Challenges of Large-Scale Smart Home Studies

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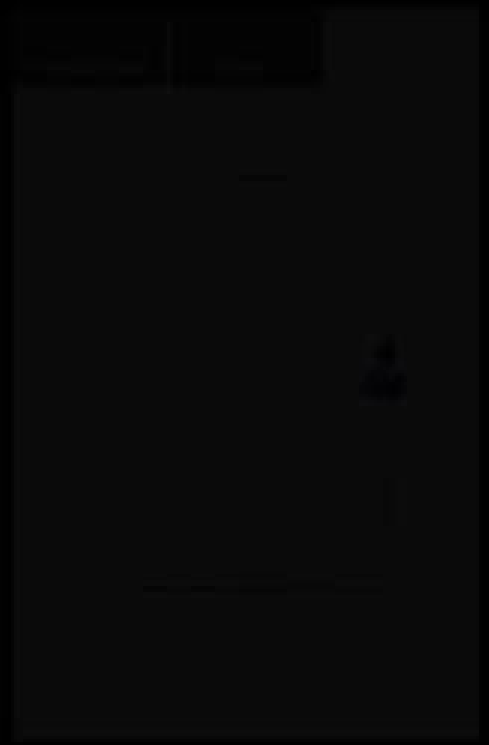
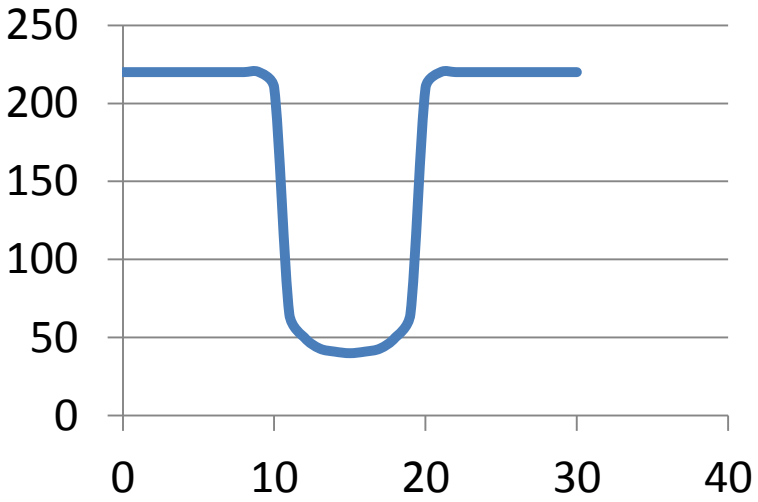
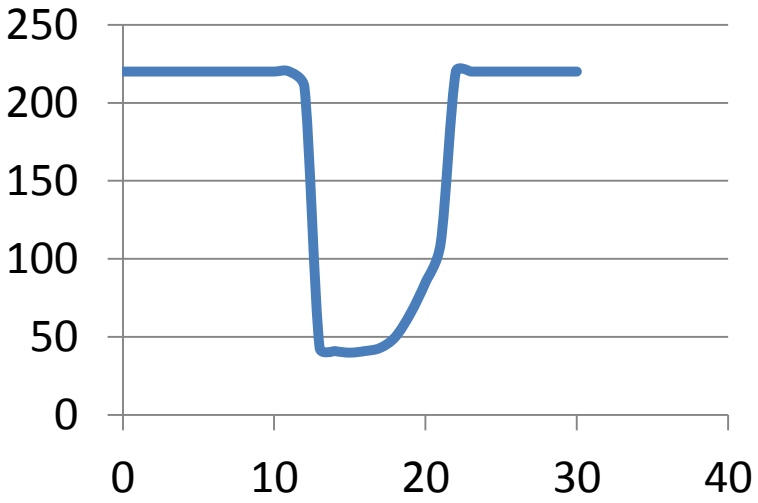
U. Virginia

Micoroft Faculty Summit
July 15, 2013



Door
Temperature
Motion
Ultrasound
Magnetometer
Light


250
200
150
100
50
0
0
10
20
30
40


250
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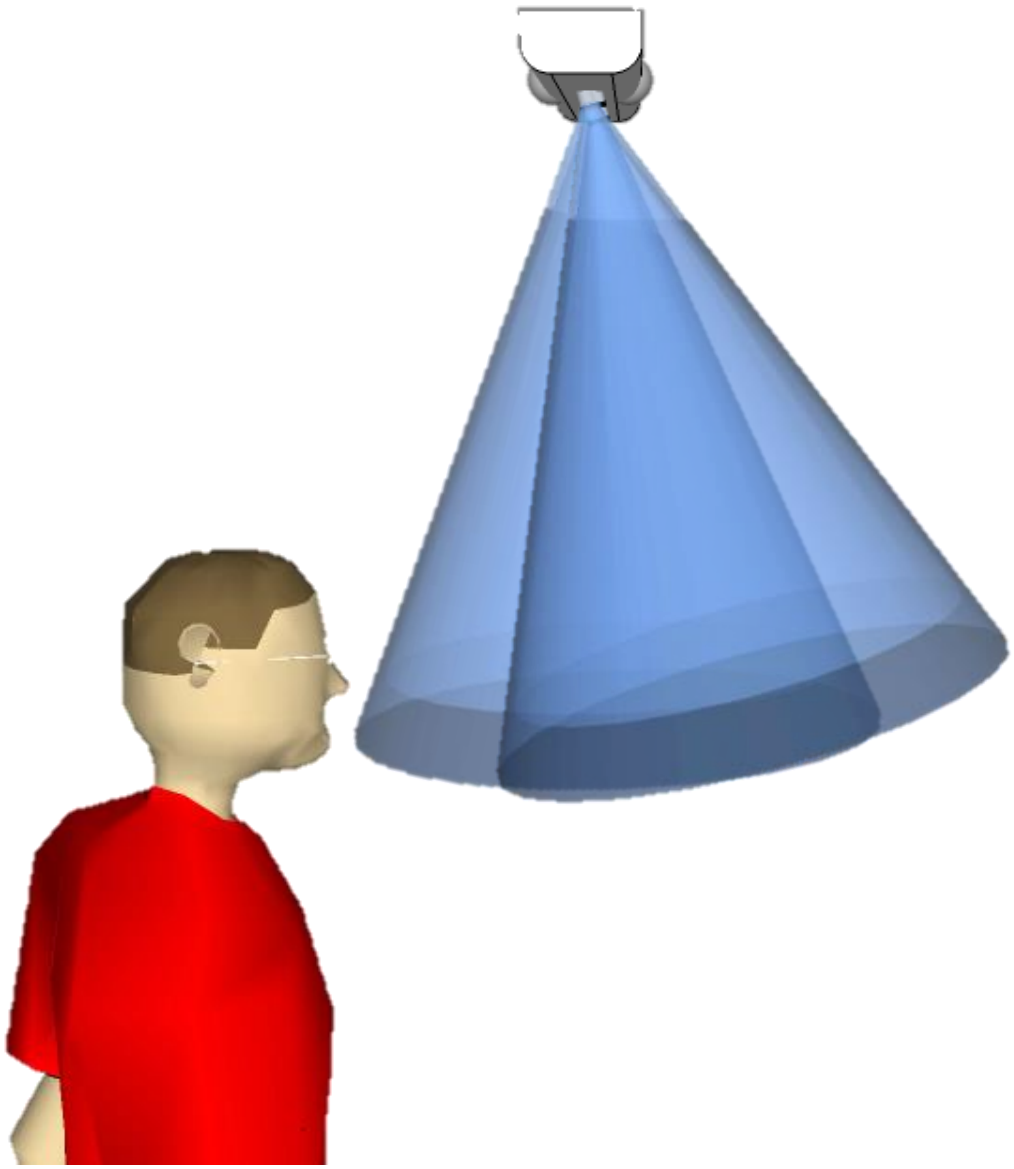

