Continuous Sensing on Intermittent Power

EDL Edge Workshop, June 4th 2021

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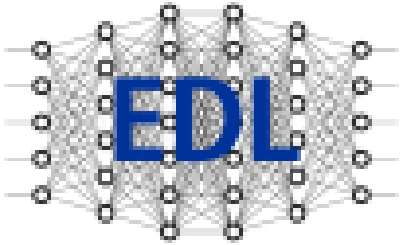
Edge computing

… is a distributed comput
brings computation and da
to the location where it is nee
improve response times and save bandwidth.

if this is the solution, then what is the **problem?**



Deep learning

… is a class of machine learning algorithms that uses multiple layers to progressively extract higher-level features from the raw input.

Machine learning

… involves computers dis
they can perform tasks wit
explicitly programmed to do so.

if you have no clue what to do, you can always use ML**!**

Machine learning

… involves computers discovering how they can perform tasks without being explicitly programmed to do so.

- requires data
- takes time/computing

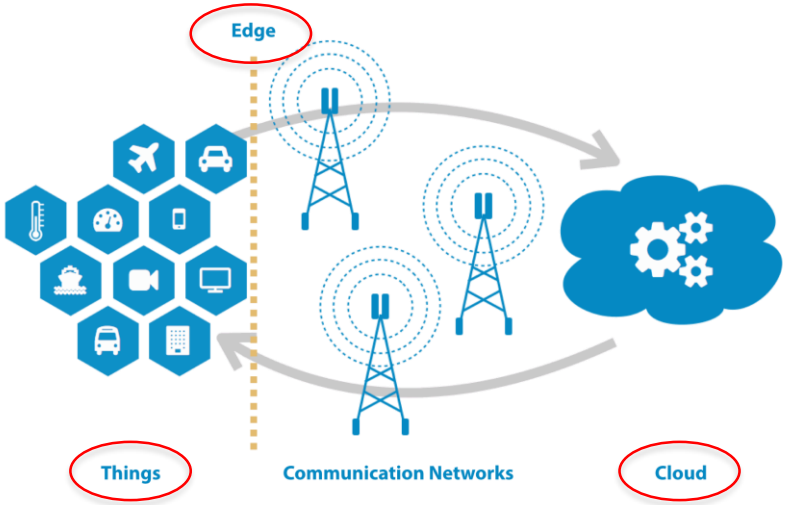
} model

ML + Edge computing

- ML: data → learn → model

how to map this?

- EC:



Poll

1. where to put the **data**?
   - things, edge, cloud
2. where to do the **learning**?
   - things, edge, cloud
3. where to run the **model**?
   - things, edge, cloud

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Mapping discussion

- Consensus amongst participants?
  - not really (as intended ☺)

- Majority voting
  - data @ things (3x), edge (6x), cloud (6x)
  - learning @ things (-), edge (5x), cloud (10x)
  - model @ things (2x), edge (12x), cloud (1x)

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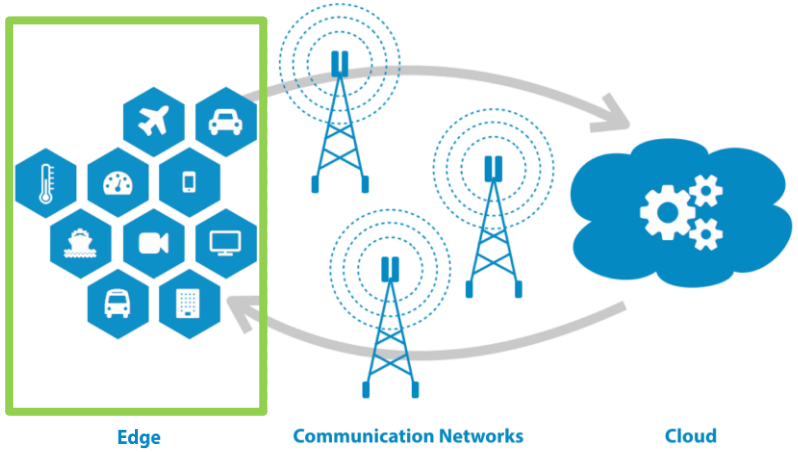
Koen's take = device centric

- ML: data → learn → model

… @ the Edge

- EC:



