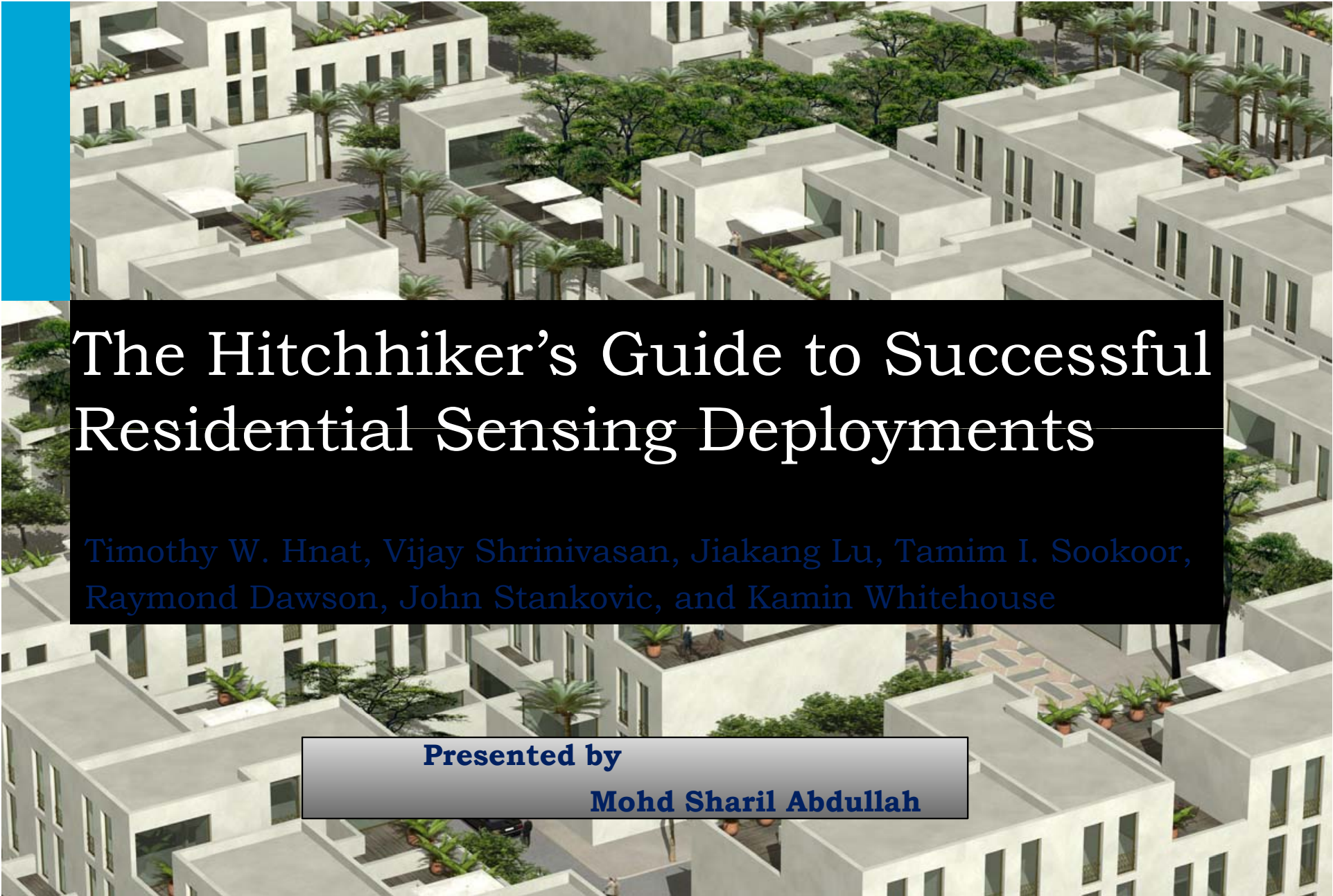




# The Hitchhiker's Guide to Successful Residential Sensing Deployments

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**Presented by**