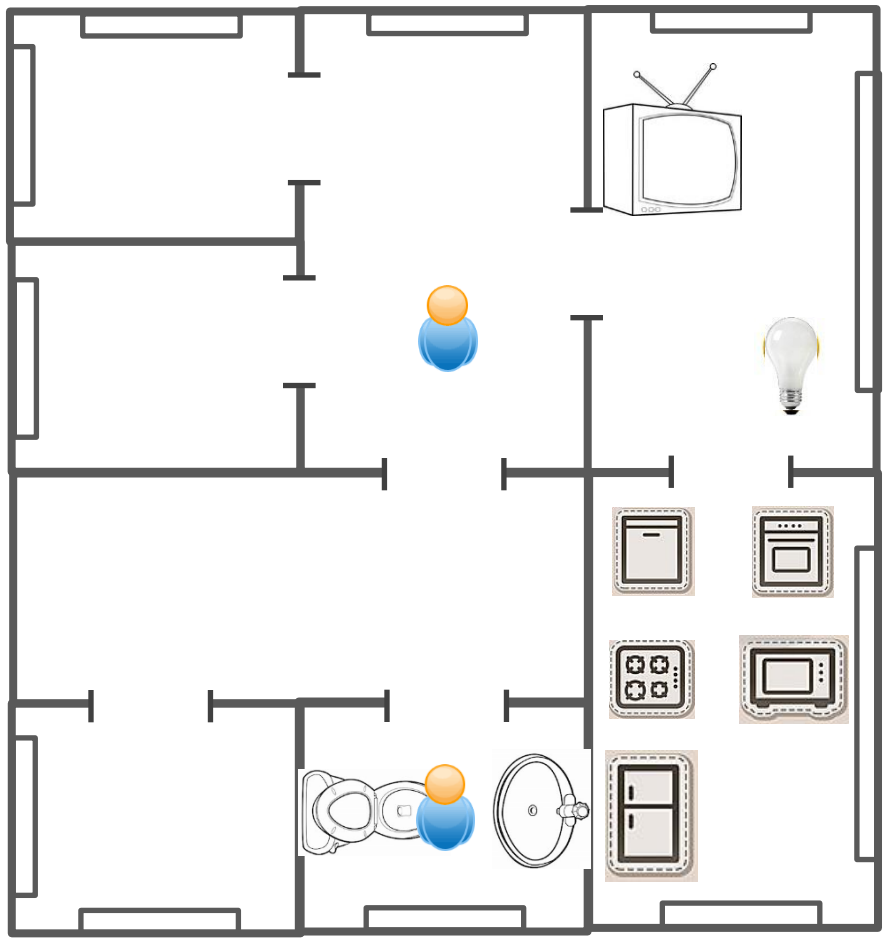

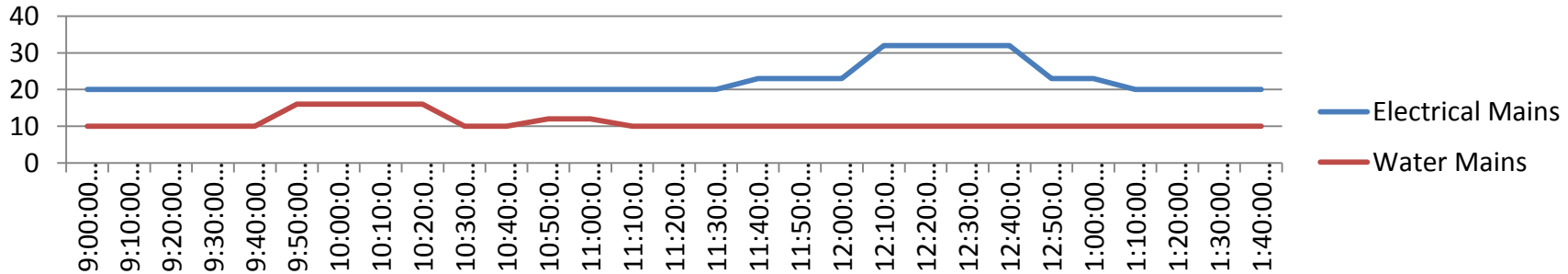
40
30
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0
9:00:00...
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12:30:0...
12:40:0...
12:50:0...
1:00:00...
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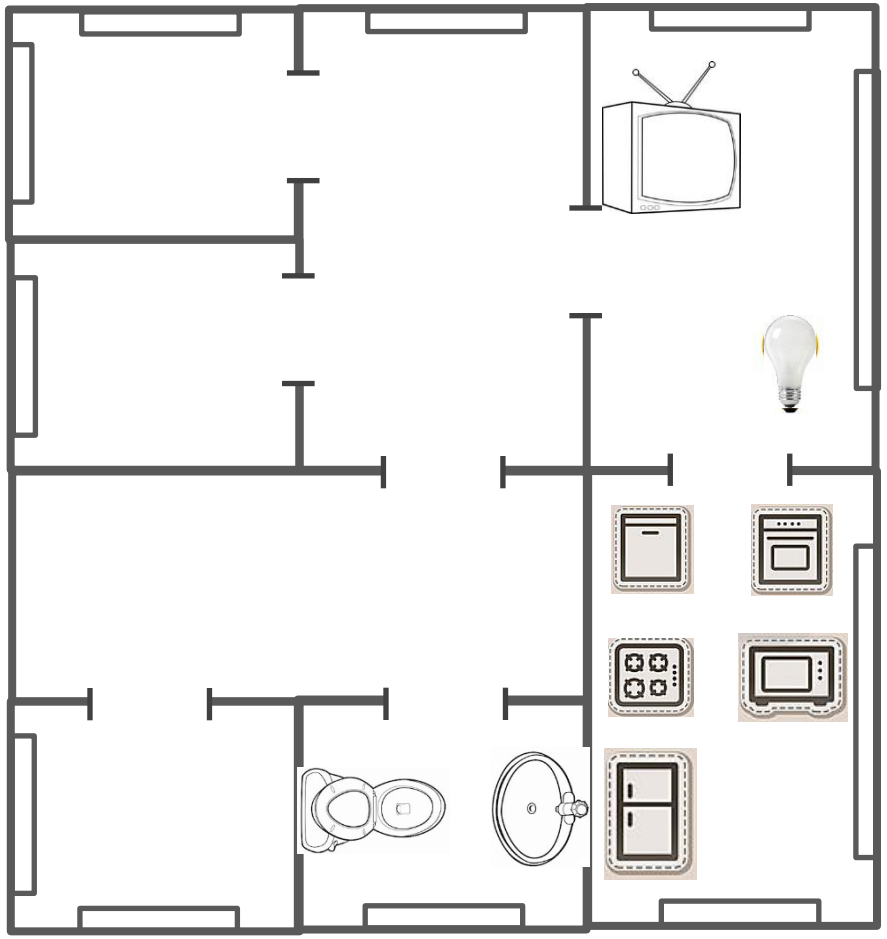
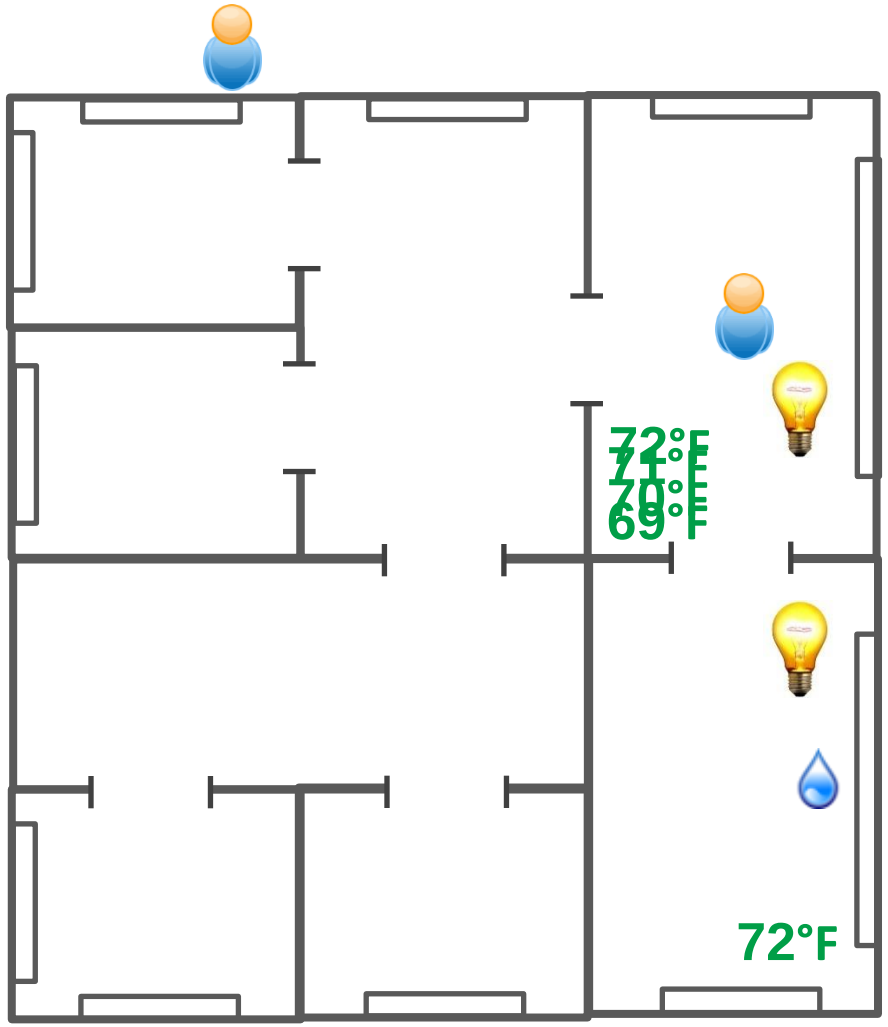
1:30:00...
1:40:00...
Electrical Mains
Water Mains

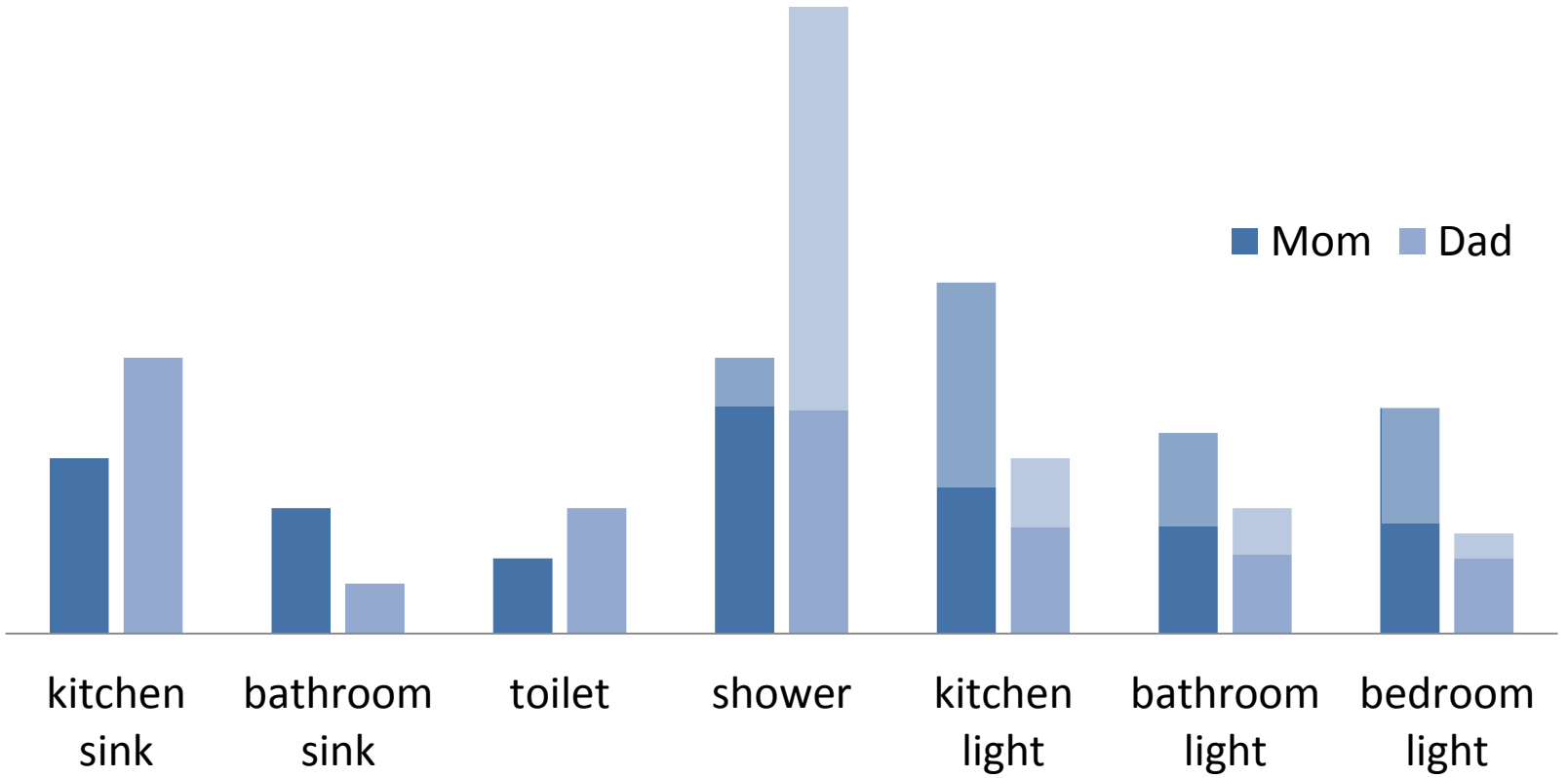


Living Room

Kitchen

Bathroom


72°F
71°F
70°F
69°F
72°F


Mom
Dad
kitchen sink
bathroom sink
toilet
shower
kitchen light
bathroom light
bedroom light

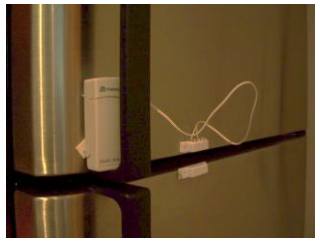
~15

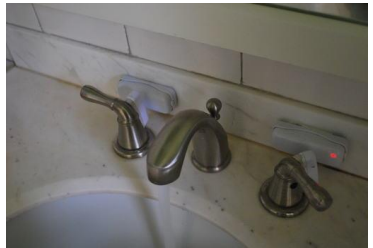
from http://www.theenergydetective.com

from http://www.shenitech.com

~190

~100





from http://www.theenergydetective.com

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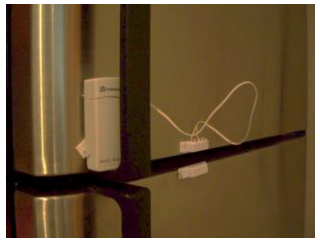
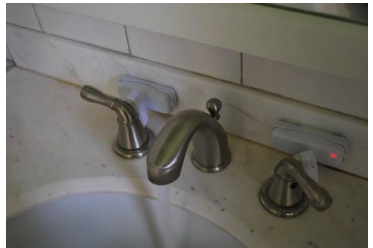




More than:

1200 Sensors

20 Homes

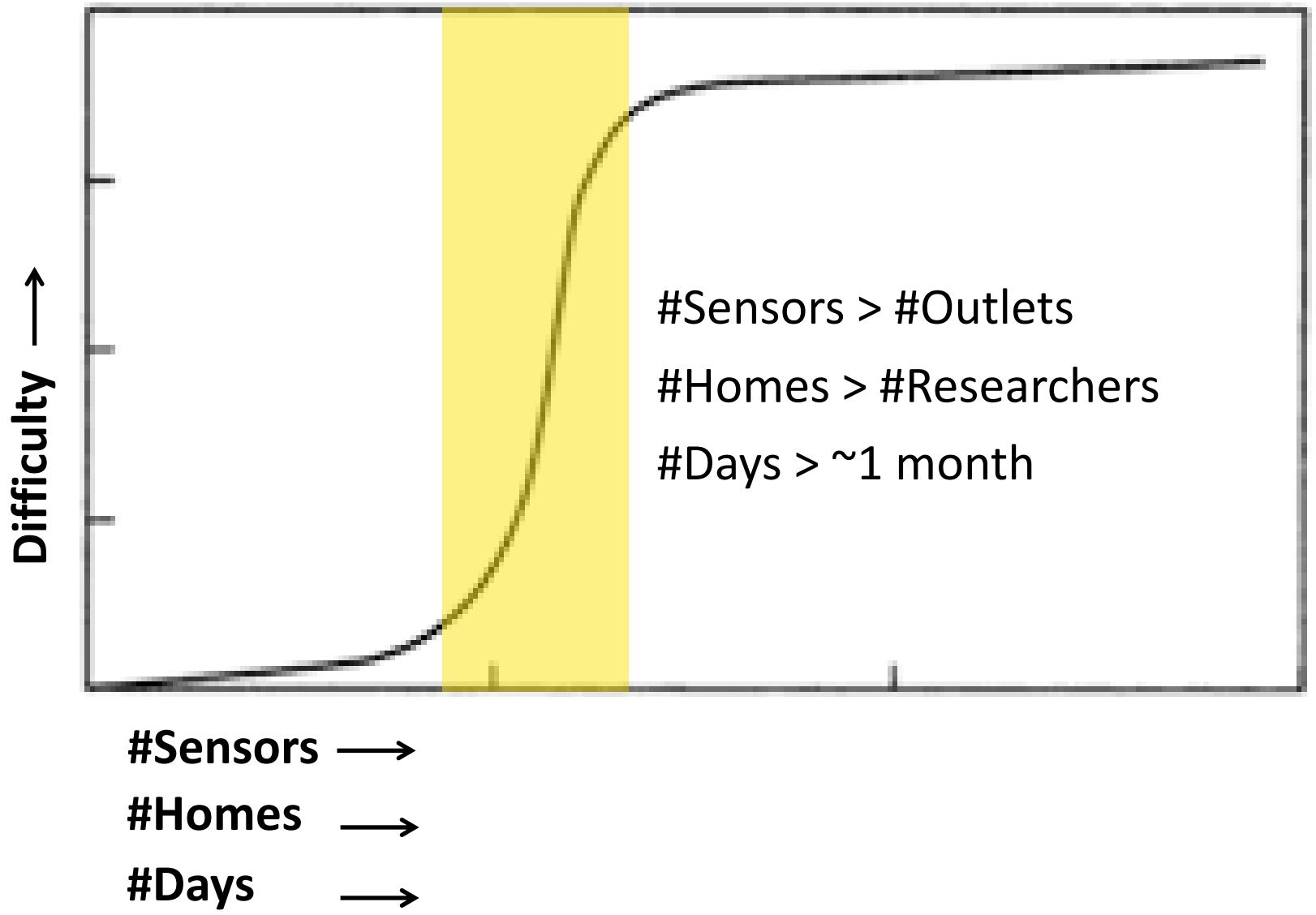
1 year

Indoor Sensor Networks?

Outdoor Deployment

Photo courtesy of: Jan Beutel

Indoor Deployment


Difficulty →
#Sensors > #Outlets
#Homes > #Researchers
#Days > ~1 month
#Sensors →
#Homes →
#Days →

