WILL: Wireless Indoor Localization Without Site Survey

Chenshu Wu[1], Zheng Yang[1,3], Yunhao Liu[1,3], Wei Xi[2]

[1]MOE Key Lab for Information System Security,
School of Software, TNList, Tsinghua University
[2]Xi' an Jiao Tong University
[3]Department of Computer Science and Engineering, HKUST

27 Mar 2012

Outline

- Background
- Overview
- System Design
- Evaluation
- Limitations and Discussion
- Conclusions

Background

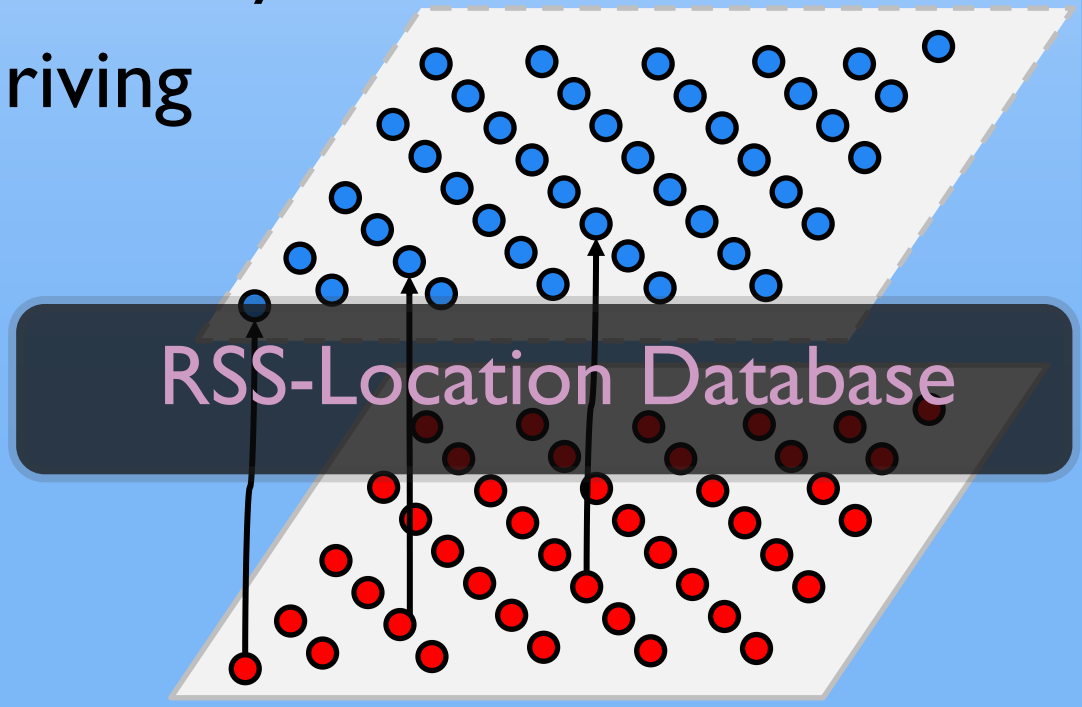
Motivation

- Location, Location, Location!

- Indoor localization is widely studied.
  - Model-based methods
    - ARIADNE (Ji et al 2006), EZ(Chintalapudi et al 2010), etc.
  - Fingerprinting-based methods
    - RADAR(Bahl et al 2000), Horus,(Youssef et al 2008) LANDMARC(Ni et al 2004), SurroundSense(Azizyan et al 2009), etc.
    - Ekahau, Skyhook

Motivation

- Limitations
  - Model: Require extra infrastructure, inaccurate
  - Fingerprinting: Need RSS-location database, which is usually built by site survey.
- Site survey / War-driving
  - Time-consuming
  - Labor-intensive



Logical Localization

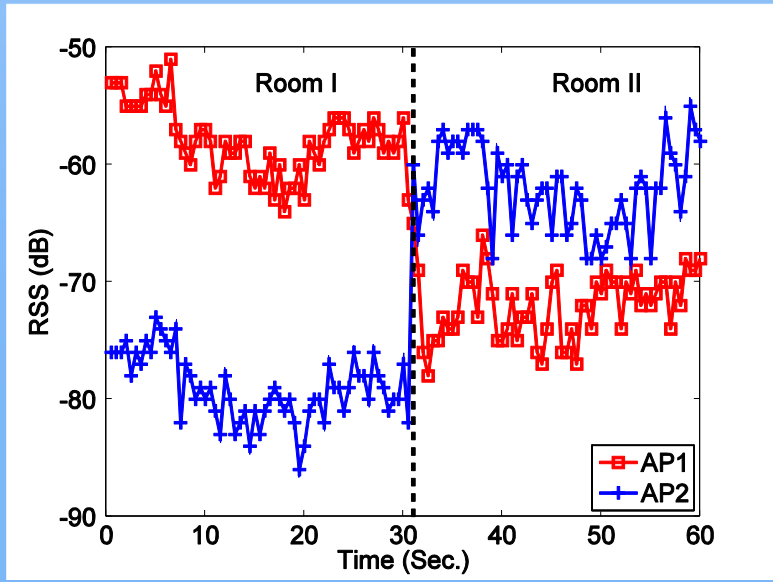
- Small physical errors result in large logical mistakes!