Przemek Pawelczak

Autarkic computing

- Autonomous operation
  - sense
  - compute
  - communicate
  - energy harvesting

if this is the solution, then what is the **problem?**

Batteries are evil

"An estimated 11 million tons of spent lithium-ion batteries will flood our markets by 2025" [The Guardian, 2017]

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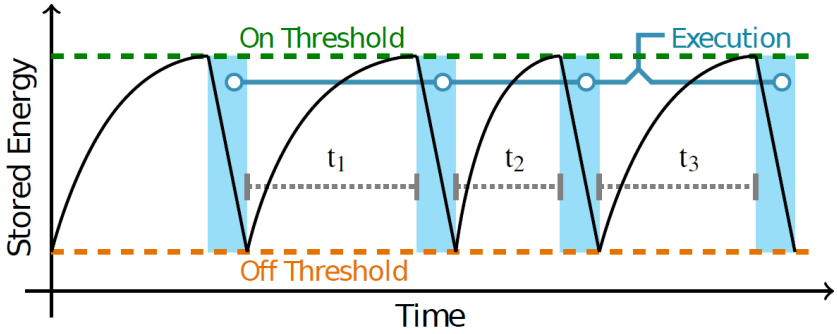
Energy Harvesting

- Harvested energy is stored in a ~~battery~~ capacitor

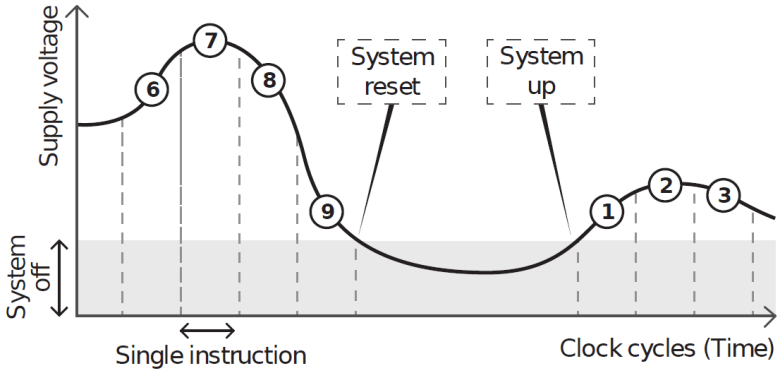
- Less capacity ☹

Intermittent computing

- Less capacity
  → multiple reboots **per second**



- Checkpointing to non-volatile RAM



Continuous Sensing on Intermittent Power

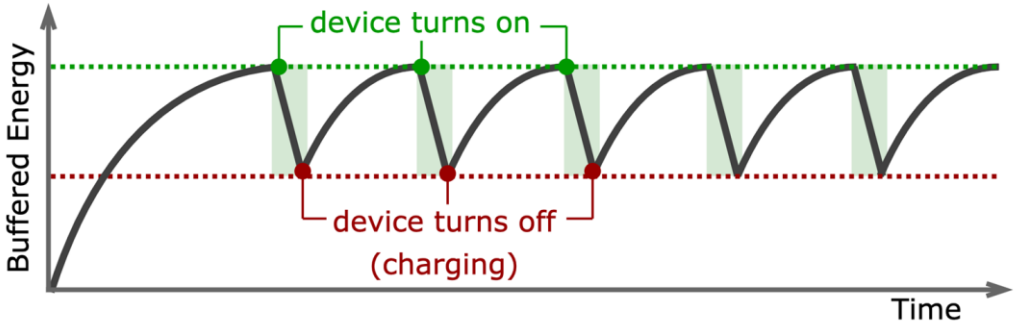
A.Y. Majid, P. Schaper, K. Langendoen

TU Delft

IPSN, April 23rd 2020

Energy Harvesting (EH) Battery-free sensors

- Perpetual energy (sun, RF, vibrations, ...)
- EH Batteryless sensors operate **intermittently**

