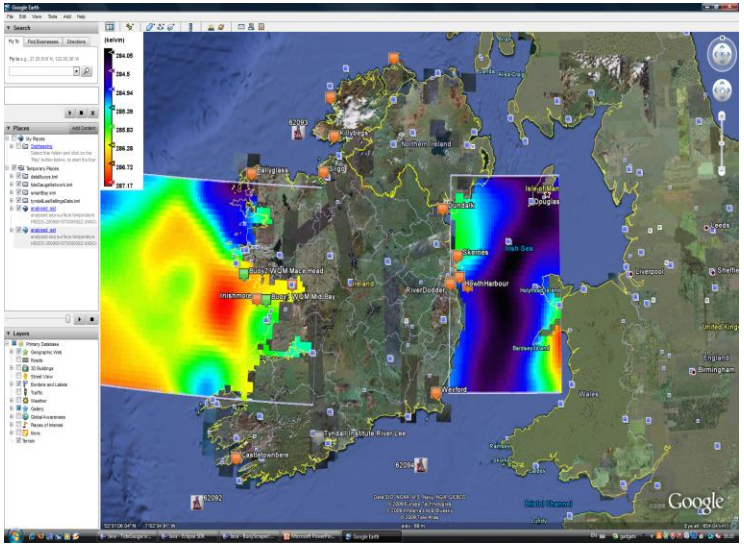



# Data Aggregation – Satellite data



# In-situ sensor data and context data

## Deploy: River Lee

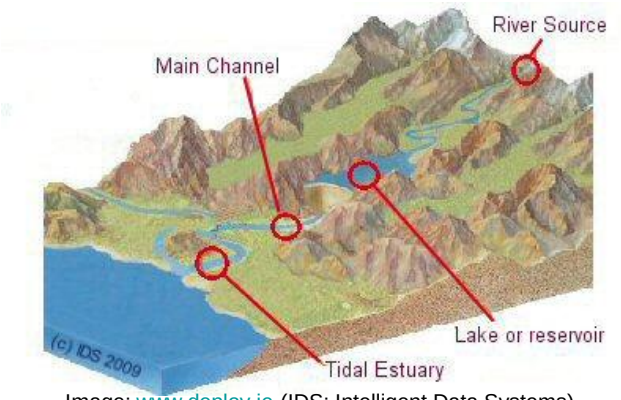
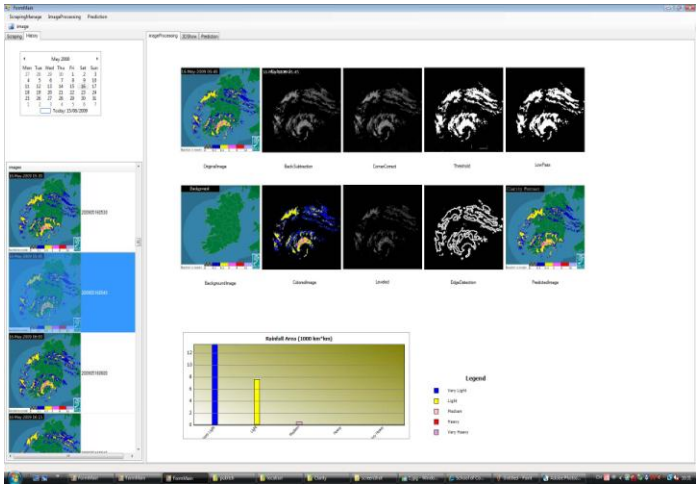



Image: www.deploy.ie (IDS: Intelligent Data Systems)

