UC San Diego
JACOBS SCHOOL OF ENGINEERING
Electrical and Computer Engineering

RFID
IEEE Council on RFID
Bridging the physical to the digital

WCSNG
Wireless Communications Sensing and Networking

SenSync: Real-Time and Accurate Passive Sensing





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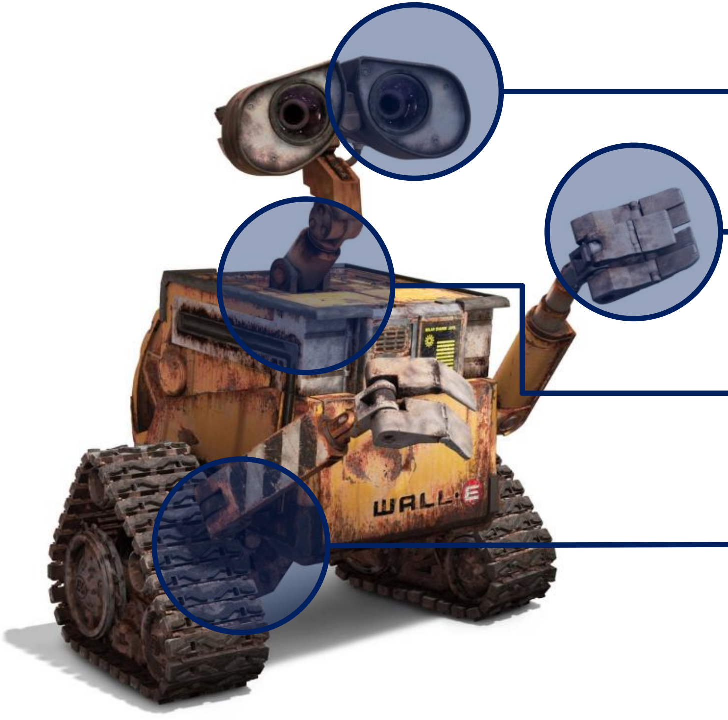
Sensing the World, One Byte at a Time