**Mohd Sharil Abdullah**

# Smart Home

Energy Monitoring

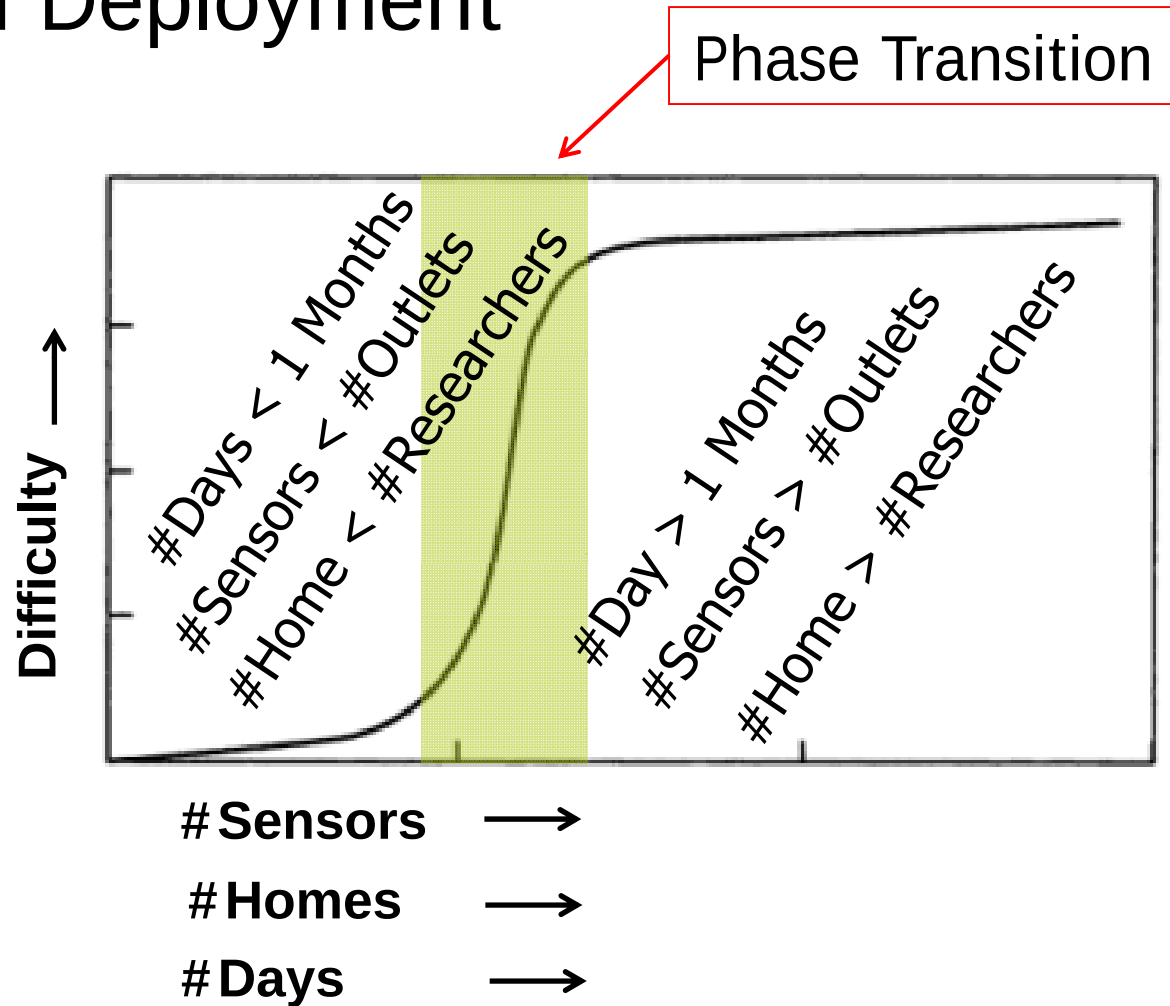


[ <http://rashapictures.com/smart-house-systems/> ]

