# Embracing Localization Inaccuracy: A Case Study

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FONDAZIONE BRUNO KESSLER

# Motivation

- Localization in wireless sensor networks has been studied for a decade now
  - Increasing complex localization techniques to achieve tens of cm accuracy
  - Use costly specialized hardware (UWB, Antenna arrays)
- Experiences from the real environments are still limited!

**Question: Is the high localization accuracy really required for common monitoring and surveillance applications?**

# Goals of This Work

- **Not** to propose yet another localization technique

- Evaluate localization techniques in a **real-world nursing home**
  - **Requirement are representative of diverse localization systems**

- Unveil the relationship between system level performance and application level objectives
  - **What a WSN geek want?** **vs.** **What an end user want?**

- To give guidelines to improve both the system level performance and end user satisfaction

**Ambient Assisted Living (ACube):**

**Goal:** Higher quality of life for impaired and elderly in nursing homes

**Services:** Monitoring to the medical support staff

**Testbed:** A single floor of a nursing home in Trento, Italy

- 10 Public spaces, 20 Patients, 4 Nurses

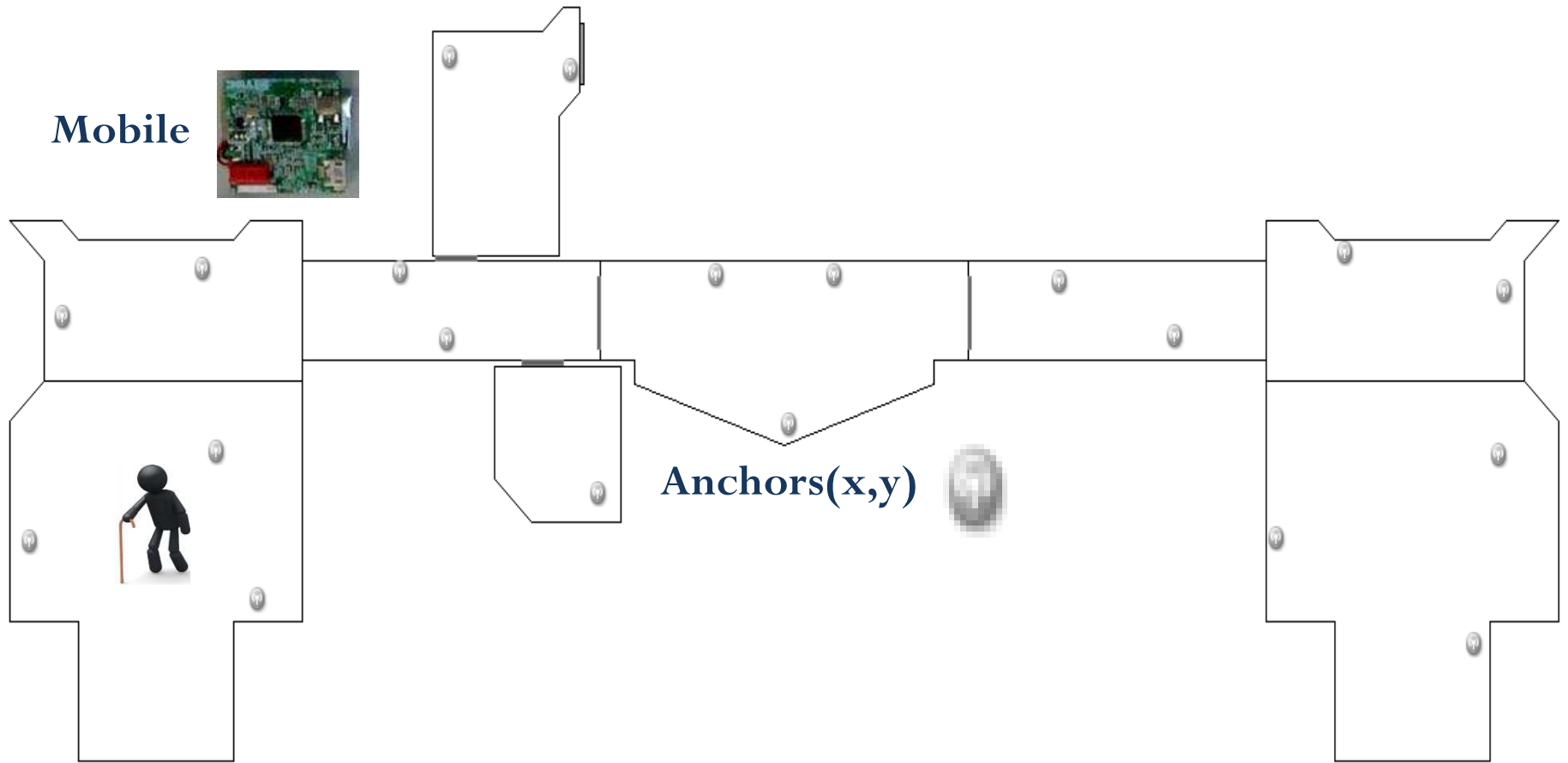# Monitoring in Nursing Homes - Services

- Doctors
  - **Offline** evaluation of patient movement
    - To assess the general health of the patient
    - To diagnose the progression of *Alzheimer's disease*