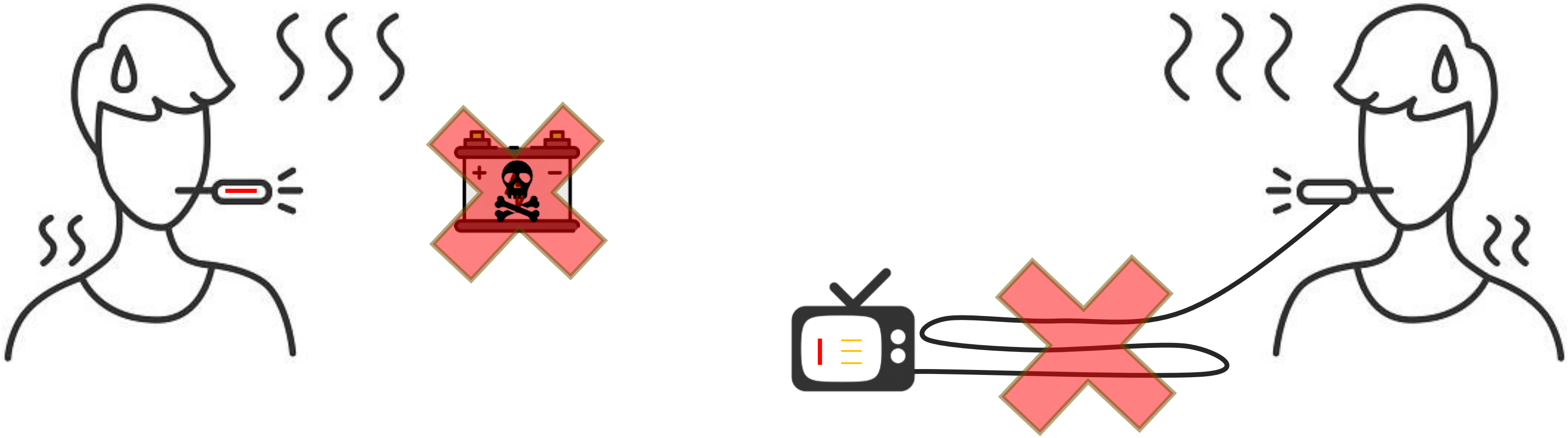
Luminosity Sensor

Slip Detector

Thermal Sensor

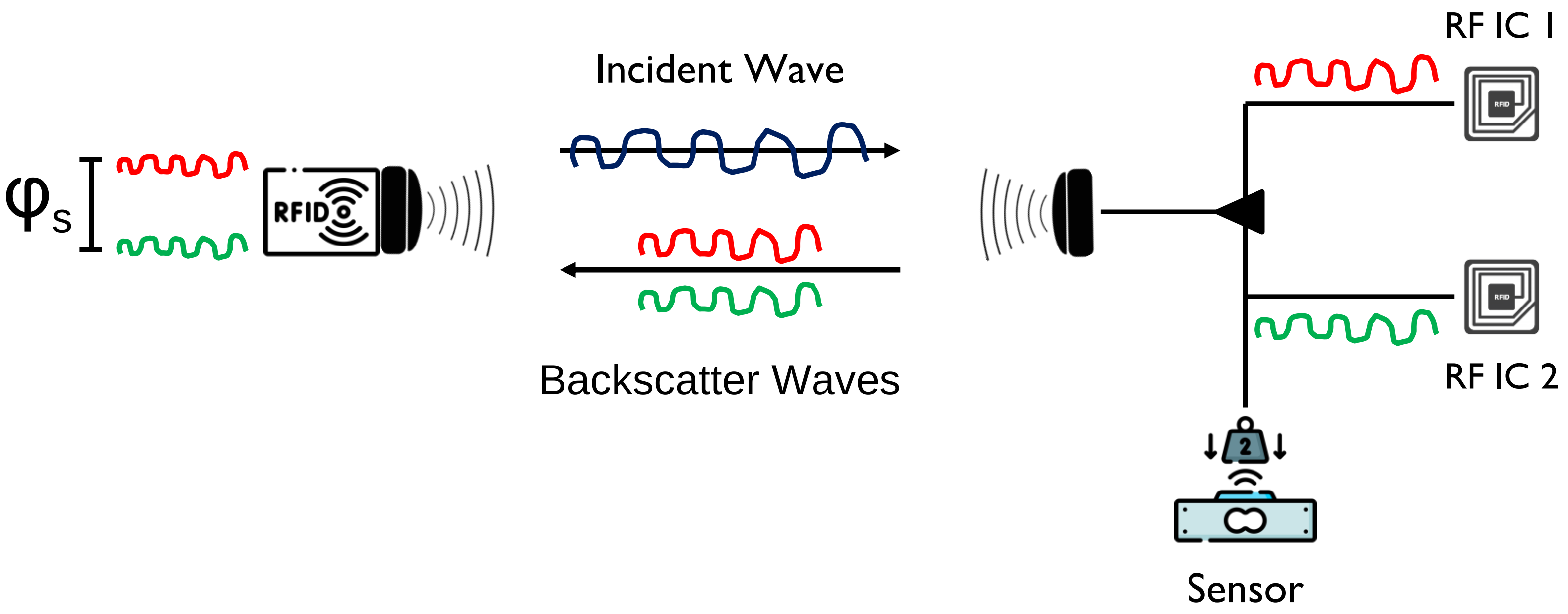
Force/Torque Sensor

Not so Ubiquitous – The Ball and Chain Problem



Wires and Batteries are the shackles for Ubiquitous Sensing

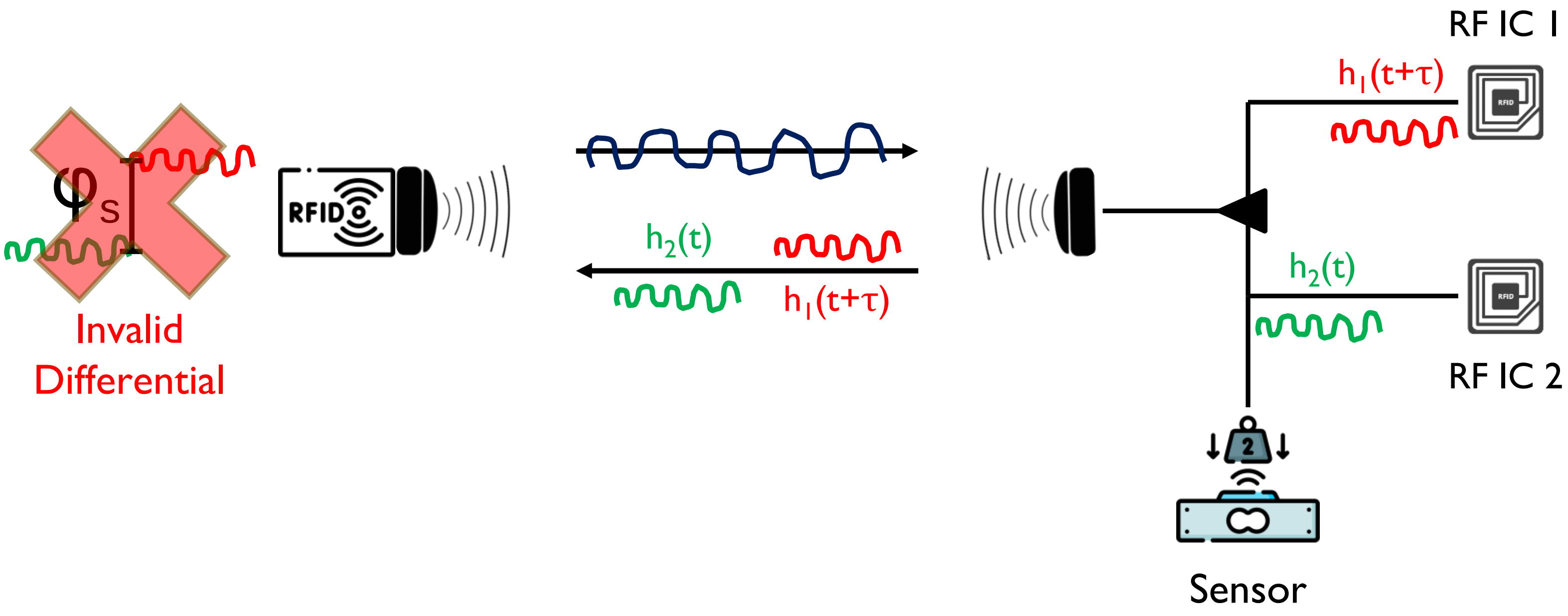
Unplugging the Future: RFID Sensor Networks



Beyond the Noise: Unlocking Accuracy with Differential Sensing[1,2]