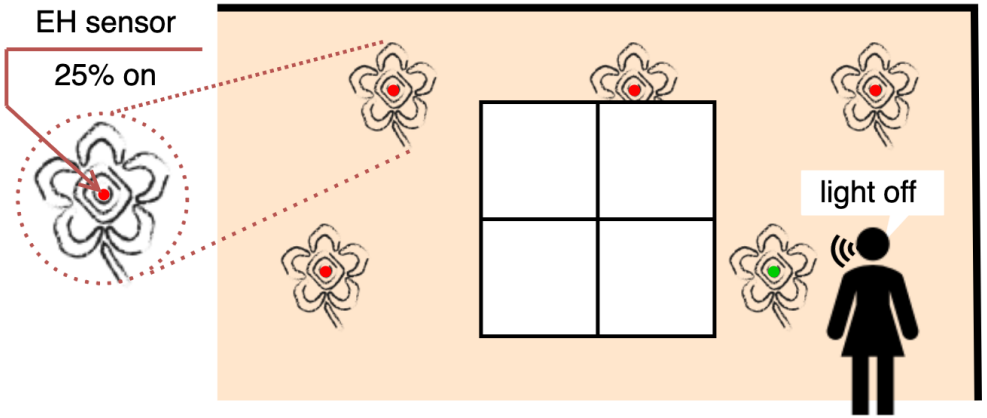


http://wispsensor.net/

Individual EH batteryless sensors have little value

- Prior work has tackled many challenges
  - Intermittent computing
  - Data freshness
  - Event-driven execution

- **Intermittency** is a fundamental shortcoming!



Research Challenges

- Approaching **continuous sensing** on intermittent power

  - exploit **redundancy**
  - yet be **efficient**

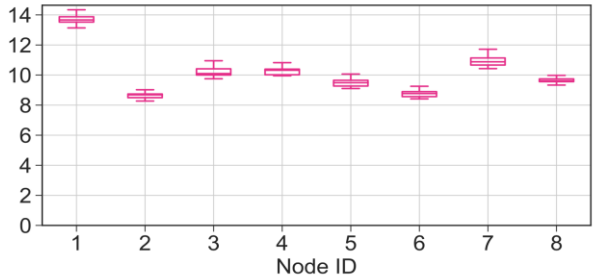
Coalesced Intermittent Sensor (CIS)

Continuous Availability Challenge

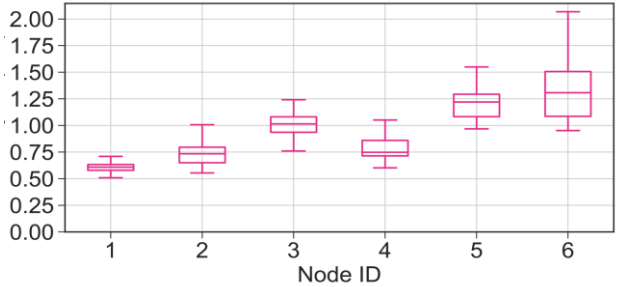
- No Sensing

Power Cycle (Seconds)

