LoT

LAB of THINGS

SIGCSE
Atlanta
2014

A Devices Research and Teaching Platform for Home and Beyond

A.J. Brush, Senior Researcher
Microsoft Research

Thank you

Microsoft®
Research

Collaborators















Microsoft®
Research

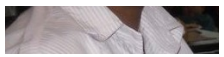
Collaborators





touchdevelop









What did the 0 say to the 8?

What did the 0 say to the 8?

Nice belt!

Industrial Internet

Internet of Everything

Ambient Data

M2M

Cyber-Physical Systems

Internet of Things

Thinking Things

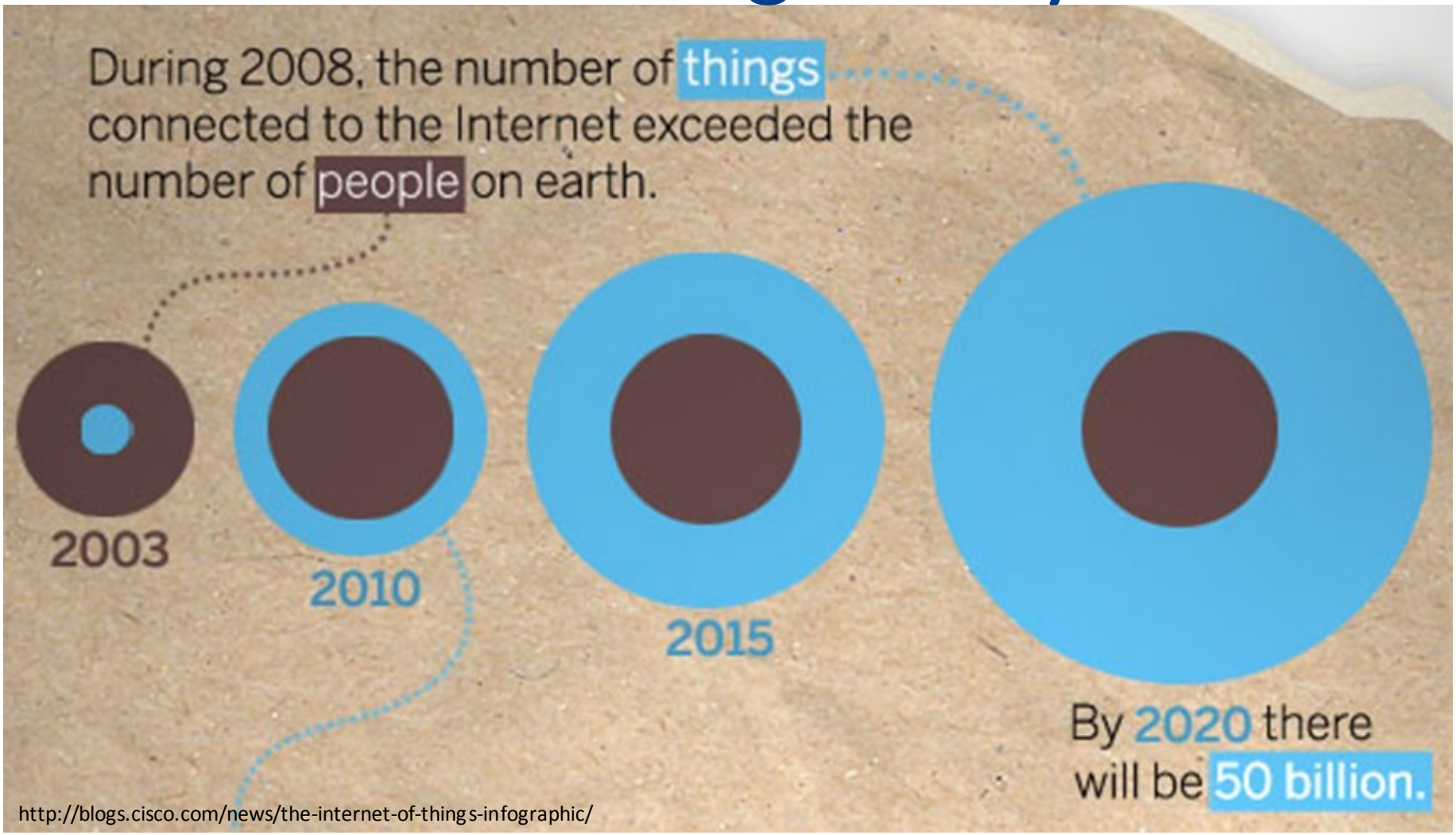
Smarter Planet

Cloud of Things

Intelligent Systems

System of Observations

Connected things everywhere



http://blogs.cisco.com/news/the-internet-of-things-infographic/

Internet of Things

Networks of low-cost sensors and actuators for data collection, monitoring, decision making and process optimization. McKinsey Global Institute





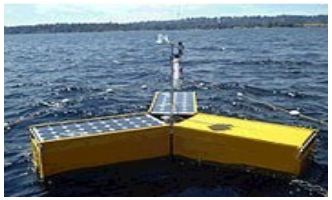






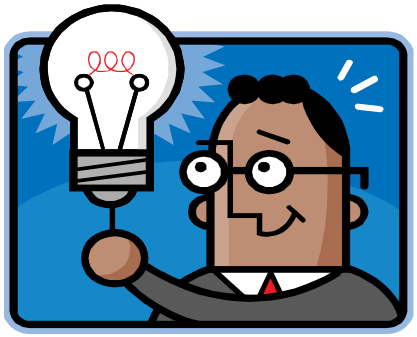







Things for Home

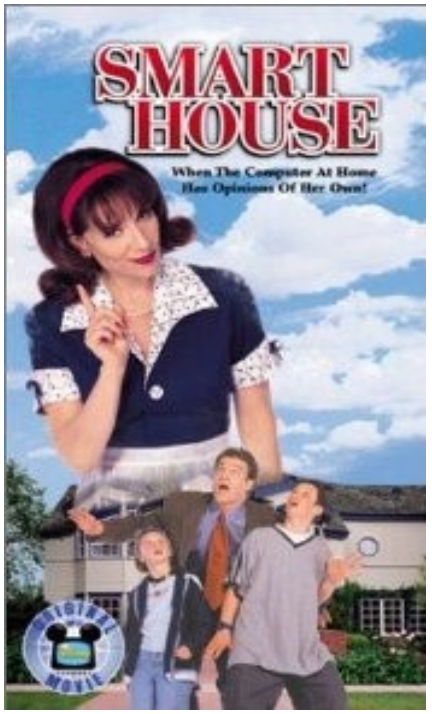
Enable a range of applications



Long anticipated…

Microsoft Home of Future 1994

Georgia Tech Aware Home, 2000



Disney, 1999

The Adaptive House, Mozer et al., 1997

Duke Smart Dorm, 2007

Why now?

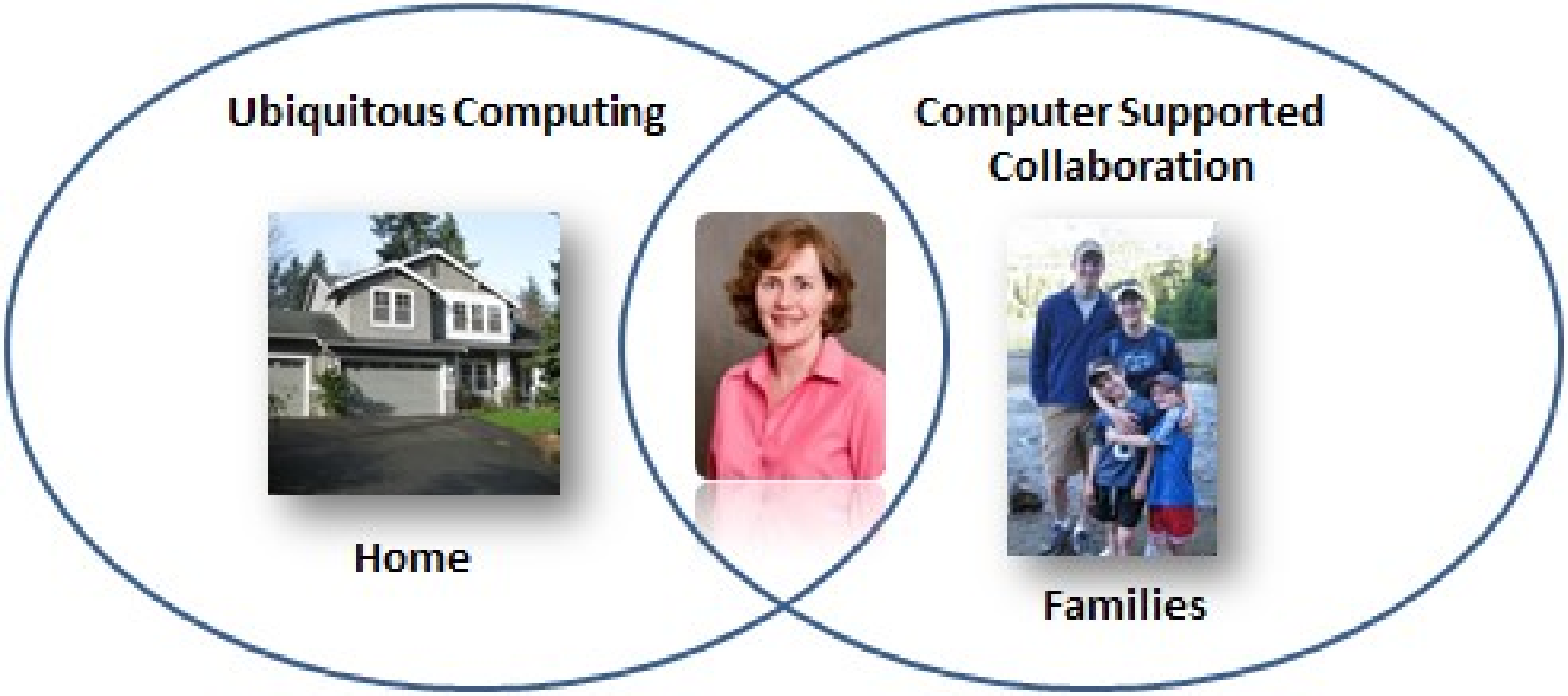
Inexpensive devices

Need no new wires

Maturing standards

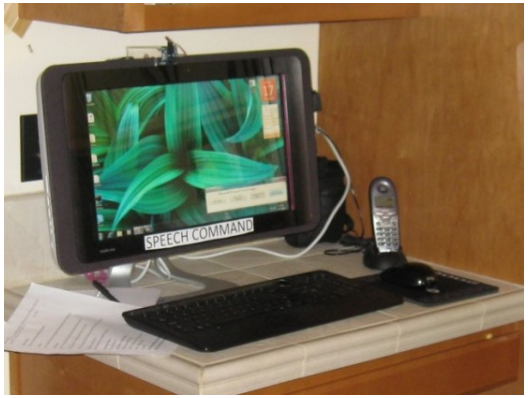
Mobile devices

I study and build technologies for homes and families.