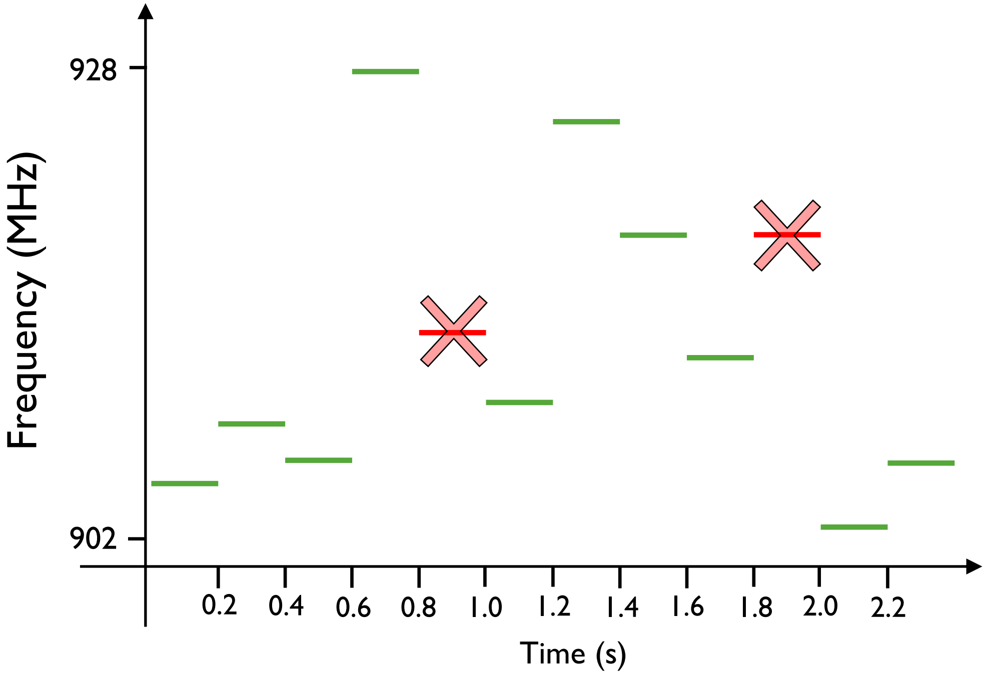
[1]: https://dl.acm.org/doi/10.1145/3666025.3699342, [2]: https://dl.acm.org/doi/abs/10.1145/3631442

Is Differential the Answer… Or Just Another Layer?