WILL: Wireless Indoor Logical Localization Without Site Survey

Overview

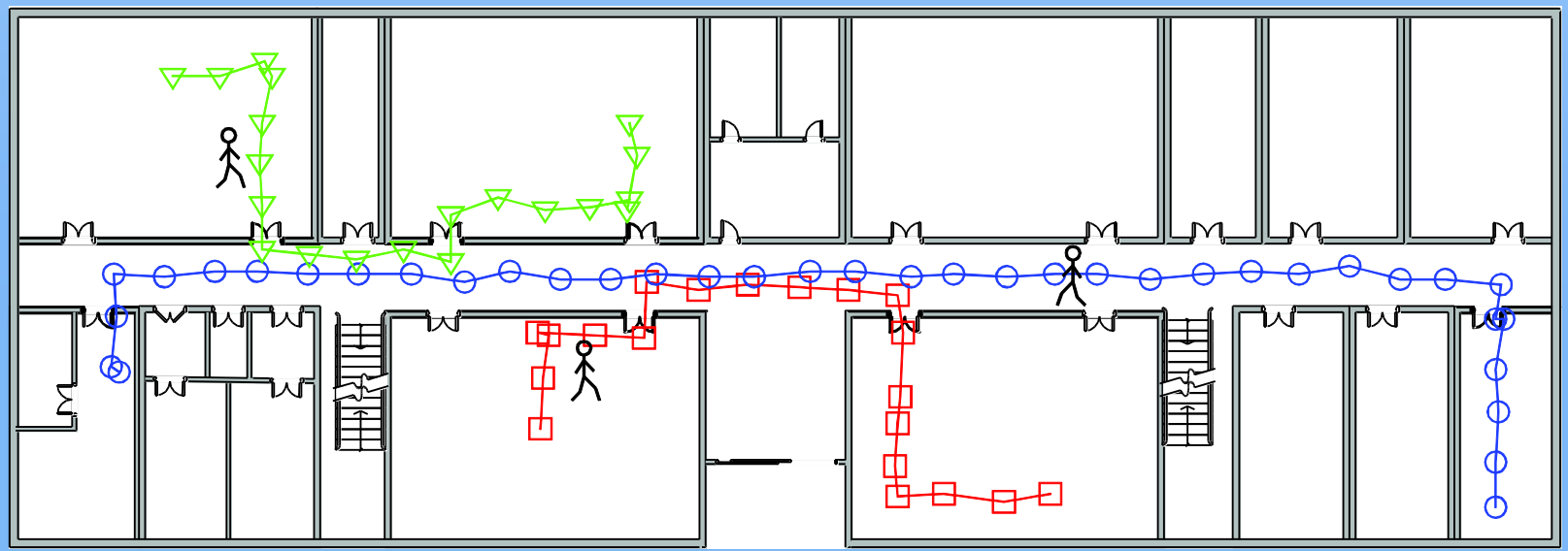
Key Insights

- Insights (1)
  - Wall-penetrating effect: Signals may encounter a considerable abrupt change while passing through a wall

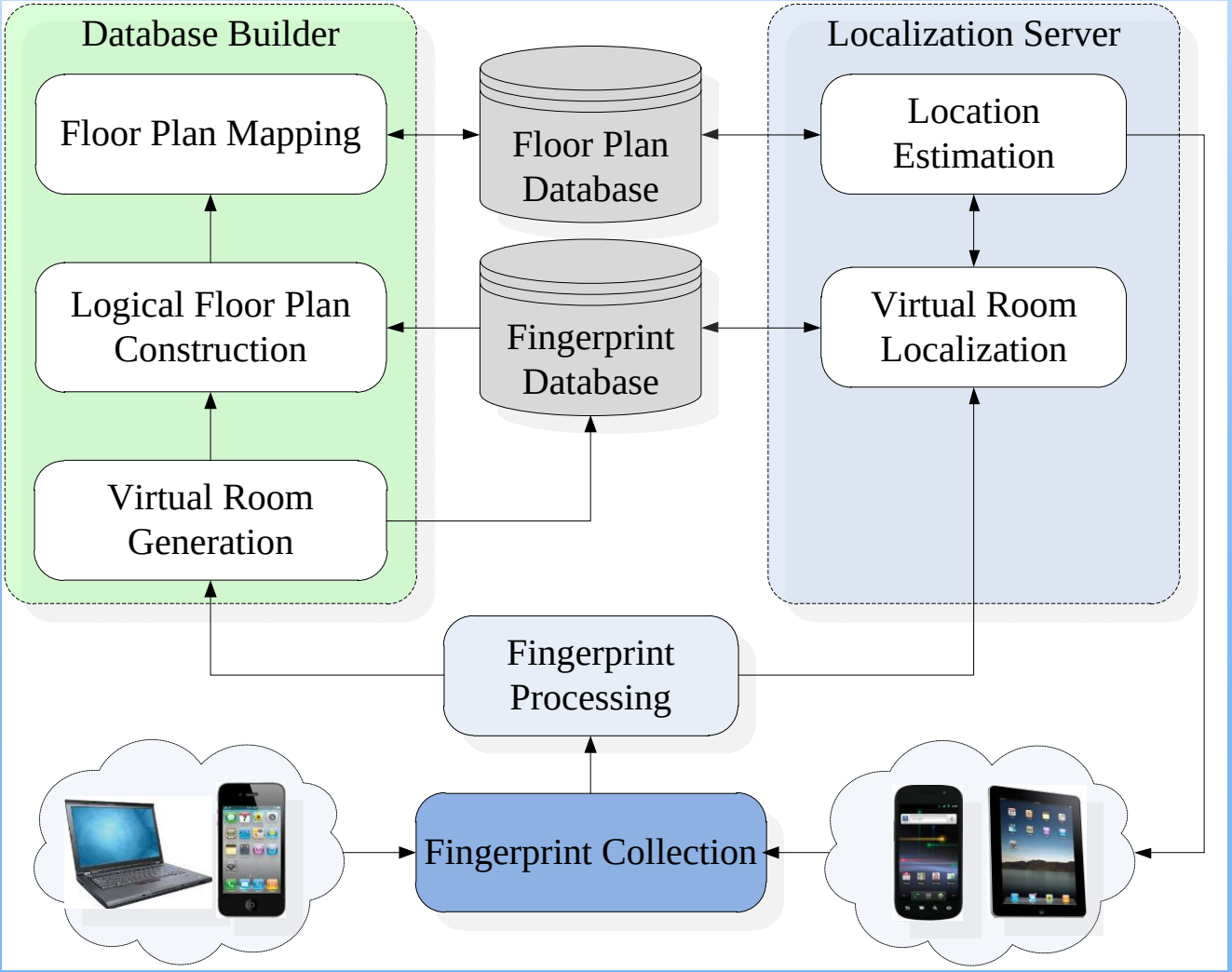


Key Insights

- Insights (2)
  - Considering user movements (collected from mobile phone), originally separated RSS fingerprints are spatially connected under certain semantics.



