DancingAnt: Body-empowered Wireless Sensing Utilizing Pervasive Radiations from Powerline

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Wireless technologies: from communication to sensing

- **Various applications**

Health care

HCI

Disaster rescue

Wireless sensing

- **Diverse sensing signals**

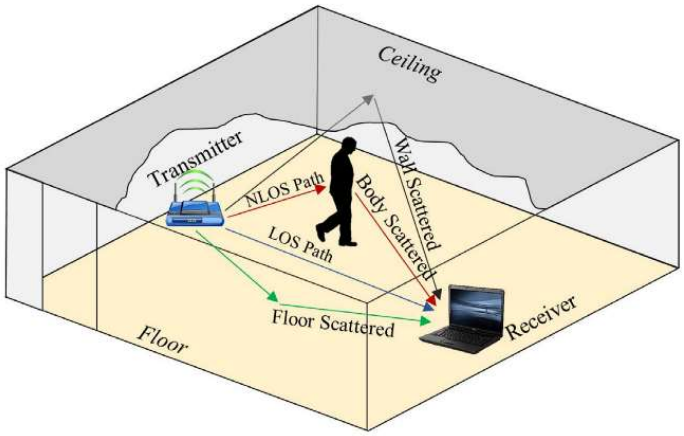
RF

Sound

Light

Practical limitations of wireless sensing

Laboratory

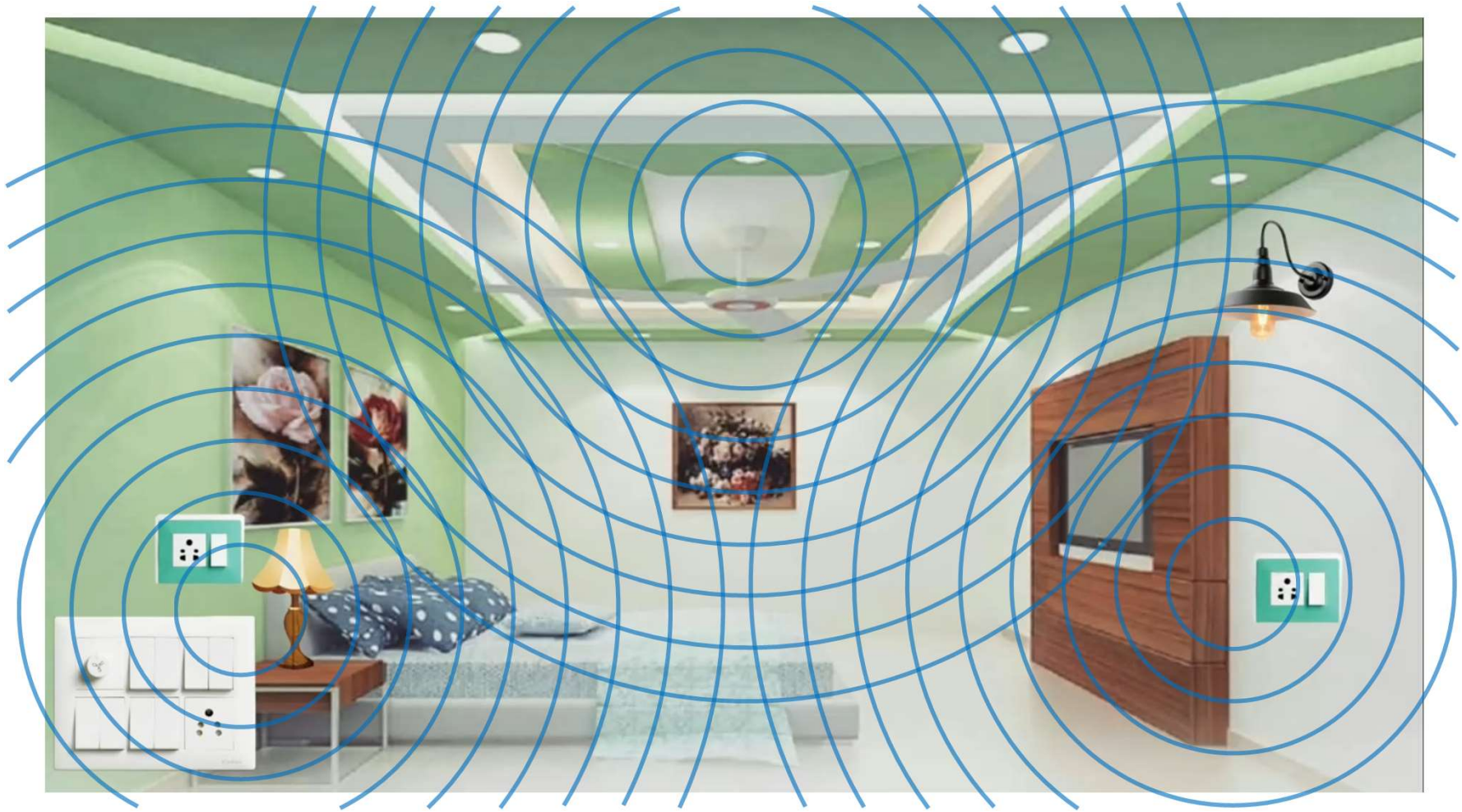


Real world

- Dedicated devices/signals
- Limited Sensing coverage
- Affecting original function