Scaling #Sensors

Homes are Not a Power Panacea

- 30-40 outlets per house
- Long wires
- 2.3x more down time than batteries

- More maintenance calls

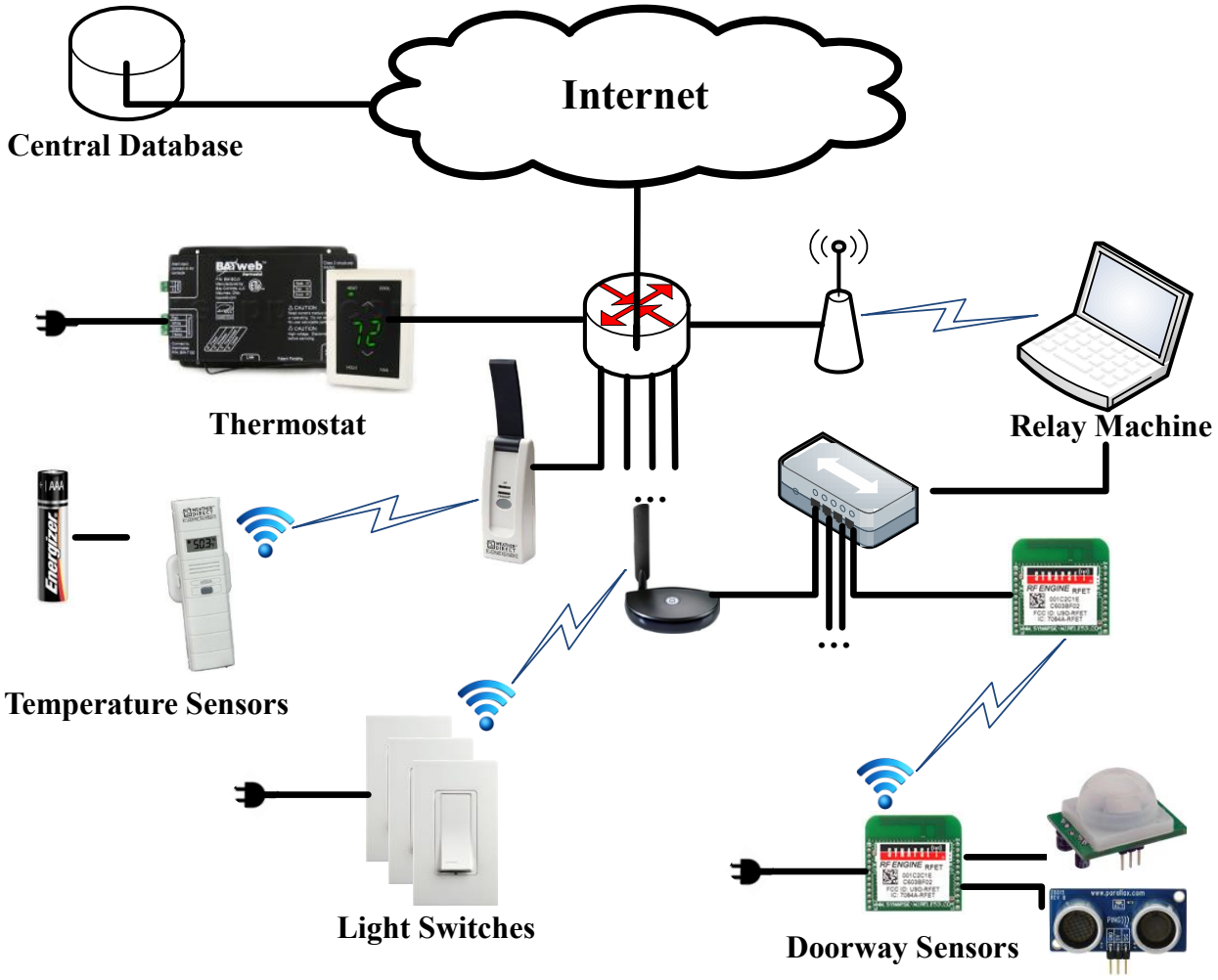
Homes Have Poor Connectivity

- Wireless connectivity

- Power line communications
  - Wires
  - 180bit/s
  - 5 min polling rate

Exploiting Home Automation Protocols
for Load Monitoring in Smart Buildings

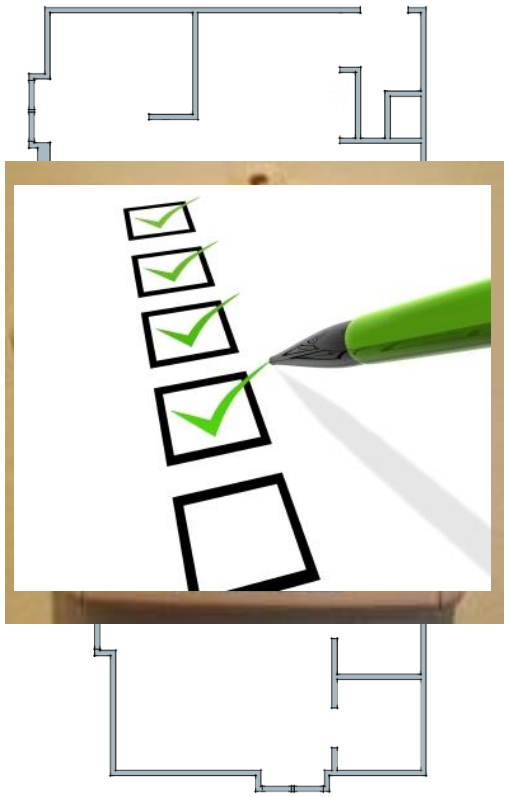
COTS Are Double-edged



Scaling #Homes

Homes are Remote Environments

- Minimize installation time
  - Scout
  - Lab assembly and configuration
  - Checklists



Scaling #Days

Expect Limited User Participation

- Button Tracking
- Wearable Tracking
- Self-reporting
- Surveys

Aesthetics Matter in Homes

- Disappear into the woodwork
- Leave no trace
- No LEDS at night
- Noise

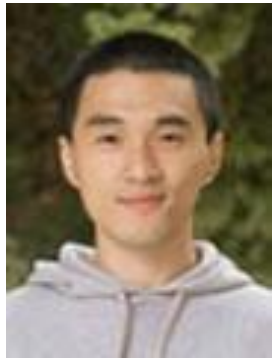
Homes are Hazardous Environments

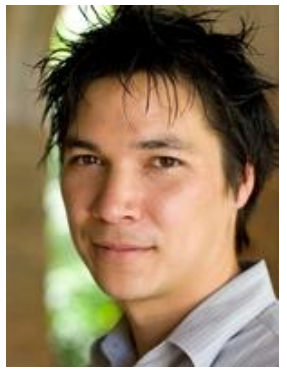
- Children
- Mobile objects
- Roomba
- Guests and cleaning services

Summary of Challenges

- AC Power is not abundant or reliable
- Wireless connectivity is worse than expected
- COTS are a double-edged sword
- Houses are remote environments
- User participation is limited
- Aesthetics are important
- Unexpected environmental hazards