**People spend 65 % of time in their homes**

# Challenges in Deployment

- 1200 sensors
- More than 20 homes
- 1 week to 12 Months





# Outline

- Overview of Residential Deployments
- Reliability and Failure Analysis
- A Hitchhiker's Guide
- Conclusion

# Sensors In Homes



Light Switch Sensors



Doorway  
Sensors

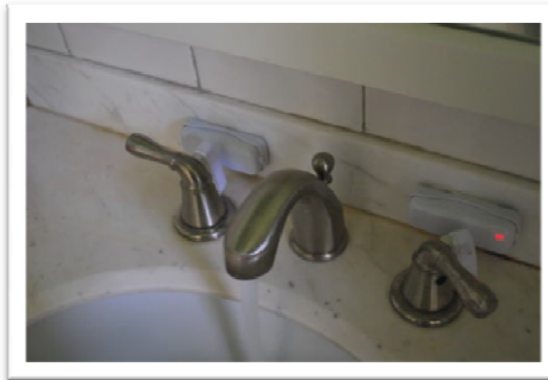


Plug Load Monitor



Water Flow Meter

# Sensors In Homes

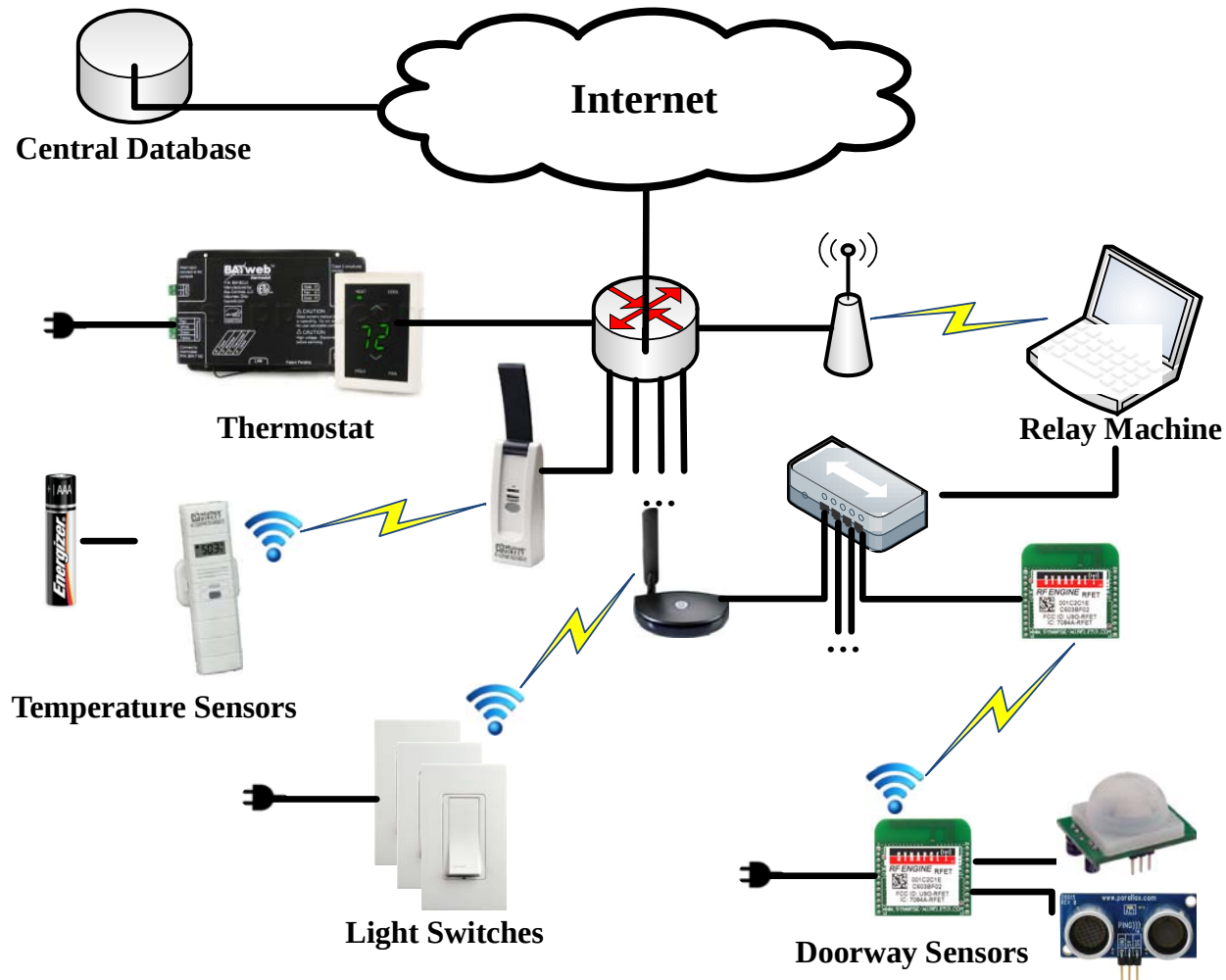


Reed Switches on  
Water Fixtures



Active Registers

# The Architecture of System



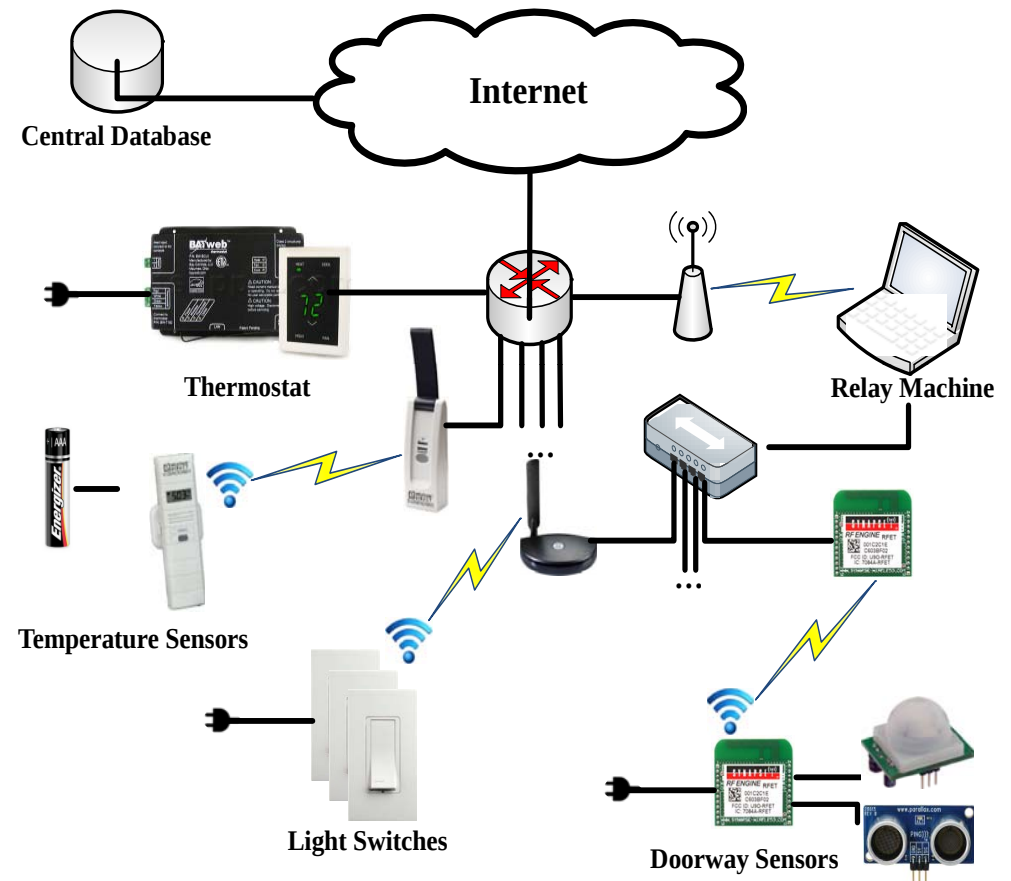
| Deployment | # Homes | Weeks | Motion | Object Use | Door<br>Leakage | Wearable<br>Tracking | Light<br>switch | Power<br>(Blue) | Power<br>(Circuit) | Power<br>(Main) | Water<br>Main | Custom<br>Thermometer | Active<br>Detector | Light/Temp<br>Humidity |
|------------|---------|-------|--------|------------|-----------------|----------------------|-----------------|-----------------|--------------------|-----------------|---------------|-----------------------|--------------------|------------------------|