Is there a new sensing modality that can utilize truly **ambient** signals for sensing **without** **interfering** existing communication?

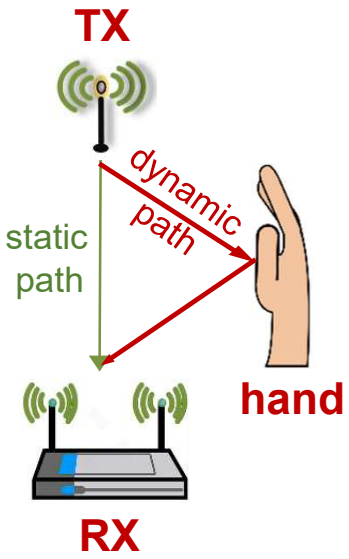
Ambient EM signals leaked from powerlines

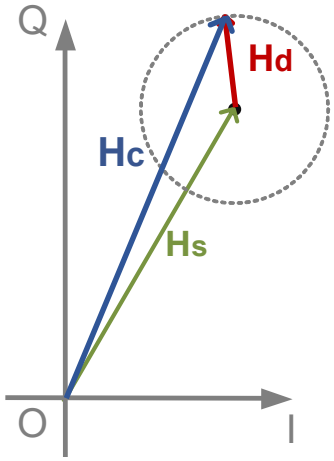


Challenges & Solutions

Challenge I: Motion influence on the leaked signal is negligible

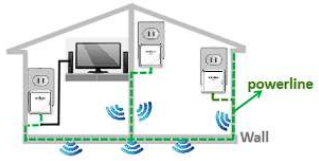
Sensing based on Wi-Fi signals (5 GHz)

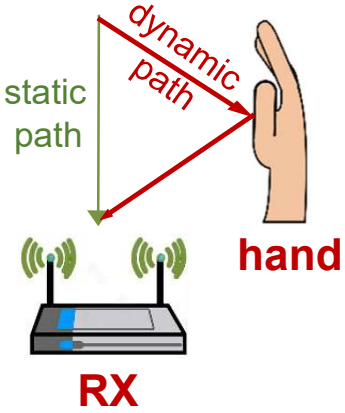


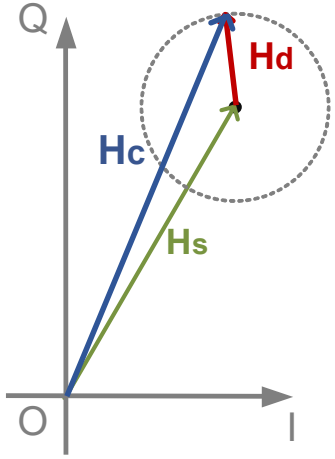


0.5 cm displacement causes 60 degrees phase change

Sensing based on leaked signals (60 Hz)