Credits and Questions

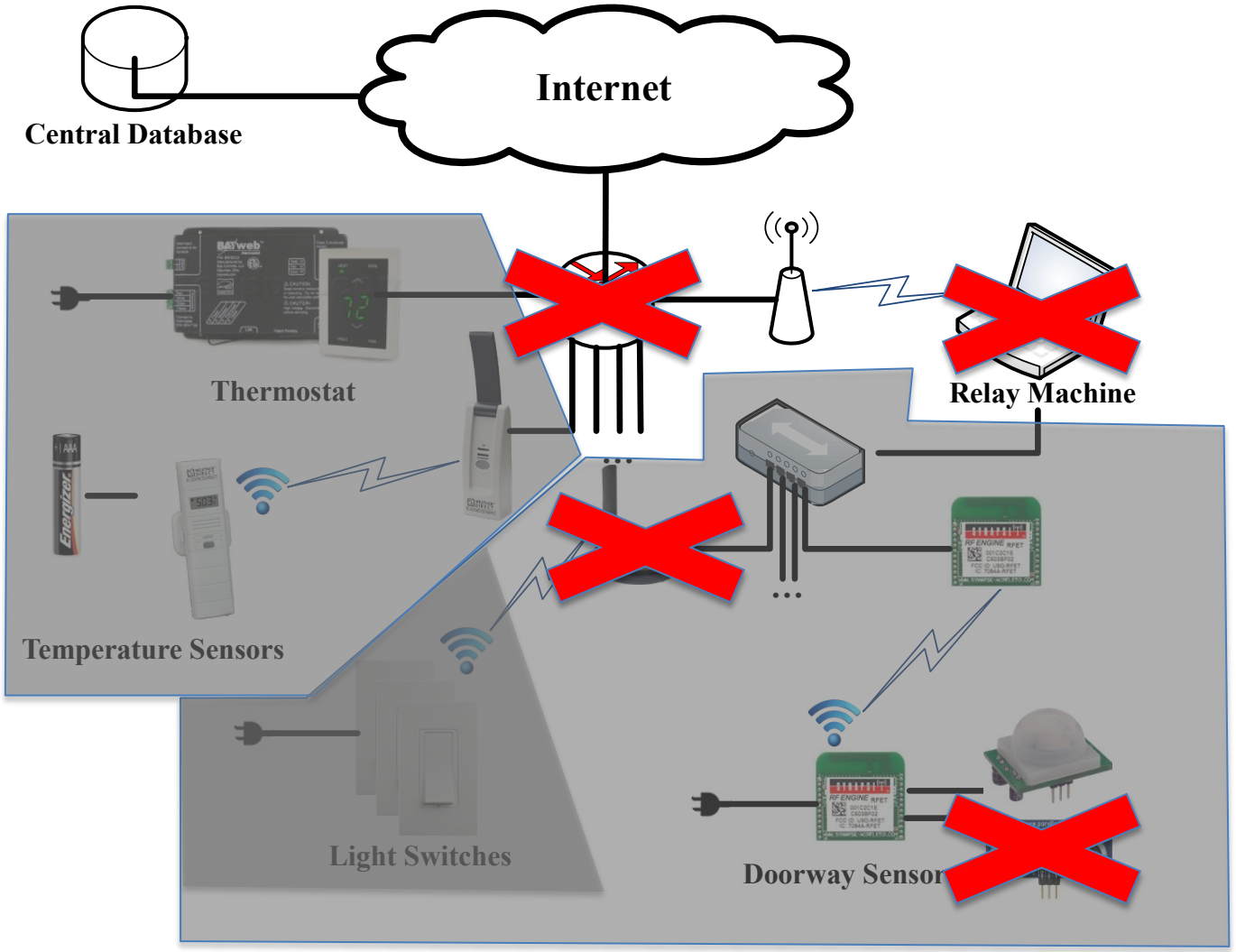




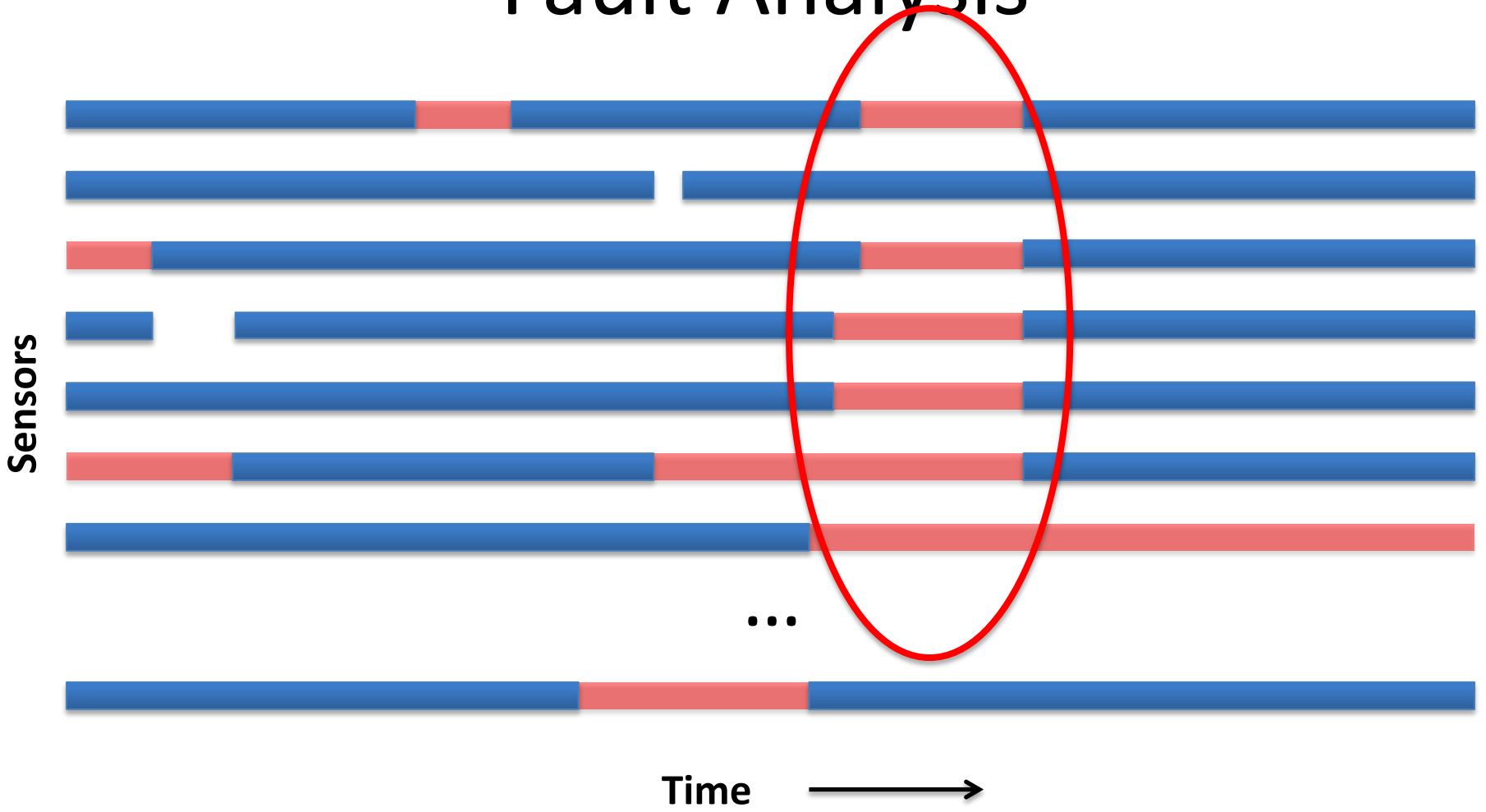
Root Failures

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

Fault Analysis

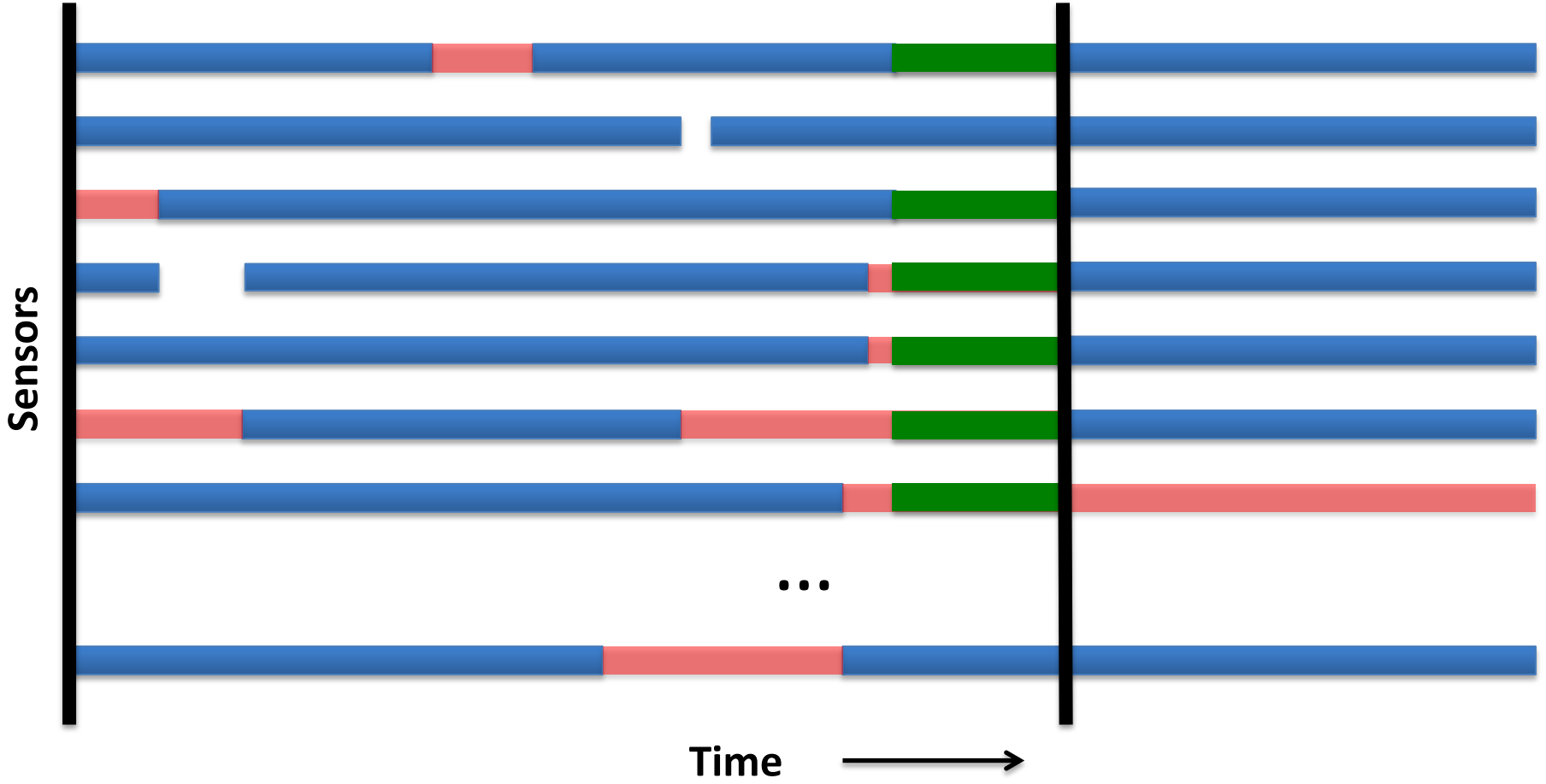


Fault Analysis



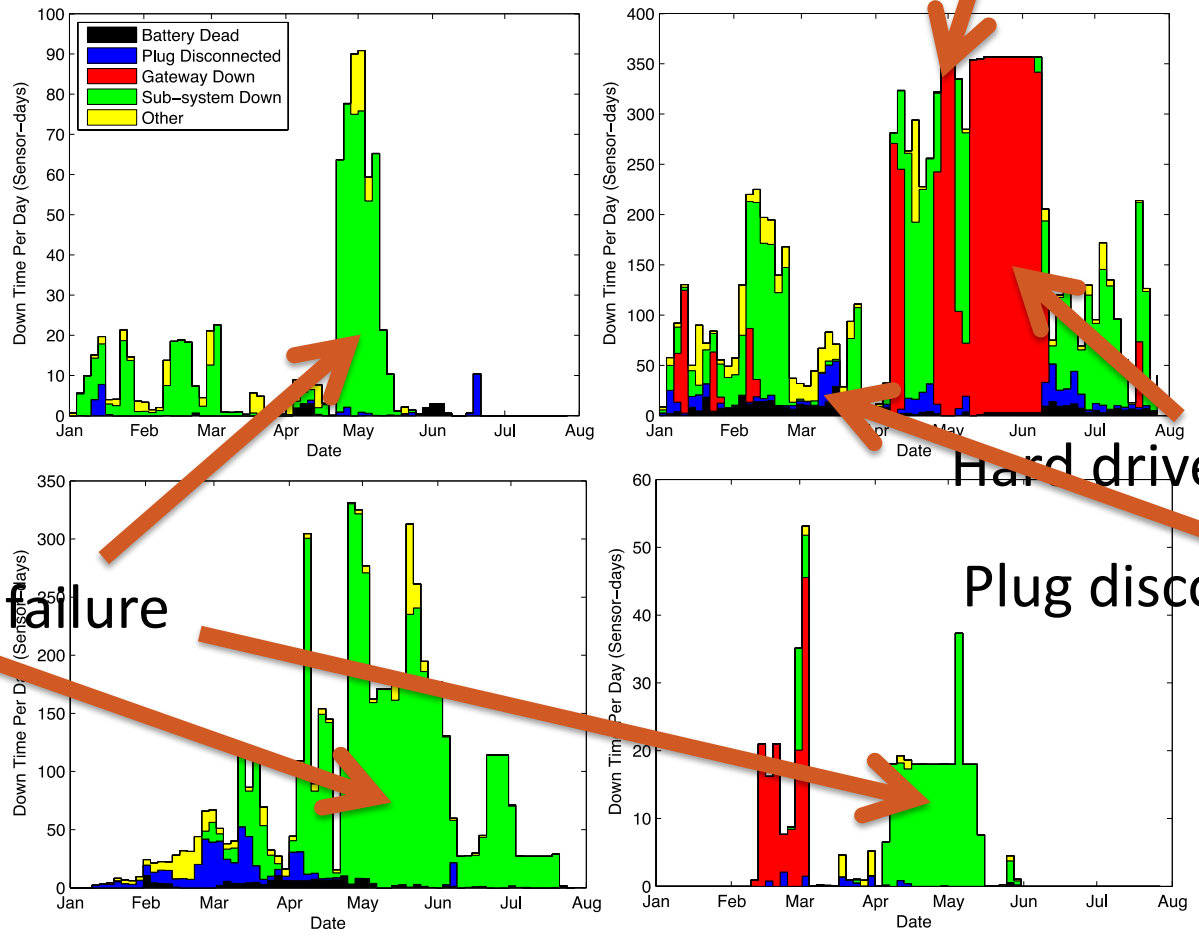
Fault Analysis

Power Outage



Sensor-Days – down time × number of sensors

Fault Analysis



Reinstall

Hard drive failure

Sub-system failure

Plug disconnections