Why homes & families?

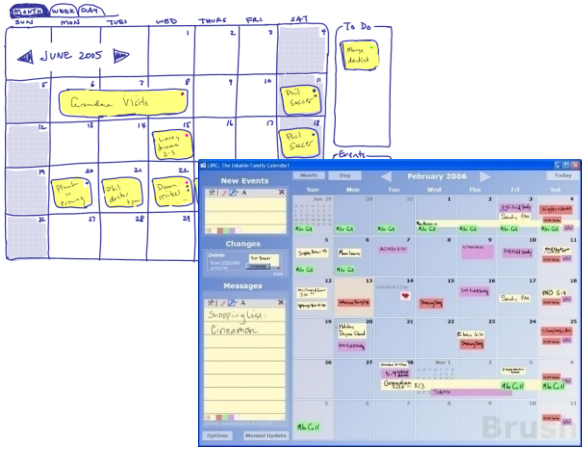
Built-in prototyping lab

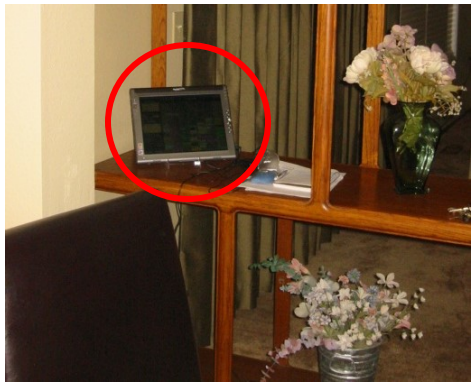


User-Centered Design

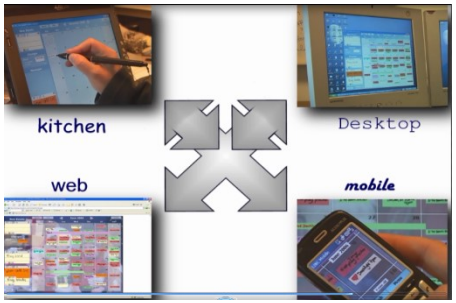
Process in which the needs, wants, and limitations of end users of a product are given extensive attention at each stage of the design process. (Wikipedia)

Understand Current Behavior and User Needs	Build Prototype	Does it work? Use of Technology



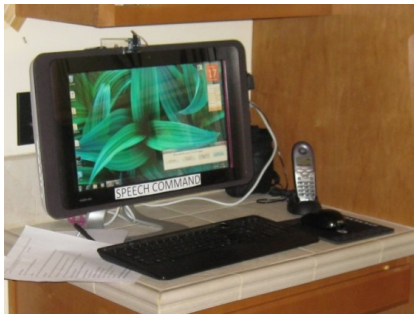


Deployments, Deployments, Deployments



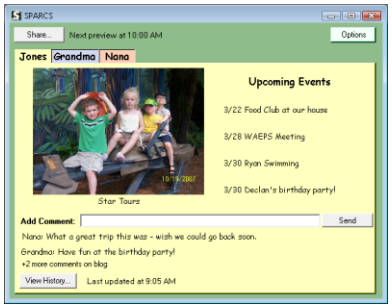
LINC

4 homes, 4 weeks



Speech@Home

6 homes, 2 weeks



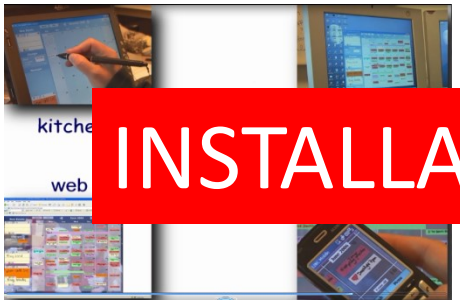
SPARCS

14 homes, 5 weeks

PreHeat

5 homes, 8 weeks+

~~Deployments, Deployments,~~ pain pain pain ~~Deployments~~



INSTALLATION

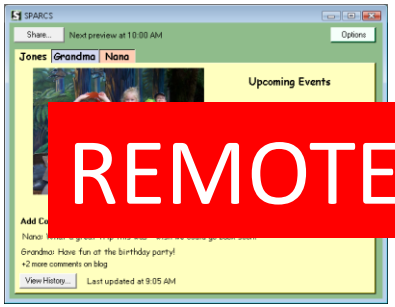
LINC

4 homes, 4 weeks

LOST DATA

Speech@Home

6 homes, 2 weeks



REMOTE SETUP

SPARCS

14 homes, 5 weeks

ROBUSTNESS

PreHeat

5 homes, 8 weeks+

Other people feel deployment pain too

Limited access

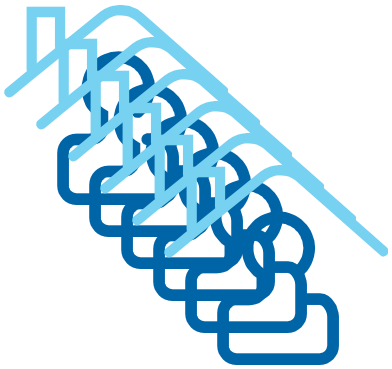
Environmental Hazards

Scarce Resources

Hnat, T., Srinivasan, V., Lu, J., Sookoor, T., Dawson R., Stankovic, J., Whitehouse, K. (2011) The Hitchhiker's Guide to Successful Residential Sensing Deployments. Paper presented at SenSys'11, 2-4, November 2011

It’s hard to deploy technology in homes

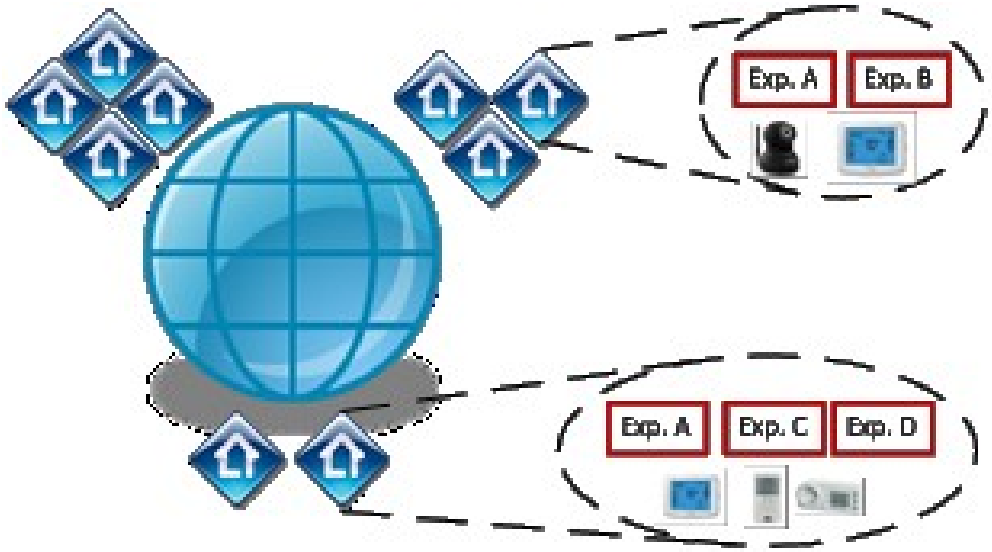
Limited number of homes often without geographic diversity



Large engineering effort that is not easily re-used

Lab of Things

Change the scale and pace of research on connected devices in homes

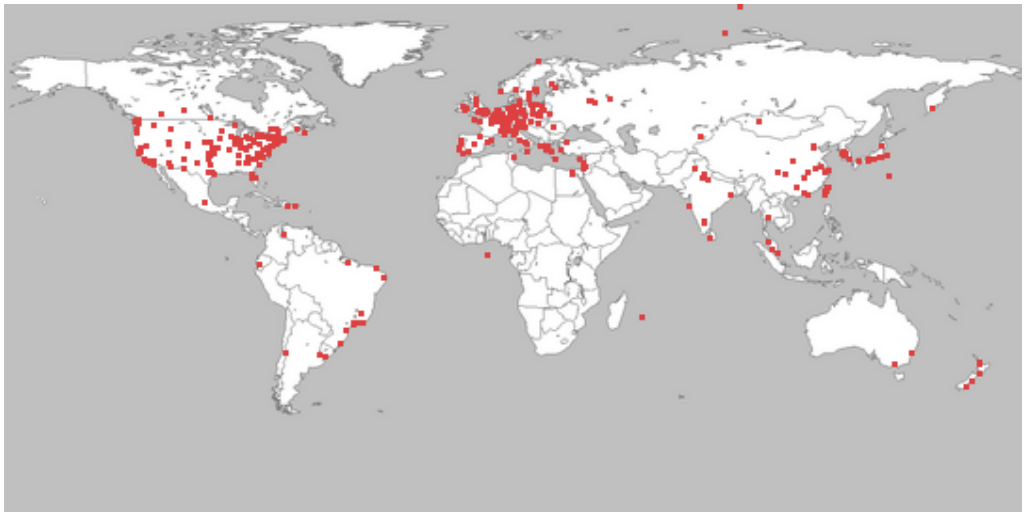


A large number of geographically distributed households, each running a common, flexible framework in which experiments are implemented.