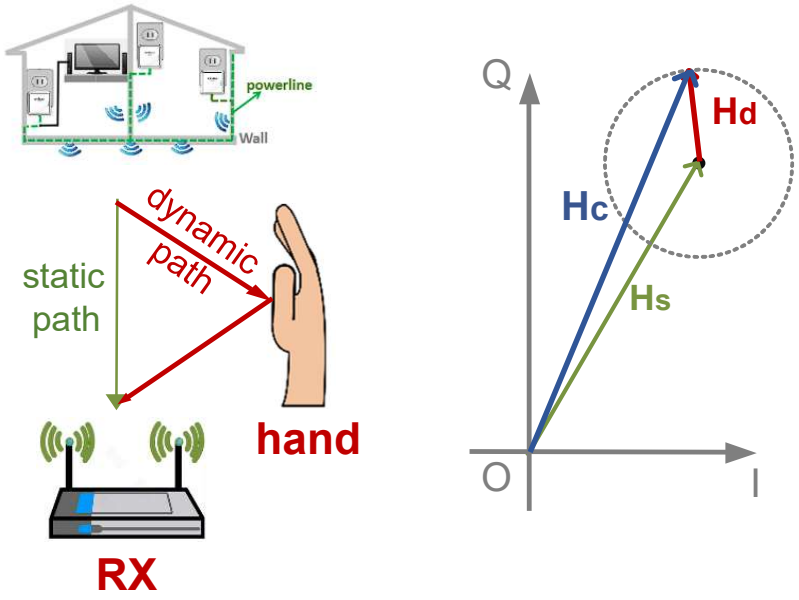




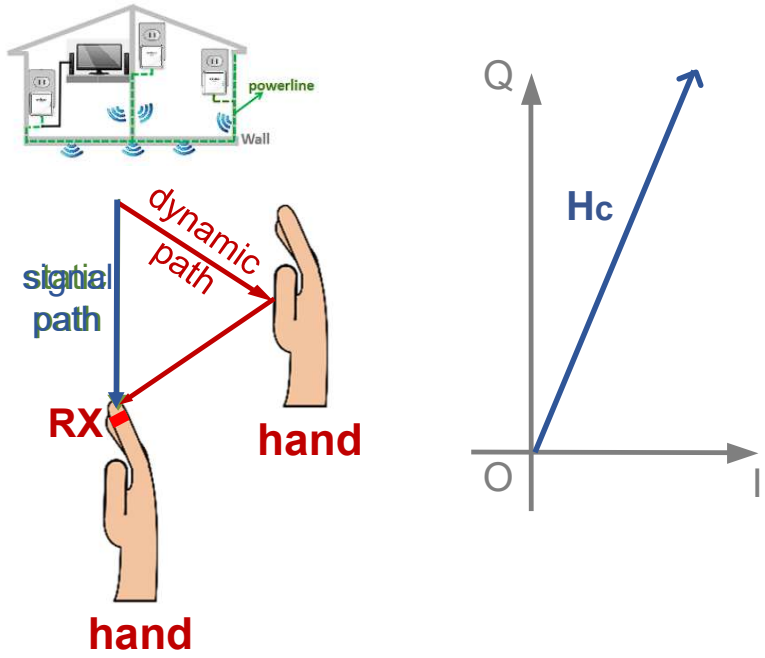
0.5 cm displacement causes 3.6×10^{-6} degrees phase change