| A          | 11      | 1-2   | 25-30  | 12-20      | -               | -                    | -               | -               | -                  | -               | -             | -                     | -                  | -                      |
| B          | 1       | 1     | -      | -          | 12              | 12                   | -               | -               | -                  | -               | -             | -                     | -                  | -                      |
| C          | 3       | 3-4   | 15-25  | -          | -               | -                    | -               | -               | -                  | -               | -             | -                     | -                  | 12-25                  |
| D          | 1       | 2     | 4      | -          | -               | -                    | -               | 2               | -                  | -               | -             | -                     | -                  | -                      |
| E          | 1       | 2     | 5      | -          | -               | -                    | -               | -               | 1                  | -               | -             | -                     | -                  | -                      |
| F          | 1       | 28    | 65     | 13         | 13              | 16                   | 22              | -               | -                  | 1               | 1             | 1                     | 12                 | 86                     |
| G          | 1       | 44    | 54     | 7          | 31              | 14                   | 22              | 8               | 37                 | 1               | 1             | 1                     | 12                 | 29                     |
| H          | 1       | 39    | 15     | 7          | 14              | -                    | 11              | 4               | -                  | 1               | 1             | -                     | -                  | -                      |
| I          | 1       | 32    | 25     | 10         | 30              | -                    | 31              | 3               | 48                 | 1               | 1             | -                     | -                  | 8                      |
| J          | 1       | 25    | 14     | 5          | 17              | -                    | 7               | 2               | -                  | 1               | 1             | -                     | -                  | -                      |

