INDOOR LOCALIZATION SYSTEM BASED ON OFDM SELECTED SUBCARRIERS RSSI

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Overview

- Indoor Localization
Preview Works

- Latency-based solution
  - ToA
  - TDoA
- Angulation-based solution
  - AoA/DoA
- RSSI-based solution
  - RADAR
Our Goals

- Obtain reliable RSSI from OFDM subcarriers
  - Use selected trustworthy RSSI only
- Build self-adaptive model for localization
- Implement indoor localization system in GNU Radio
- Evaluate performance in real-world environments
Challenges

RSSI from each subcarrier?

Atheros AR9170
RealTek RTL8192SU

GNU Radio
the gnu software radio
GNU Radio

- Open-source platform in C++/Python
- Ready-to-use functional blocks
- Support customized blocks
- OFDM Receiver in GR
I & Q symbol
I & Q symbol
I & Q symbol

Power on subcarrier 20

Power

symbol index

0 100 200 300 400 500 600 700 800 900

0 200 400 600 800 1000 1200 1400 1600

0 100 200 300 400 500 600 700 800 900

0 200 400 600 800 1000 1200 1400 1600
I & Q symbol

Symbol error distance at the 50th symbol

Euclidean distance

subcarrier index
I & Q symbol
Stable Subcarriers
Stable Subcarriers
Stable Subcarriers

6 feet
Stable Subcarriers

11 feet
Stable Subcarriers

13 feet
Stable Subcarriers
Stable Subcarriers
Equalization
Equalization
Equalization distance on subcarrier 60

Equalization distance

packet index
Equalization

Equalization distance on subcarrier 60

Euclidean distance

Standard Deviation (SD)

mean
Equalization distance on subcarrier 60

pkt index

Euclidean distance

0 0.0005 0.0006 0.0007 0.0008 0.0009 0.0010 0.0011 0.0012 0.0013

0 200 400 600 800 1000
Localization – Model

- RSSI-based localization
  \[ P_{rcvd} = c \frac{P_{tx}}{d^\alpha} \iff d = \alpha \sqrt{\frac{cP_{tx}}{P_{rcvd}}} \]

- Transmission Power \( P_{tx} \)
- Received Signal Strength \( P_{rcvd} \)
- Path lost coefficient \( \alpha \)

- Instead of using combined average signal strength, we use the more trustworthy RSSIs
- Continuously training to calibrate the model
Localization – Training and Predict

- **Training:** We have $P_{rcvd}$ and $d$, we can obtain $\alpha$

  $$P_{rcvd} = c \frac{P_{tx}}{d^\alpha} \Rightarrow d^\alpha = \frac{cP_{tx}}{P_{rcvd}} \Rightarrow \alpha = \log_d \frac{cP_{tx}}{P_{rcvd}}$$

- **Predict:** We have $P_{rcvd}$ and $\alpha$

  $$P_{rcvd} = c \frac{P_{tx}}{d^\alpha} \iff d = \alpha \sqrt{\frac{cP_{tx}}{P_{rcvd}}}$$
A measurement, subcarrier 20

We cannot map the signal strength to the distance in a general model.
We develop a general model that fits to most points

- One model for EACH distance
  - Measurements are discrete, we need a model to give continuous results.
- Further improvement, one model per subcarrier

Training:
- we have subcarrier $P_{rcvd}$ and $d$, we want $\alpha$
- Each subcarrier RSSI trains corresponding model

Testing:
- we have subcarrier $P_{rcvd}$ and $\alpha$, we want $d_{predicted}$
- Find the closest model that has similar $P_{rcvd}$
- Use that model to obtain $d_{predicted}$
Localization – Model Improvement (2/2)
Localization – Symbol Filter

- One model per distance per subcarrier (unfiltered)
- One model per distance per subcarrier (filtered)

Error rate vs. Subcarrier index
Discussion

- One model per distance per subcarrier does improve the performance.
- In testing phase, it is possible that there are several closest signal strength model, each of them means a different distance.
  - If the program can choose the right model, the error is usually below 0.03%
  - If the program is not able to choose the right model, the predicted distance is usually incorrect. This is the main source of error.
## Examples

<table>
<thead>
<tr>
<th>Distance</th>
<th>RSS</th>
<th>Reference distance</th>
<th>prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>96 inches</td>
<td>1413.107765</td>
<td>96 (7.710355)</td>
<td>95.67854</td>
</tr>
<tr>
<td></td>
<td></td>
<td>132 (47.228760)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>120 (93.6972)</td>
<td></td>
</tr>
<tr>
<td>120 inches</td>
<td>1291.31303159</td>
<td>120 (28.3028)</td>
<td>121.480977981</td>
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<tr>
<td></td>
<td></td>
<td>150 (44.917)</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>132 (74.771240)</td>
<td></td>
</tr>
<tr>
<td>126 inches corner</td>
<td>1045.764572</td>
<td>156 (25.354963)</td>
<td>158.157</td>
</tr>
<tr>
<td></td>
<td></td>
<td>102 (47.589963)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>90 (89.126212)</td>
<td></td>
</tr>
<tr>
<td>160 inches door</td>
<td>616.5</td>
<td>126 (51.73425)</td>
<td>121.1827</td>
</tr>
</tbody>
</table>
Examples
Conclusion

- Three steps to get accurate RSS measurement
  - Symbol filter
  - Stable subcarrier identification
  - Equalization filter
- Accurate RSS is not enough
  - RSS dose NOT monotonously decreasing along with distance
  - More information such as subcarrier diversity needs to be explored for determining which model should be selected.
Thanks

- Q&A