Light

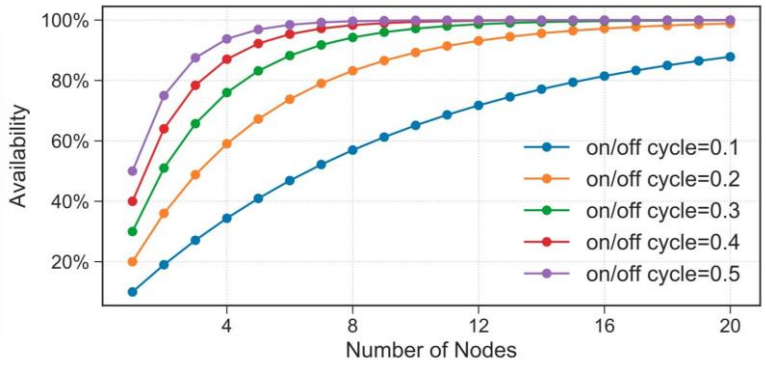


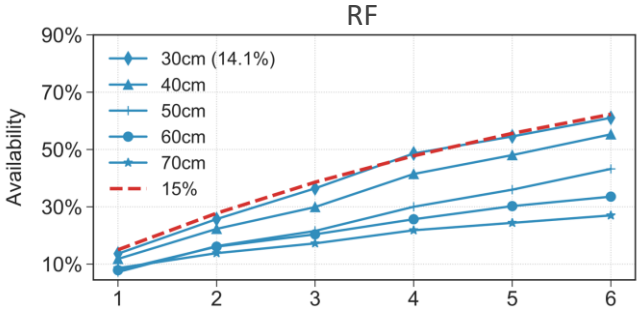
RF

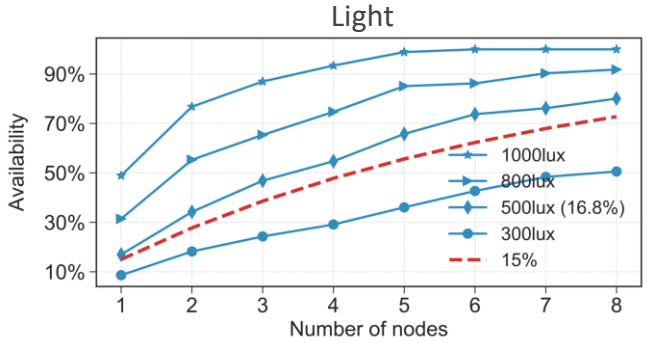


Continuous Availability – theory & practice

$$A_{\mathrm{v}}(N) = A_{\mathrm{v}}(N-1) + (1 - A_{\mathrm{v}}(N-1)) \times \frac{t_{\mathrm{on}}}{t_{\mathrm{p}}},$$



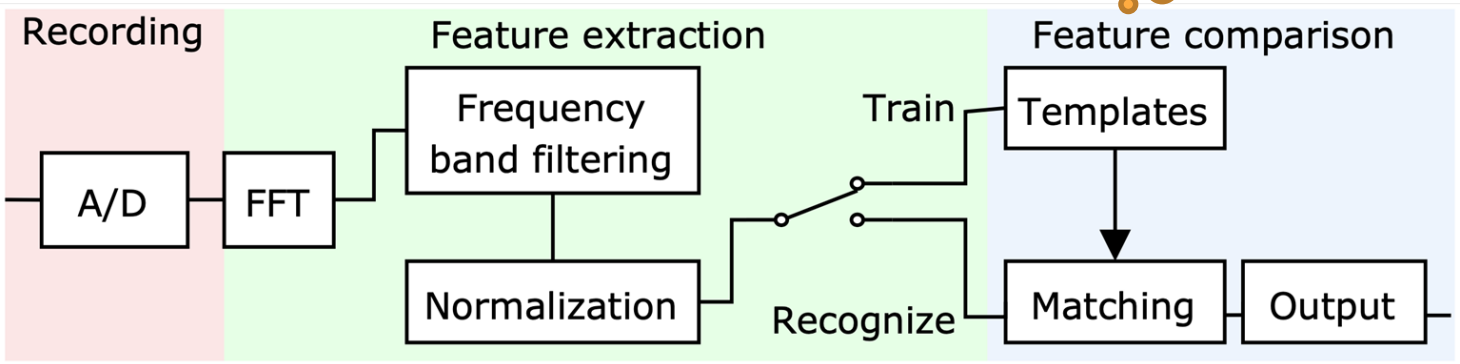




Continuous Sensing – command recognizer app

- 8 solar-powered word recognizer nodes (MCU + Microphone)

ML to the rescue!