- Nurses
  - **Real time** use of **approximate** patient location
    - To find the patient
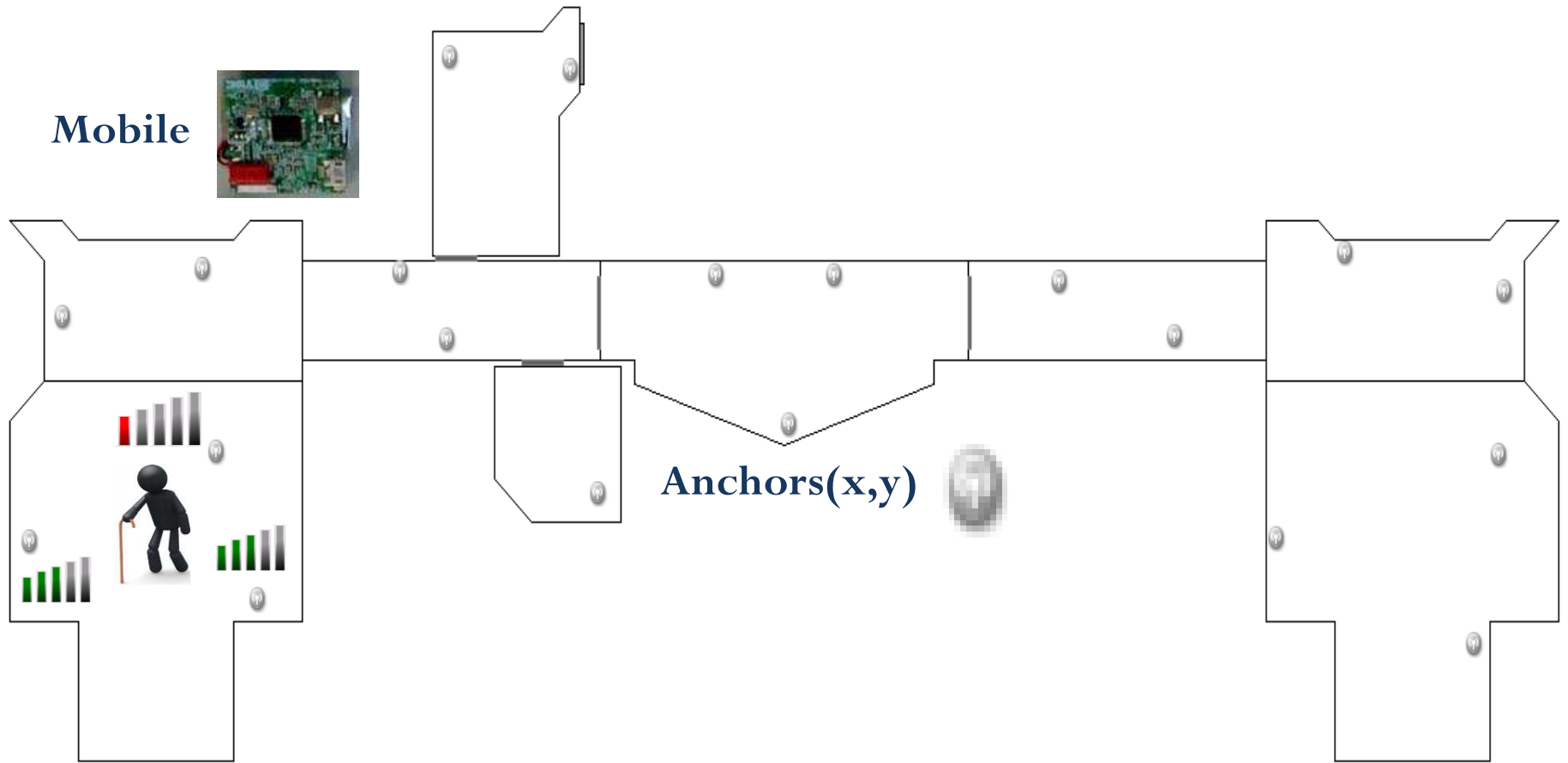    - To raise an alarm if patient leaves the facility