Sequential Reads: The Devil in the Data's Details

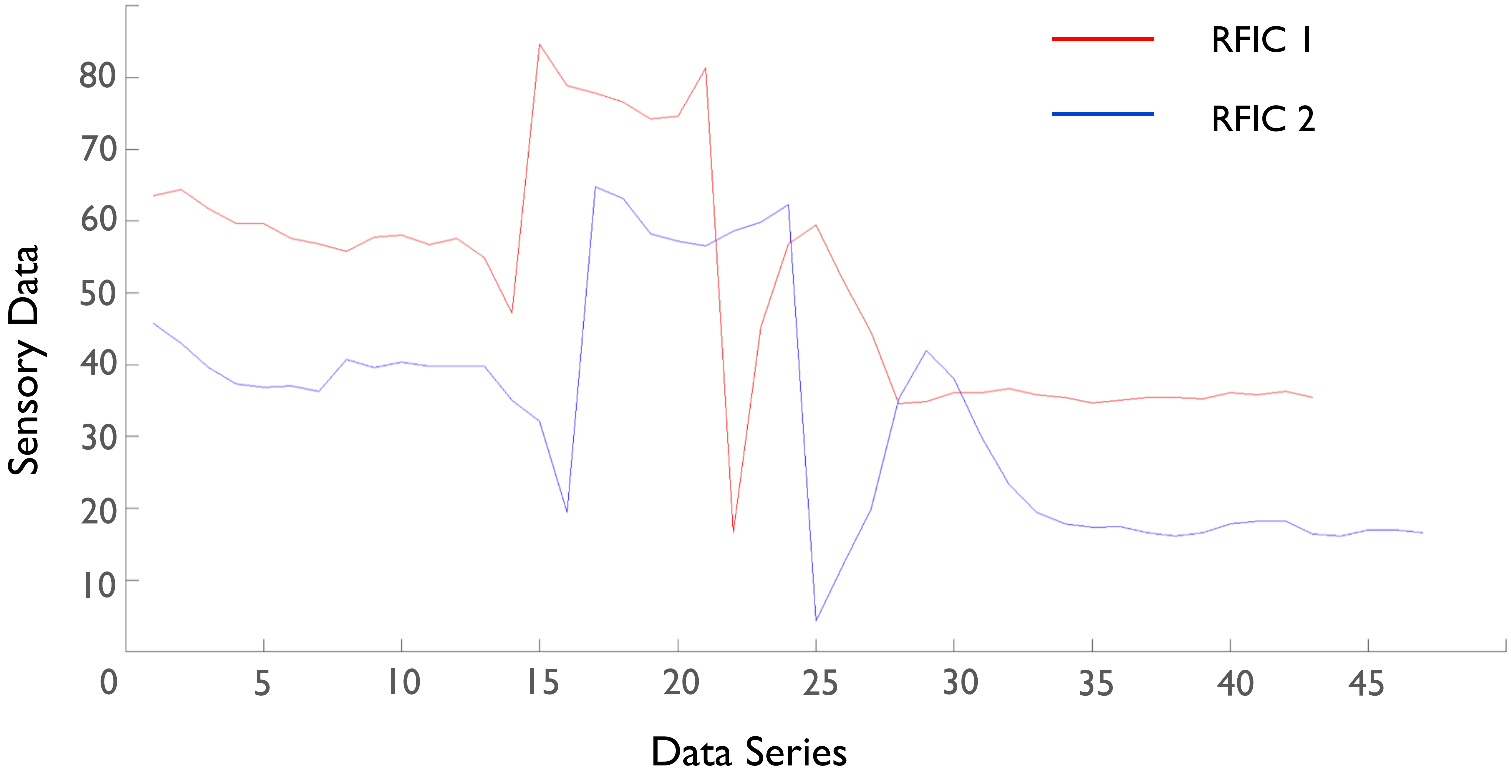
Two Signals Hopped to a Bar…



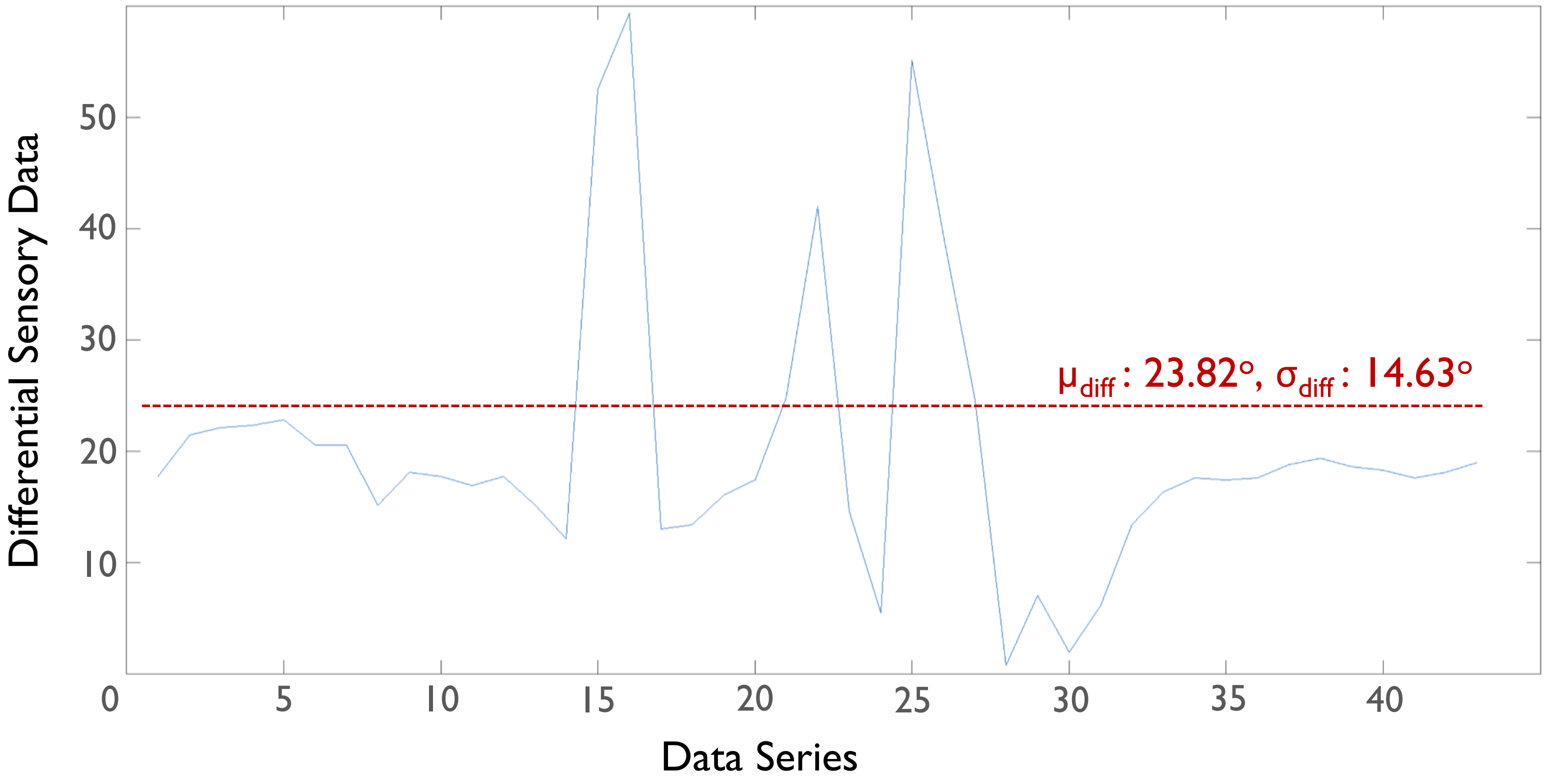
- FCC requires the reader to hop frequencies to prevent congestion which happens every **200ms**
- Readers have an internal caveat which forces arbitrary phase jumps of π **15%** of the times
- This makes phase a **volatile** and **unreliable** metric for direct sensory measurement