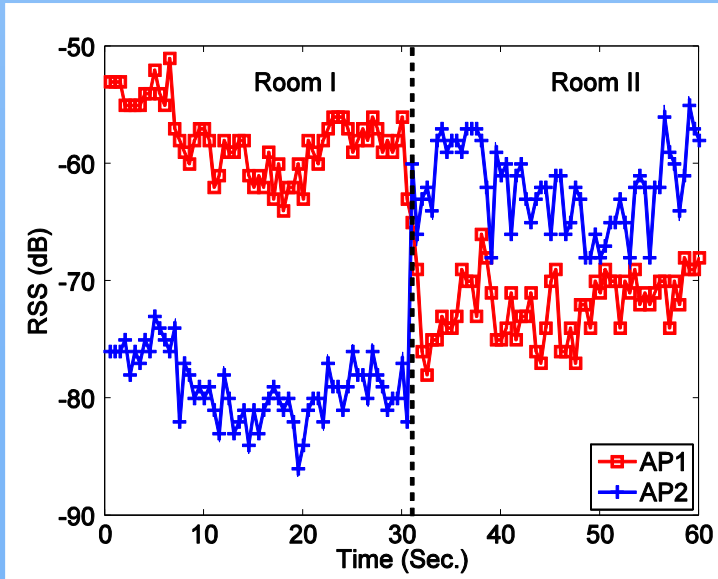
System Architecture



System Design

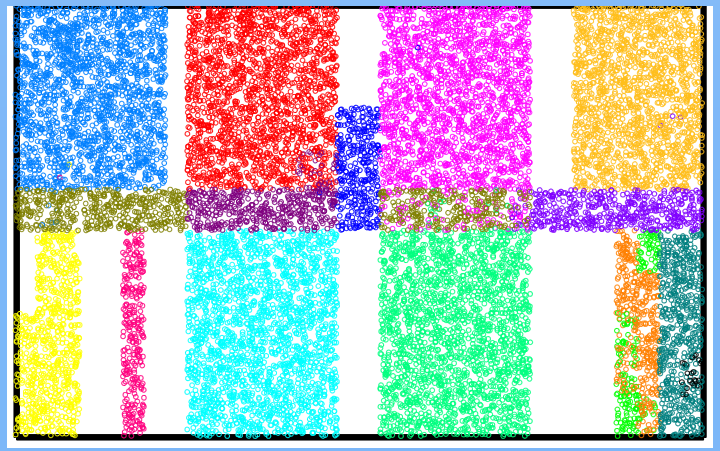
Virtual Room Generation

- Fingerprint Collection
  - Collect information through mobile phones
  - Participators are unaware of the collection.
- Fingerprint Feature
  - RSS stacking difference
    - RSS varies over time
    - Staking difference maintains



Virtual Room Generation

- Virtual Rooms
  - Generated by clustering fingerprints
  - Each cluster is a virtual room
- Virtual Room Update
  - Each room has a representative fingerprint F[R] and a dissimilarity threshold ξ



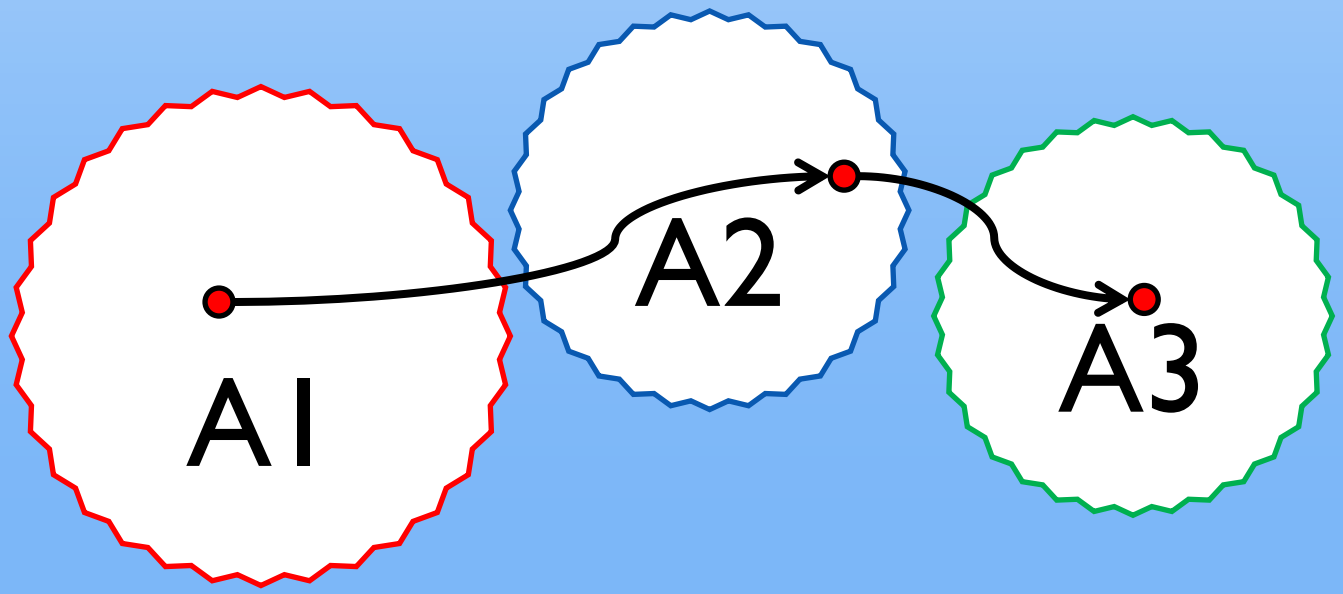
Logical Floor Plan

- A **unique** component of WILL
- A logical floor plan is a diagram showing the view of the reachability among virtual rooms
- Logical graph P = (V, E)
  - $v \in V$ denotes a virtual room and
  - $e = (u, v) \in E$ indicates virtual room u and v are reachable.

- How to construct it without location knowledge of virtual rooms?