# WSN Localization -  Architecture

**Mobile**

**Anchors(x,y)**

| Proximity Detection | Localization Technique |
|---|---|

**Localization**

# WSN Localization - Architecture

**Mobile**

**Anchors(x,y)**

| Proximity Detection | Localization Technique |
|---|---|

**Localization**

# WSN Localization - Architecture

**Mobile**

**Anchors(x,y)**

*(x,y) (x,y)*
*(x,y)*

| Proximity Detection | Localization Technique |
|---|---|

**Localization**

# WSN Localization - Architecture

**Mobile**

**Anchors(x,y)**

| Proximity Detection | Localization Technique |
|:---:|:---:|

**Mobile(x,y)**

**Localization**

**Visualization**

# WSN Localization - Architecture

**Mobile**

**Anchors(x,y)**

**WSN geek** – How far is the estimate to the actual position?

**Nurse** – Does the visualization allows me to find the patient?
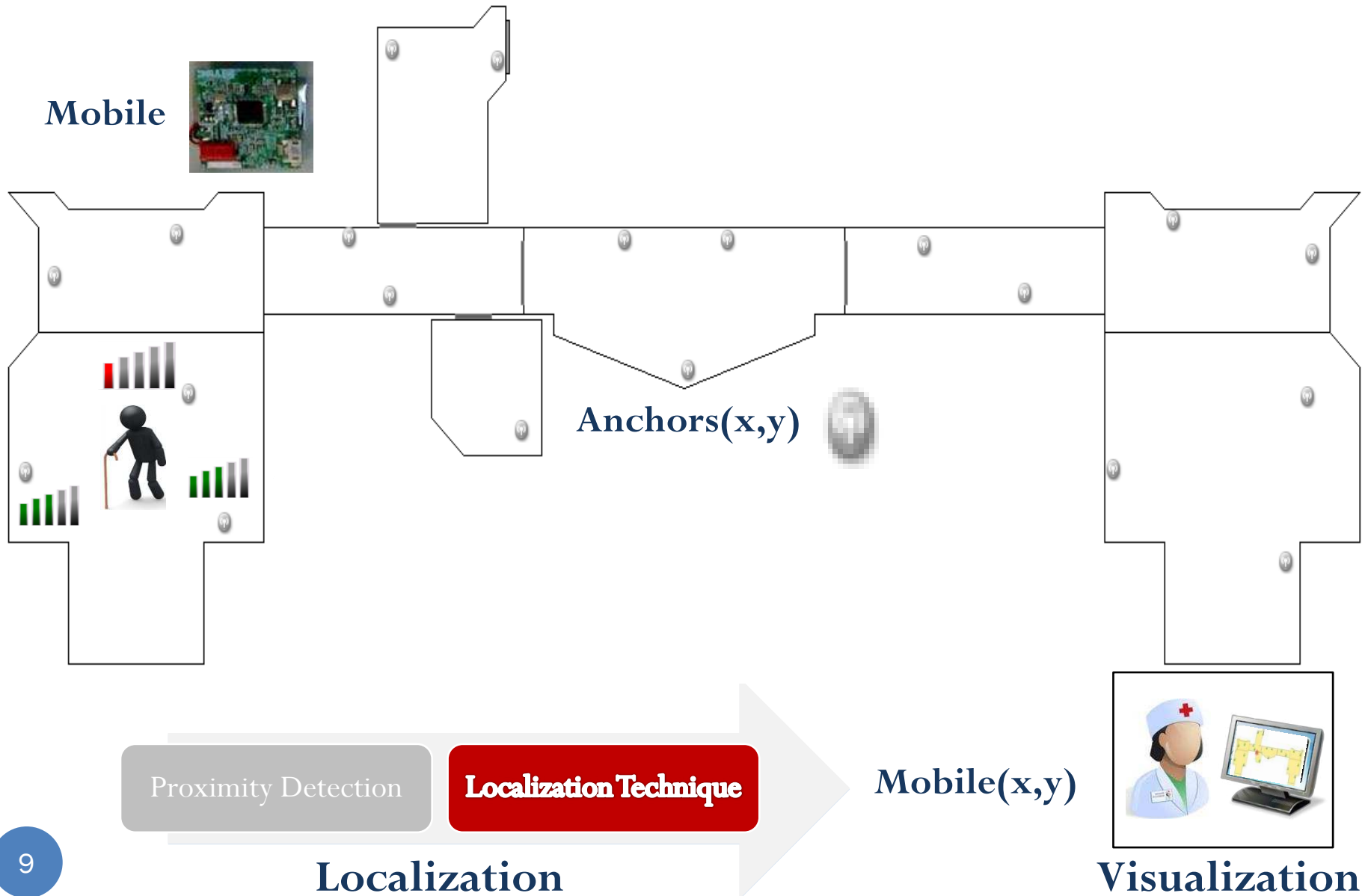
Proximity Detection | Localization Technique
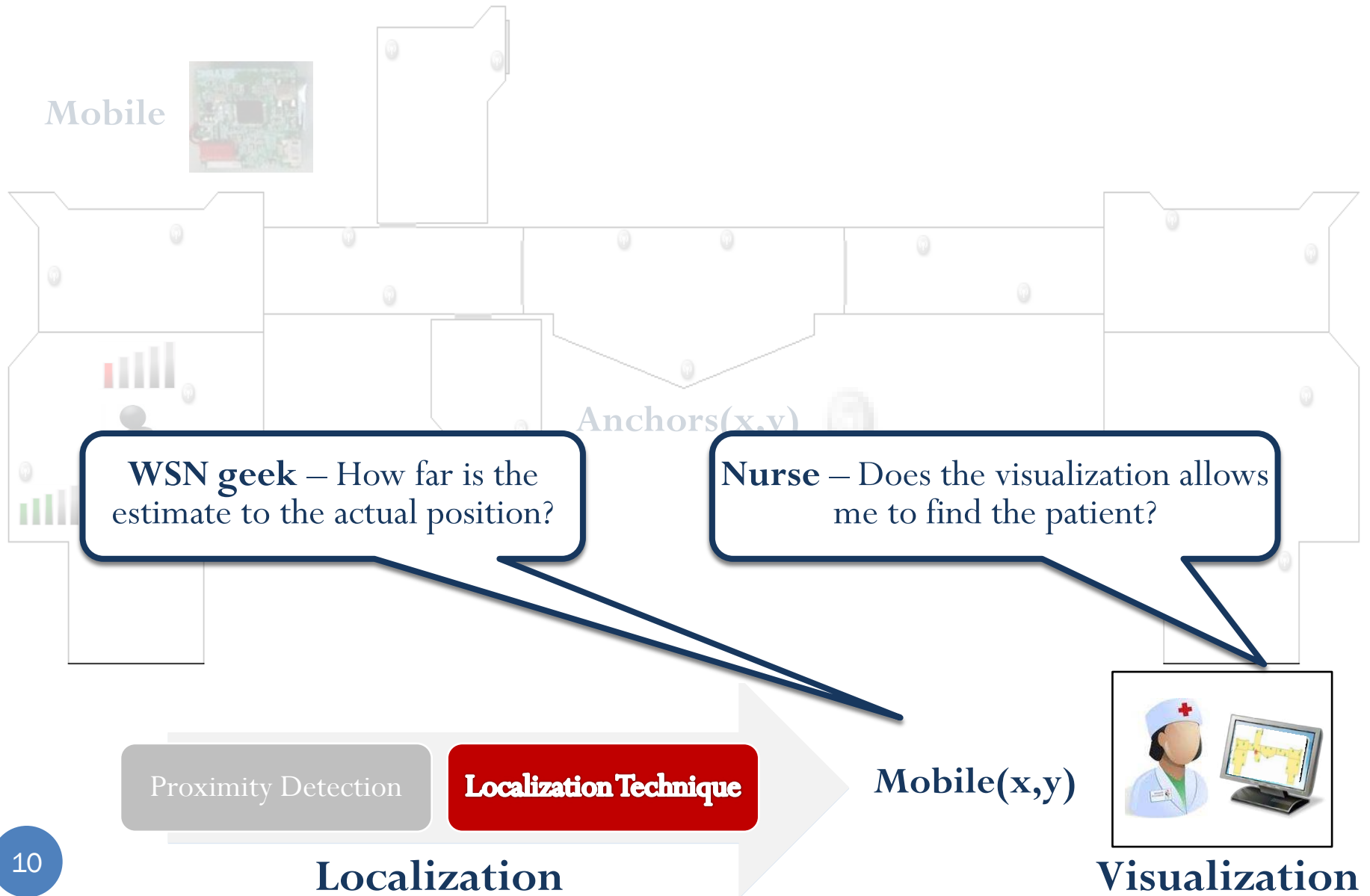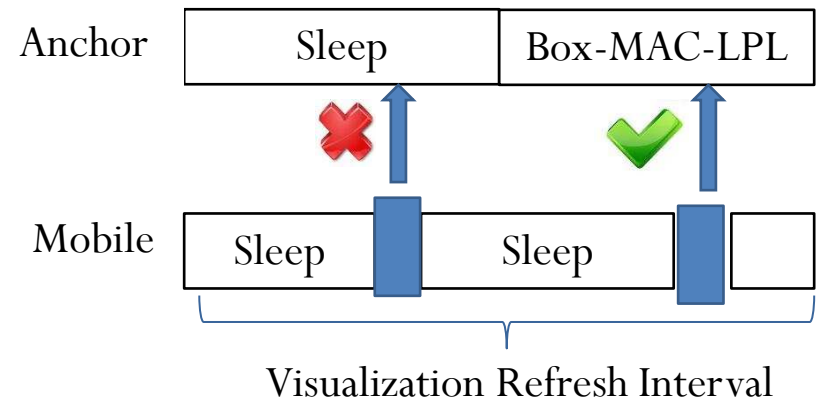
**Mobile(x,y)**