Phase Detection fails when the Carrier Jumps

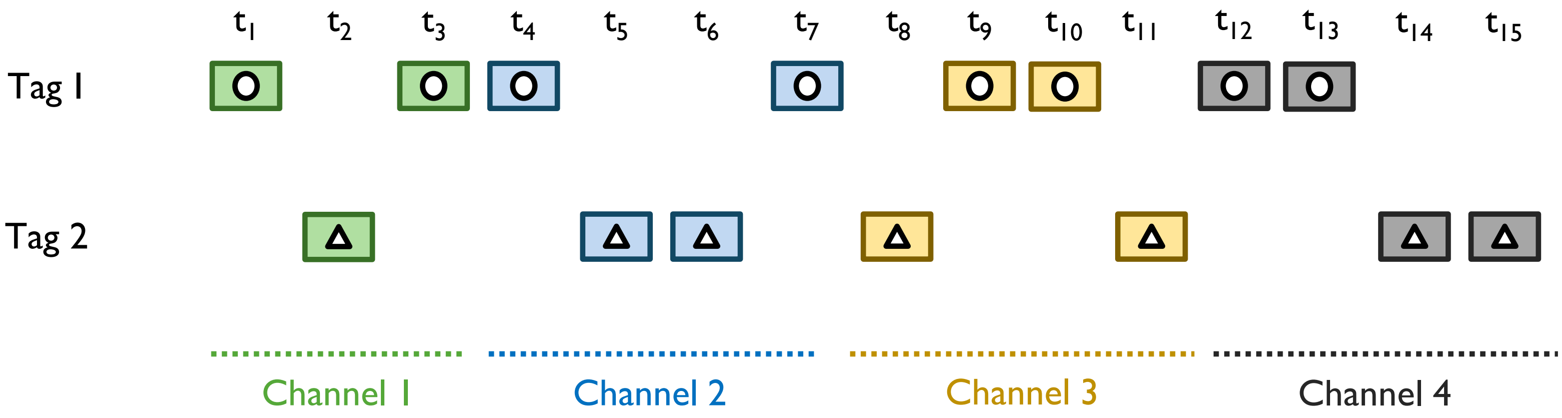
How do Things Stack up in Reality…



Like a Real Mess…



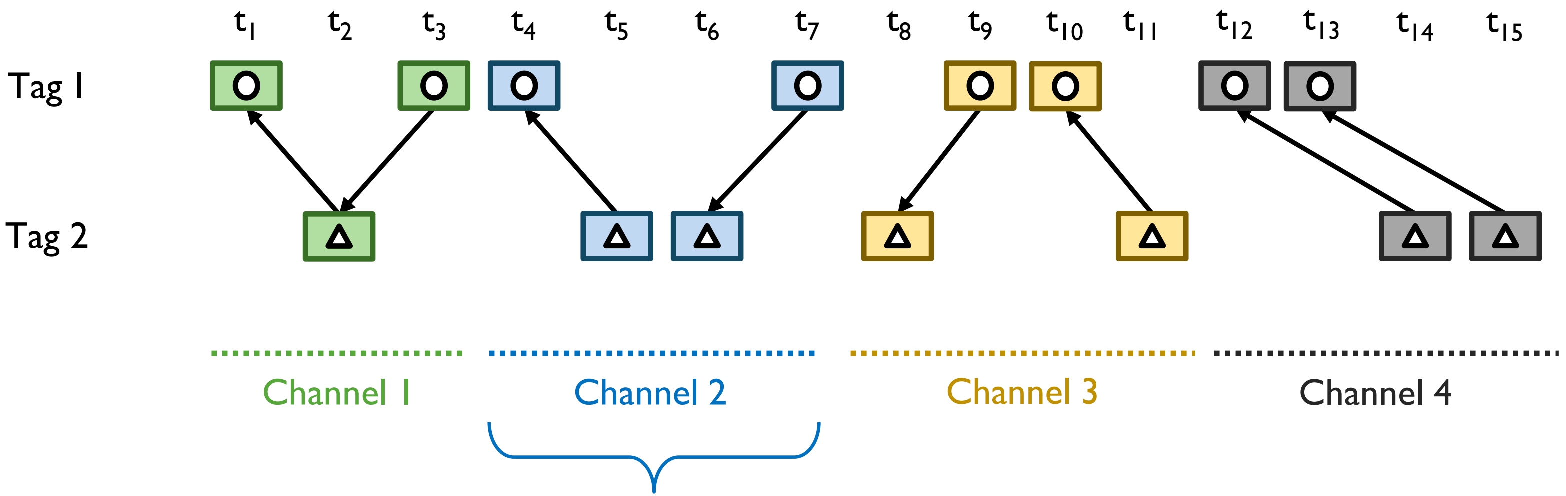
Solving the Data Puzzle



$$\Phi_1 = \{\, \Phi_1^c(t_n) \mid c \in \{1, 2, \ldots, C\}, n \in \{1, 2, \ldots, N\} \,\}$$

$$\Phi_2 = \{\, \Phi_2^c(t_m + \tau_{c,m}) \mid c \in \{1, 2, \ldots, C\}, m \in \{1, 2, \ldots, M\} \,\}$$

Secret Sauce: Dynamic Time Warping

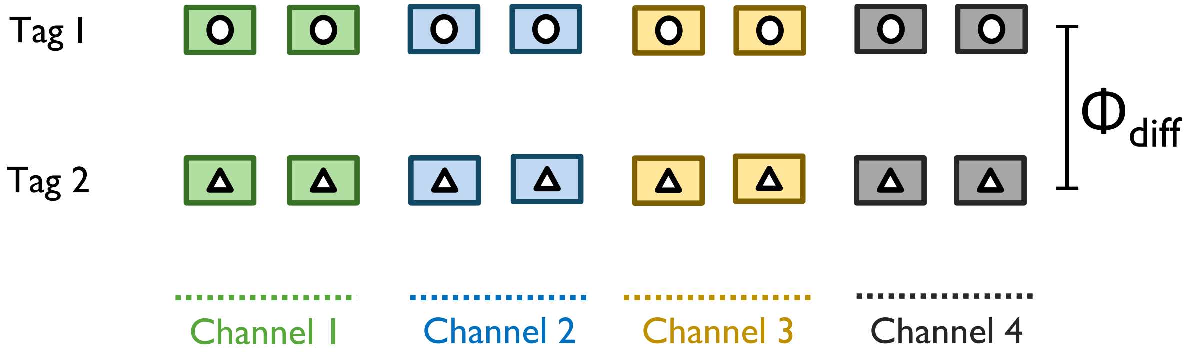


$$\Phi_1 = \{\ \Phi_1(t_i)\ \}\ \forall\ t_i \in W$$

$$\Phi_2 = \{\ \Phi_2(t_i)\ \}\ \forall\ t_i \in W$$

... W = Warping Path from DTW

Unlocking Similarity: Art of Alignment



$$\Phi_{diff}^{c}(t_i) = |\, \Phi_1^{c}(t_i) - \Phi_2^{c}(t_i) \,|\ \forall\, t_i \in W,\ c \in \{1, 2, 3, 4\}$$

$$\Phi_{diff} = (\overline{\Phi}_{diff}^{1}(t_i) + \overline{\Phi}_{diff}^{2}(t_i) + \overline{\Phi}_{diff}^{3}(t_i) + \overline{\Phi}_{diff}^{4}(t_i)) \,/ \sum_{1}^{N} i$$