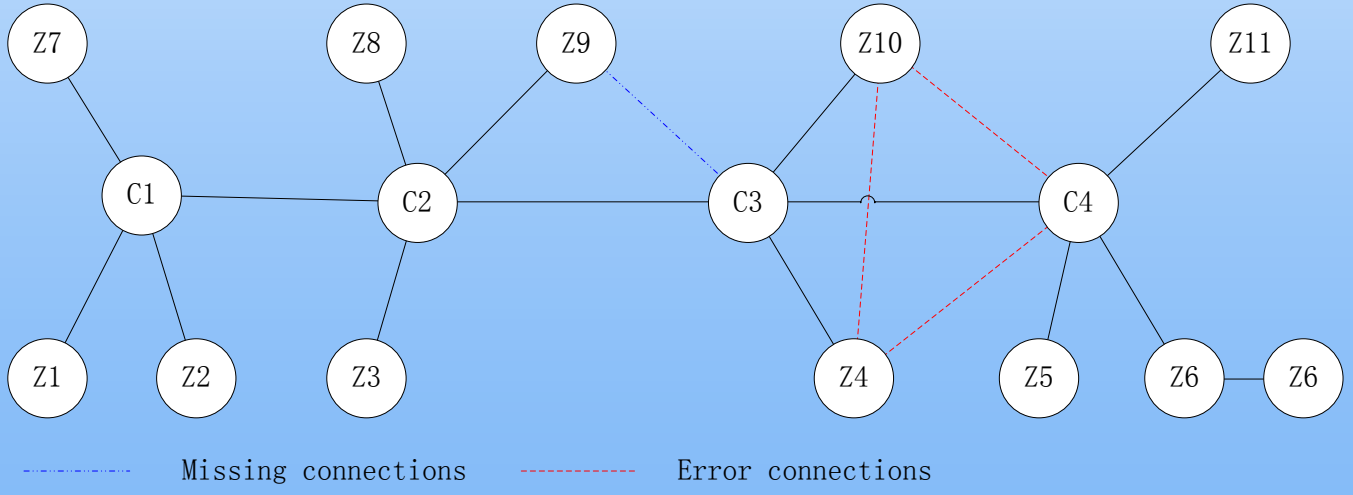
Logical Floor Plan

- Using user movements!
  - Movements natively indicate reachability.



Logical Floor Plan

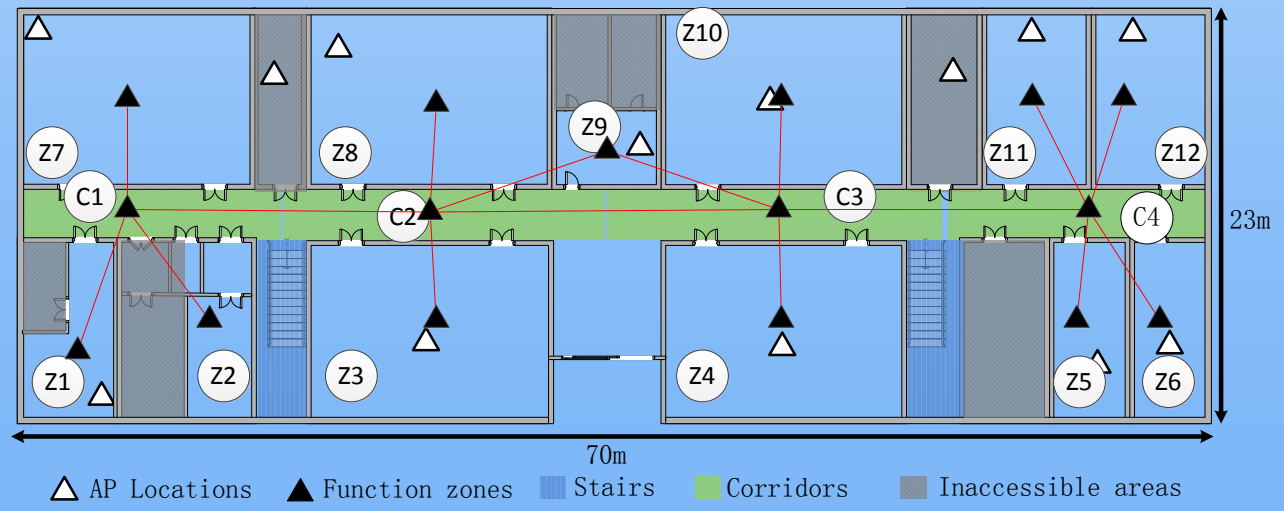
- Logical floor plan (logical graph)



- Recall the biggest challenge:
  - How to get the RSS-location associations?

Floor Plan Mapping

- Map the logical floor plan to the physical one!
- Physical floor plan → physical graph



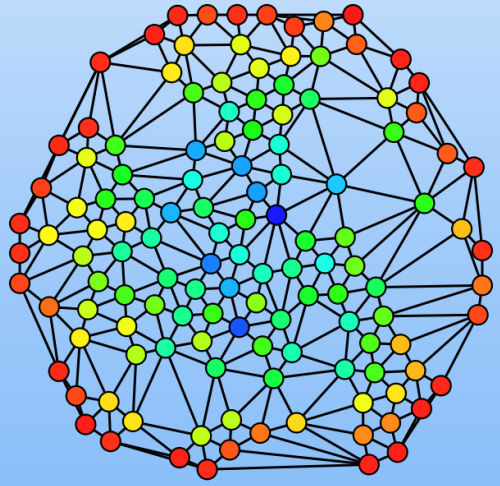
Floor Plan Mapping

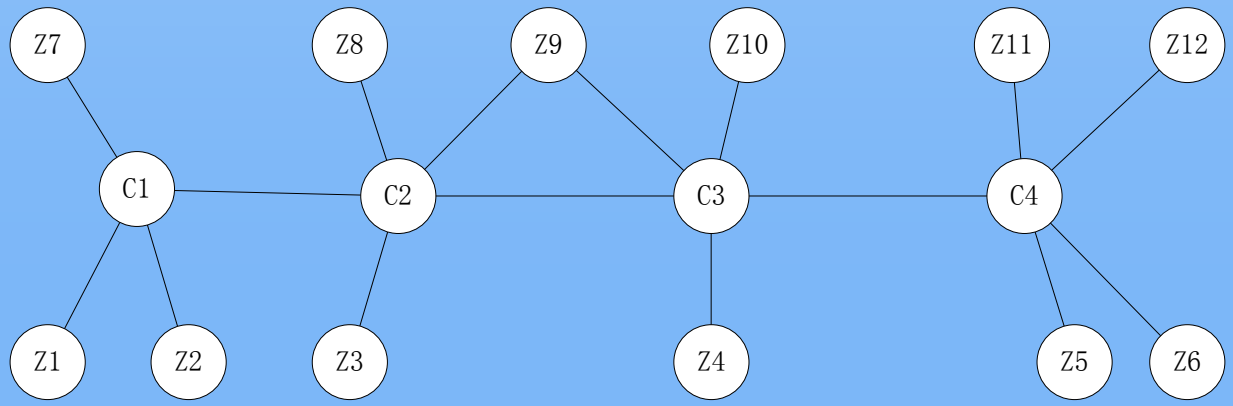
- How to map?

