Paving the road for the future IoT and AmI applications

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Presentation overview

- **Research pathway**
- **Existing IoT ecosystem**
- **IoT technologies for Ambient Intelligence apps**
  - Devices and applications
  - Communication networks
  - Data processing
    - Time series data analyses
    - Sensor data uncertainty
    - Sensor data anomaly detection

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Research pathway

- **Ubiquitous Computing**
  - Computers are everywhere, and its services follow users
- **Ambient Intelligence**
  - Ubiquitous, adaptive, context aware, personalised
- **Internet of Things**
  - Device to device communication, at first, to interconnected everything together
- **End-Edge-Cloud architecture, and cloud/edge computing**

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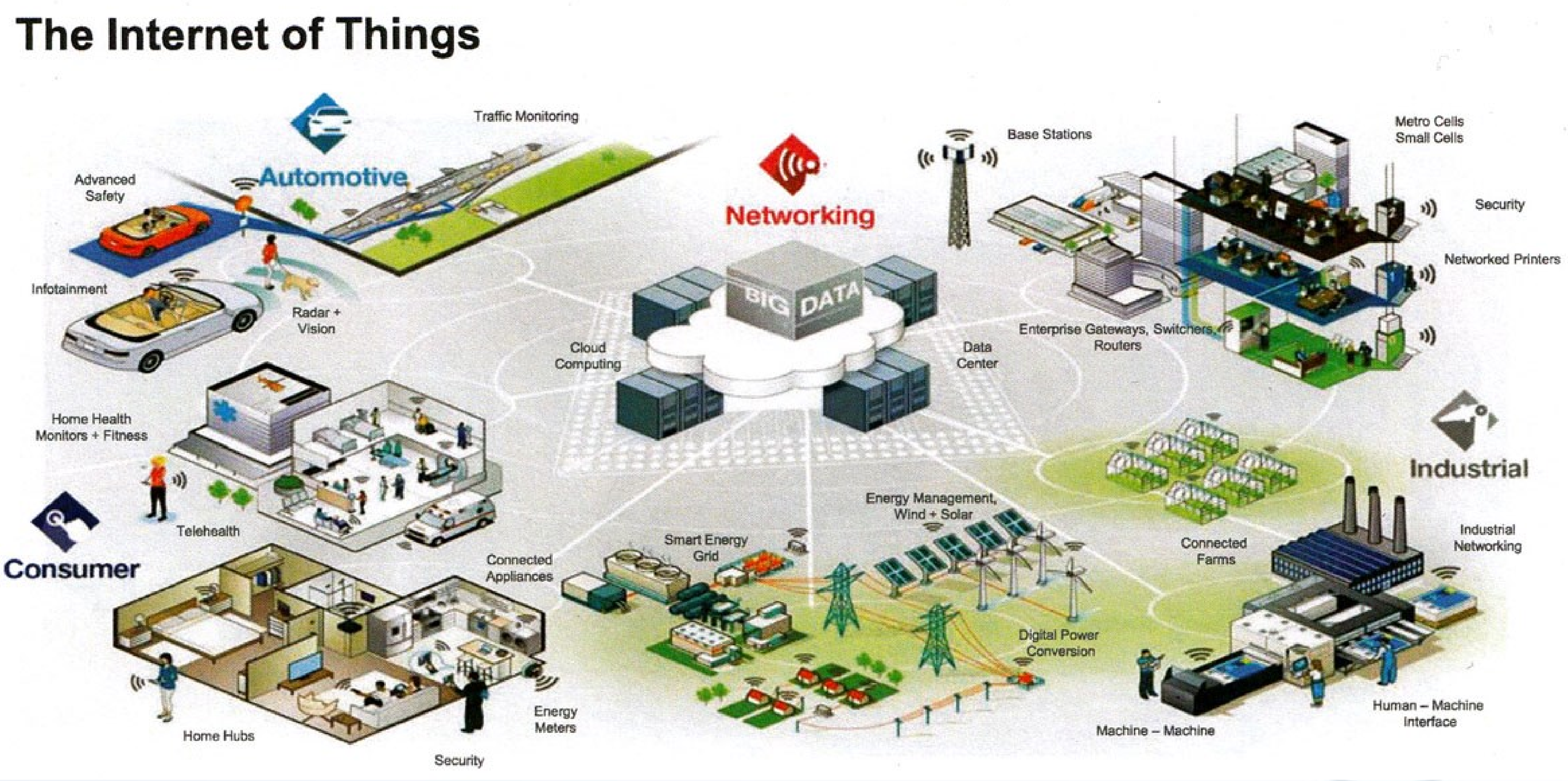
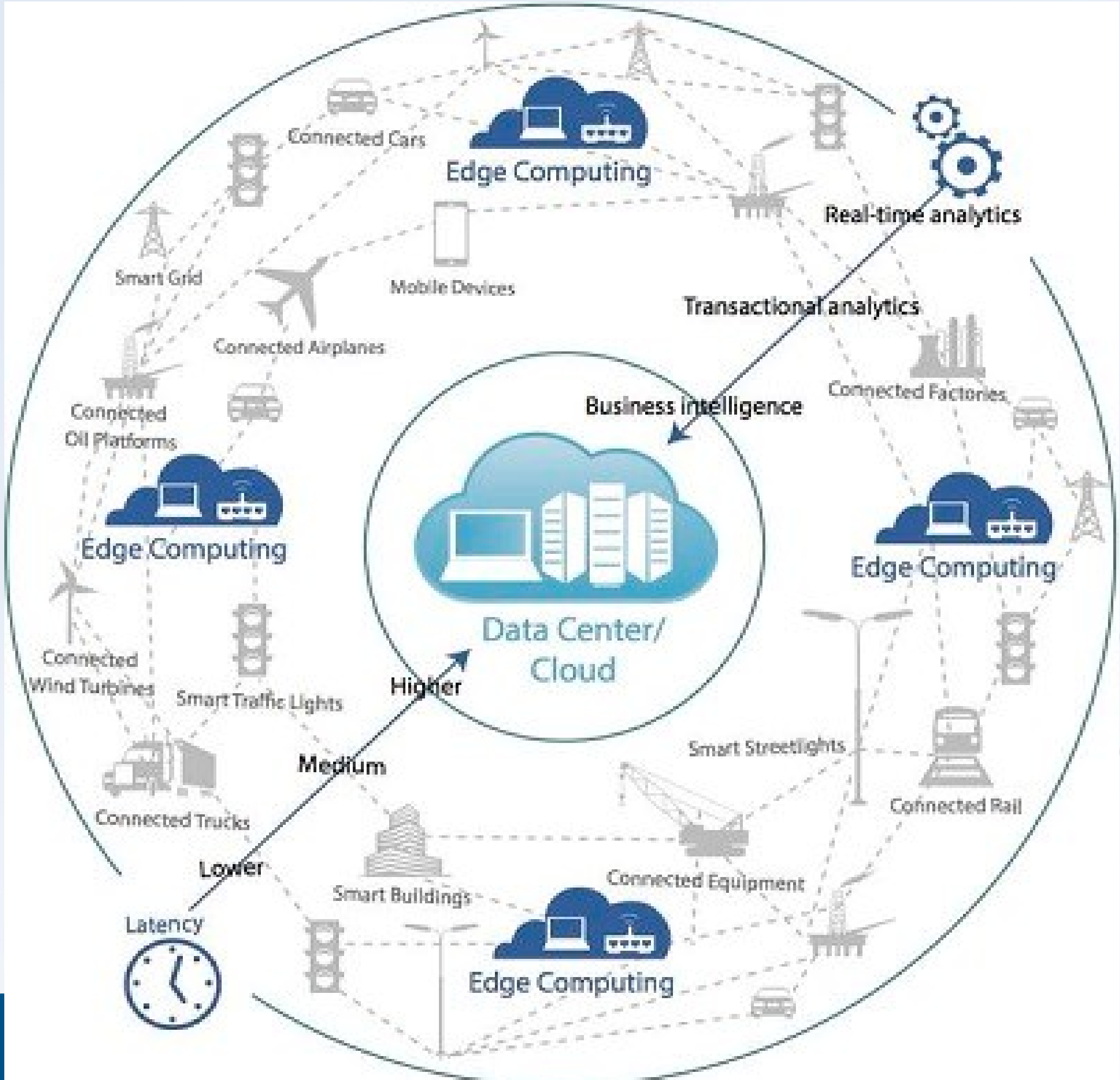
Current IoT eco-system



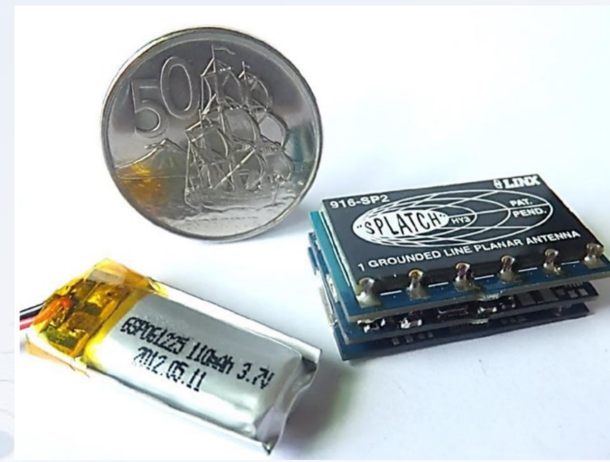
Current IoT eco-system

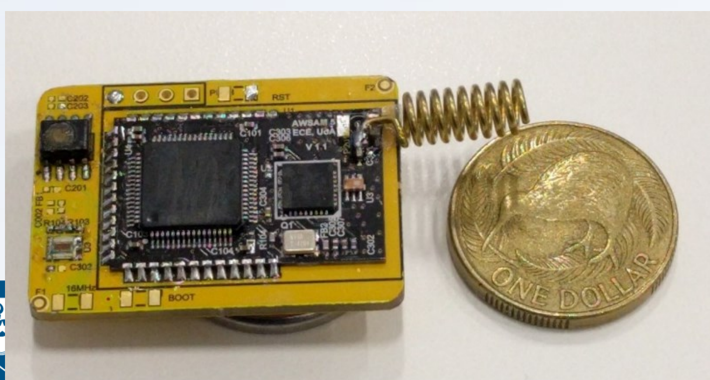


- **Hierarchical and isolated:**
  - End device -> edge -> cloud
- **Challenges:**
  - Interconnectivity
  - Interoperability
  - Scalability
- **Cross layer design**

The "Things"

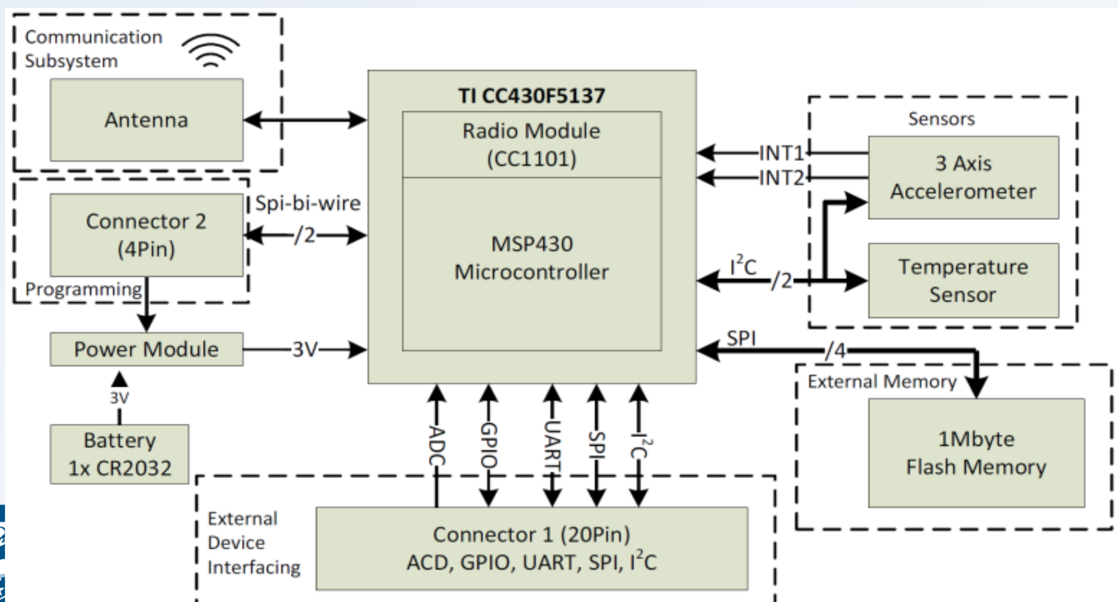
- **The goal is to achieve unobtrusive, ubiquitous sensing and interaction**
  - with immediate physical environment, human, or other "Things"
- **Challenges**
  - **Ubiquity**: small physical size
  - **Longevity**: long operating life
  - **Interoperability**: for large scale, distributed, remote monitoring and control
  - **Intelligence**: real-time data analytics