Our solution: Involving human body into the sensing system

Traditional sensing system

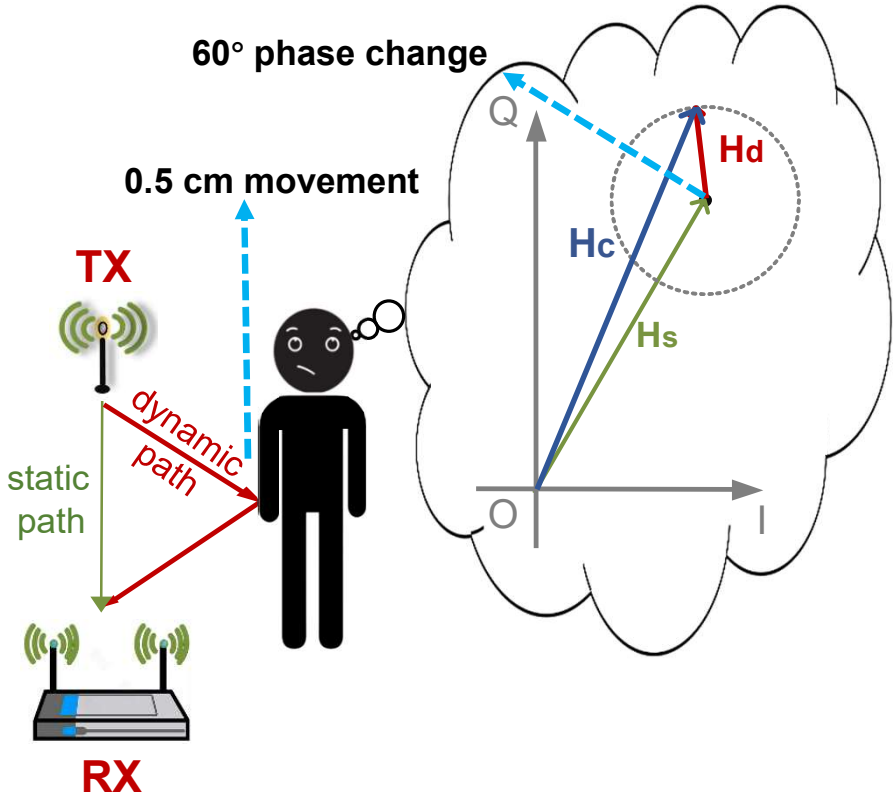


DancingAnt sensing system

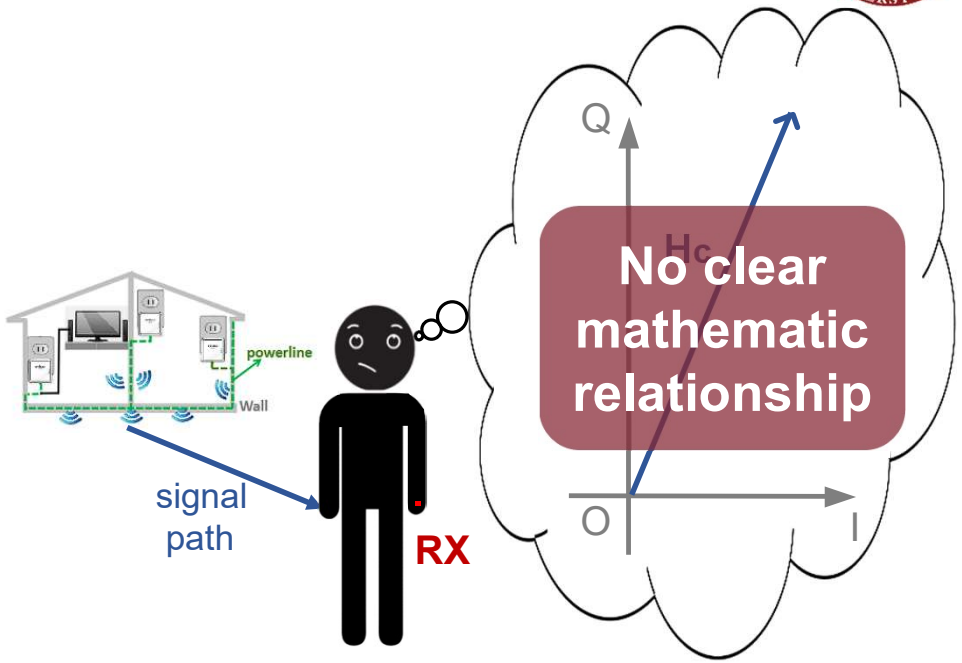


The traditional sensing system with the leaked signals does not work

Challenge II: How to infer motion from body-received signals

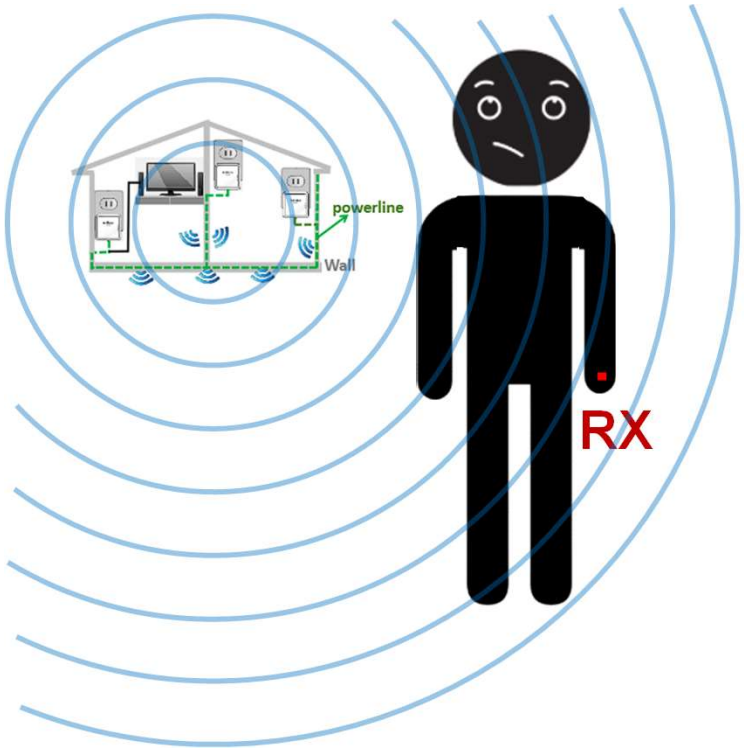


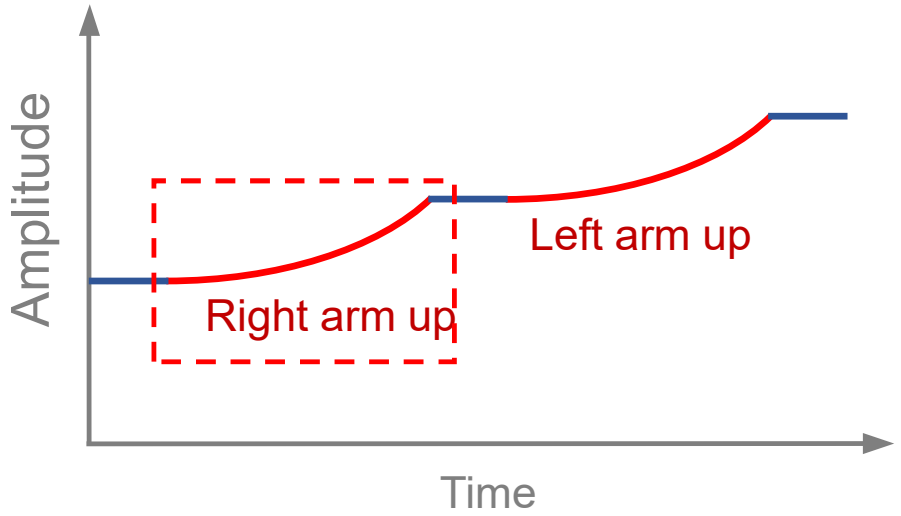
Body as reflection object



Body as part of RX

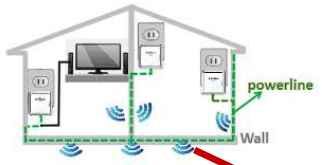