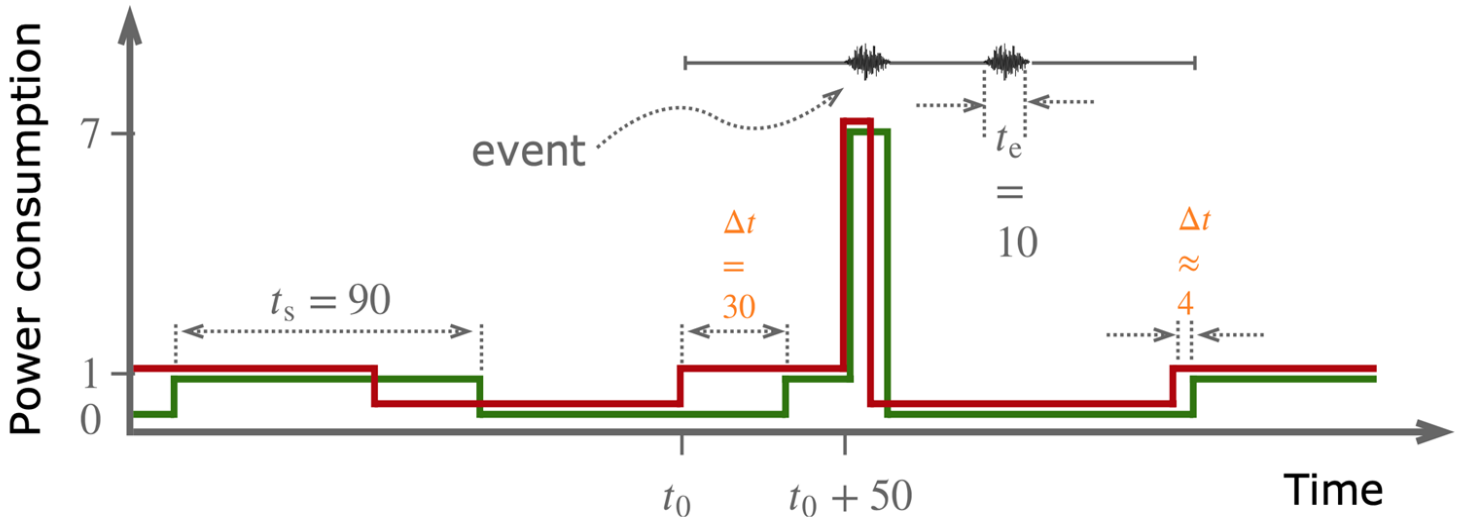


Continuous Sensing Challenges

BAD NEWS:
Sensing is evil

Unwanted Uptimes Synchronization

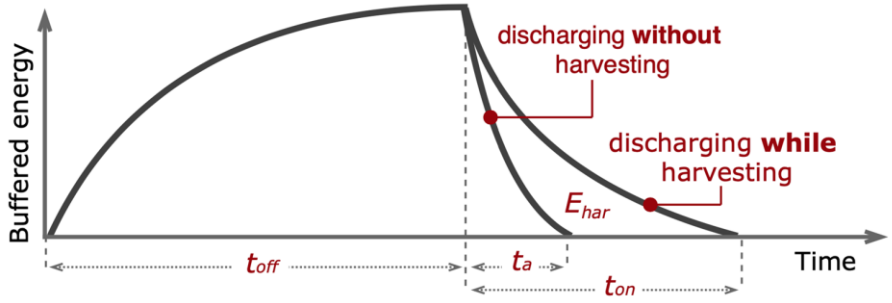
- Low-power mode and favorable energy conditions may lead to unwanted synch.



Solution Strategy

- Communication
- Probabilistic approach
  - A node needs to know
    - Number nodes in CIS
    - Duty cycle

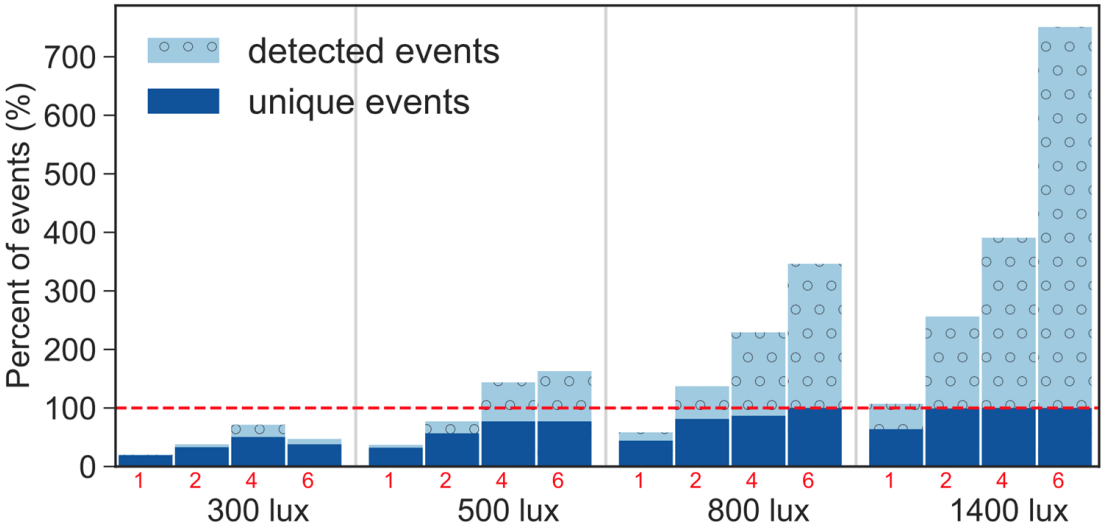
$$\textbf{if } \text{random}() < \frac{1}{\text{Av(N)}} \textbf{ then}$$
$$\text{respond to event}$$