**Localization**

**Visualization**

# Localization
# Step 1– Proximity Detection

- Objective
  - Identify the proximity of the mobile patient to an anchor
- Requirement – Low maintenance
  - Energy Efficiency

- System Design
  - A custom proximity detection protocol

| Anchor | Sleep | Box-MAC-LPL |
|---|---|---|

| Mobile | Sleep | Sleep | |
|---|---|---|---|

Visualization Refresh Interval

**Lifetime  Anchors – 45 days (2 AA batteries)
Mobile – 5 days (1 coin battery)**

# Localization
# Step 2– Localization Techniques

- Max-RSSI Localization
  - Localizes patient at the anchor detecting proximity with maximum signal strength
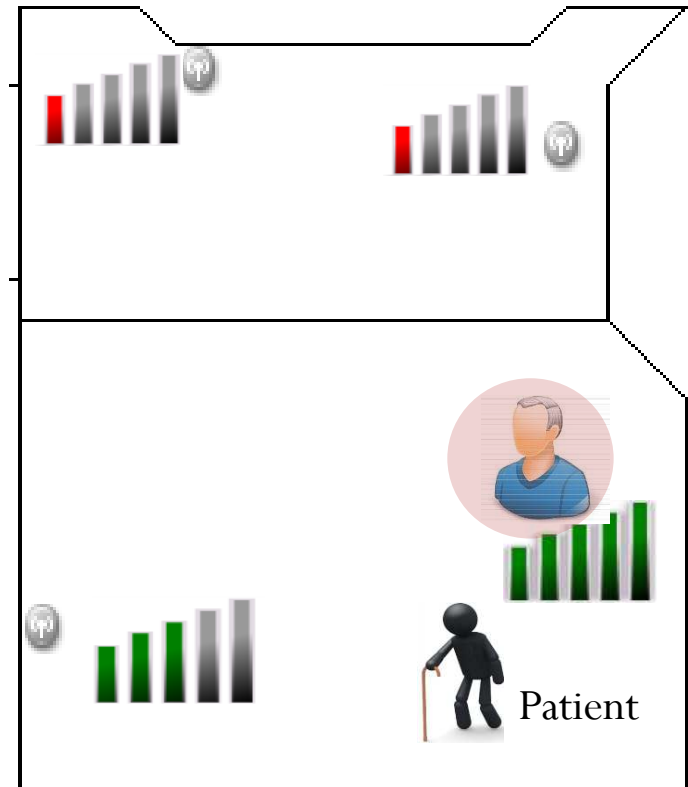