Our solution: Body-empowered sensing model





Larger physical size posture larger received signals

Challenge III: Signal information for motion recognition is limited



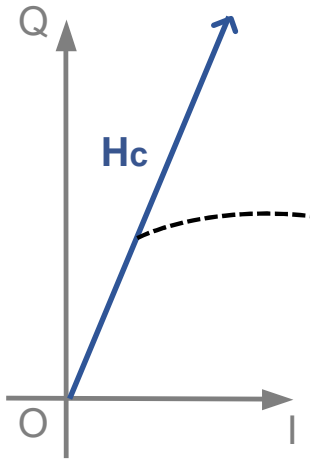
signal path

$3\ X\ 10^8 / 60 = 5\ X\ 10^6$ meters wavelength

tens of centimeters movement

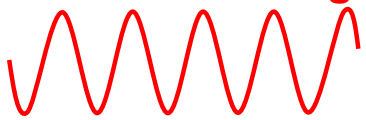
RX

hand



phase variation

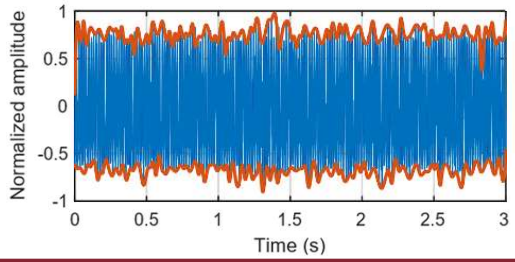
phase variation in Wi-Fi sensing



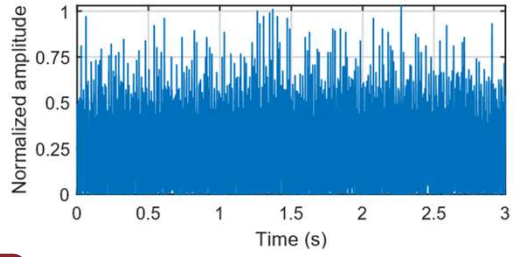
Body motion has no influence on the signal phase