Inspiration

PLANETLAB

An open platform for developing, deploying, and accessing planetary-scale services

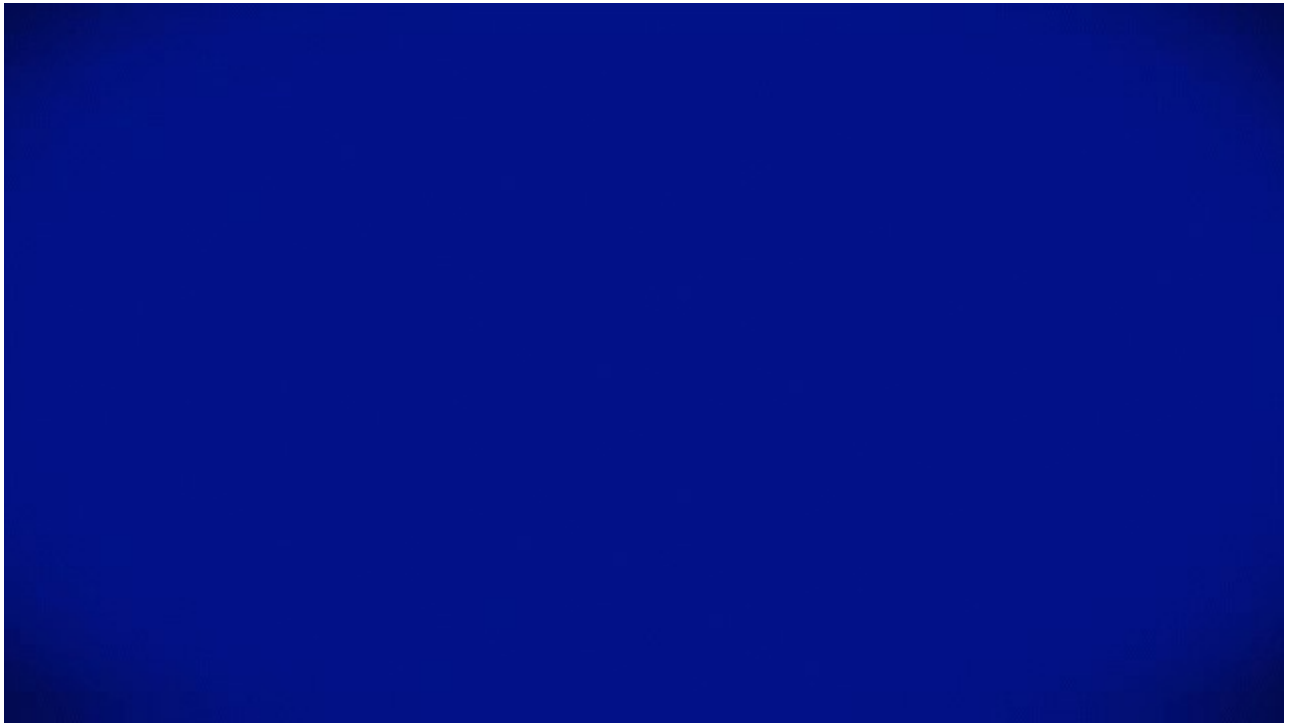


PlanetLab is a global research network that supports the development of new network services. Since the beginning of 2003, more than 1,000 researchers at top academic institutions and industrial research labs have used PlanetLab to develop new technologies for distributed storage, network mapping, peer-to-peer systems, distributed hash tables, and query processing.

All images and information from http://planet-lab.org/

Video available here

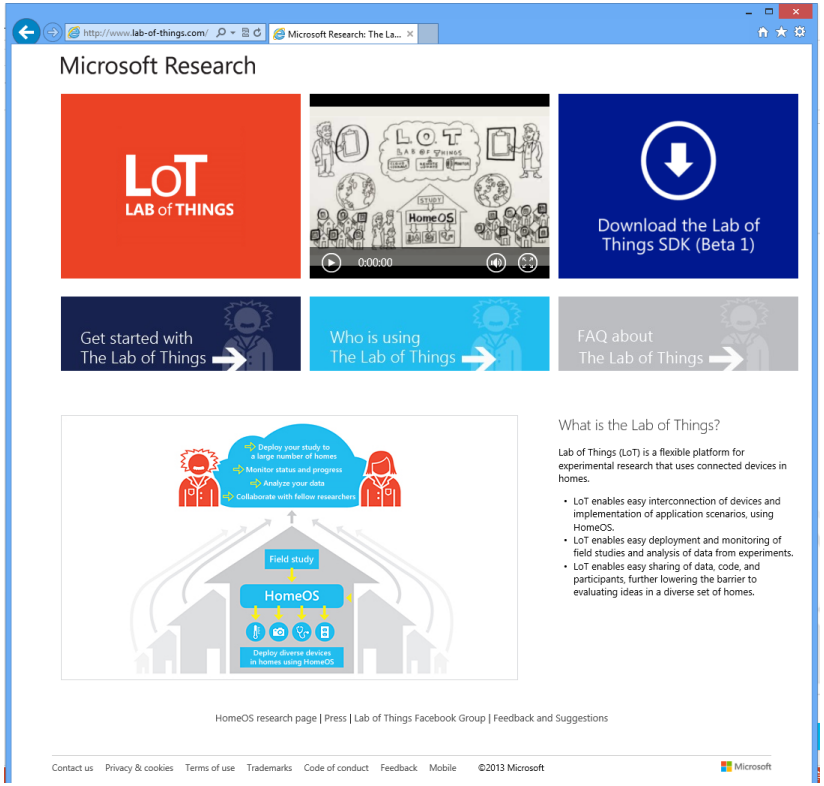
LoT
LAB of THINGS



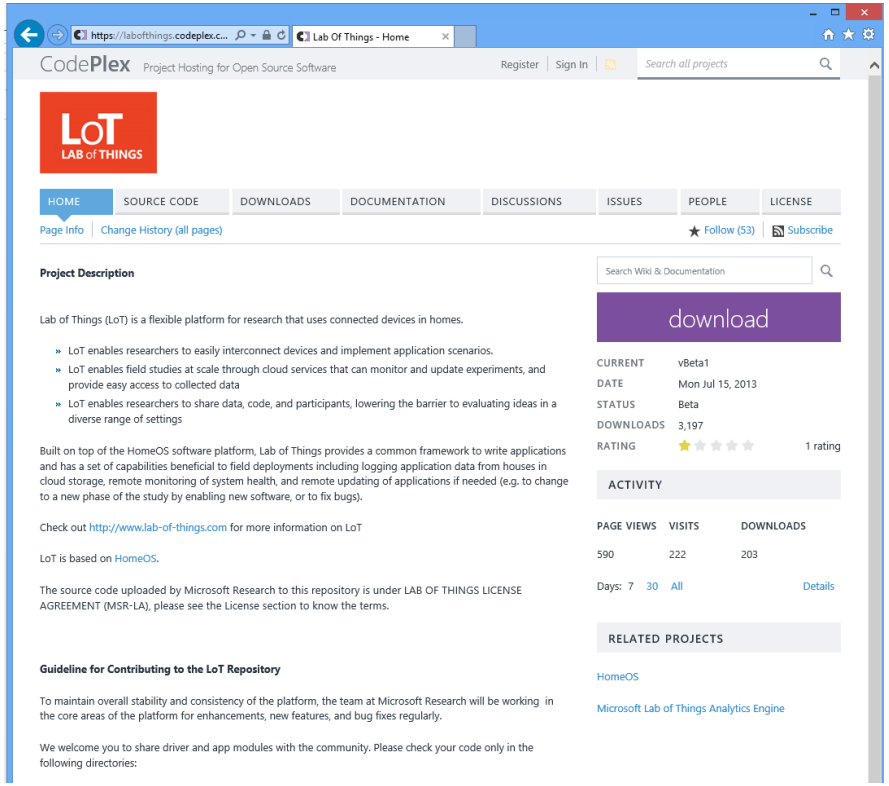
Enable research and student projects
that use connected devices in homes and beyond

Lab of Things

http://www.lab-of-things.com

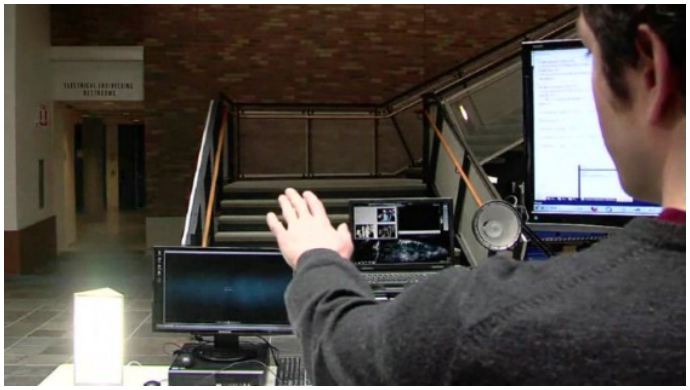


https://labofthings.codeplex.com

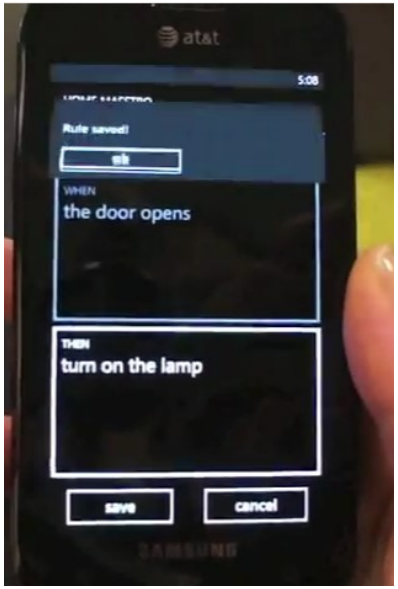


Taste of student projects

Home Energy Models
Omid Ardakanian, Ryan Case
University of Waterloo
May 2010



Gesture Controlled Lights
Jehad Affoneh, Sterling Swigart, David Nufer
CSE 481m, Spring '11
University of Washington



Rules by Example
Shaun Salzberg
MIT, Feb. 2012

What did the fish say when he ran into the wall?