## Rainfall Radar processing



## SmartBay: Galway Bay

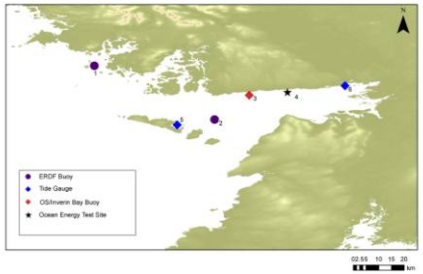
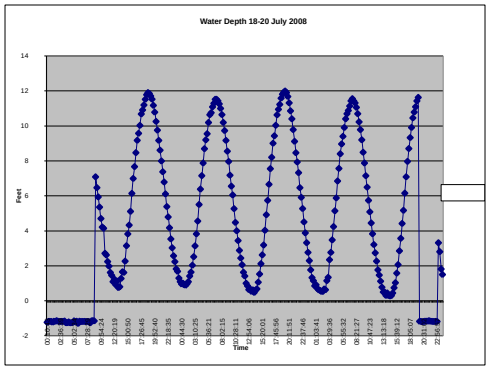
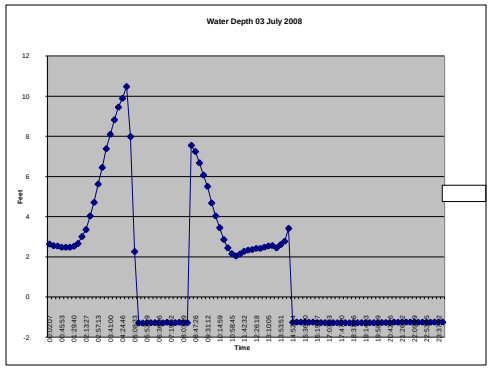



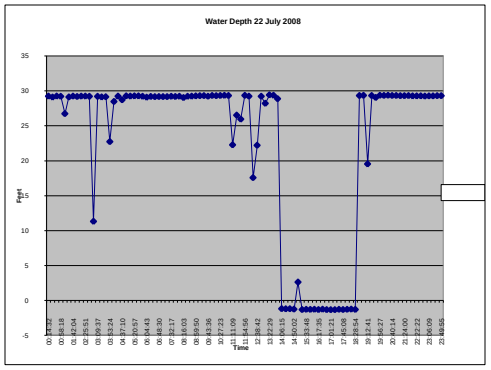


Image: Marine Institute

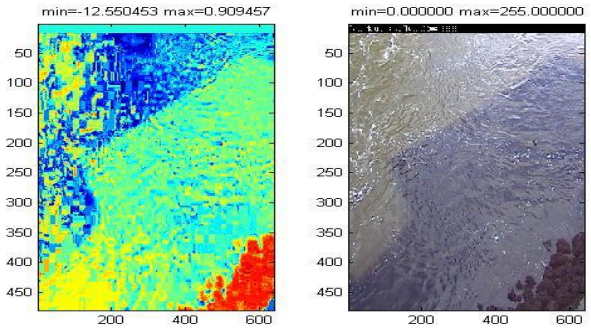
# River Lee Water Depth Study




| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| Class Distance Error | 0.642 | 0.537 | 0.302 |
| Classification Rate | 0.467 | 0.732 | 0.750 |





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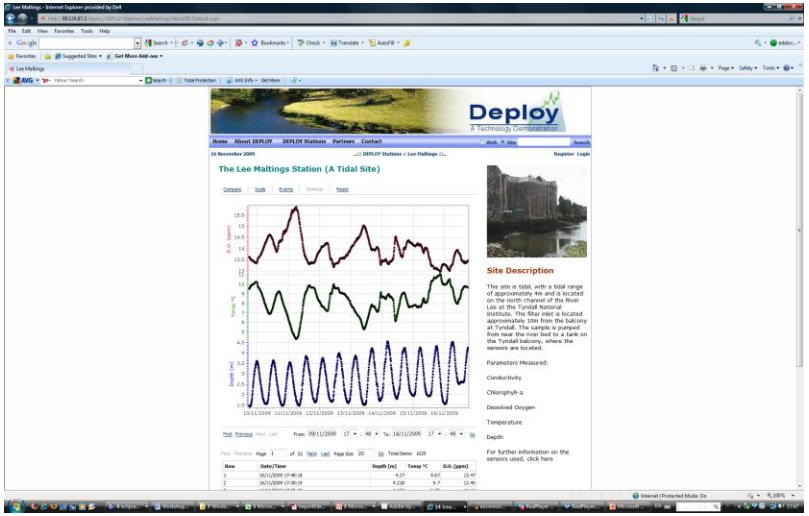
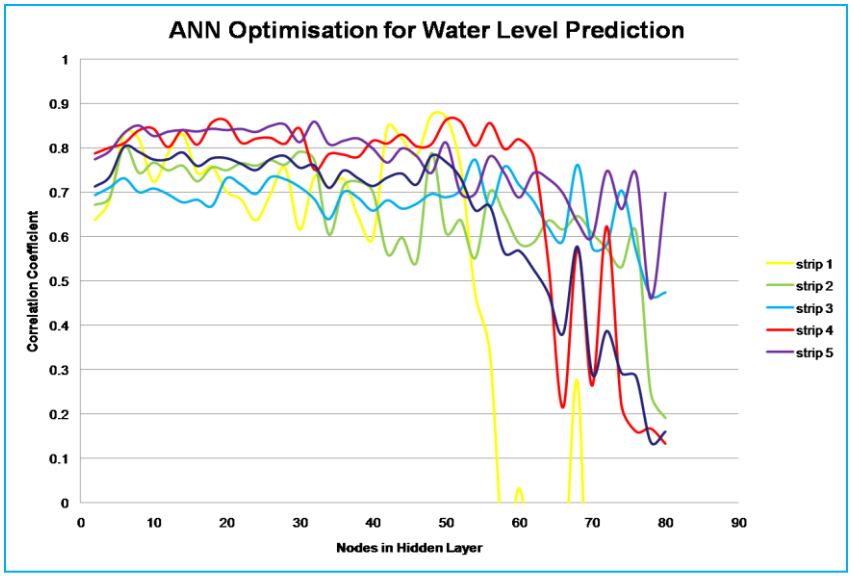
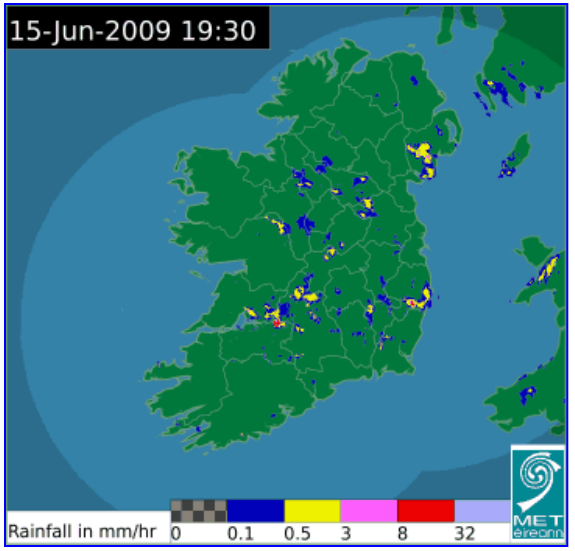
# Multi-modal sensor networks – adaptive sampling

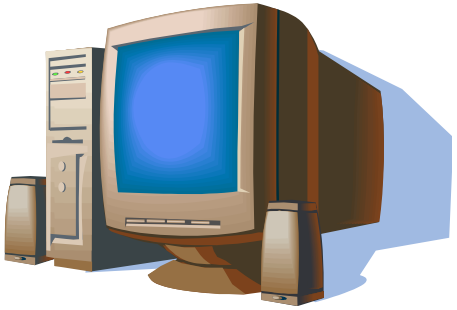


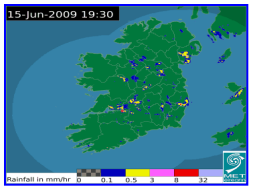



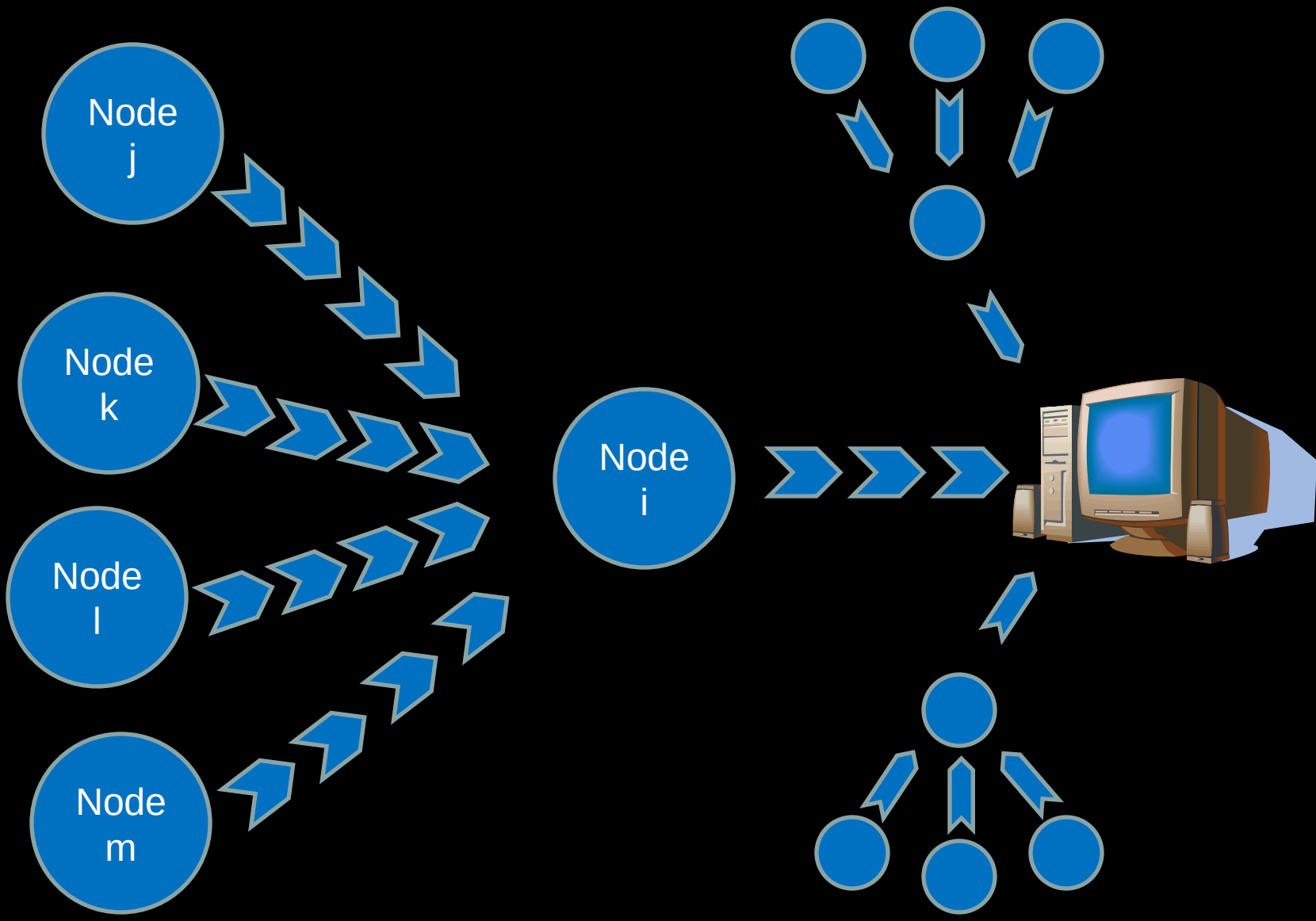
# Reputation and Trust-based multi-modal sensor network

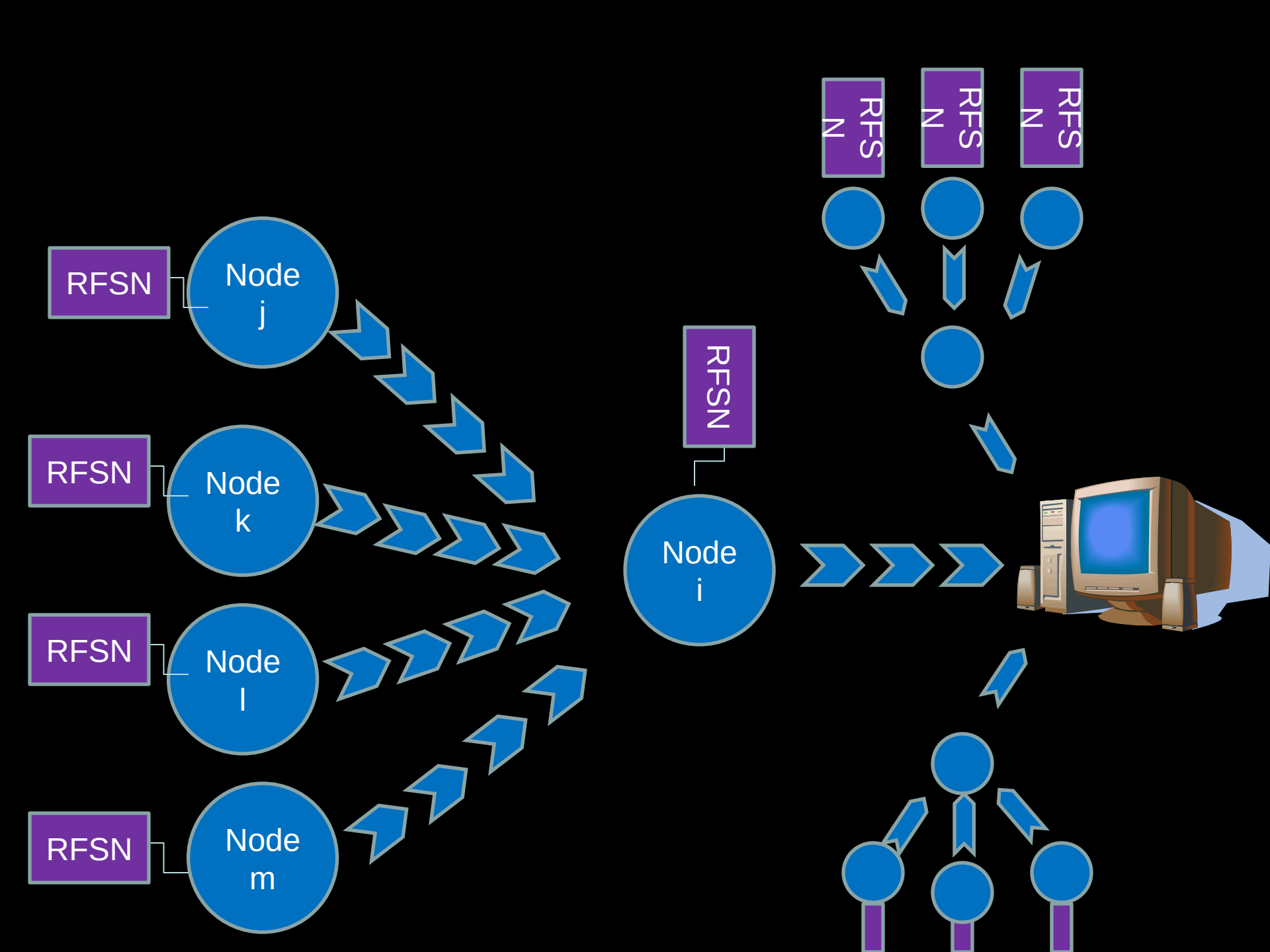
- Development of a reputation and trust-based multi-modal sensor network
- Adaptation of a model developed for in – situ sensor networks known as RFSN (RFSN Ganeriwal & Srivistava 2008).
- Adapation of this model to multi-modal sensor networks





# Community of Sensor Nodes




RFSN
Node j
RFSN
Node k
RFSN
Node l
RFSN
Node m
RFSN
Node i
RFSN
RFSN
RFSN

# Community of Sensor Nodes

## RFSN

[j,k,l,m]

### WATCHDOG

Series of outlier detection protocols, outputs cooperation metrics for each of the nodes.

Cooperation metrics

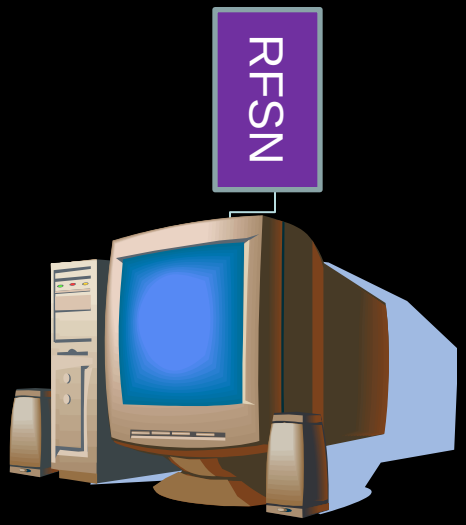
### REPUTATION

Updates reputation for each of the nodes [I, j, k,l] i.e. $R_{ij}$, $R_{ik}$, $R_{il}$, $R_{im}$

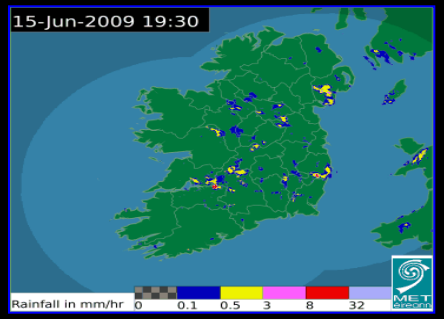
trust

External evidence

# Community of Sensor Nodes







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# To sum up…….

- Multi-modal sensor networks provide:
  - Increased information and early warning information regarding environmental events.
  - More efficient and effective sensing.
  - More reliable event detection which leads to improved monitoring and scientific analysis.
  - A smarter adaptive sensor network that continuously monitors our environment, detects changes in the quality of our environment and reacts to those changes.

# Acknowledgements


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