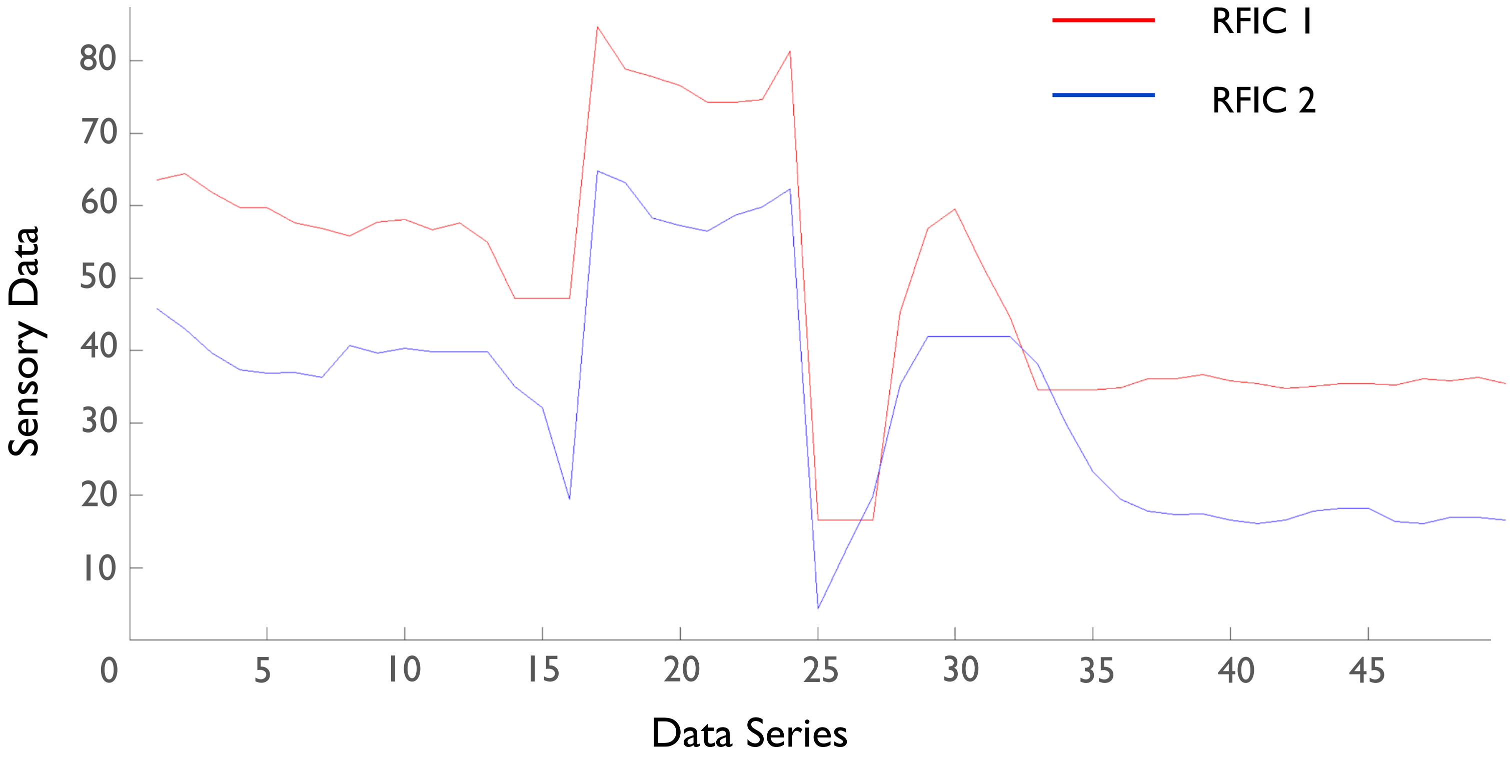
Empirical data shows that 15% of the frequency hops are corrupted

We chose 4 channels for DTW frame since there is a 90% chance that at least 3 channels are accurate

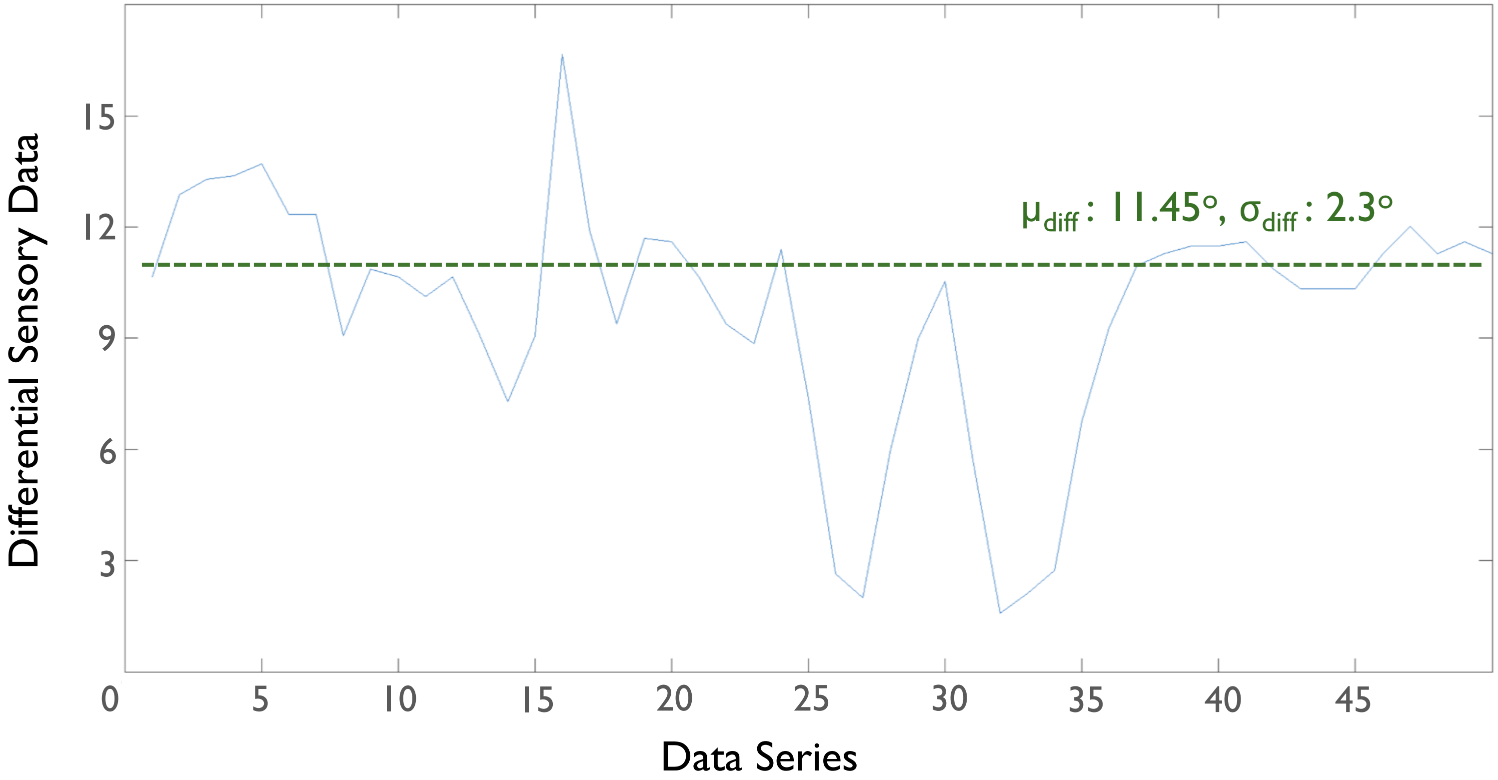
Each channel is 200ms, which gives us a resolution latency of 0.8s