Patient

# Localization
# Step 2– Localization Techniques

- Max-RSSI Localization
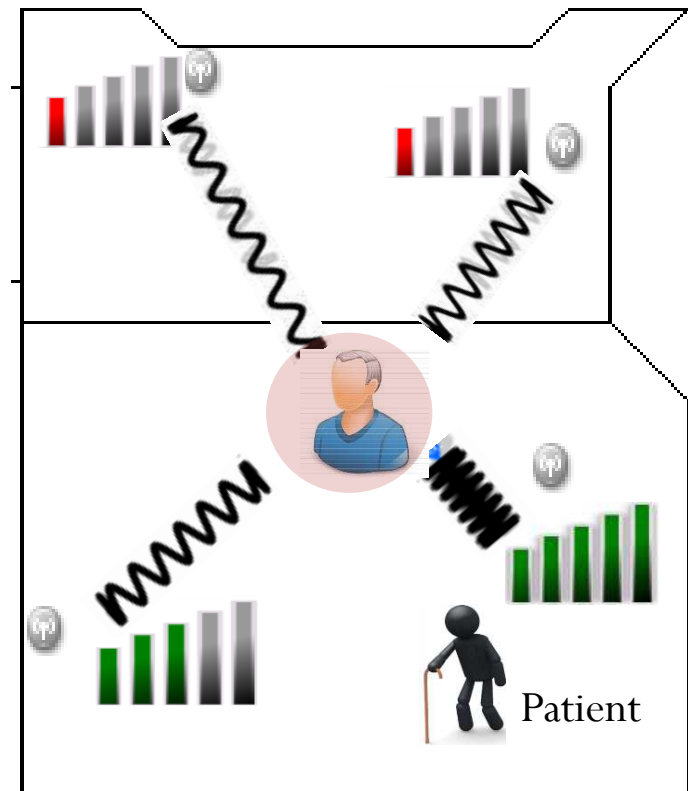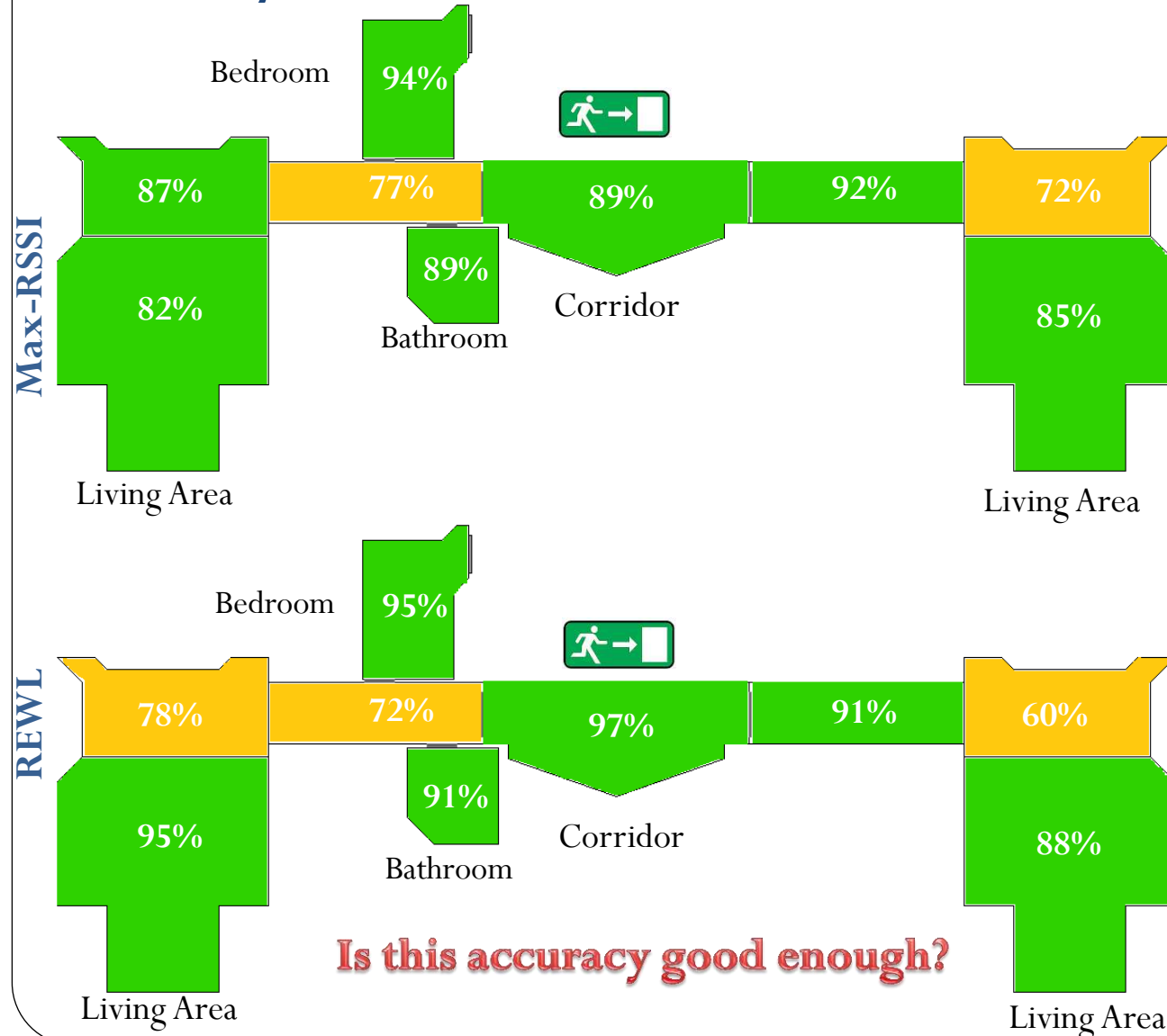  - Localizes patient at the anchor detecting proximity with maximum signal strength