Results: Event Detections

- 8 nodes solar-powered CIS
- Duplicate detections increase with increment in
  - ambient energy levels and
  - inter-arrival time

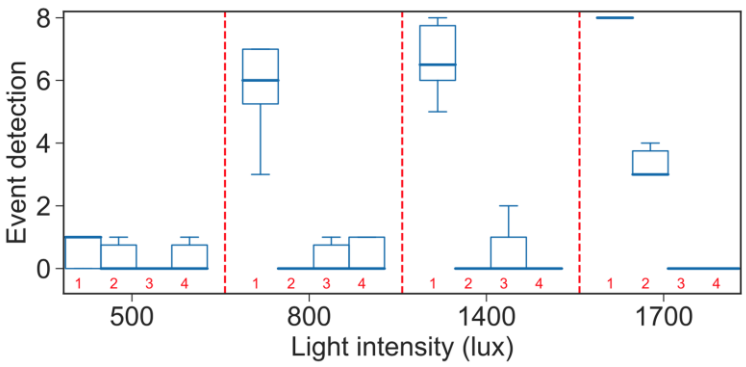
- Enabling probabilistic response reduces
  - 50% of duplicates
  - 7% of unique events



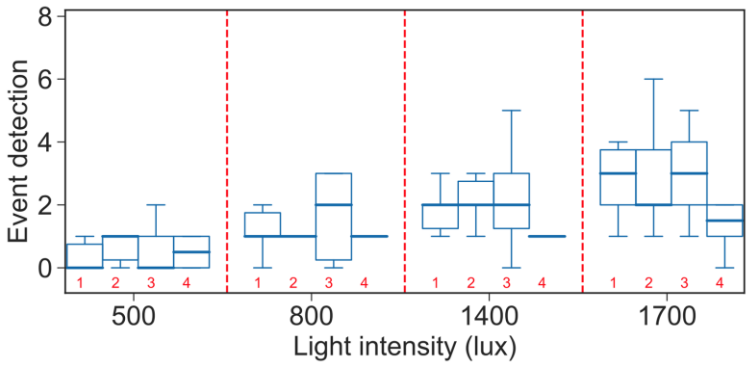
Results: Burst of Events

- Randomized response significantly improves burst detection

Blind Response

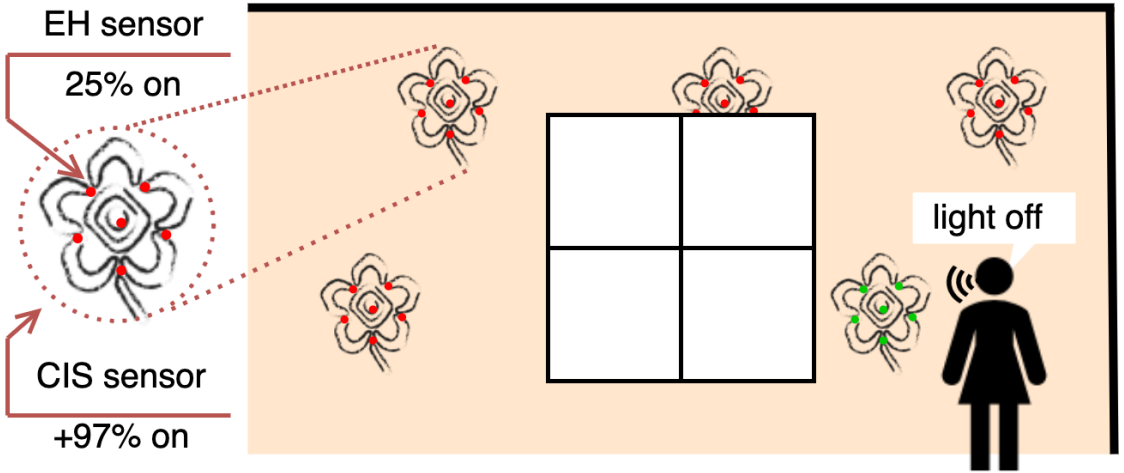


Probabilistic Response



Conclusions

- Problem: how to make intermittent execution interactive?
- Solution: redundancy + probabilistic response



- Bottom line: CIS can enable real-world applications

IoT + ML

Research challenges

- run models with limited resources
- adapt models to local circumstances
- learning @ device
- collective intelligence
  - copy & paste
  - federated learning

Life is boring

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