- Subsection Mapping Method (SSMM)
  - Skeleton mapping: Recognize central vertices (corridors)
  - Branch-knot mapping: Mapping branch vertices (rooms)
  - Correction

Floor Plan Mapping

- Skeleton mapping
  - Recognize corridor vertices using *Betweenness centrality*.



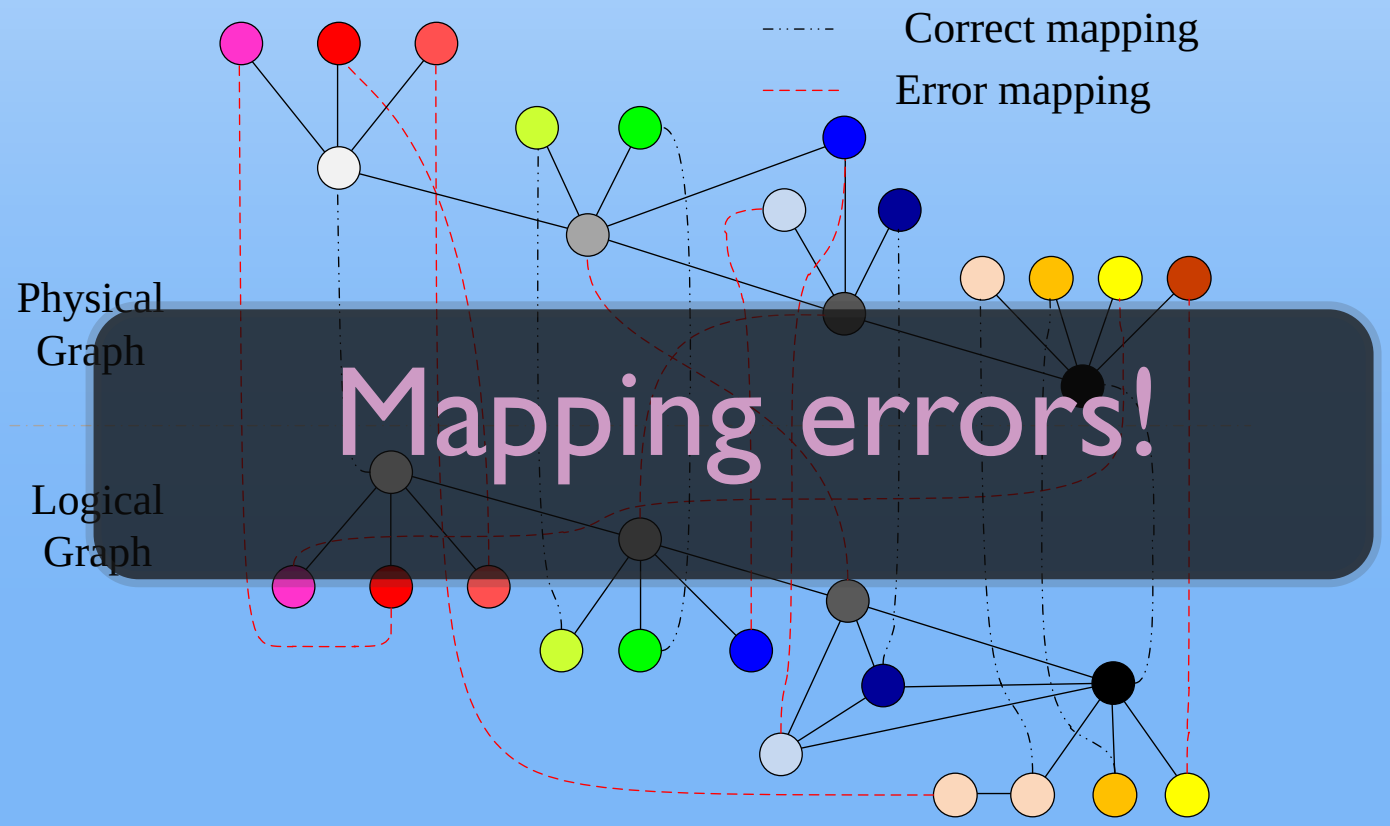


Floor Plan Mapping

- Branch-knot mapping
  - Weight each vertices with the sum of all shortest paths
  - Mapping goal: minimize the total weight difference
  - *Weighted minimum bipartite matching (Kuhn-Munkras algorithm, i.e., KM)*