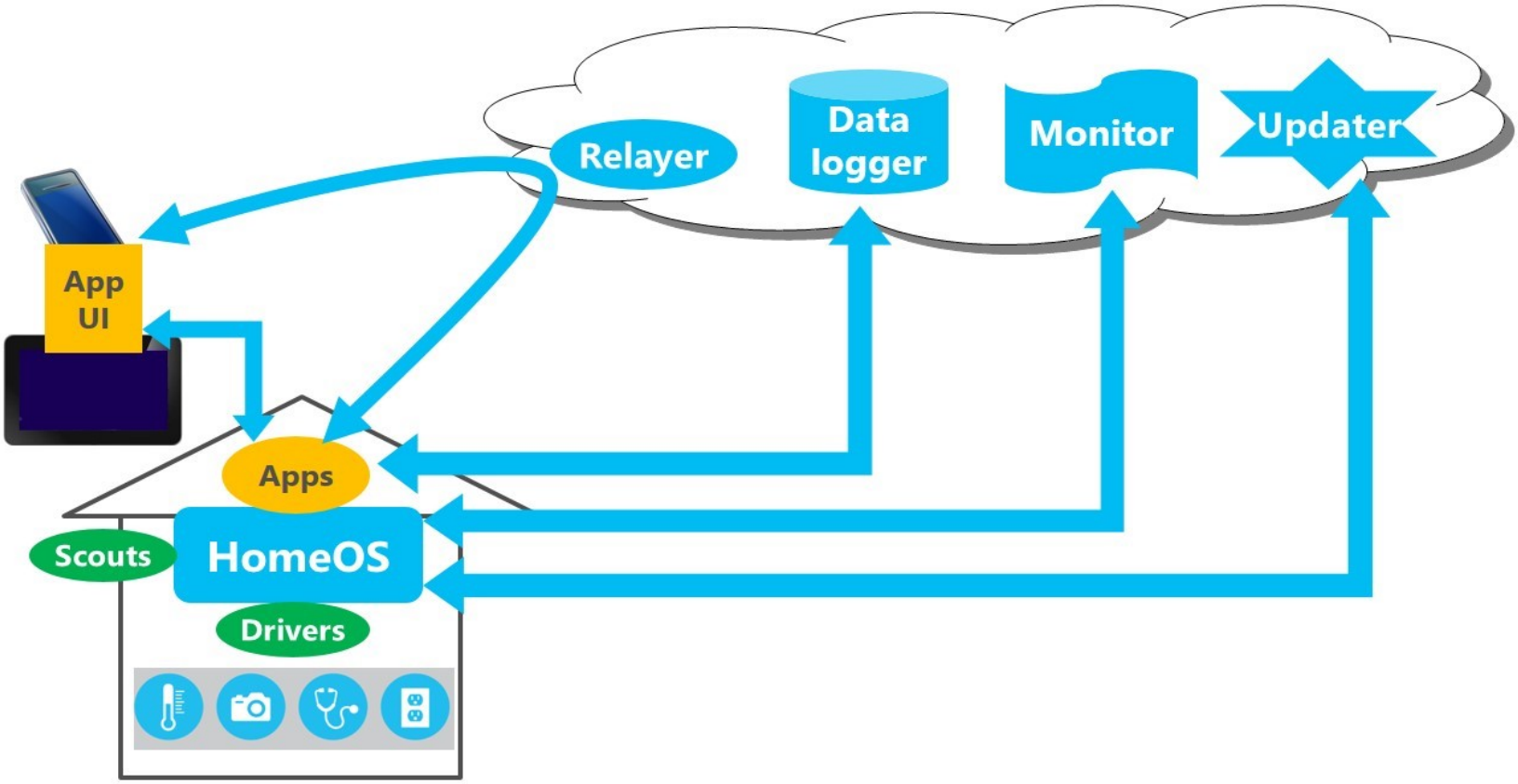
What did the fish say when he ran into the wall?

Dam!

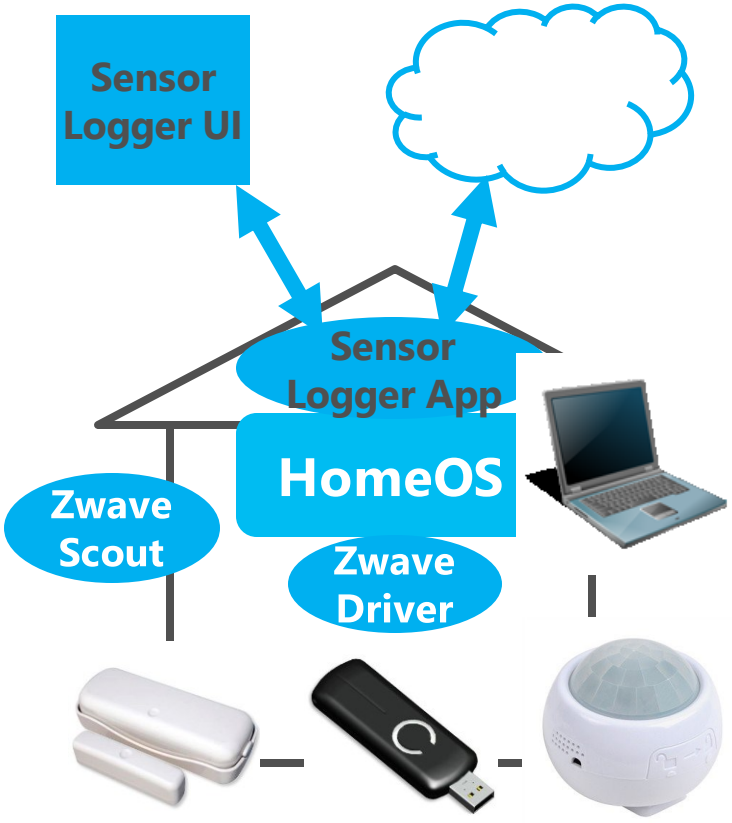
Lab of Things Design Goals

1. **Easy setup of an extensible range of devices including custom ones.**
2. **Monitoring and updating**
3. **Ongoing data collection**
4. **Scale and diversity of deployment sites**

LoT Platform

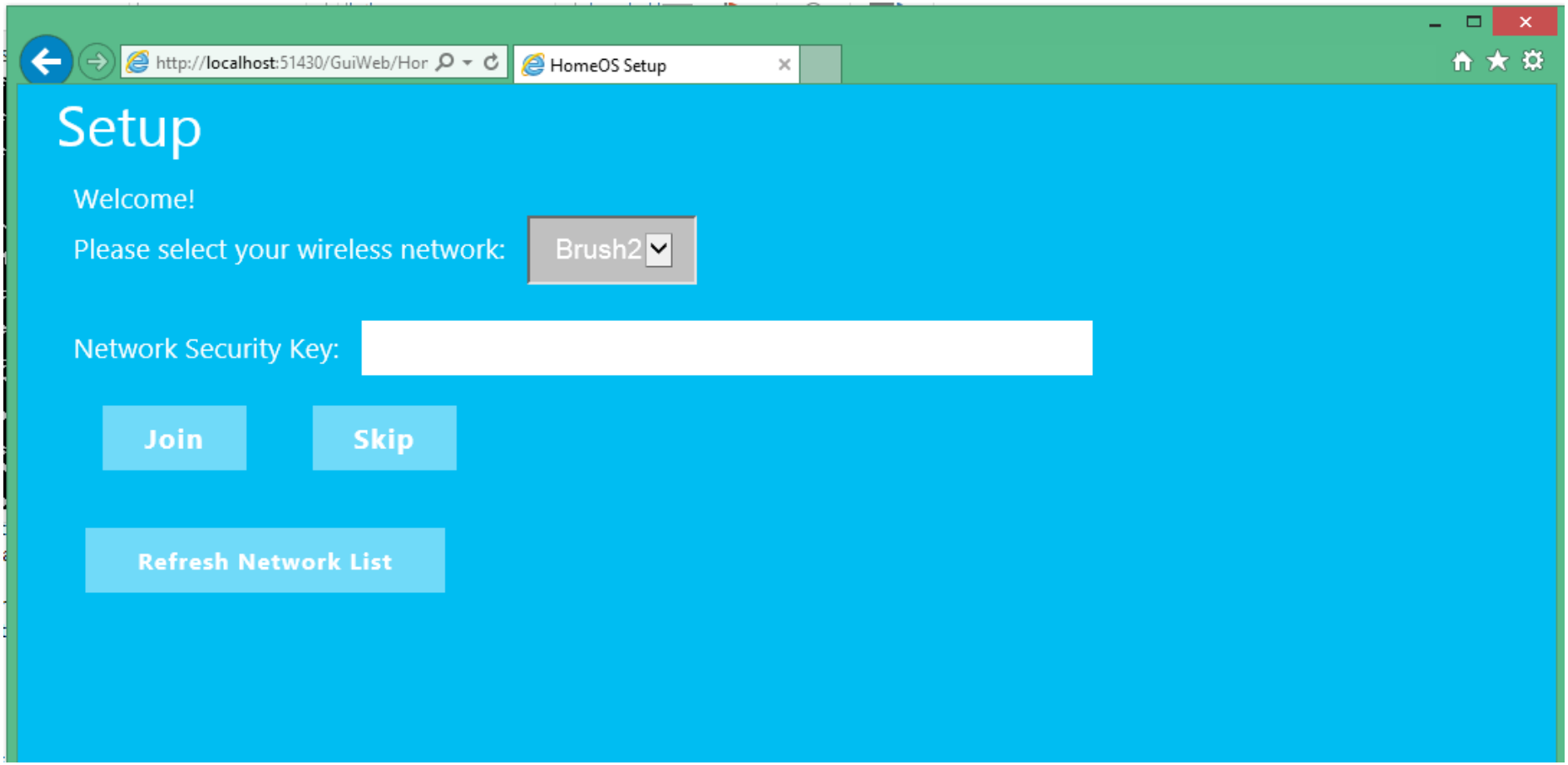


How often do you use your main door? (Simple Study #1)