- Relative Span Exponential Weighted Localization (REWL)
  - Localizes patient at **weighted centroid** of all anchor coordinates

Patient

# Experimental Evaluation

- System level: WSN geek's perspective
  - <u>Accuracy:</u> Percentage of time the patient is correctly detected in its current **area/room**

- Application level: Nurse's Perspective
  - Satisfaction level : moderate, fair, excellent!
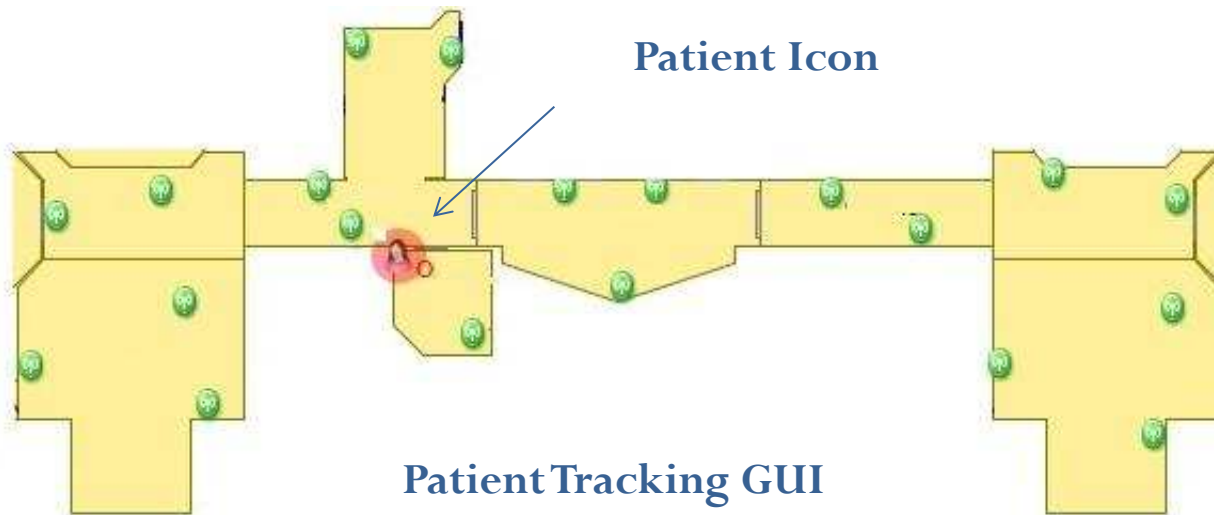
# System Level Evaluation - Accuracy

**Max-RSSI**

Bedroom **94%**

Living Area **87%** | **77%** | **89%** | **92%** | **72%**

**89%** Bathroom

Corridor

**82%**

Living Area **85%**

**REWL**

Bedroom **95%**

**78%** | **72%** | **97%** | **91%** | **60%**

**91%** Bathroom

Corridor

Living Area **95%**

Living Area **88%**

*Is this accuracy good enough?*

- Reasonable accuracy
- No clear winner
- REWL outperforms in key areas e.g. living and exit areas

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# Application Level Evaluation - Methodology