Our solution: Demodulating motion influence from 60 Hz signals

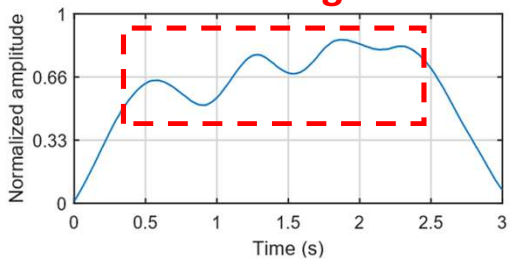
Time domain



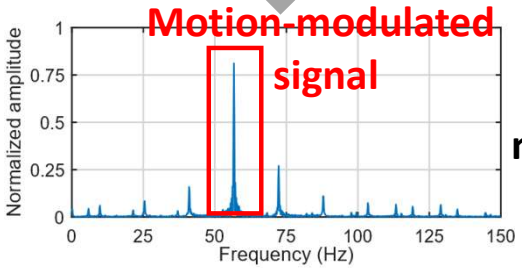
The motion signal is still not clear



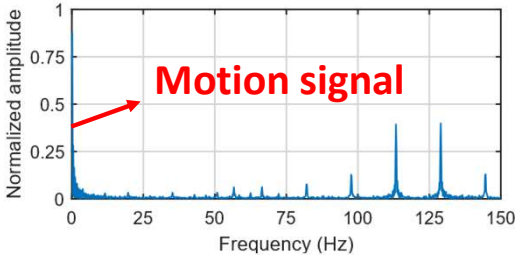
Motion signal



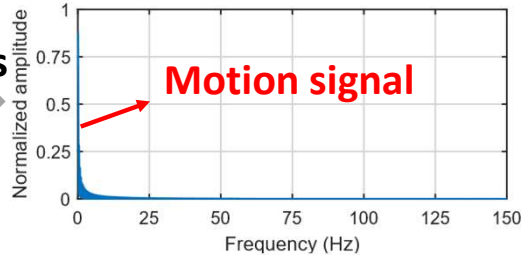
