IMPROVED WIFI-BASED RESPIRATION TRACKING VIA CONTRAST ENHANCEMENT

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IEEE ICASSP 2023 (PAPER ID: 4381)

INTRODUCTION

Respiratory rate tracking has gained interest in the past few years because of its potential in exploring pathological conditions of human beings.

Earlier Methods:

- Contact (Chest Belt, Nasal Mask)
  - Intrusive and uncomfortable for users
  - May affect natural respiration of users
- Non-Contact (Camera, MM Wave/Radar)
  - Dedicate devices required
  - Coverage limited

Promising Candidate:

- WiFi Based
  - Low-cost and privacy-preserving
  - Can reuse the existing WiFi devices
- **Existing works: Inflexible device placement**

We propose **WiResP**, a WiFi-based respiratory rate tracking system allowing **more flexible deployment** and a **larger sensing coverage**.

STATISTICAL CSI MODEL

Considering the multipath propagation of wireless signals, the CSI of link m at time t in frequency f, is written as

$$H^{(m)}(t,f) = \underbrace{\sum_{i\in\Omega_D(t)} a_i(t) e^{\frac{-j2\pi f d_i(t)}{c}}}_{} + \underbrace{\sum_{i\in\Omega_S} a_i e^{\frac{-j2\pi f d_i}{c}}}_{} + n(t,f).$$

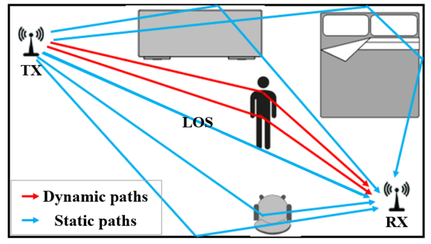


Figure 1: Multipaths of Wireless Signals

WIRESP SYSTEM DESIGN

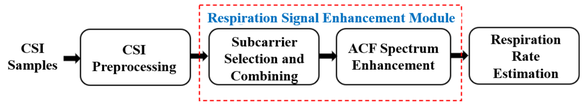


Figure 2: System Design

METHOD

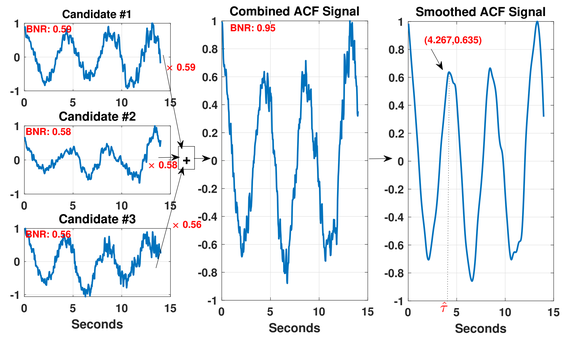
Utilizing AutoCorrelation function (ACF) of the amplitude of CSI, $\boldsymbol{s}_i^{(m)}$, $\boldsymbol{\rho}_i^{(m)}(\tau) = \frac{COV[\boldsymbol{s}_i^{(m)}(t), \boldsymbol{s}_i^{(m)}(t+\tau)]}{COV[\boldsymbol{s}_i^{(m)}(t), \boldsymbol{s}_i^{(m)}(t)]}$.

Two Stage Boosting Modules

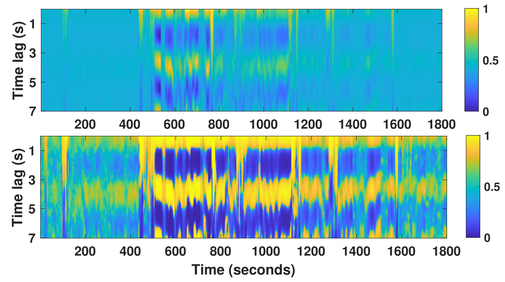
- ***Subcarrier Selection & Combining***

Enhanced ACF using weighted combining with Breathing-to-Noise (BNR) Ratio

$$\boldsymbol{\rho}_{combined} = \sum_{i\in\mathcal{S}} \boldsymbol{\rho}_i \times BNR_i.$$



- ***ACF Spectrogram Enhancement***



Original/Enhanced ACF

Applying Histogram Equalizer to redistribute the intensity of the ACF to enhance the breathing trace.

Respiratory Rate Estimation

Respiratory Rate can be estimated by $\frac{60}{\hat{\tau}}$ BPM, where $\hat{\tau}$ denotes the time lag of the first peak in ACF.

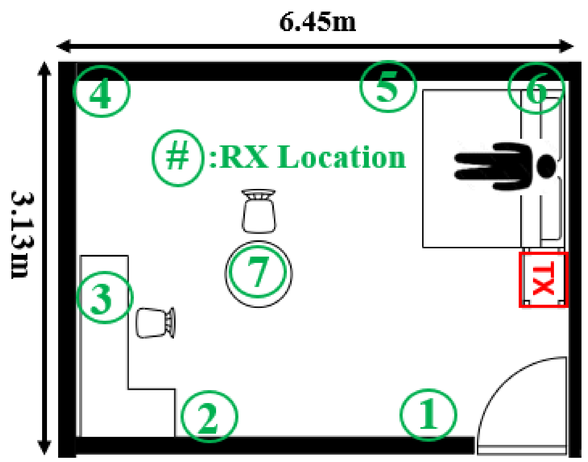
EXPERIMENTAL RESULTS

System is evaluated with a pair of commercial WiFi devices operated at 5.805 GHz with sounding rate 30 Hz in a realistic home environment. The bandwidth is 40 MHz, and there is 1 antenna on the TX while the RX has 2 antennas.

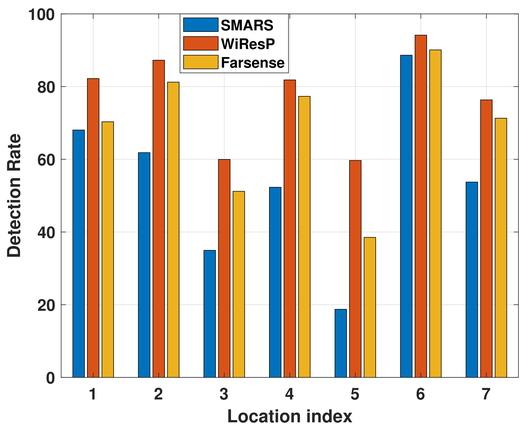
- 7 different device locations were tested (determined by the existing power outlet).
- Natural overnight sleep data (85 hours in total)were collected without constraining the sleeping positions and postures of testers.
- Compared with other two state-of-the-art methods, SMARS and FarSense.

Accuracy of the system:

- median error/90%-tile error: 0.78 BPM and 2.49 BPM



(a) Illutstration of deployments



(b)Detection rate of RX locations

CONCLUSION

- WiResP greatly enhances the sensing capability of WiFi-based respiration tracking.
- WiResP allows flexible device deployments.
- WiResP reuses existing WiFi devices without any additional hardware.

FUTURE WORKS

- Evaluation in more environments.
- Complexity Reduction.

REFERENCES

[1] Wei-Hsiang Wang, Xiaolu Zeng, Beibei Wang, Yexin Cao, K. J. Ray Liu. Improved wifi-based respiration tracking via contrast enhancement. In *ICASSP 2023 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, 2023.