# Outline

- Overview of Residential Deployments
- **Reliability and Failure Analysis**
- A Hitchhiker's Guide
- Conclusions

# Root Causes of FAILURES

- Wireless Link Loss
- Battery Dead
- Plug Disconnected
- Sub-system Down
- Internet Down
- Power Outage
- Gateway Down



# Total Sensor Down Time

## Jan 1 - Aug 1, 2011 (7 Months)

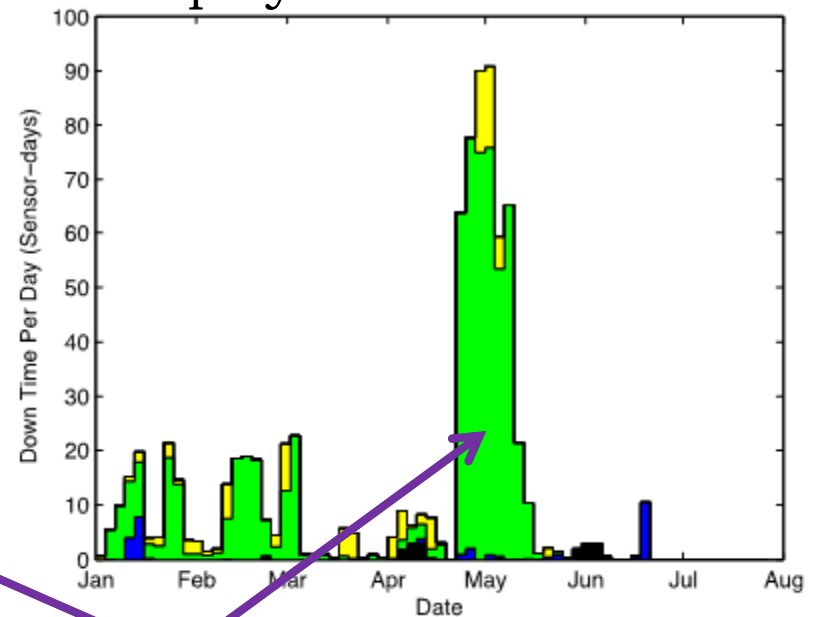
| Root Cause         | House G | House H | House I | House J |
|--------------------|---------|---------|---------|---------|
| Sensing Sub-System | 4107    | 642     | 4757    | 274     |
| Gateway Down       | 5596    | 0       | 3       | 136     |
| Plug Disconnected  | 509     | 30      | 474     | 10      |
| Battery Dead       | 452     | 17      | 168     | 0       |
| Wireless Link Loss | 410     | 0       | 122     | 1       |
| Internet Down      | 251     | 97      | 178     | 9       |
| Power Outage       | 21      | 0       | 87      | 2       |

**Sensor-Days** = down time × number of sensors

# Fault Analysis

Deployment – House G

Deployment – House H



Gateway Down

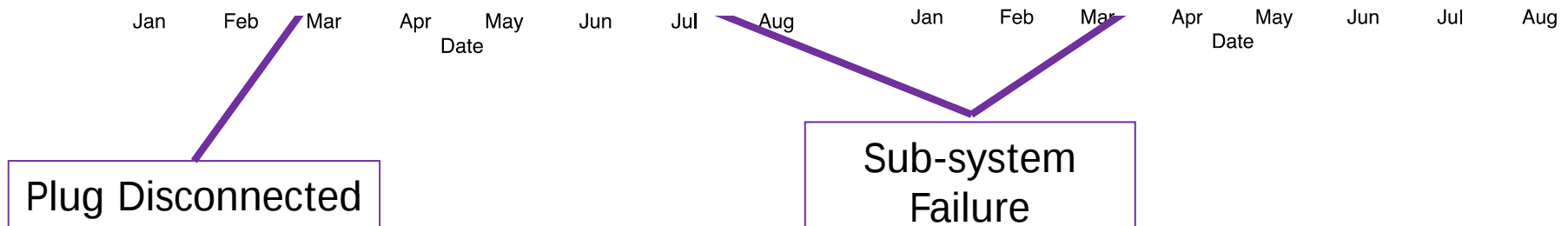
Sub-system  
Failure

# Fault Analysis

Deployment – House I

Deployment – House J

ay



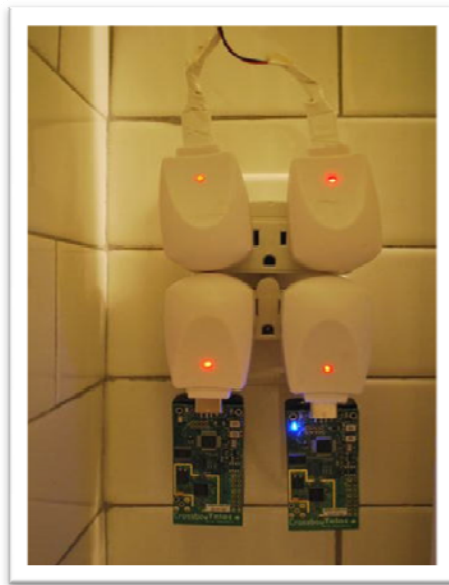
# Outline

- **A Hitchhiker's Guide**

- Homes Are Not A Power Panacea
- Homes Have Poor Connectivity
- Homes Are Hazardous Environments
- Homes Are Remote Environments
- Expect Limited User Participation
- Aesthetics Matter In Homes
- Simplify The Architecture

