Less is More: Efficient RFID-based 3D Localization

Kai Bu, Zhejiang University
Xuan Liu, Jiwei Li, Bin Xiao, The Hong Kong Polytechnic University
IEEE MASS 2013
RFID 3D Localization

Leverage Reference Positions

Estimate Object Positions

projection plane
Proposal:
Efficient Localization Scheme

\[(x_i, y_i) \quad (x, y) = \text{opt}(f(x_i, y_i))\]
Proposal: Efficient Localization Scheme

\[(x_1, y_1) \quad (x, y) = \left( \frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right) \quad (x_2, y_2)\]

Probing Some instead of Collecting All
Benefits

Still can locate ✓
Much more efficient ✓
May be even more accurate ✓
Behind The Scenes

Why RFID?
Why RFID Localization?
Why Efficiency Matters?
RFID
Radio Frequency IDentification
Internet of Things

- Sensor
- RFID
- Cloud
- ...

Diagram: Internet of Things connected to Sensor, RFID, Cloud, and an ellipsis.
RFID Tag

Communicate

Compute
RFID Powder

0.4 × 0.4 mm!
Location Is Important
Location Is Important
1.35 Billion
2013 (Expected)

IDTechEx.com
Efficient Protocols for Large RFID Systems
RFID 3D Localization Schemes Focus SOLELY On Accuracy
Existing Work: Passive Scheme

locate target tag
deploy reference readers reference tags
(with known locations)

\[ \text{dist(\text{ref-reader, tar-tag})} = \text{dist(\text{ref-reader, ref-tag})} \]

distances to \( \geq 3 \) ref-readers locate a tar-tag
Existing Work: Active Scheme

locate target reader
deploy reference tags
(with known locations)

location estimation:

\[(x_c, y_c) = \min \sum (R_c - \sqrt{(x_c - x_i)^2 + (y_c - y_i))^2)}\]
\[(x_f, y_f) = \min \sum (R_f - \sqrt{(x_f - x_i)^2 + (y_f - y_i))^2)}\]

\[(x, y) = \left(\frac{x_c + x_f}{2}, \frac{y_c + y_f}{2}\right); \quad z^2 + R_f^2 = (H - z)^2 + R_c^2 = R^2\]
Existing Work: Limitations

Inefficiency
read all activated tags

Contaminated Optimization
optimized location may not be accurate

Less references may yield
more accurate location estimate
Why Not Collect Less?

more efficient

not necessarily less accurate
Probe Some instead of Collect All

- efficient passive scheme
- efficient active scheme
Proposal: Efficient Passive Scheme

distance estimation

find $l$: min power level for ref-reader to read tar-tag
estimate $d_{eps}$: distance from ref-reader to tar-tag
probe co-row/column ref-tags at power level $l$ with increasing distance;
till Probe $N_{ps}$ w/o response;

$$d_{eps} = \frac{(N_{ps} - 1)d + N_{ps}d}{2}$$

location estimation
distance estimates to $\geq 3$ ref-readers + ref-reader locations
Proposal: Efficient Passive Scheme

distance estimation
find \( l \): min power level for reader to read tar-tag
estimate \( d_{eps} \): distance from reader to tar-tag
probe co-row/column ref-tags at power level \( l \) with increasing distance; ✔
till Probe \( N_{ps} \) w/o response;
\[
d_{eps} = \frac{(N_{ps} - 1)d + N_{ps}d}{2}
\]

location estimation
distance estimates to \( \geq 3 \) ref-readers + ref-reader locations
Proposal: Efficient Passive Scheme

distance estimation
find $l$: min power level for reference reader to read tar-tag
estimate $d_{eps}$: distance from reference reader to tar-tag
probe co-row/column ref-tags at power level $l$ with increasing distance;
till Probe $N_{ps}$ w/o response;
\[
d_{eps} = \frac{(N_{ps} - 1)d + N_{ps}d}{2}
\]

location estimation
distance estimates to $\geq 3$ ref-readers + ref-reader locations
Proposal: Efficient Passive Scheme

distance estimation

find $l$: min power level for ref-reader to read tar-tag
estimate $d_{eps}$: distance from ref-reader to tar-tag
probe co-row/column ref-tags at power level $l$ with increasing distance;
till Probe $N_{ps}$ w/o response;

$$d_{eps} = \frac{(N_{ps} - 1)d + N_{ps}d}{2}$$

location estimation
distance estimates to $\geq 3$ ref-readers + ref-reader locations ✓
Proposal: Efficient Active Scheme

three nodes confine the center of their circumscribed circle
probe ≥3 concyclic reference tags
Simulation Results
95% Efficiency Increase
Conclusion

RFID 3D Localization Made Efficient but not necessarily less accurate

Future work: empirical evaluation accuracy evaluation localization application (e.g., misplacement pinpointing, activity sensing)
References

1. RFID-Based 3-D Positioning Schemes
   Chong Wang, Hongyi Wu, and Nian-Feng Tzeng
   INFOCOM 2007

2. Fault-Tolerant RFID Reader Localization Based on Passive RFID Tags
   Weiping Zhu, Jiannong Cao, Yi Xu, Lei Yang, and Junjun Kong
   INFOCOM 2012
Thank You

Kai Bu
kaibu@zju.edu.cn
www.comp.polyu.edu.hk/~cskbu