The envelope is not clear enough



Self-multiply

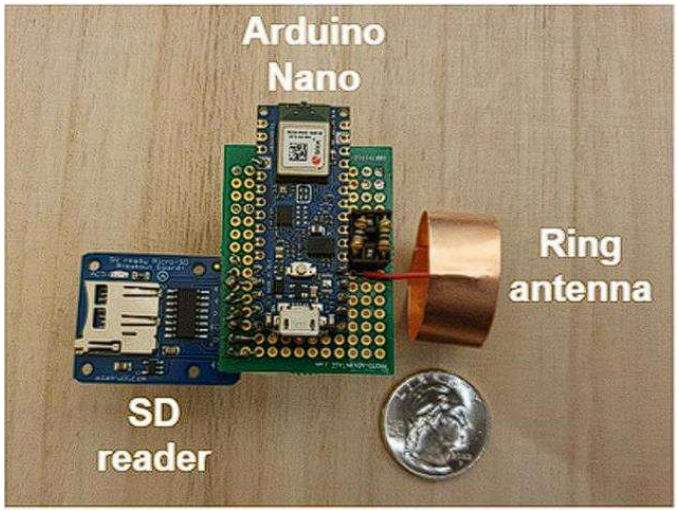


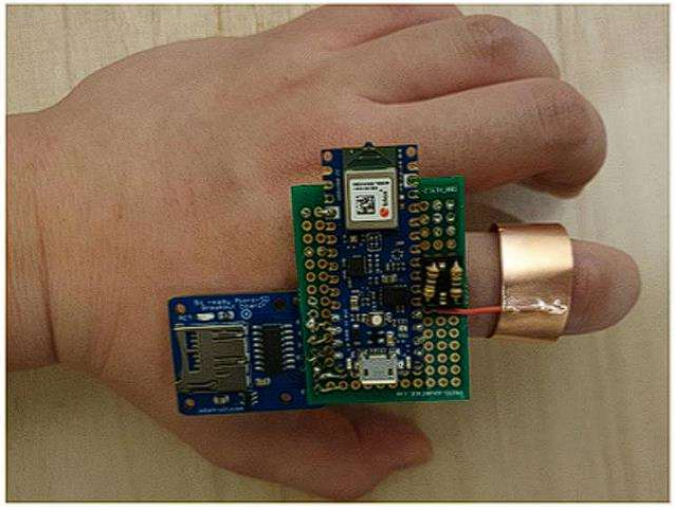
lowpass filter



Frequency domain

Implementation

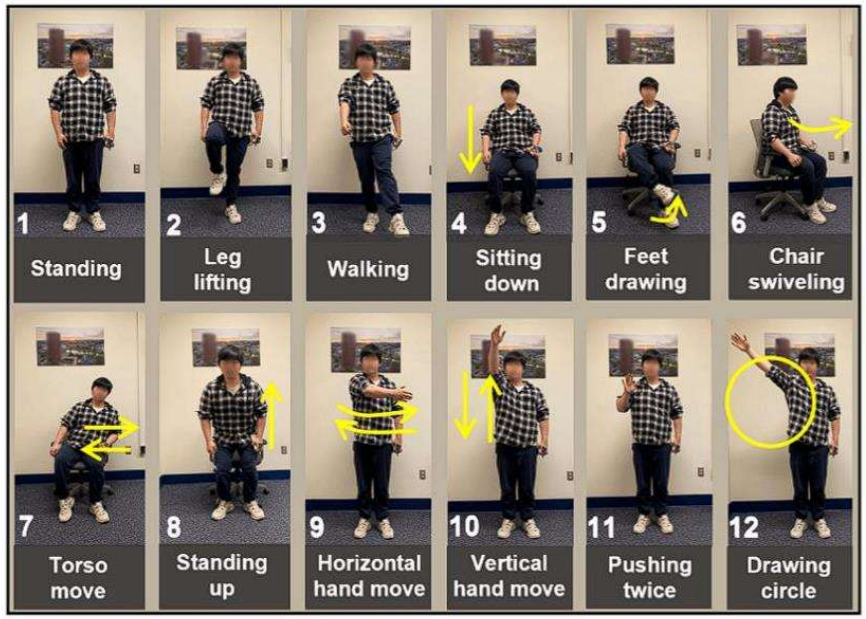


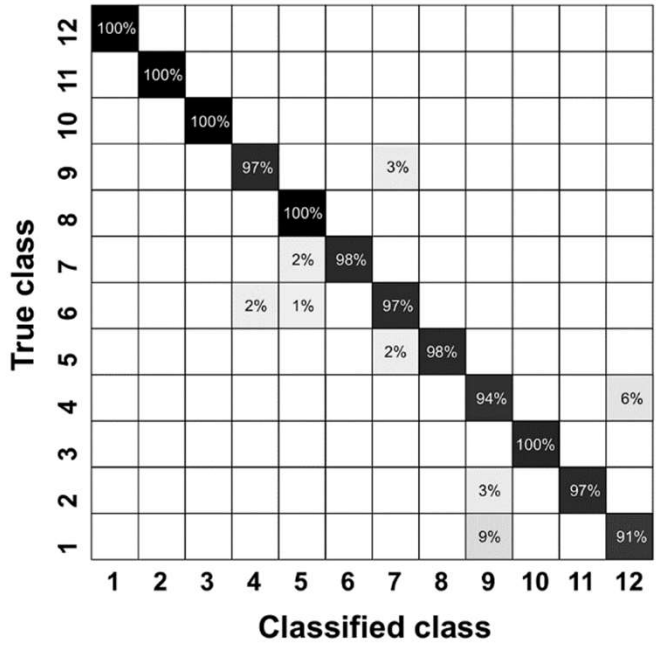


The ring antenna is easy to wear and cheap (<$10)