- Operator was asked to **evaluate** multiple localization and visualizations
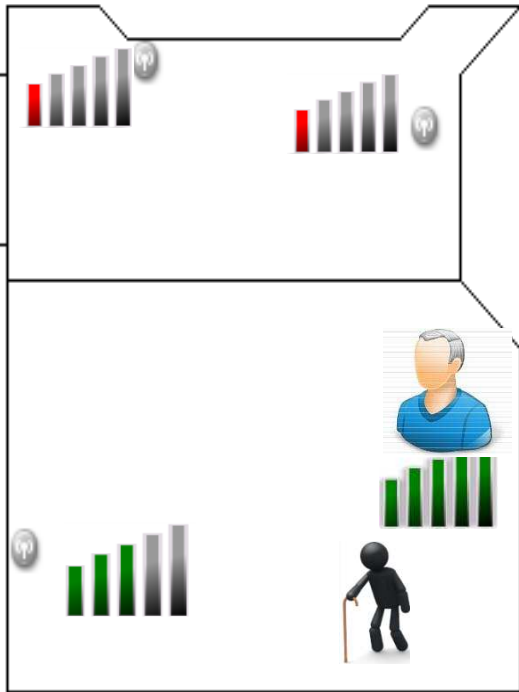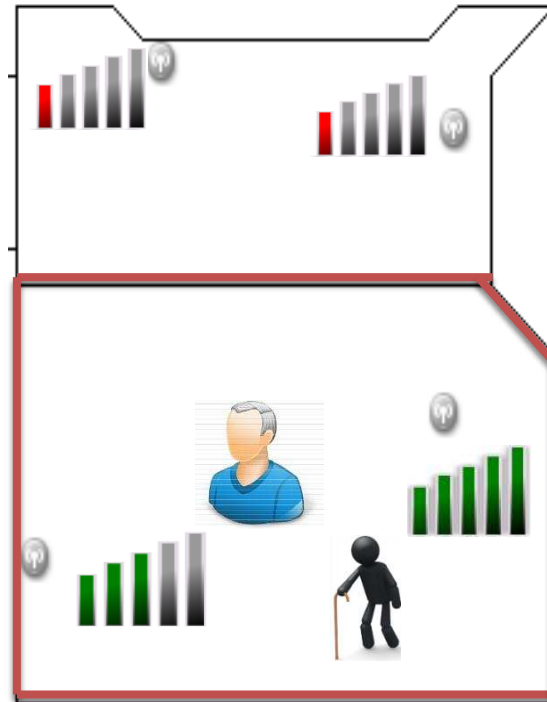  - Find the patient
  - Raise an alarm