Resolves chaotic RFID signals into clear outcomes **5x** faster than State of Art

Reality Realigned: Temporal Distortions Addressed

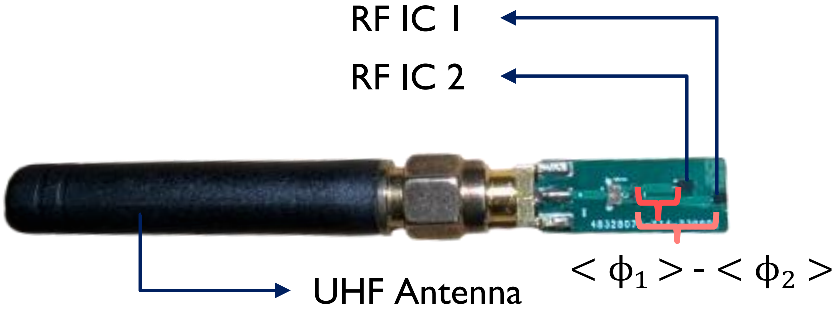


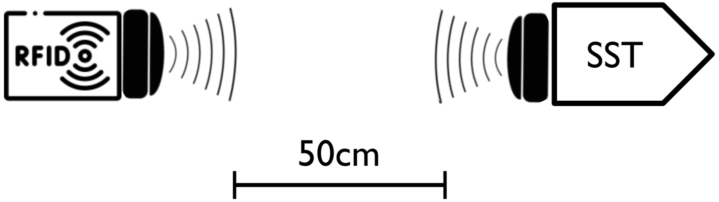
Cleaning up the Mess…



The Proof of the Pudding…

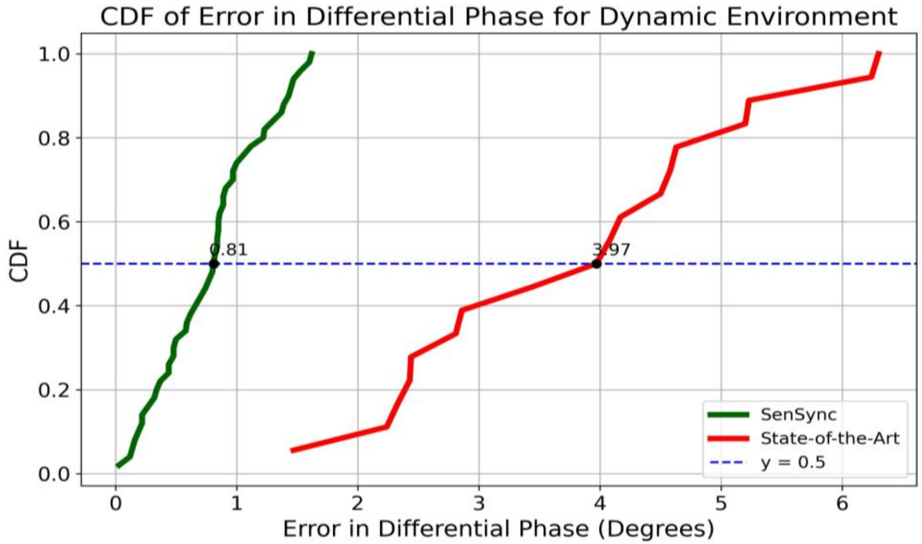
Simulatory Stubbed Tag

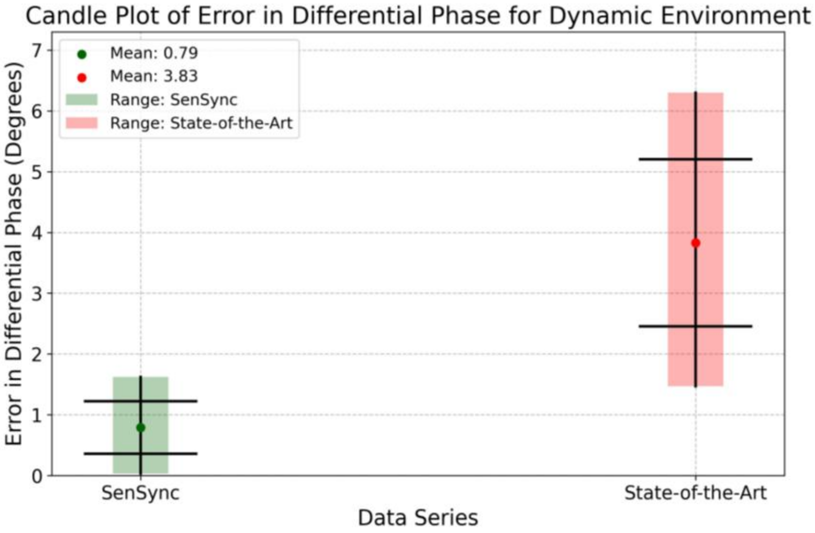




$\Delta\varphi = \Delta Electrical\ Length = 5.95°$ → Round−Trip $\Delta\varphi = 11.9°$