# Homes Are Not A Power Panacea

MYTH : Sensors in homes **can easily be powered** using the **wall socket**



- Wall Sockets
- In-line Power
- Indoor Solar

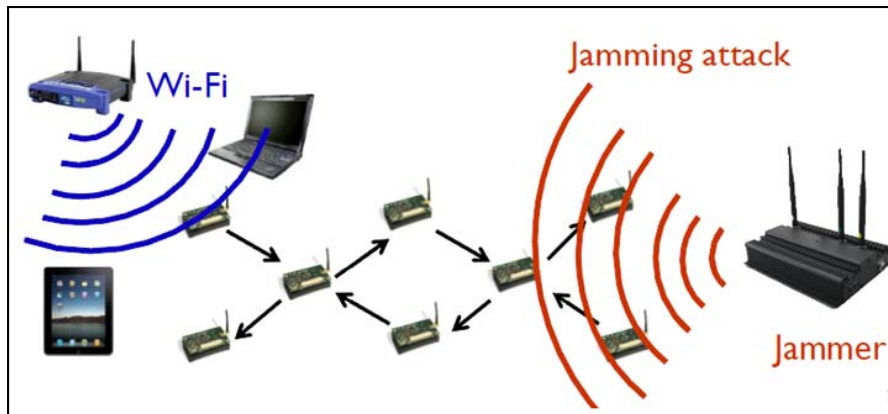


FACT : Wall sockets provide neither **abundant** nor reliable power, especially when **deploying hundreds of nodes**

# Homes Have Poor Connectivity

MYTH: **Communication** in homes can be achieved with **single-hop wireless and/or power line modems**

Wireless Coverage



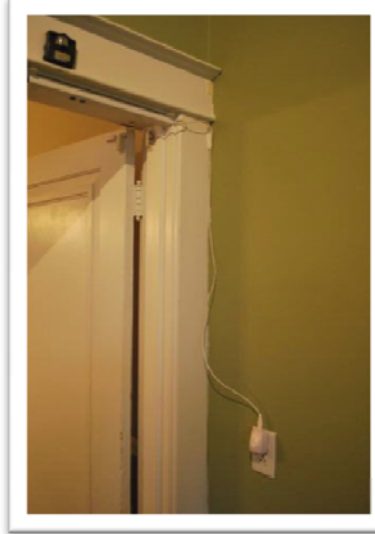
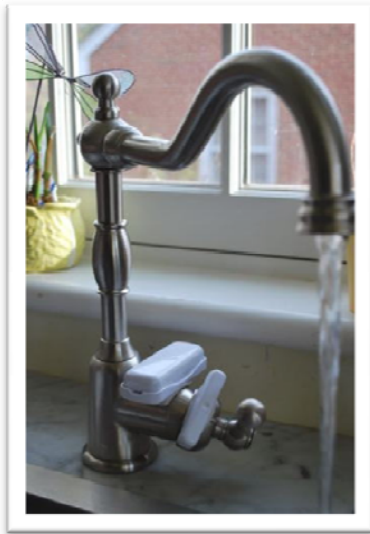
Power Line Communications



FACT: Homes are small but can still be **challenging RF environments**, particularly for **large-scale, dense, and heterogeneous networks**

# Homes Are Hazardous Environments

MYTH: **Robust** enclosures are only **important** for **extreme outdoor environments**.



FACT: Homes are **safe** environments for **humans** but can be **hazardous** for **sensors**.