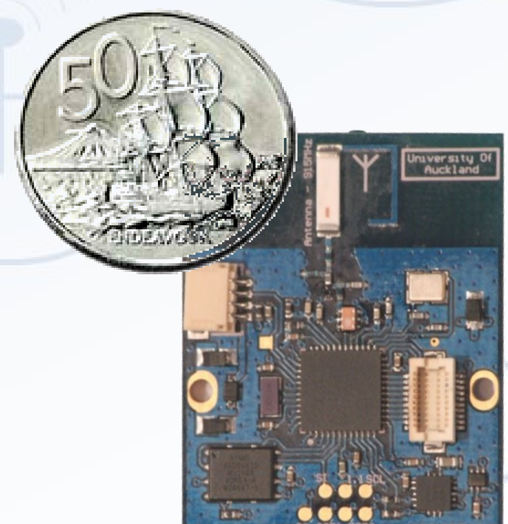




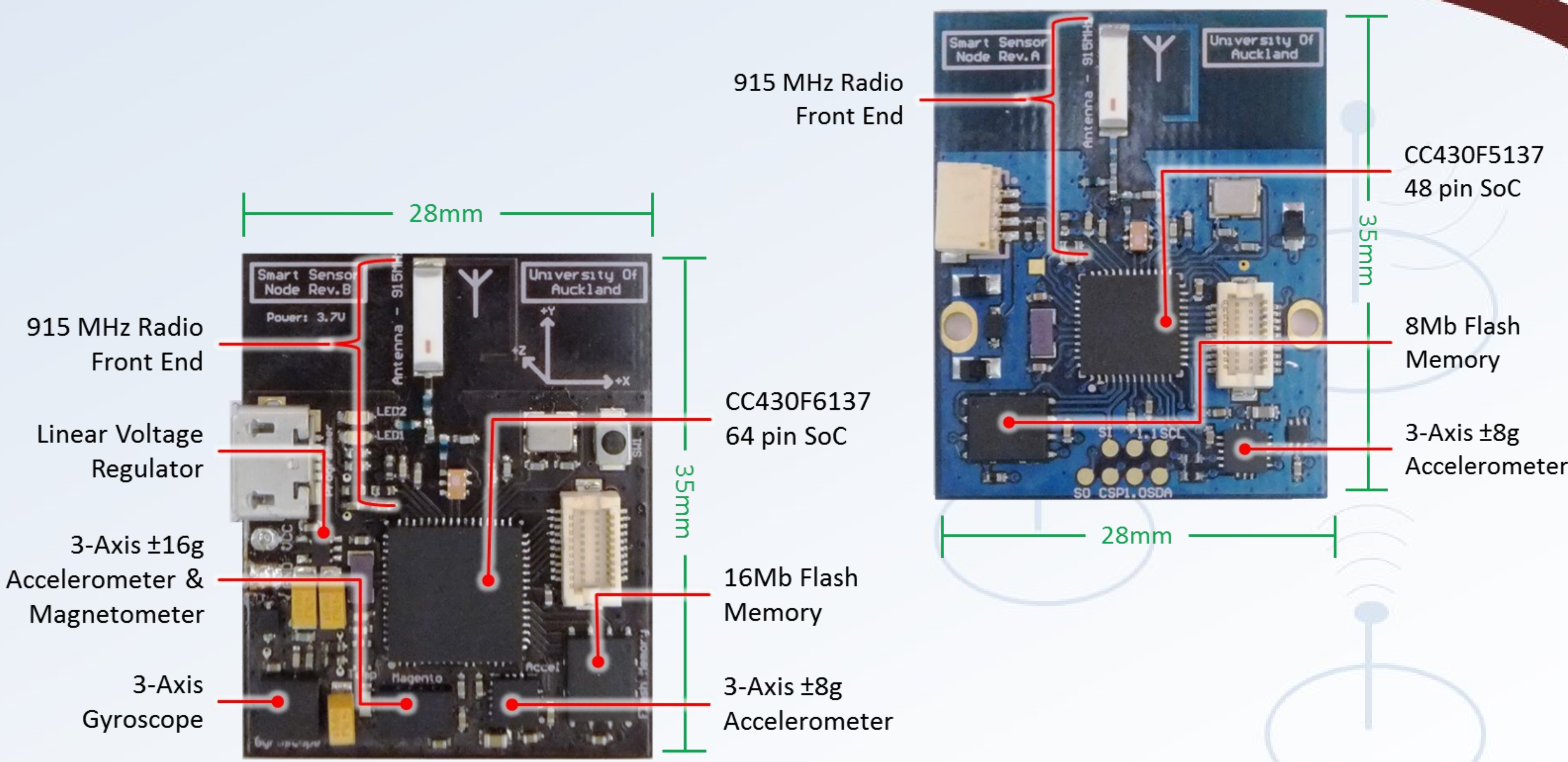
Hardware platform - AWSAM

- **Auckland Wireless Sensing and Actuating Mote**
- **Ultra low power, miniaturised sensor node:**
  - cc430 based wireless mote with 4KB RAM & 32KB flash
  - Physically small and unobtrusive (35 mm x 28mm)
  - Short communication range (100 meters)
  - Short operating life (~10 hours)





AWSAM-1&2 implementation



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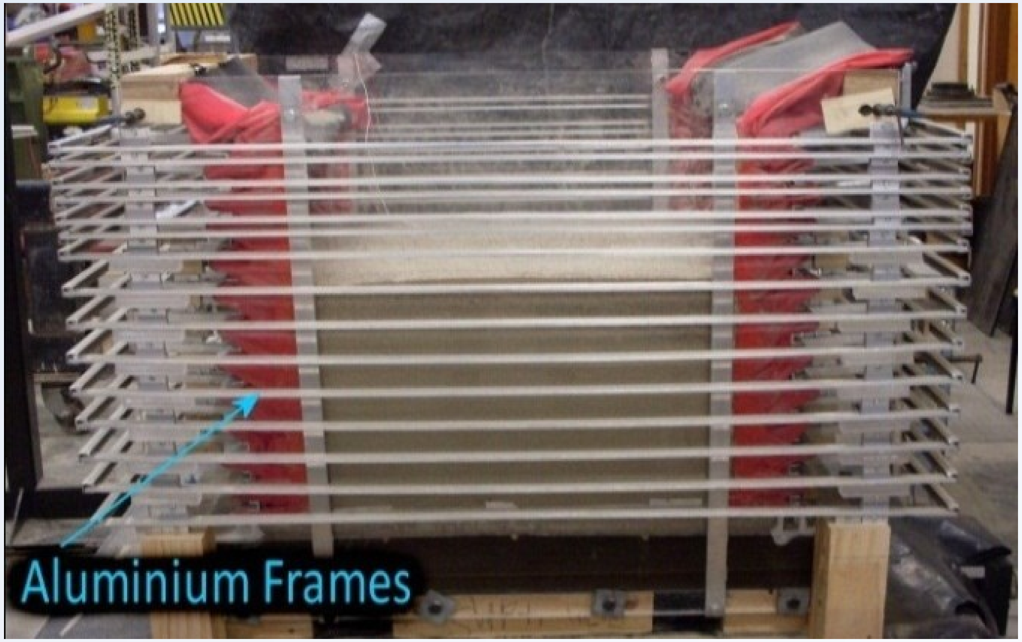
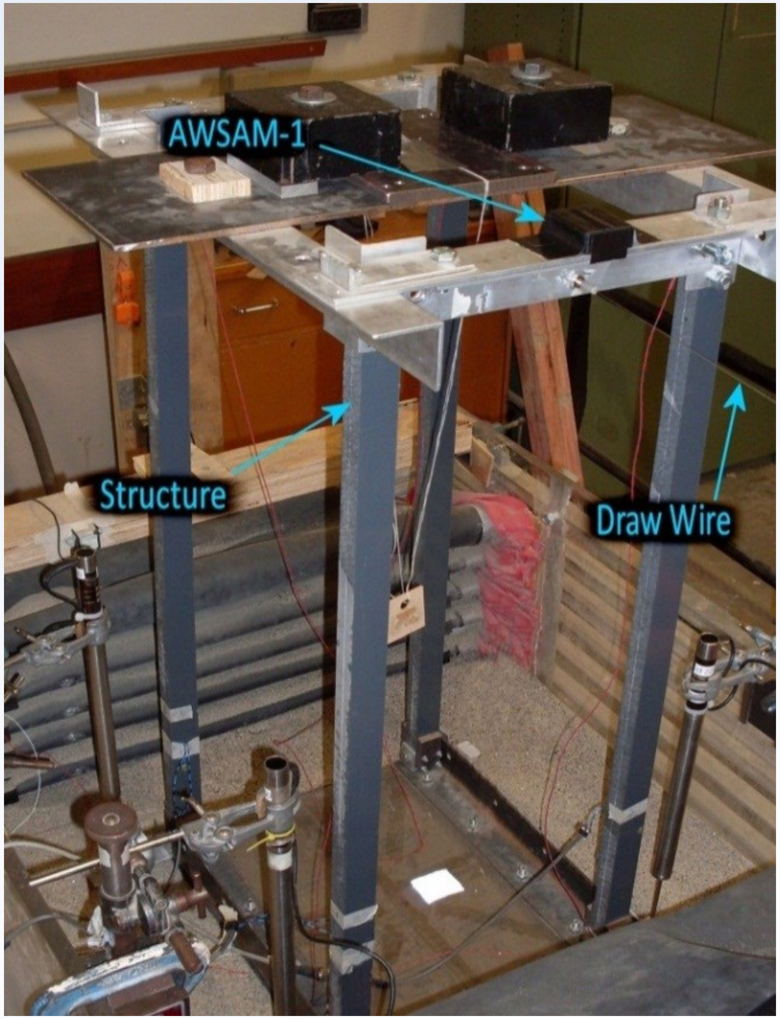
Building monitoring