8 homes, 2 weeks+

Simple Study #1 Setup



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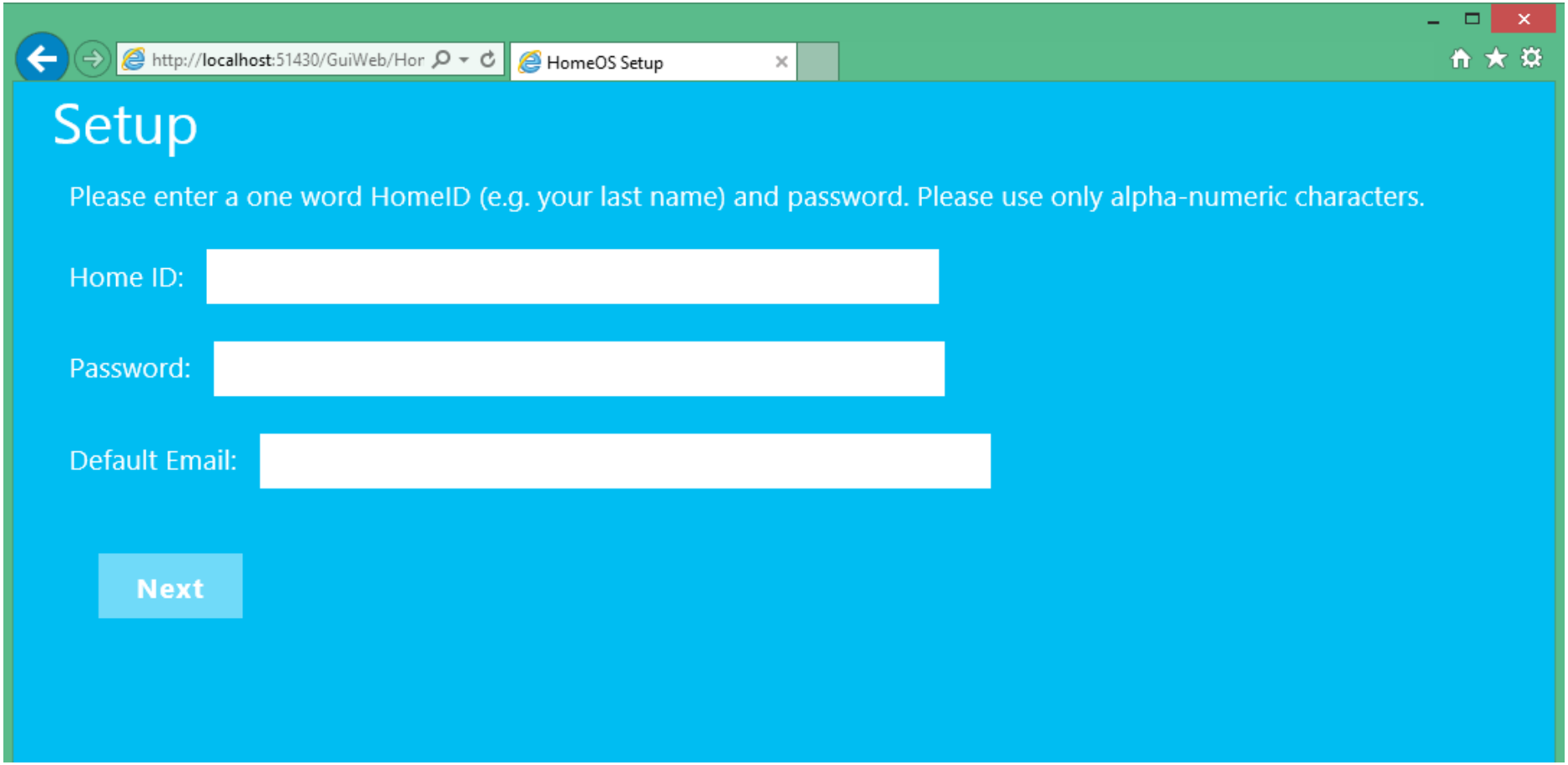
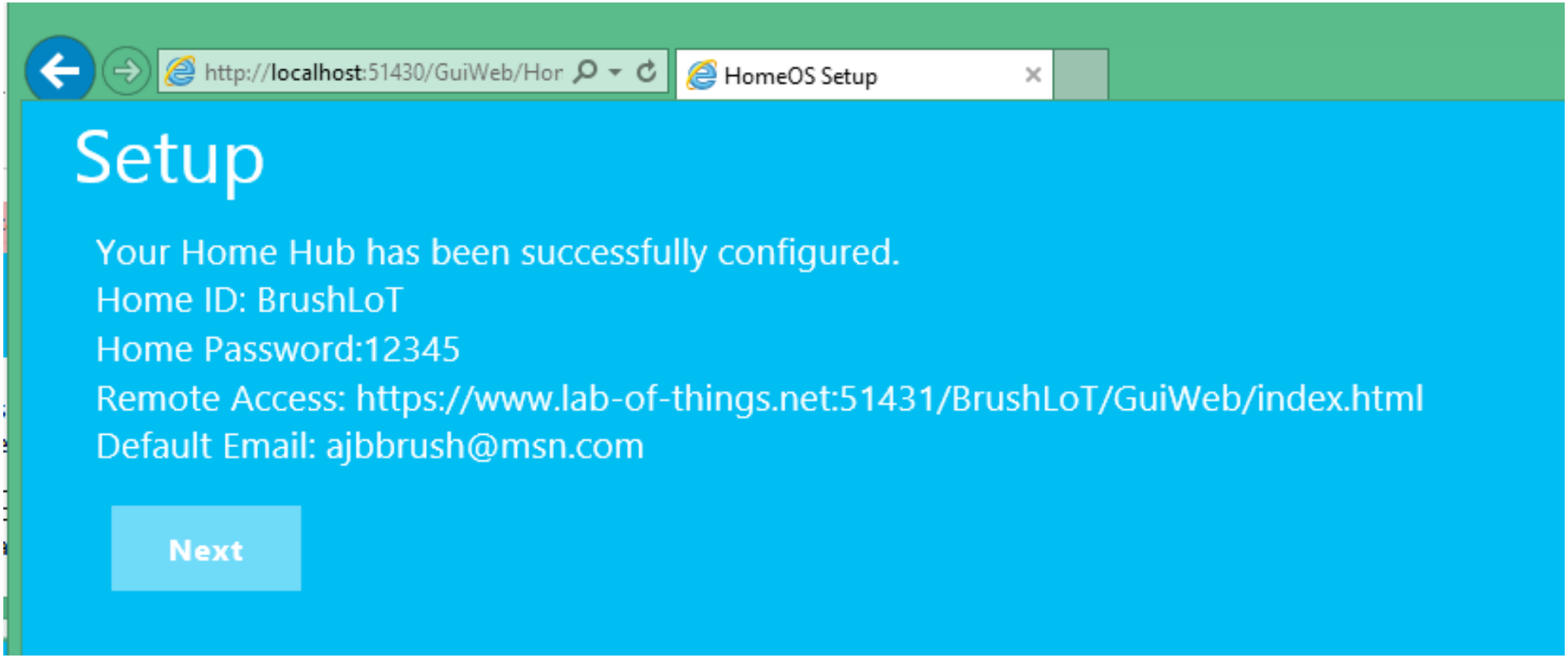
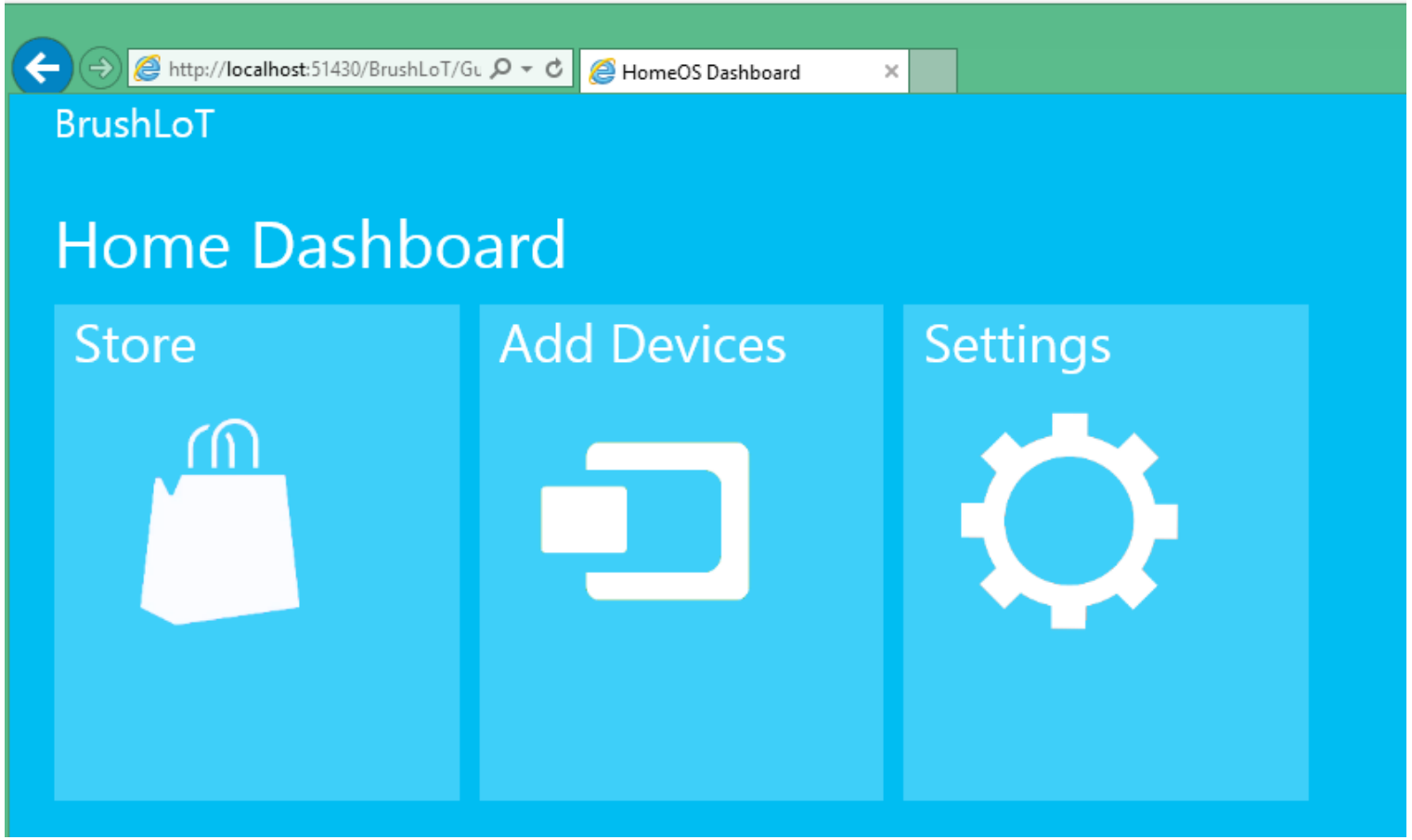


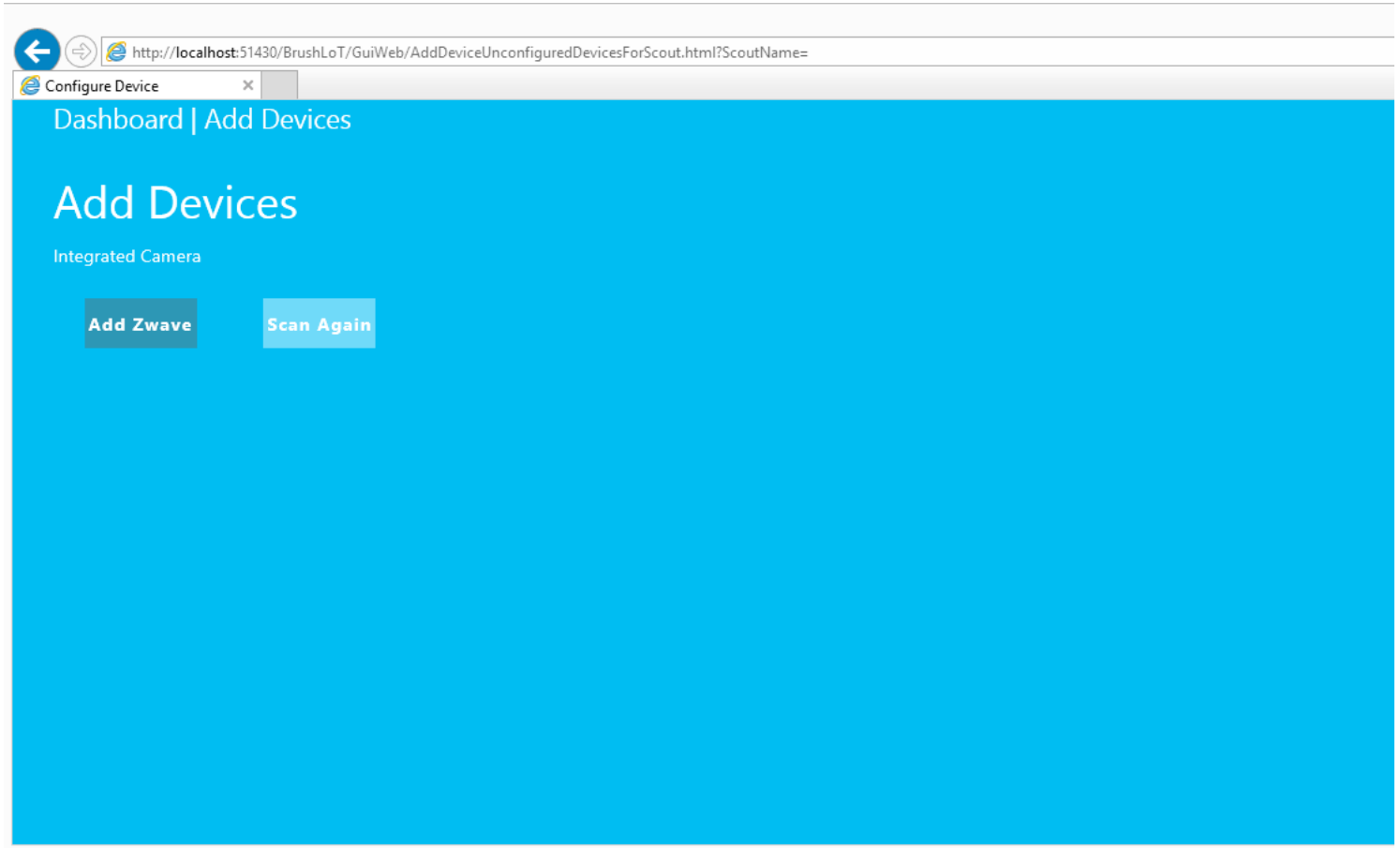
Simple Study #1 Setup



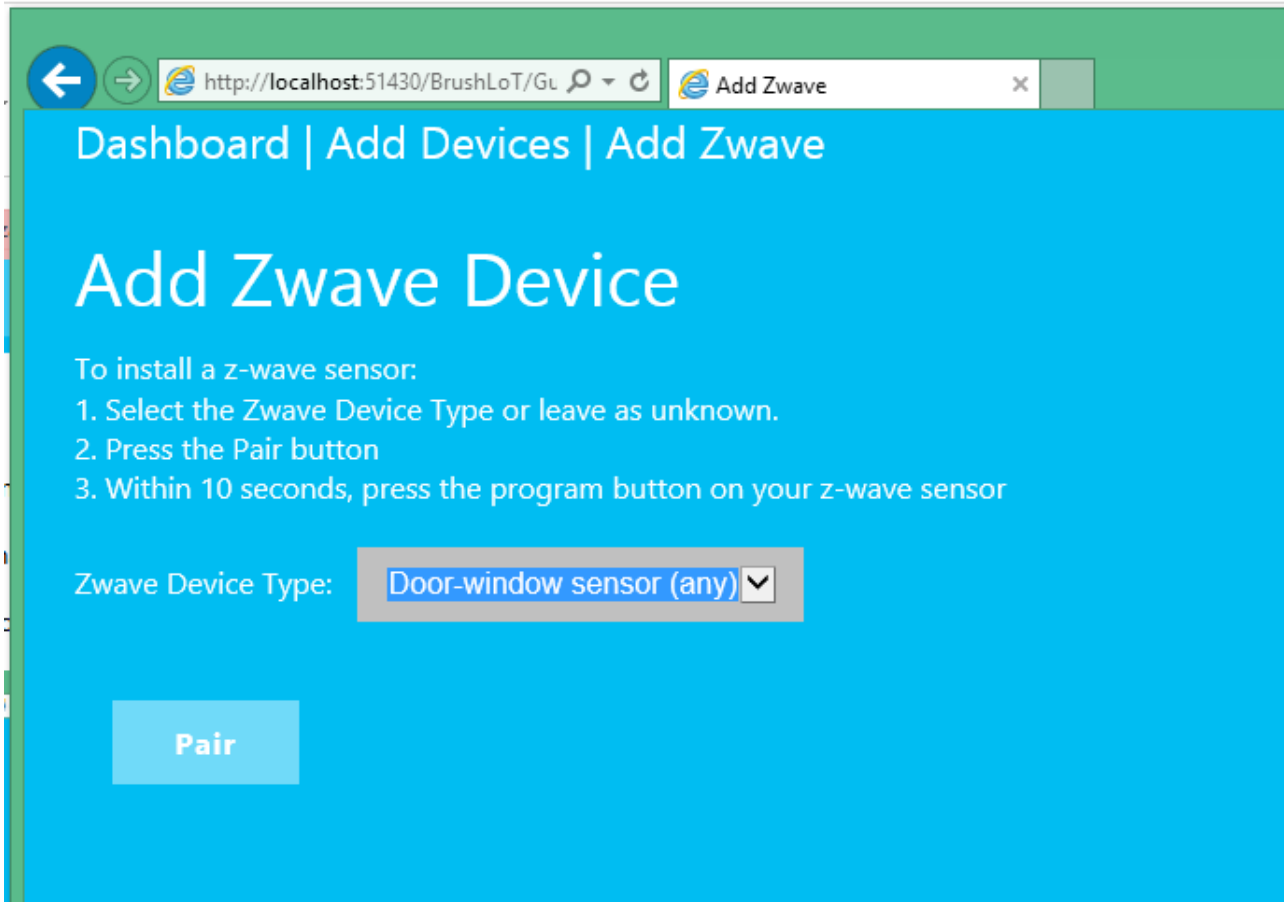
Simple Study #1 Add Devices

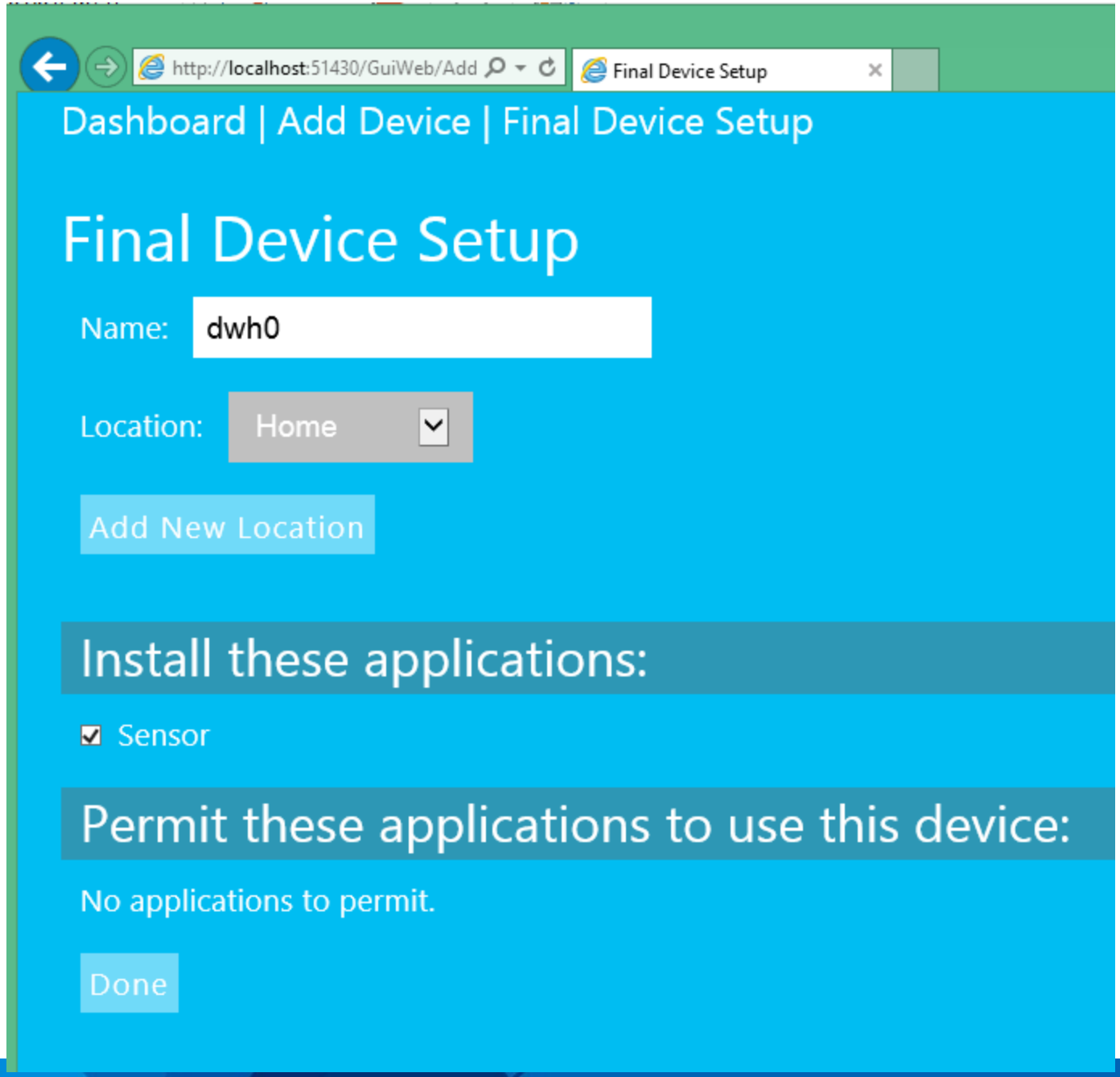


Simple Study #1 Add Devices

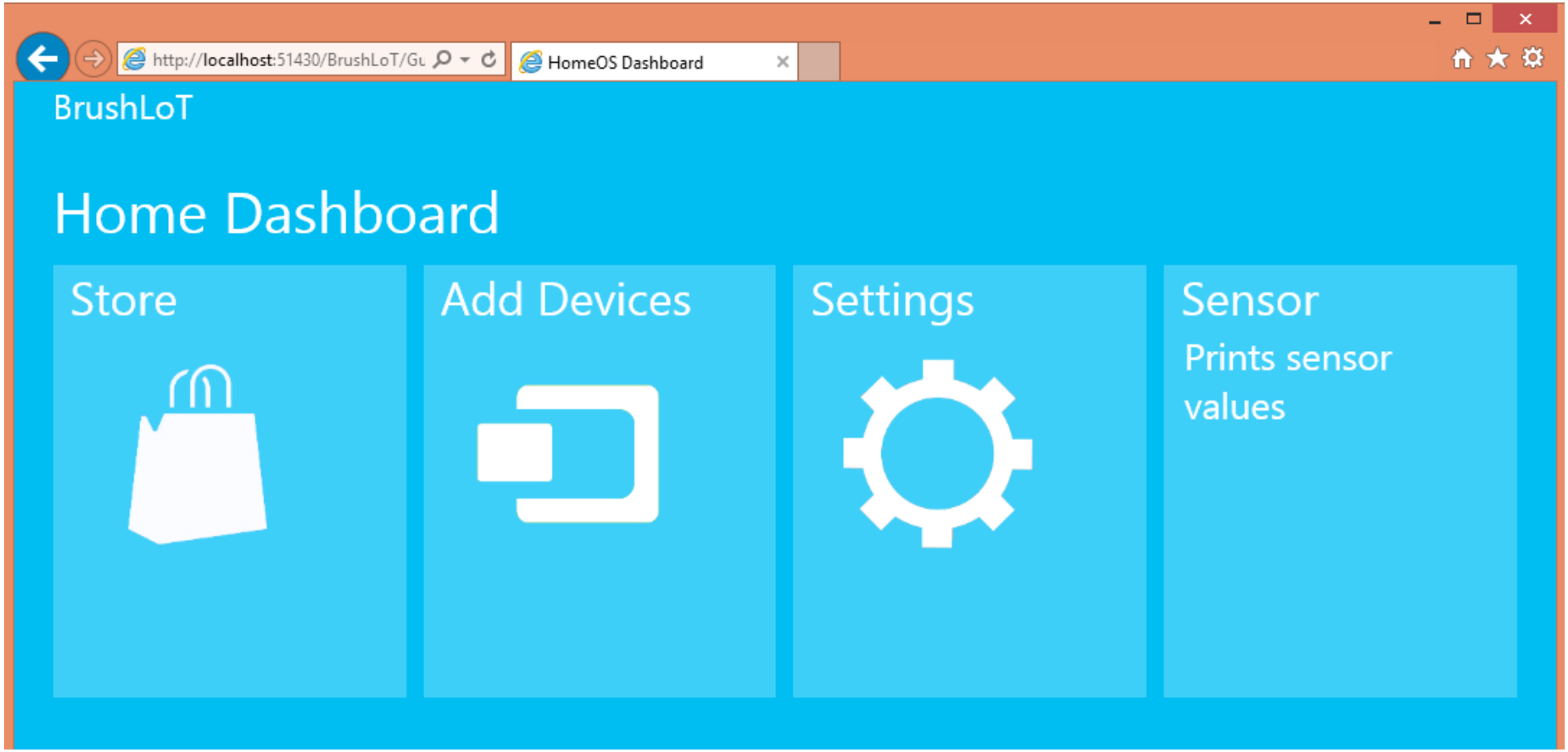


Simple Study #1 Add Devices