- Children
- Mobile objects
- Roomba
- Guests and cleaning services

# Homes Are Remote Environments

MYTH: Maintenance visits are not a problem for homes



- ✓ Custom Tailor Each Deployment
- ✓ Test Three Times

FACT: Investigators have very limited access to deployments not in their own homes

# Expect Limited User Participation

MYTH: Users can help **maintain** the system and **provide** validation data



- ✓ Tracking
- ✓ Self-Reporting
- ✓ Survey

FACT: A user's **ability to monitor** and **report activities** in the home **is limited** by the need to do those activities, particularly in **long-duration deployments**

# Aesthetics Matter In Homes

MYTH: Users **won't mind a few sensors** around the house

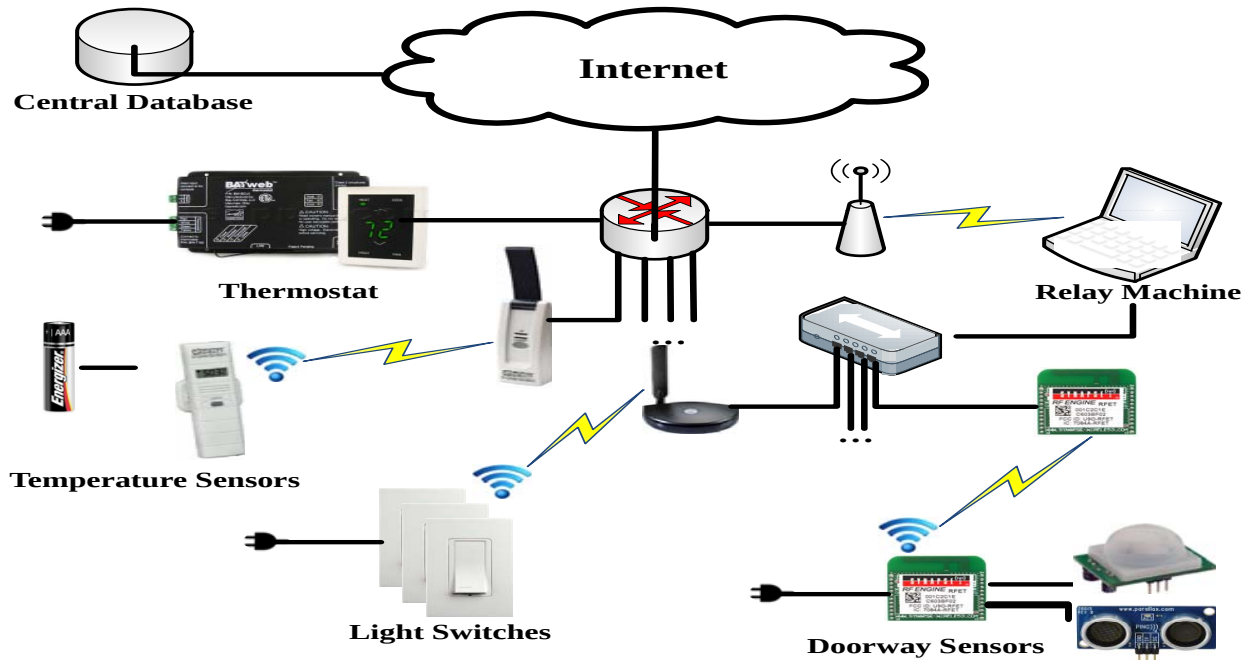


- ✓ Invisible structure
- ✓ Leave No Trace
- ✓ No LEDs at Night
- ✓ No Noise

FACT: **Aesthetics** constrain deployments, especially at **large scale** and over **long time** durations

# Simplify The Architecture

MYTH: **Industry** has already produced a wide range of **Suitable residential sensing systems**.



FACT: Many **Commercial Off-The-Shelf** devices were **not** designed for **large scale** deployments, and **integration** of many COTS platforms **increases** the possible modes of system failure.

# Outline

- Overview of Residential Deployments
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- **Conclusions**

# Conclusions

- Deployment of 1200 sensors over 20 home contributes to a set of guidelines that can be prevented other researcher to repeat same mistakes
- Indoor and outdoor sensing have a common challenges:
  - Scale
  - Realities of a hazardous environment
  - Limited Access
  - Energy Management
  - Wireless Communication
- Sensor deployment activities on site is more difficult than installing sensors in a lab or testbed.
- Large scale and long-duration of deployment make sensing activities become more challenging.

# Q & A Session