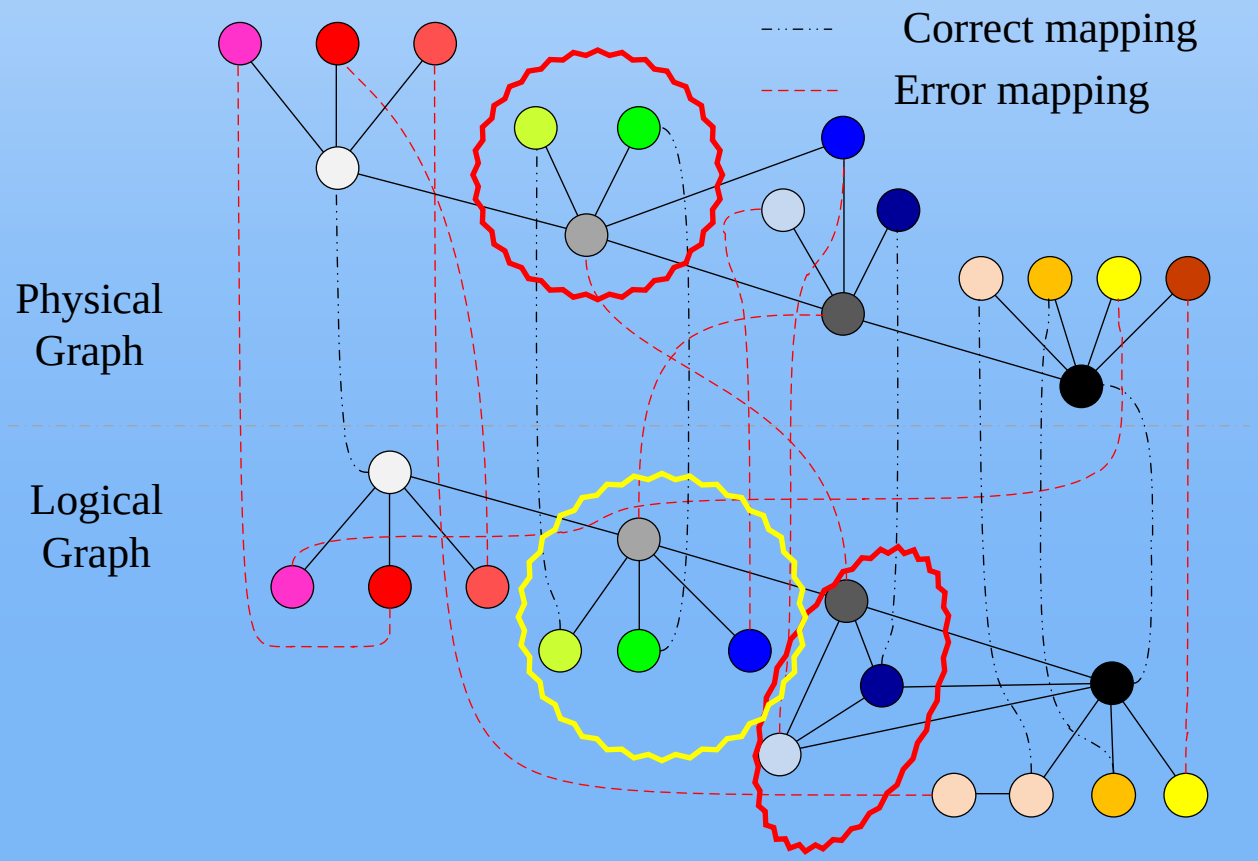
Floor Plan Mapping

- Primary mapping result
  - Skeleton & Branch-knot mapping



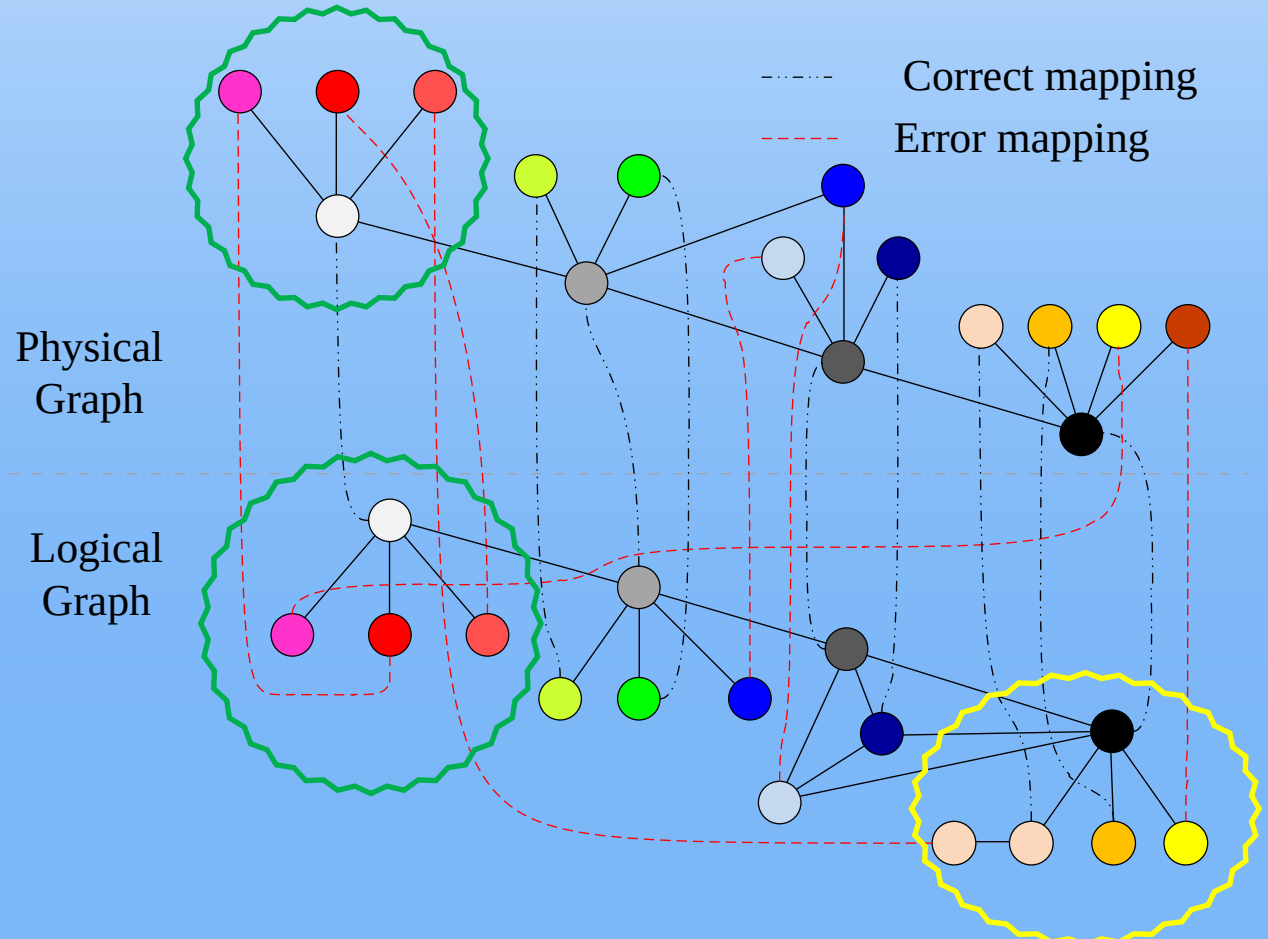
Floor Plan Mapping

- How better?
  - Correct the primary mapping using neighbors



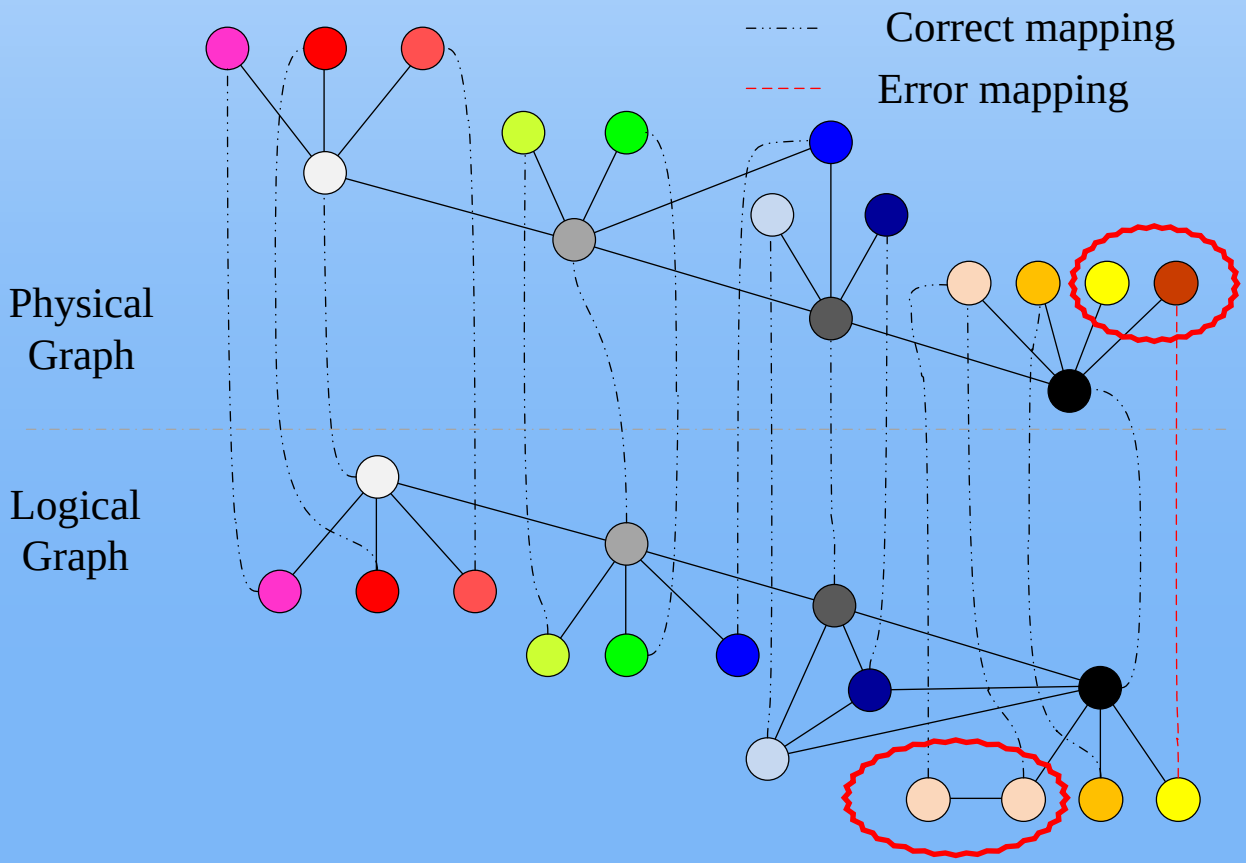
Floor Plan Mapping

- Correct the primary mapping using neighbors



Floor Plan Mapping

