Principles of Wireless Communication and Mobile Networks

IE 304

Wi-Fi based Respiration Sensing

Dr. Haiming Jin

We sincerely thank Prof. Xiaohua Tian for sharing his slides.
Wi-Fi
Beyond communication, Wi-Fi Sensing

Beyond communication, Wi-Fi Sensing

Example 1: Respiration detection

https://dl.acm.org/citation.cfm?id=2971744
Beyond communication, Wi-Fi Sensing

Example 2: Action detection

http://tns.thss.tsinghua.edu.cn/~yangzheng/
Goal: Use Fresnel zone model to explain how this can be done?
What is Fresnel Zone?

Properties of Fresnel Zone?

How human respiration detection can be done?
Augustin-Jean Fresnel
French civil engineer and physicist

10th May, 1788 - July 14th, 1827
A series of prolate ellipsoidal regions of space

Project the ellipsoidal regions to x-y plane

\( Q_n: \) any point on \( n \)th ellipsoidal zone,

\[
|P_1 Q_n| + |Q_n P_2| = |P_1 P_2| + n \cdot \lambda / 2
\]
Guiding communication system design
Fresnel Zone clearance

\[ c_1 \geq r_1 \times 60\% \]
Basic idea of Wi-Fi Sensing

Wi-Fi signal

Reflected Wi-Fi signal

TX

RX

Respiration
Observation 1: Reflection phase offset

Reflection from a conducting surface
Phase offset of $\pi$
Observation 2: Path phase offset

\[ |P_1 Q_1| + |Q_1 P_2| = |P_1 P_2| + \lambda/2 \]

Path phase offset of \( \pi \)
Received signal

Reflection phase offset of $\pi$

Path phase offset of $\pi$

Total phase offset of $2\pi$

$|P_1Q_1| + |Q_1P_2| = |P_1P_2| + \frac{\lambda}{2}$

In phase
Received signal

Reflection phase offset of $\pi$

$|P_1Q_2| + |Q_2P_2| = |P_1P_2| + \lambda$

Path phase offset of $2\pi$

Total phase offset of $\pi$

Out of phase
Fresnel Zone Model for Wi-Fi Sensing

LoS

Odd
Constructive

In phase

Even
Destructive

Out of phase
Influence of respiration on the reflected signal
Respiration Detection

Signal vectors model

- **TX** (Transmitter)
- **RX** (Receiver)
- **Multipath**
- **Los** (Line of Sight)
- **Static signal** $H_S$
- **Dynamic signal** $H_d$
- **Received signal** $H$
- **Inhale**
- **Exhale**

**Odd numbered**

**Even numbered**

**$H_d$**

**$H_s$**

**$\theta$**
Respiration incurs phase offset of reflection signal
Respiration Detection

Relationship between chest displacement and phase offset

Chest displacement = $\Delta L$

Path length change $\approx 2\Delta L$

If $2\Delta L = \lambda$

then $\theta = 2\pi$

$\theta \approx \frac{2\pi \cdot 2\Delta L}{\lambda}$
Respiration Detection

Relationship between chest displacement and phase offset

\[ \theta \approx \frac{2\pi \cdot 2\Delta L}{\lambda} \]

\[ \Delta L \approx 5 - 12 mm \quad \rightarrow \quad \theta \approx 60^\circ - 150^\circ \]
Summary

- **What** is Fresnel Zone?

- **Properties** of Fresnel Zone?

- **how** human respiration detection can be done?

\[ \theta \approx 60^\circ - 150^\circ \]