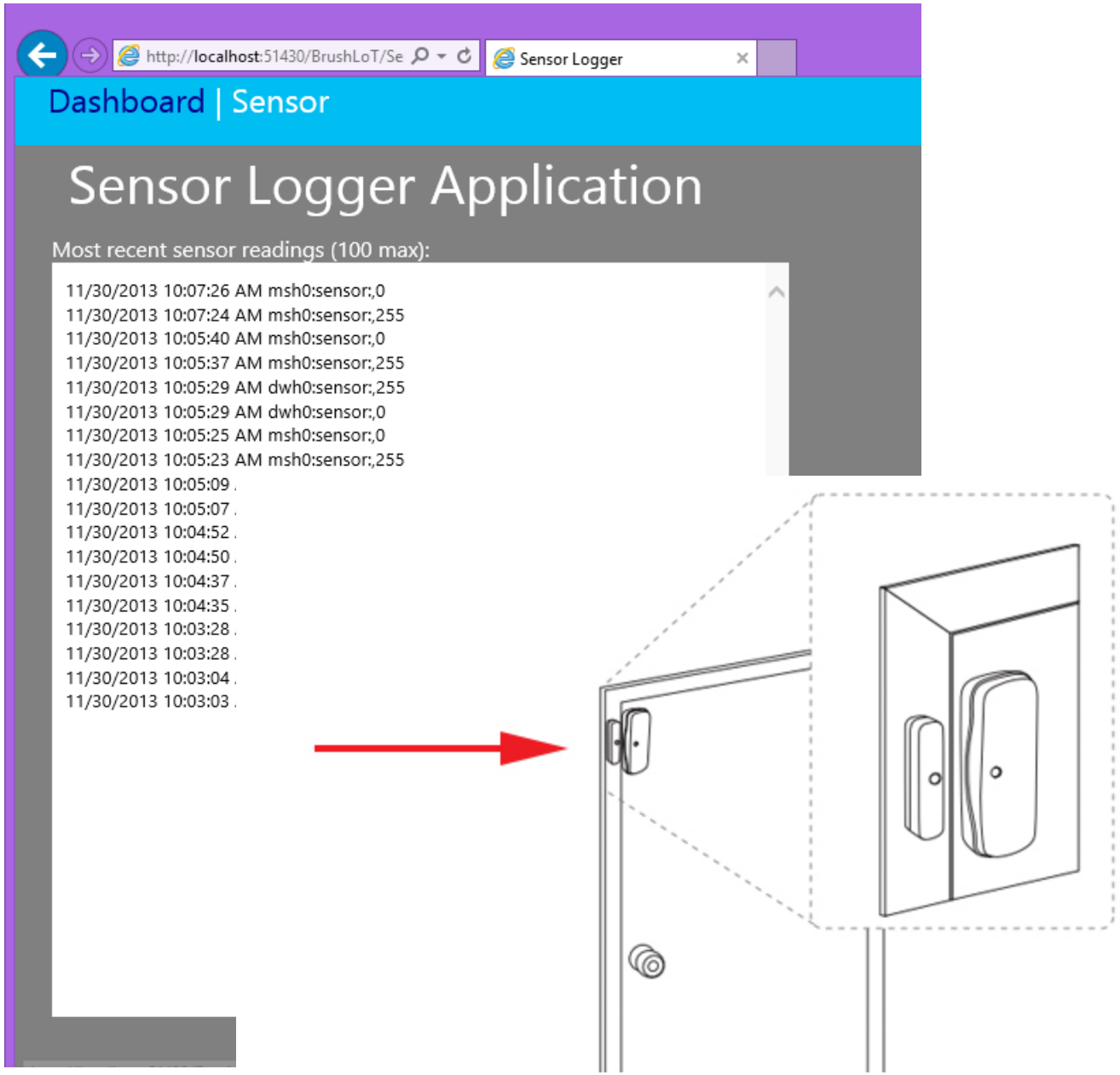



http://localhost:51430/GuiWeb/Add
Final Device Setup
Dashboard | Add Device | Final Device Setup
Final Device Setup
Name:
dwh0
Location:
Home
Add New Location
Install these applications:
Sensor
Permit these applications to use this device:
No applications to permit.
Done