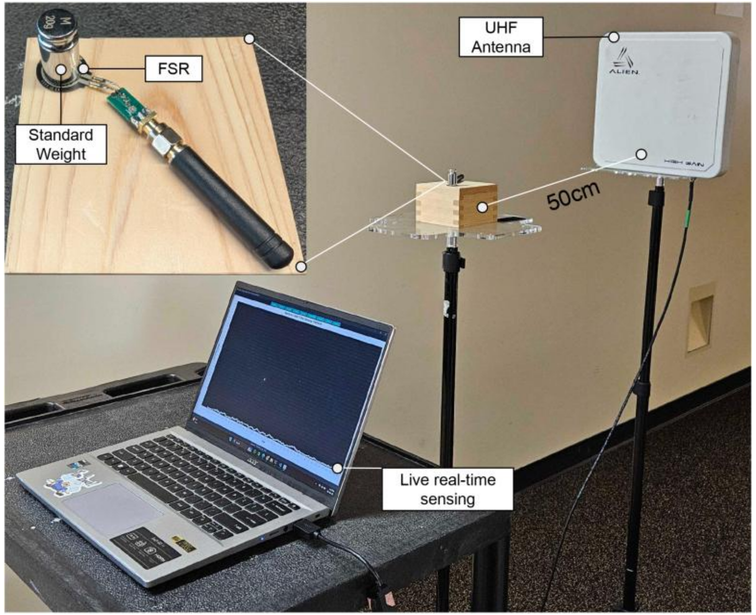
… is in the Eating

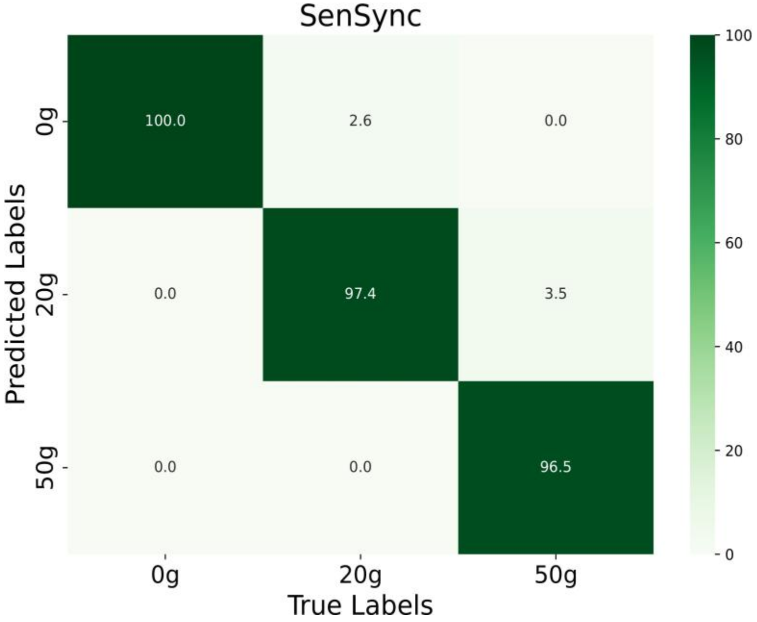




When Less is More: SenSync is **4x** better than State-of-the-Art sensing systems

Closing the Loop: Real World evaluation





From Lab to Life: **97%** classification accuracy when measuring weights

In Sync with the Senses

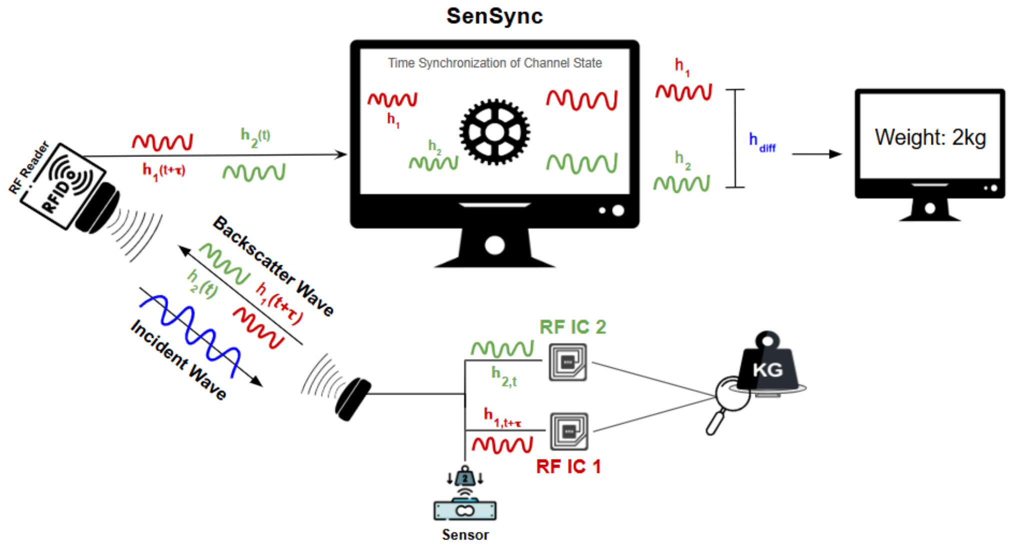
ZenseTag
(COTS Sensing Interface)
ACM SenSys 2024

Trifecta of RFID Sensing

Forcesticker
(Miniaturized Force Sensor)
ACM IMWUT 2023

SenSync
(Real-Time Algorithm)
IEEE RFID 2025

In a Nutshell



SenSync achieves -

- **5x** better sensing latency
- **4x** better at resolving stimuli
- **97%** weight detection accuracy

Questions ?

Check our work out at: