SpinLoc: Spin Around Once to Know Your Location

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Context

Advances in localization technology

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Location-based applications (LBAs)

(iPhone AppStore: 6000 apps, Android: 1000 apps)
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Mostly outdoor apps
Indoor Localization Technology

- Limited by accuracy, wardriving and deployment cost
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GPS ineffective indoors
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WiFi based:
Horus, Place Lab, Horus
Most need **war-driving**
Indoor Localization Technology

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  - GPS ineffective indoors
  - WiFi based: Horus, Place Lab, Horus
    Most need **war-driving**
  - Infrastructure based: Cricket, Pinpoint
    High deployment cost
Indoor Localization Technology

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WiFi is ubiquitous
Indoor Localization Technology

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Infrastructure based:
Cricket, Pinpoint
High deployment cost

WiFi is ubiquitous

Can we improve WiFi localization without wardriving?
Angle of Arrival (AoA) based Localization
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AP1

AP2

R1
Angle of Arrival (AoA) based Localization

AP1

AP with multiple antennas.
Enterprise Settings.

AP2

R1

AP with multiple antennas.
Enterprise Settings.
Angle of Arrival (AoA) based Localization

AP1

AP with Multiple antennas

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AP2

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AP with Multiple antennas

Enterprise Settings
Angle of Arrival (AoA) based Localization

AoA localization on phone.
Enterprise Settings
Angle of Arrival (AoA) based Localization

AoA localization on phone.
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Angle of Arrival (AoA) based Localization

AoA localization on phone.
Privacy preserving.
We propose SpinLoc

AoA based localization aided by user spins
Indoor Multipath
Indoor Multipath

- Direct Path
- Reflected Path
Direct Path Energy
Direct Path Energy
Direct Path Energy
Direct Path Energy

Direct Path

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- Human body predominantly water
- 2.4GHz is water’s resonant frequency

Direct Path

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Hypothesis: Direct path energy minimum when human perfectly blocks phone
Direct Path Energy

Human
Direct Path Energy
Direct Path Energy

Compass Orientation

Direct Path Energy

Human
Direct Path Energy

Compass Orientation

Direct Path Energy

Direct Path

Human
Direct Path Energy

Compass Orientation

Direct Path Energy

Human
Direct Path Energy

Minimum when user blocks phone

Compass Orientation

Direct Path

Human
Direct Path Energy

Compass Orientation

Direct Path Energy

Human
Direct Path Energy

Compass Orientation

Direct Path Energy

Normalized Direct Path Energy

Direct Path

Human
**Direct Path Energy**

\[
\text{AoA} = \left( \text{Compass orientation corresponding to minimum direct path energy} + 180 \right) \mod 360
\]
RSSI as Direct Path Energy?
RSSI as Direct Path Energy?
Facing

$$\text{RSSI} = \text{Direct} + \text{Reflected}$$
Facing

\[ \text{RSSI} = \text{Direct} + \text{Reflected} \]

20 dB + 5 dB
Facing

$$\text{RSSI} = \text{Direct} + \text{Reflected}$$

$$20 \text{ dB} + 5 \text{ dB} = 25 \text{ dB}$$
RSSI = **Direct** + **Reflected**

- Facing: 
  - RSSI = 20 dB + 5 dB = 25 dB

- Blocking: 
  - RSSI = Direct + **Reflected**
Facing

\[
\text{RSSI} = \text{Direct} + \text{Reflected} \\
20 \text{ dB} + 5 \text{ dB} \\
= 25 \text{ dB}
\]

Blocking

\[
\text{Direct} + \text{Reflected} \\
10 \text{ dB} + 15 \text{ dB} \\
= 25 \text{ dB}
\]
But how do we estimate direct path energy?

Using off-the-shelf WiFi cards?
Channel Frequency Response

![Graph showing channel frequency response with subcarriers and phase and amplitude plots.]
Channel Frequency Response
Channel Frequency Response

Amplitude of $H(f)$

Phase of $H(f)$

Subcarrier $f$

Channel Frequency Response

Power delay profile

IFFT

Delay in microseconds

SNR in dB
Channel Frequency Response

Direct path Energy

IFFT

Power delay profile

Reflected paths
Localization using AoA
Localization using AoA
Localization using AoA

Actual Direction

Estimated Direction
Localization using AoA

Actual Direction

Estimated Direction
Localization using AoA

Actual Direction

Estimated Direction
Localization using AoA

- Actual Direction
- Estimated Direction
- Centroid
Localization using AoA and RSSI

Actual Direction

Estimated Direction
Localization using AoA and RSSI

Actual Direction

Estimated Direction
Localization using AoA and RSSI
Localization using AoA and RSSI
Localization using AoA and RSSI

- Actual Direction
- Estimated Direction
- Centroid
Localization using AoA and RSSI

1. Angle estimation error:
   Difference between actual and estimated direction
Localization using AoA and RSSI

1. Angle estimation error: Difference between actual and estimated direction

2. Localization error: Difference between actual and estimated location
Performance Evaluation

- Used off-the-shelf Intel 5300 cards to obtain direct path energy
- Evaluated SpinLoc at various settings:

- Compare with RSSI based trilateration scheme

Engineering Building
- 30 locations
- 3-5 APs

Cafeteria
- 25 locations
- 3-4 APs
Angle Estimation Error

SNR in dB

Mean angle error

10–15
16–20
21–25
26–30
31–40

0
10
20
30
40
50
Angle Estimation Error

Average error = 20 degrees, for APs stronger than 20dB RSSI
Localization Error

Average localization error = 5 meters
SpinLoc: Closing Thoughts

- AoA based localization without wardriving
  - Human body attenuates direct path to APs
  - SpinLoc identifies this direct path, extract AoA
  - Triangulates to estimate location

SpinLoc Limitations:

- Requires user involvement: spin once to know your location
- Phone listens to WiFi traffic while user spins
  - May not be able to transmit data to the internet while spinning
- Depends on existence of direct path from AP
  - May be heavily attenuated
- Require extensive testing in crowded environments
Questions, comments?

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