- Corrected result



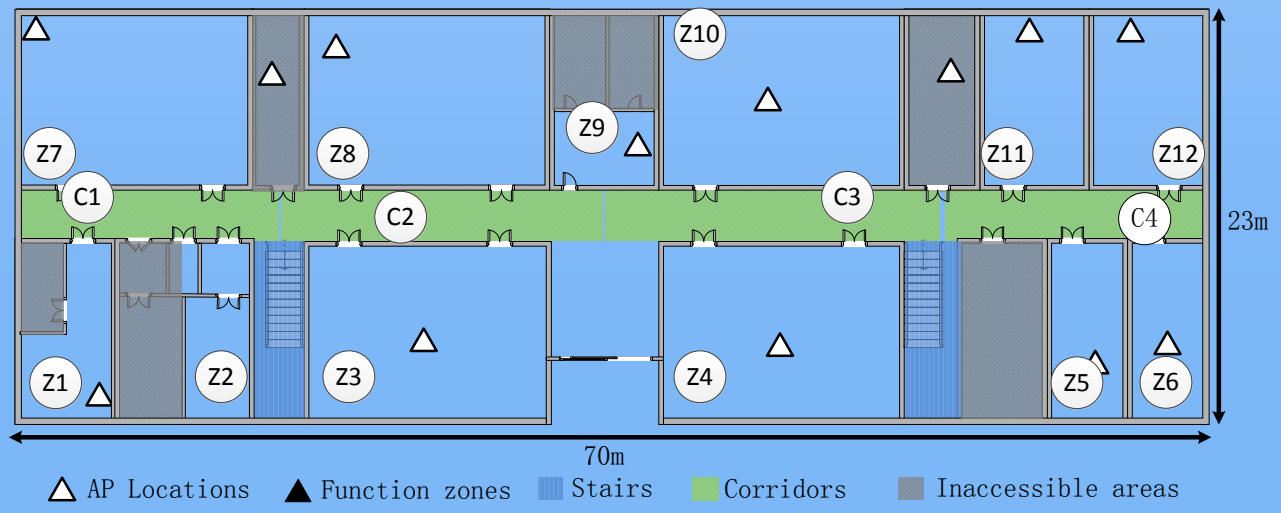
Localization

- Localize a query
  - Choose the room having maximum similarity and
  - dissimilarity < threshold value of that room
- Database Update
  - minor update: update representative fingerprints and dissimilarity thresholds
  - major update: long-term running, large data accumulated, update the RSS-location database

Evaluation

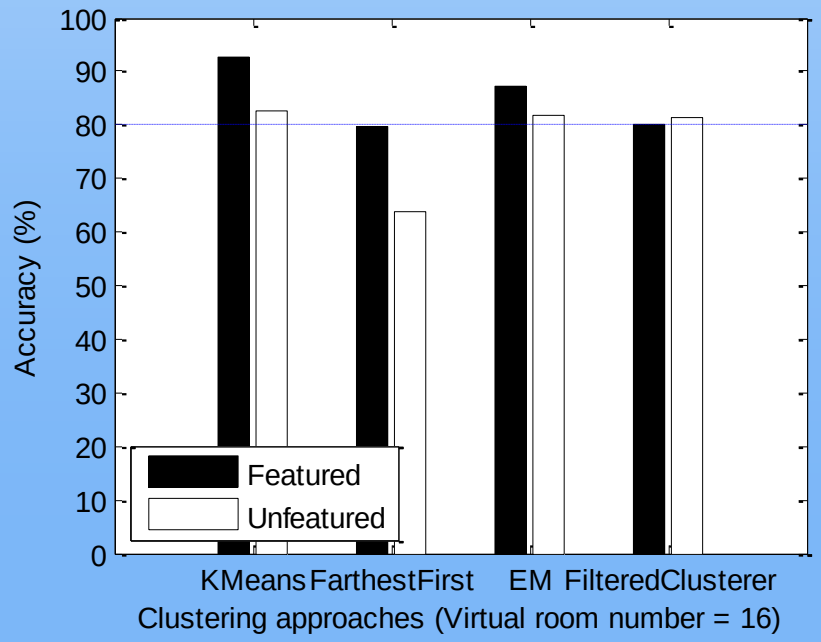
Evaluation

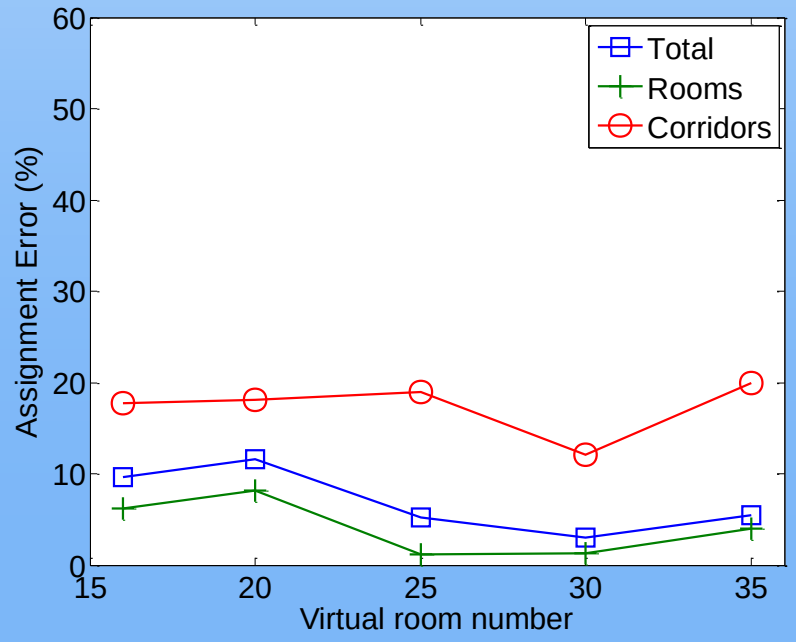
- Experiment set up
  - Experimental field: An office building in Tsinghua University
  - Platform: Google Nexus S phone (Android OS)
  - Collect data from 4 users for a half day



Performance

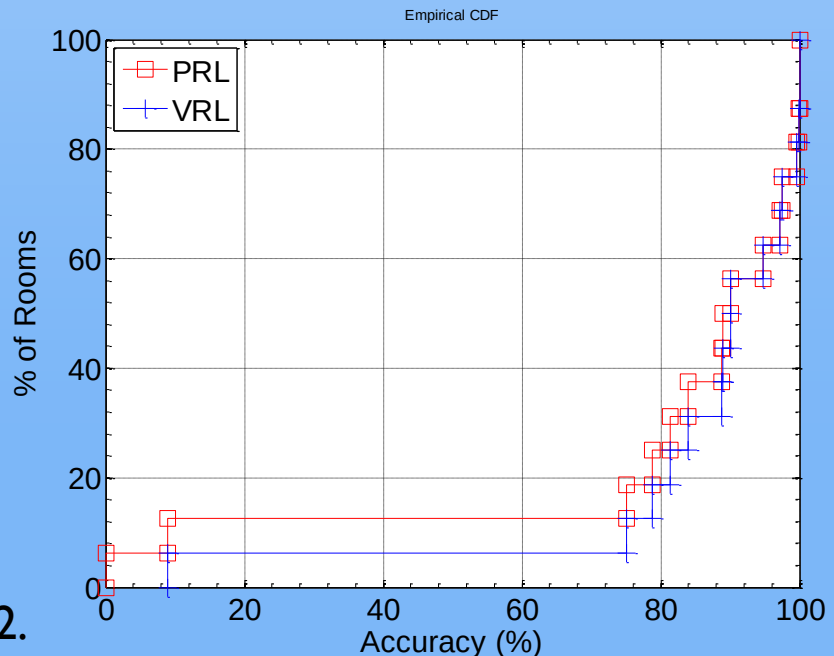
- Clustering accuracy
  - 93% using k-means when k=16
  - RSS stacking difference is better





Performance

- Mapping result
  - 15 out of 16 virtual rooms are correct
  - 14 out of 16 physical rooms are correct
- Localization accuracy
  - Average accuracy: 86%
  - Similar to SurroundSense
  - But without site survey!



M. Azizyan, et al "Surroundsense: mobile phone localization via ambience fingerprinting," in Proceedings of the ACM MobiCom, 2009, pp. 261–272.

Limitations & Discussion

Limitations

- Practical Data Collection
  - Differentiate data from indoor & outdoor
- Symmetry of floor plan graph (building)
  - Mapping limitations
  - Global reference points
  - Leverage more sensors: compass, gyroscope, etc.
- Building types:
  - Work for most office buildings, but may fail in large open environments, such as hall, atrium, gymnasium, or museum.

Future Work

- Physical floor plan construction
  - Remove the dependence on physical floor plan
  - Auto-generate the floor plan
- Sophisticated floor plan mapping
  - Advanced algorithms to achieve better accuracy
  - Move the framework to physical localization
- User behavior detection
  - Semantically meaningful localization

Conclusions

- WILL: a wireless indoor logical localization approach
- No site survey or knowledge of AP locations and power settings.

- WILL demonstrates its advantage on low human cost, a long-standing and universal will in wireless indoor localization.

Thank you!

Q&A