Patient Icon

Patient Tracking GUI

Nurse

# Application Level Evaluation - Results

**Max RSSI – at anchor**

**Max RSSI– at room center**

**REWL – at x,y**
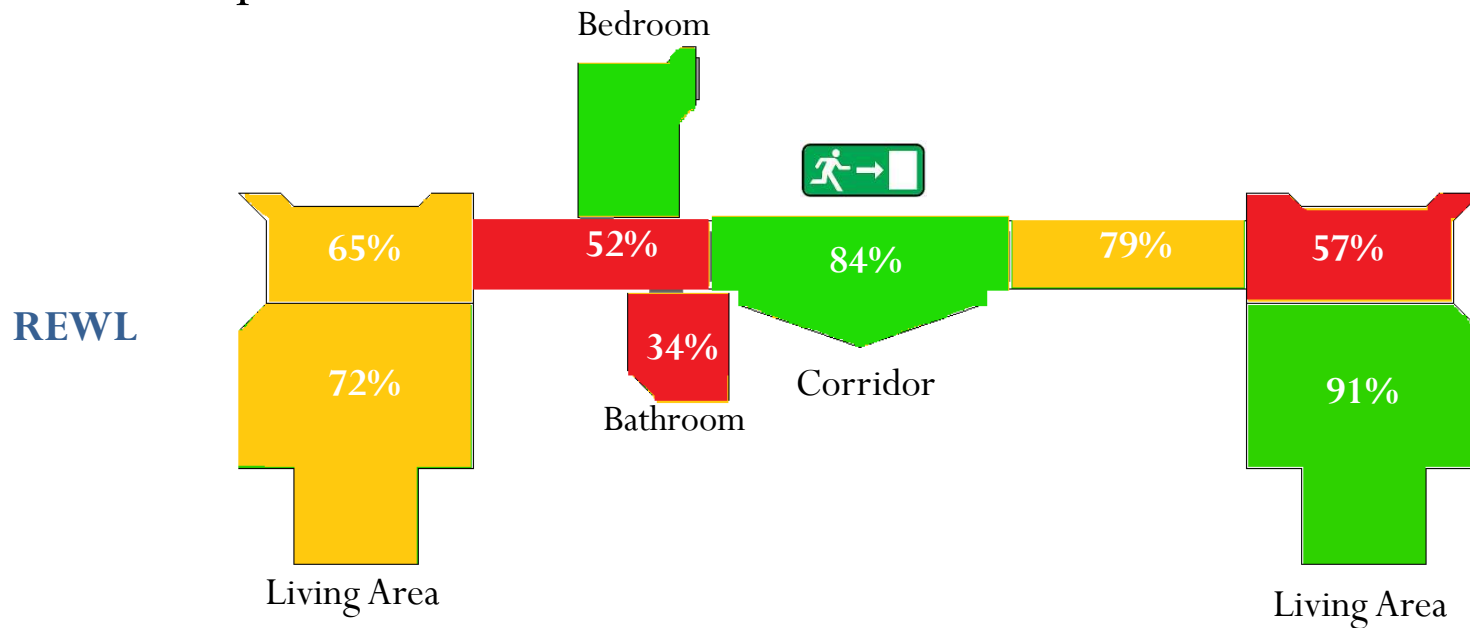


**Moderate**

**Fair**
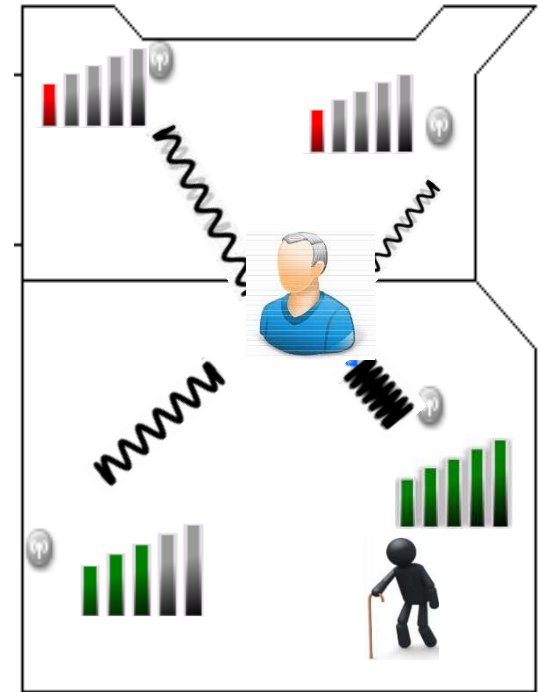
**Excellent!**

**Quality of localization system depends heavily on the visualization**

# Application Level Evaluation - Results

- **Experience with our Initial deployment:**
  - Low accuracy
  - Positive qualitative evaluation



**REWL**

Bedroom

65%  52%  84%  79%  57%

72%  34%  91%

Bathroom  Corridor

Living Area  Living Area

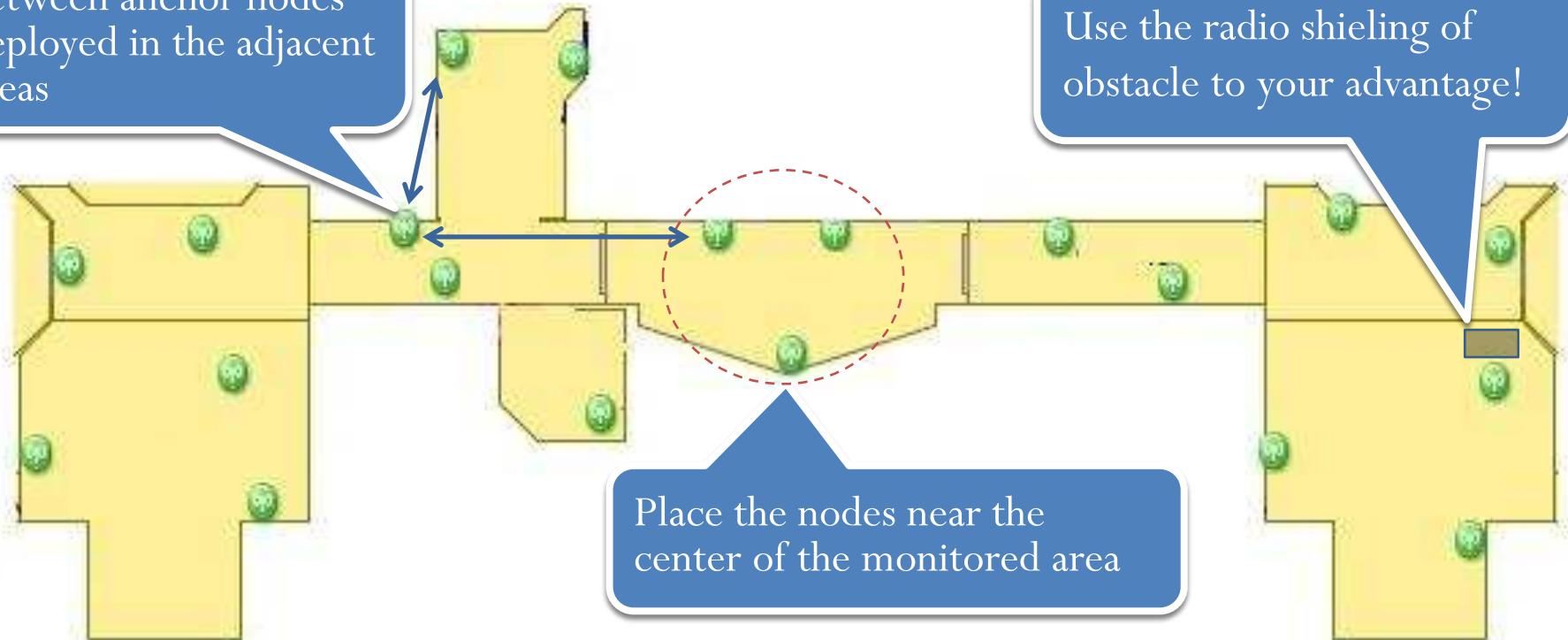**Low Accuracy ≠ Unacceptable solution to end user**

# Guidelines for Anchor Placement

- **<u>Principle:</u>** Minimize the likelihood of signal reception across the monitored areas



Maximize the distance between anchor nodes deployed in the adjacent areas

Use the radio shieling of obstacle to your advantage!

Place the nodes near the center of the monitored area

# Conclusion

**Question:  Is high localization accuracy really required for common monitoring and surveillance applications?**

**Answer**

- Simple low cost localization system is enough for many applications
- Low accuracy can still be acceptable to end user

# Thank You!

Usman Raza, Amy Murphy, Gian Pietro Picco, "Embracing Localization Inaccuracy – A Case Study ", April 2013, IEEE International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP),  Melbourne, Australia

Full Text (Pre-print) : http://disi.unitn.it/~raza/Papers/DISI_TR_12_038.pdf