Evaluation

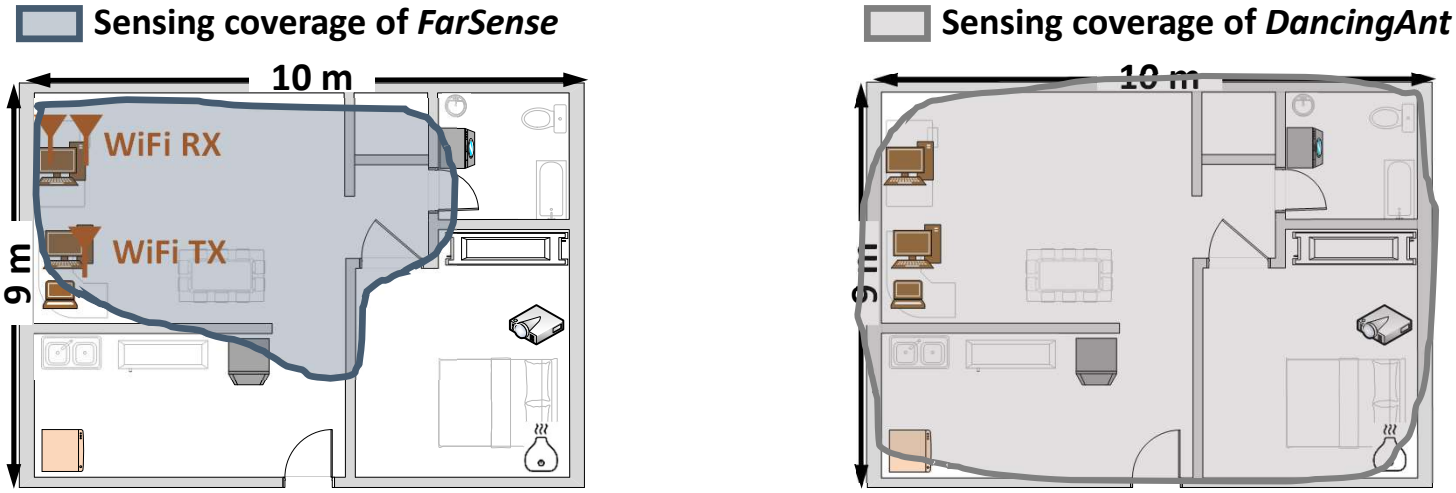
Sensing body motion





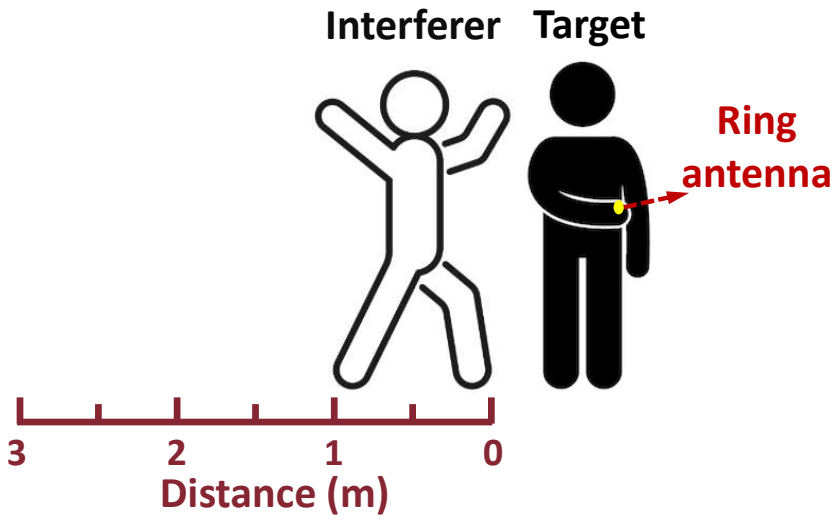
DancingAnt can recognize **twelve** motions at **97.7%** accuracy

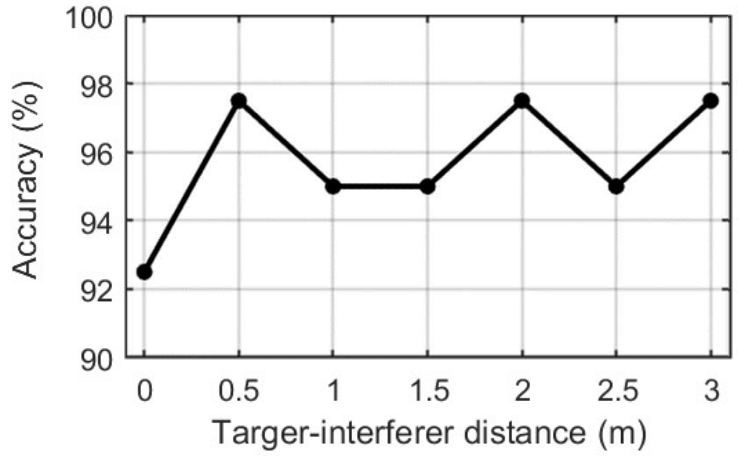
Sensing coverage



DancingAnt provides a larger sensing coverage

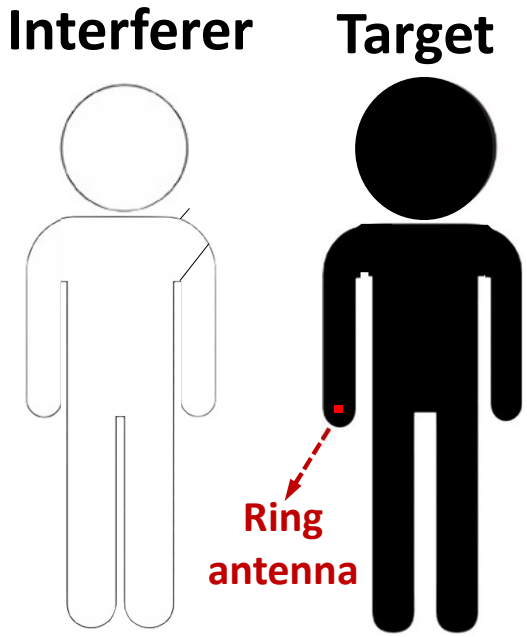
Robustness against surrounding interference





DancingAnt is robust against surrounding interference

Interesting case: interferer touches the target



DancingAnt can sense both targets with only one ring

Conclusion

Conclusions

- **Exploited** the leaked signals from powerline for sensing.
- **Involved** the human body as part of the system to enable a new sensing modality.
- **Built** the body-augmented sensing model to guide signal processing.
- **Conducted** experiments and demonstrated the proposed systems can be utilized for sensing without any **dedicated sensing signal**.

THANKS FOR LISTENING!