- **Structural health monitoring**
- **Intelligent infrastructure**





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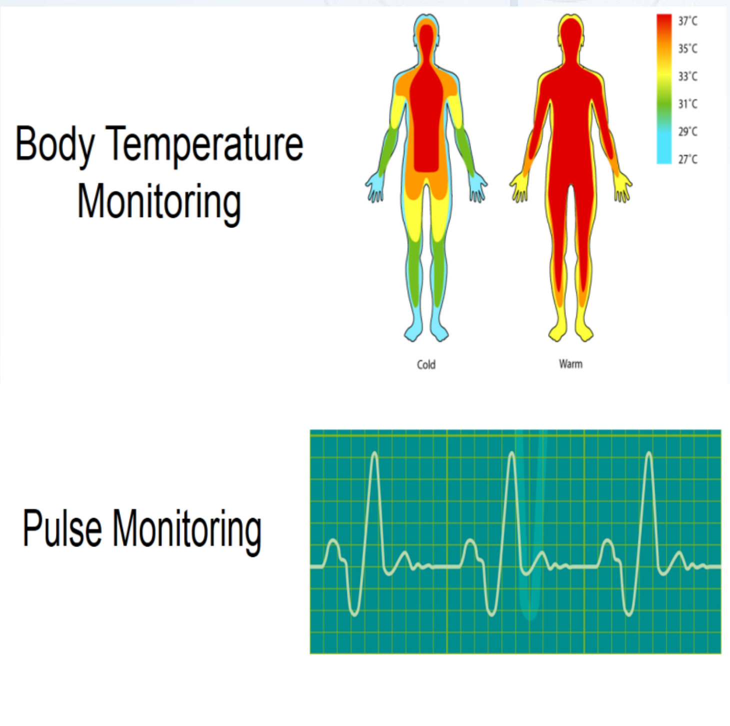
Intelligent environments

Pervasive healthcare

- Body area network (BAN) and personal area network (PAN) for pervasive healthcare applications

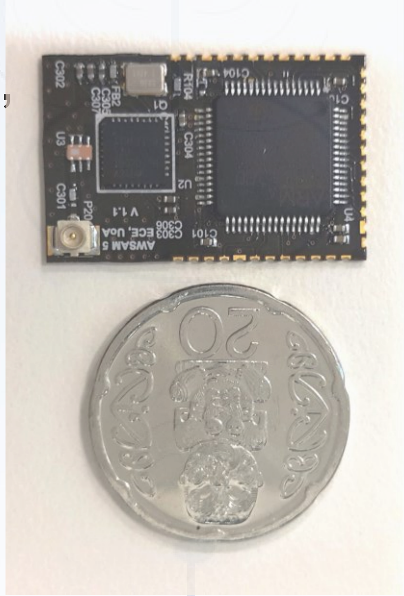


Communication

- **Wide varieties of communication technologies**
  - **Short range RF (low power, long operating life)**: RFID, Bluetooth, WiFi
  - **LPWAN (long range, low data rate)**: LoRaWAN, Sigfox
  - **Backbone (high bandwidth, fast speed)**: Cellular networks, Fibre
  - Proprietary and legacy networks
- **Challenges:**
  - What are the most suitable network(s) for your applications?

    -> Trade-offs in design
  - How to provide intuitive and integrated services?

    -> System level solution



Data processing

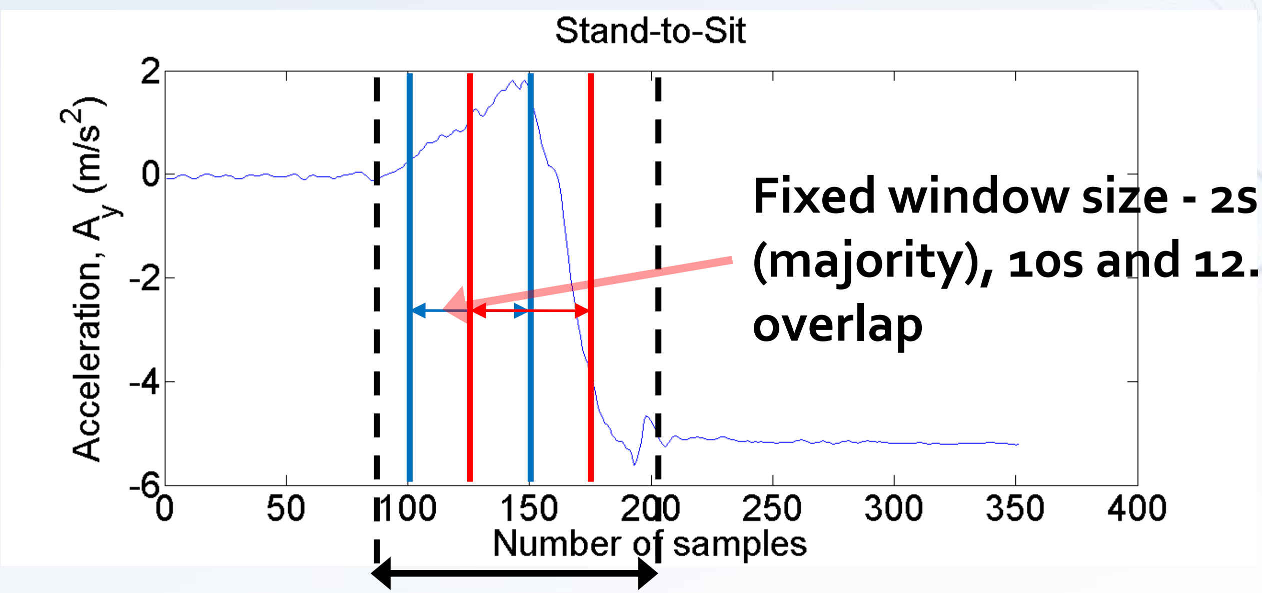
- **Data-driven or Knowledge-driven**
  - Data-driven: Typically machine learning based
    - Robust against uncertainty and noise.
    - Require large amount of labelled training data.
  - Knowledge-driven: Typically exploiting prior expert knowledge to build semantic or physics model.
    - Semantic model has good representability
    - Lack of the flexibility in dealing with uncertainties
  - Both are able to achieve very good accuracy in lab test results
- **Challenges:**
  - Application specific
  - Resource demanding – sensing, storing, transmitting, processing
  - Data quality and uncertainty
  - How to extract useful patterns and information
  - Visualisation and interpretation

Human activity recognition (HAR)

- **IoT (or specifically mobile/wearable) devices for human activity recognition (HAR)**
- **Challenges:**
  - Human motions/movements are continuous, while activities are discrete and with different durations
  - Boundaries between different activities are unknown
  - Real-time detection
- **Typically, continuous sensor data is first divided into multiple discrete segments and then to be classified into specific activity class**
  - How long should the segment be?

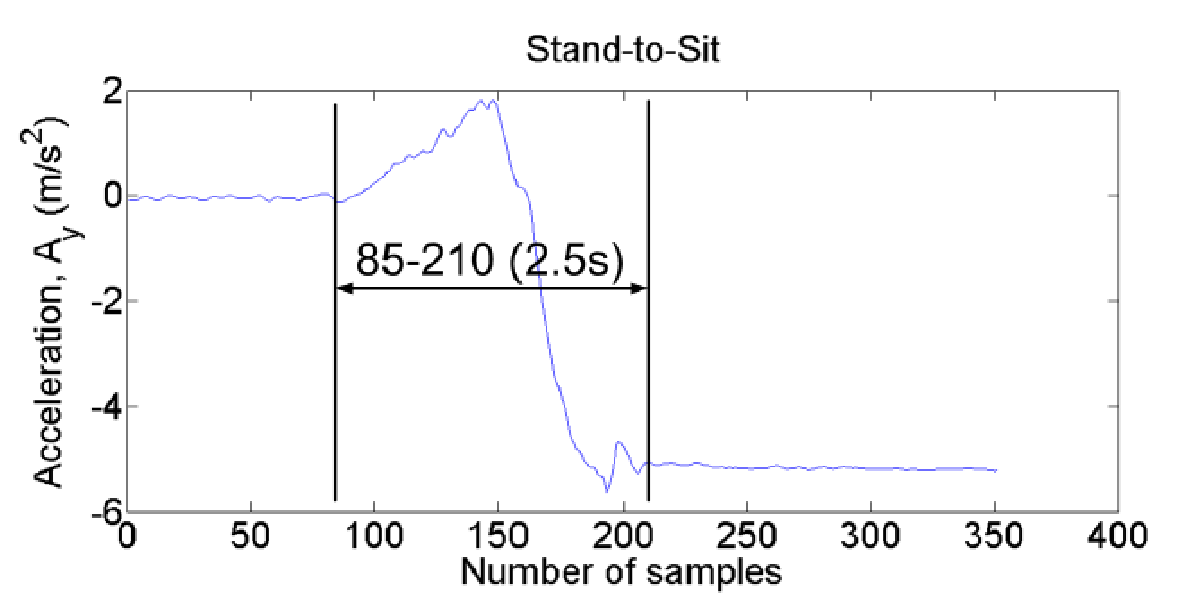
Unknown activity length

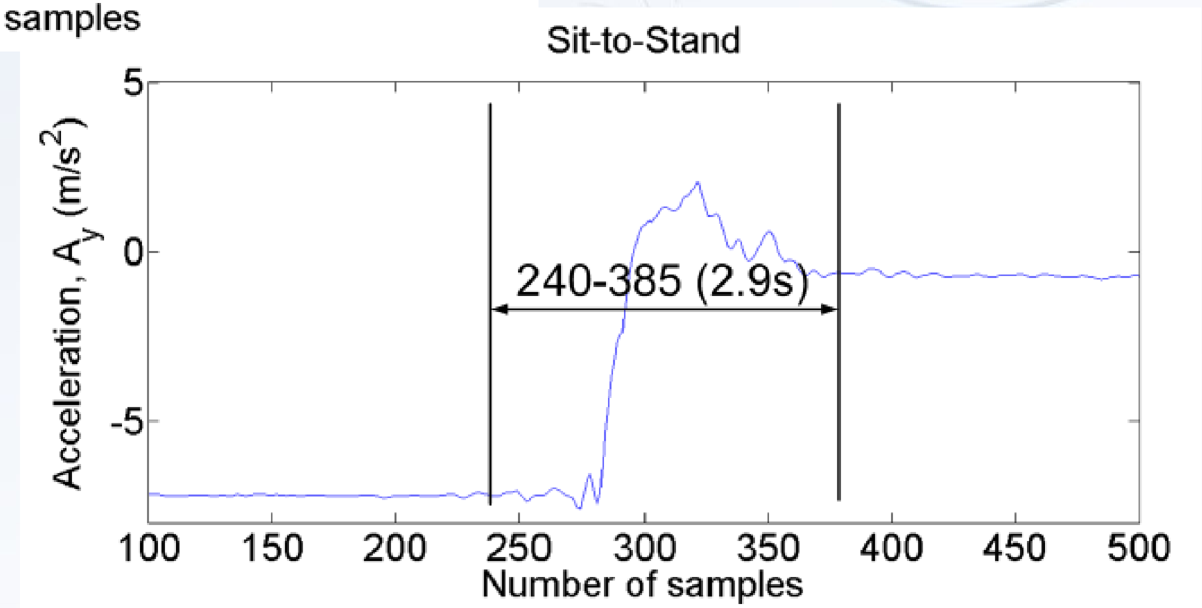
- Human physical activities can be classified into **non-transitional (static/dynamic)** and **transitional** activities
- Misclassification could happen especially for transitional activity signals because the length of transitional activity signals varies depending on the time to complete the activity



Fixed window size - 2s to 6.7s (majority), 10s and 12.8s, with 50% overlap

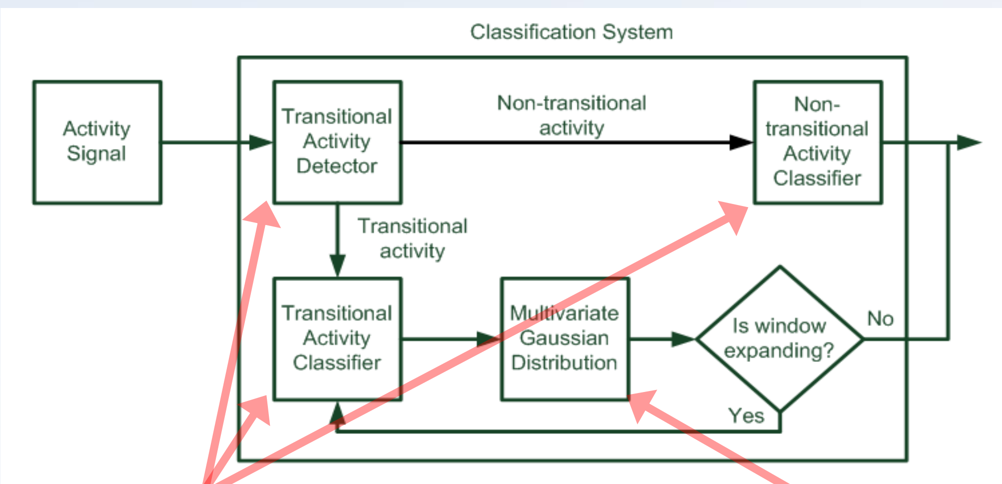
Unknown activity length - example

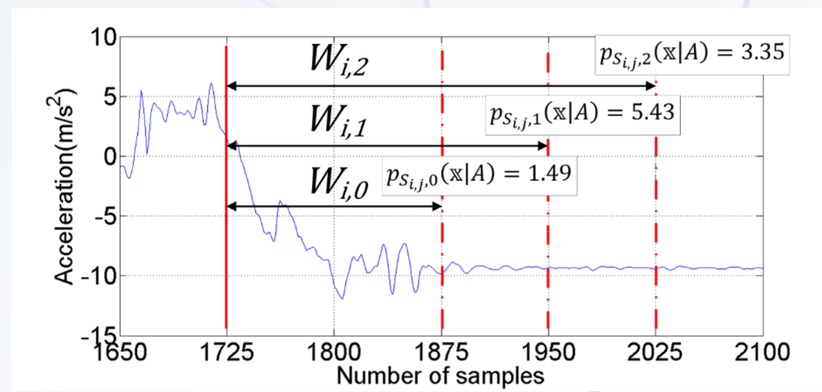




Adaptive sliding window

- A novel adaptive sliding window segmentation for physical activity recognition is developed
  - adaptively change the window size to deal with activity signals of varying lengths



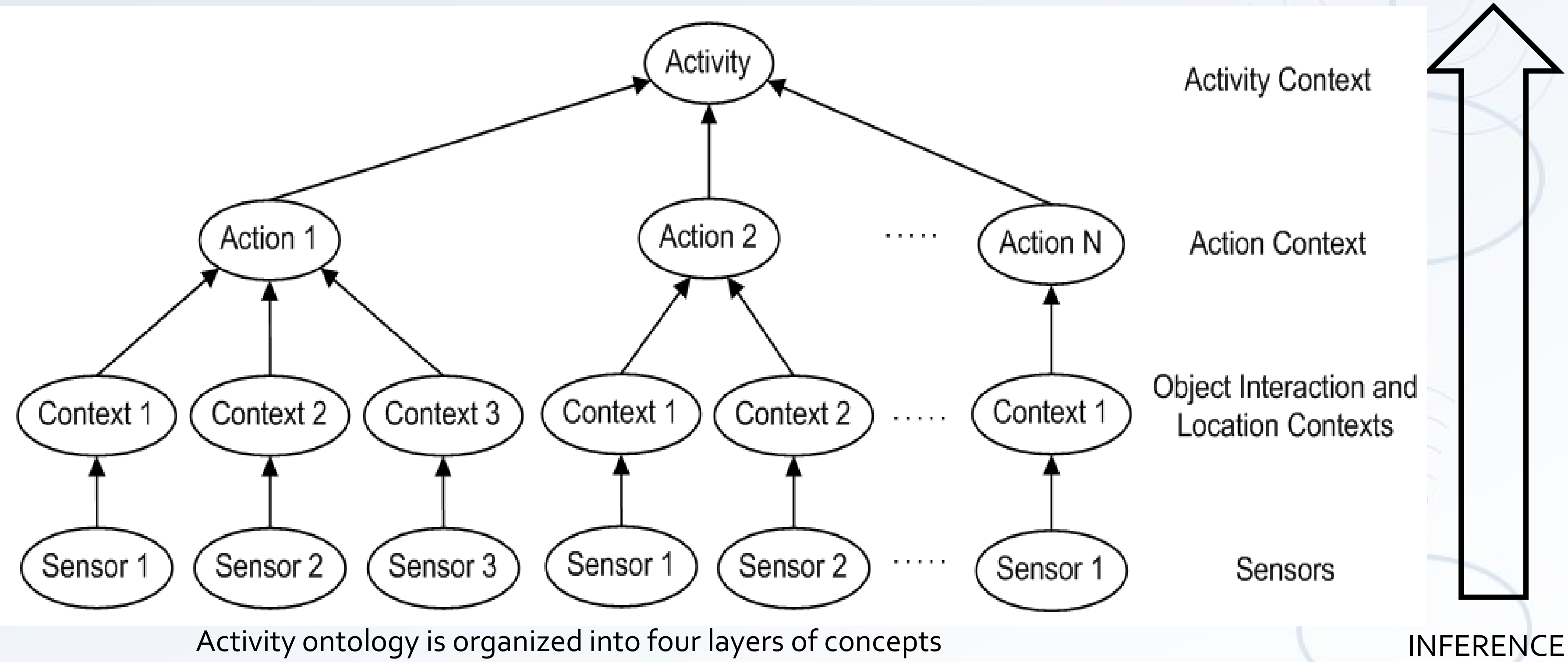


3 classifiers implemented as Decision Tree classifiers

Calculate the probability of the segmented signal belong to a particular activity (window expansion)

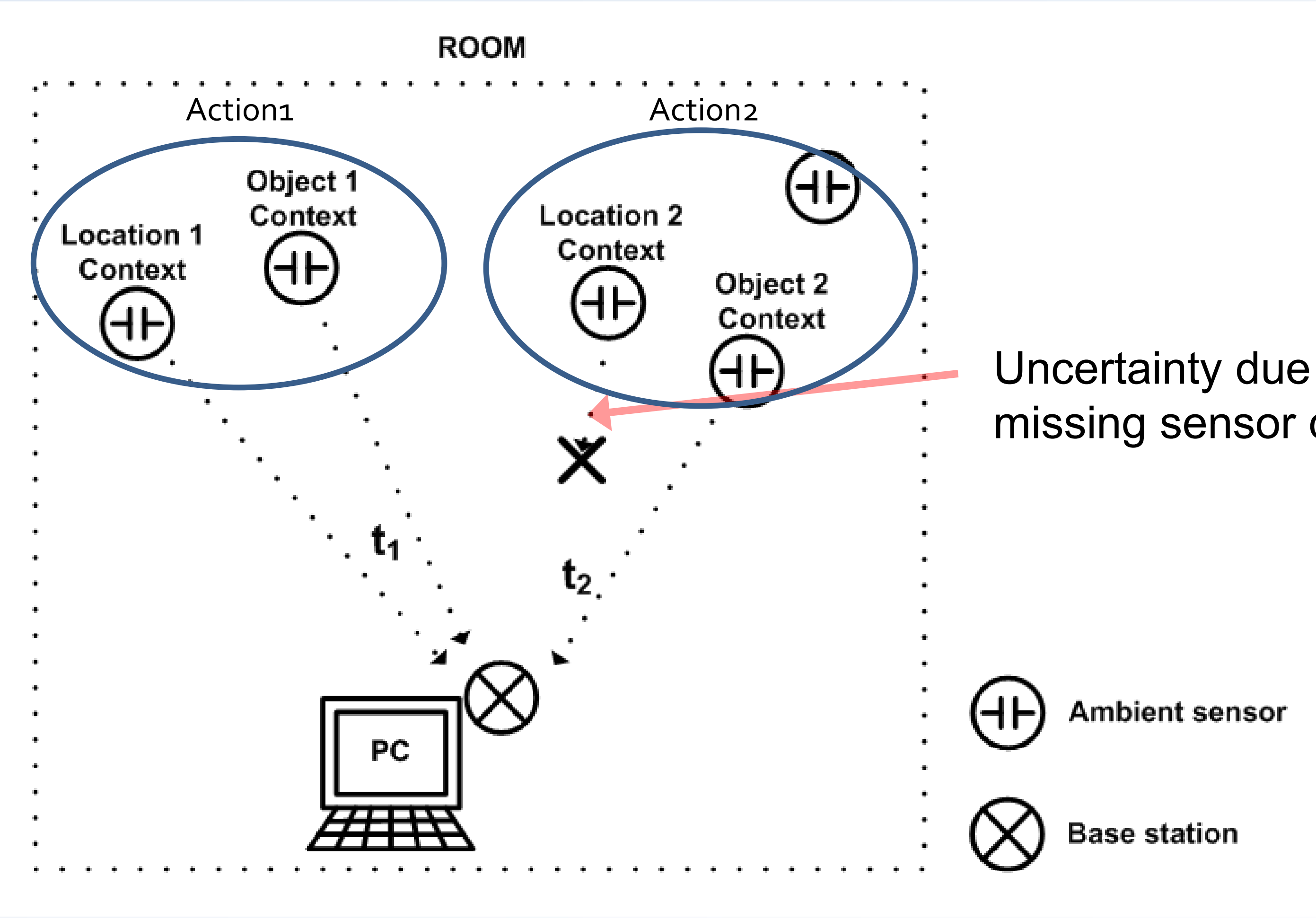
Knowledge-based ontology reasoning

- In ontology-based HAR, an activity is recognised if every action concept associated with the activity is inferred



Activity ontology is organized into four layers of concepts

Missing sensor data

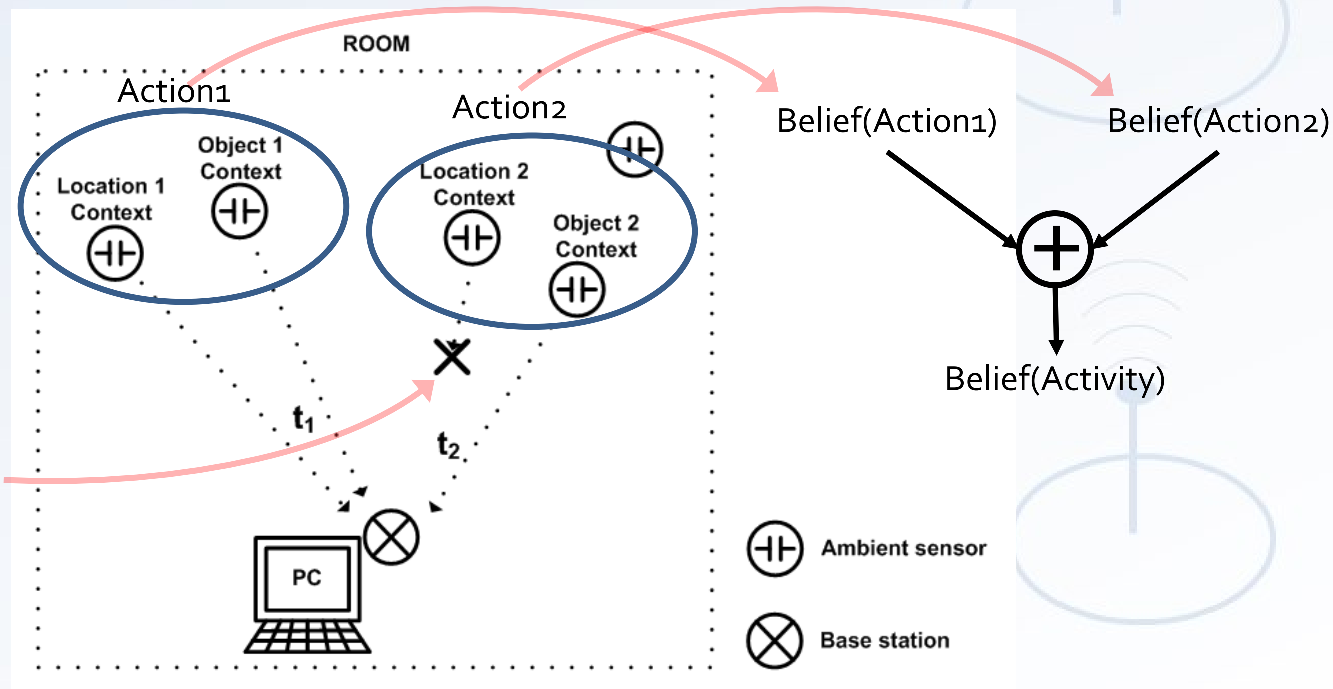


Uncertainty due to missing sensor data

Dempster-Shafer based ontology reasoning

- A reasoning algorithm is proposed that integrates ontological reasoning (represented in Description Logic) with Dempster-Shafer (DS) theory to handle missing sensor data by giving inferred activity a confidence level

DS theory assigns masses (weights) to any combination of propositions

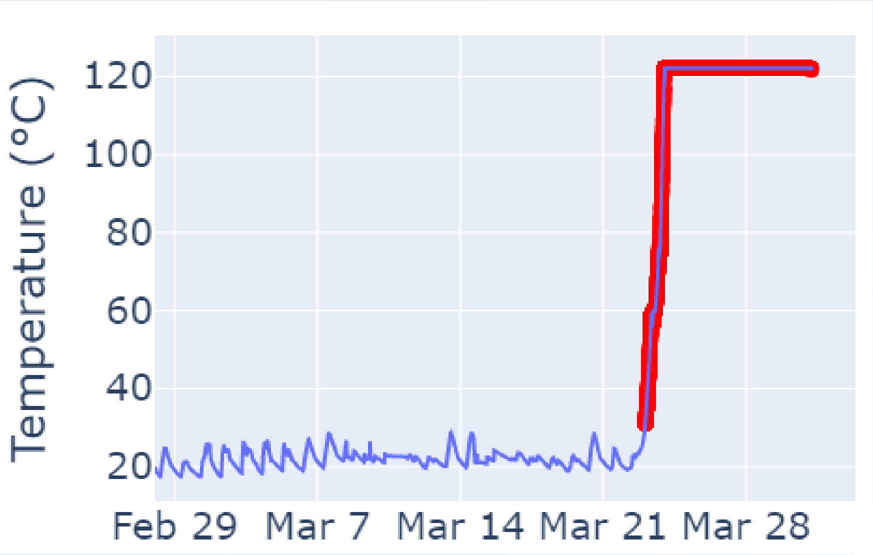


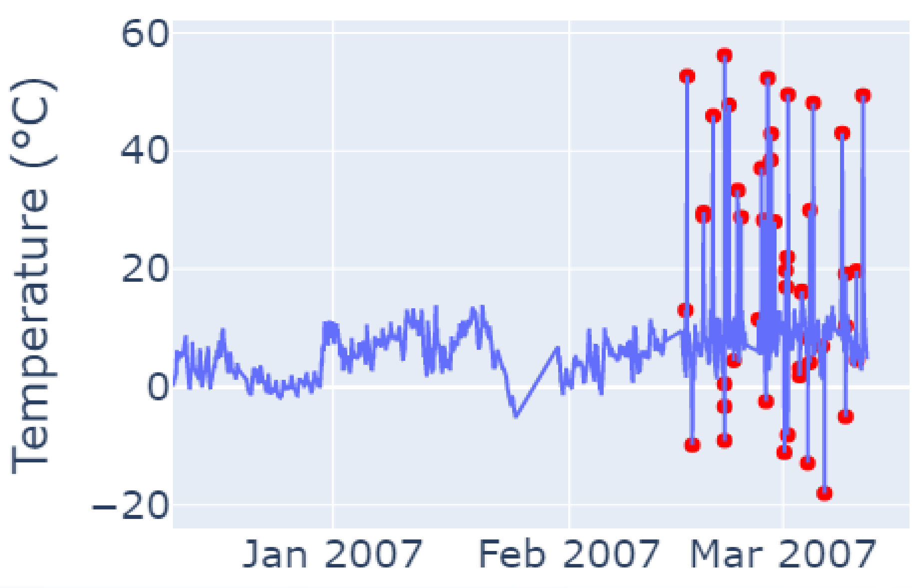
ambiguity or ignorance

Sensor data anomaly detection

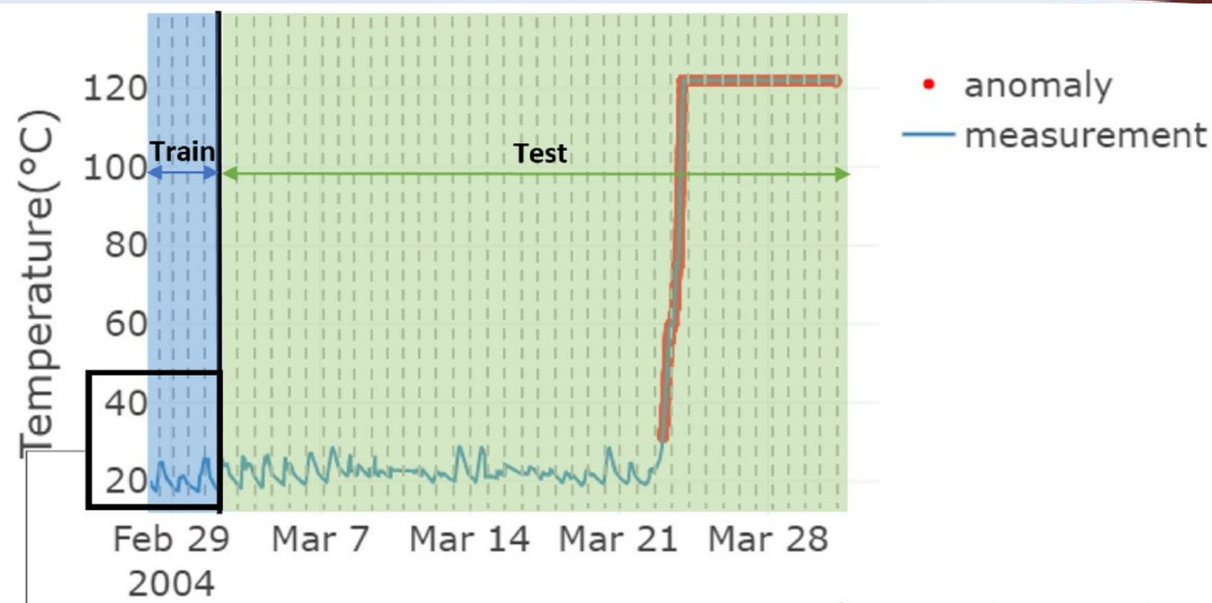
- Machine learning or data processing outcomes are heavily dependent on sensor data quality
- Sensor data suffers from many uncertainties
  - Sensor failure/drift
  - Power failure
- Challenges:
  - Calibration - Manual calibration is time and cost consuming
  - Resources - Limited resources such as data, bandwidth and computational power
  - Sensor-specific - Sensor-dependent heuristics and features related to domain

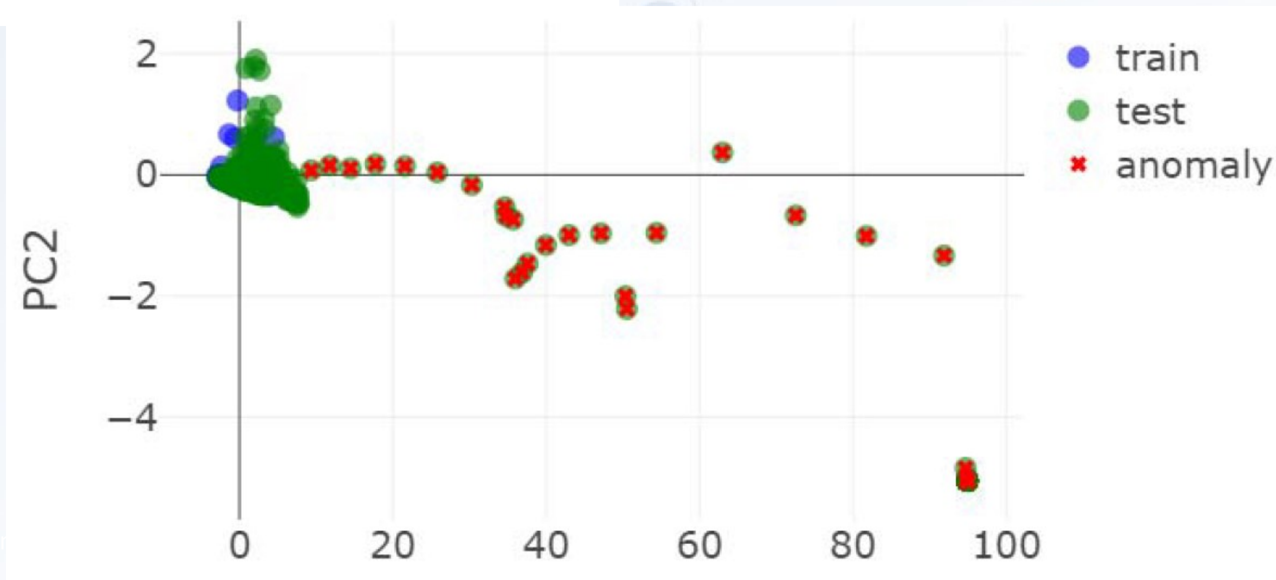
Sensor data anomaly detection





Unsupervised Feature Selection for Anomaly Detection





Thank you

Questions?