Simple Study #1 Dashboard




http://localhost:51430/BrushLoT/Se
Sensor Logger
Dashboard | Sensor
Sensor Logger Application
Most recent sensor readings (100 max):
11/30/2013 10:07:26 AM msh0:sensor:,0
11/30/2013 10:07:24 AM msh0:sensor:,255
11/30/2013 10:05:40 AM msh0:sensor:,0
11/30/2013 10:05:37 AM msh0:sensor:,255
11/30/2013 10:05:29 AM dwh0:sensor:,255
11/30/2013 10:05:29 AM dwh0:sensor:,0
11/30/2013 10:05:25 AM msh0:sensor:,0
11/30/2013 10:05:23 AM msh0:sensor:,255
11/30/2013 10:05:09 AM msh0:sensor:,0
11/30/2013 10:05:07 AM msh0:sensor:,255
11/30/2013 10:04:52 AM msh0:sensor:,0
11/30/2013 10:04:50 AM msh0:sensor:,255
11/30/2013 10:04:37 AM msh0:sensor:,0
11/30/2013 10:04:35 AM msh0:sensor:,255
11/30/2013 10:03:28 AM dwh0:sensor:,255
11/30/2013 10:03:28 AM dwh0:sensor:,0
11/30/2013 10:03:04 AM dwh0:sensor:,255
11/30/2013 10:03:03 AM dwh0:sensor:,0


http://localhost:51430/BrushLoT/Se
Sensor Logger
Dashboard | Sensor
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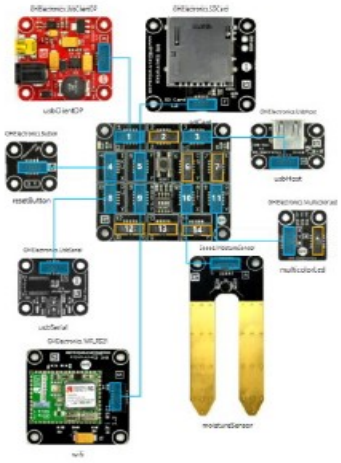
11/30/2013 10:05:40 AM msh0:sensor:,0
11/30/2013 10:05:37 AM msh0:sensor:,255
11/30/2013 10:05:29 AM dwh0:sensor:,255
11/30/2013 10:05:29 AM dwh0:sensor:,0
11/30/2013 10:05:25 AM msh0:sensor:,0
11/30/2013 10:05:23 AM msh0:sensor:,255
11/30/2013 10:05:09
11/30/2013 10:05:07
11/30/2013 10:04:52
11/30/2013 10:04:50
11/30/2013 10:04:37
11/30/2013 10:04:35
11/30/2013 10:03:28
11/30/2013 10:03:28
11/30/2013 10:03:04
11/30/2013 10:03:03

DG #1: Extensible Device Support

Current Cost Energy meter
University of Waterloo

Doorjamb occupancy
Sensor, U of Virginia



Microsoft .NET Gadgeteer

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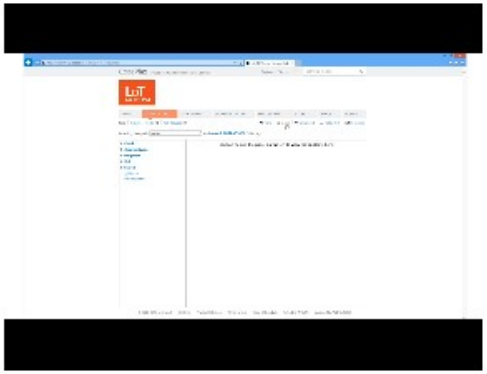
Getting Started - Introductory Videos

Topic: What is the Lab of Things?
Speaker: Arjmand Samuel

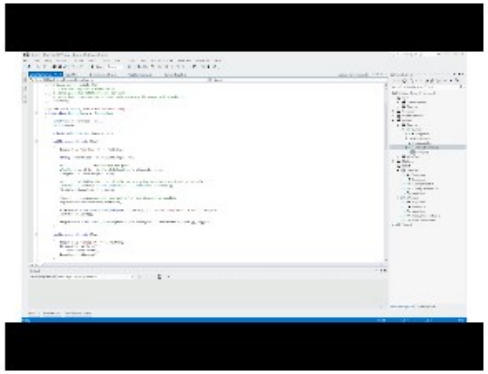
Topic: Demo of the Lab of Things
Speaker: AJ Brush

Topic: Architectural overview of the Lab of Things
Speaker: Ratul Mahajan

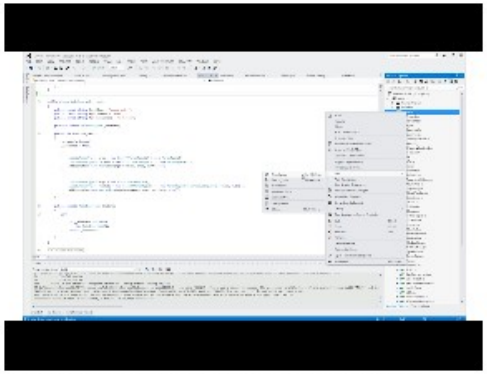
Working with the Lab of Things code



Topic: Getting started with the Lab of Things - code overview
Speaker: Ratul Mahajan

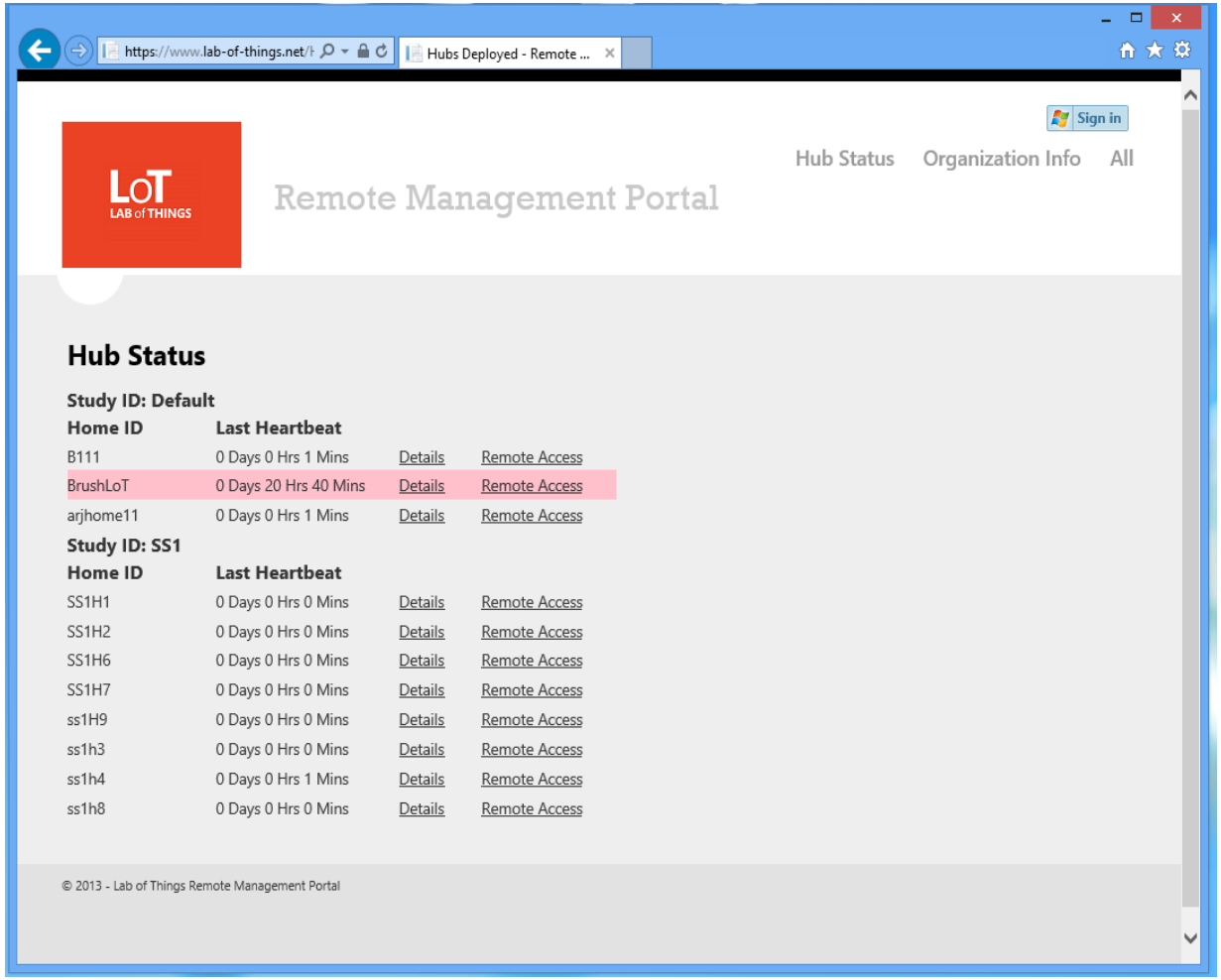


Topic: Developing applications for the Lab of Things
Speaker: Ratul Mahajan



Topic: Contributing code to the Lab of Things
Speaker: Ratul Mahajan

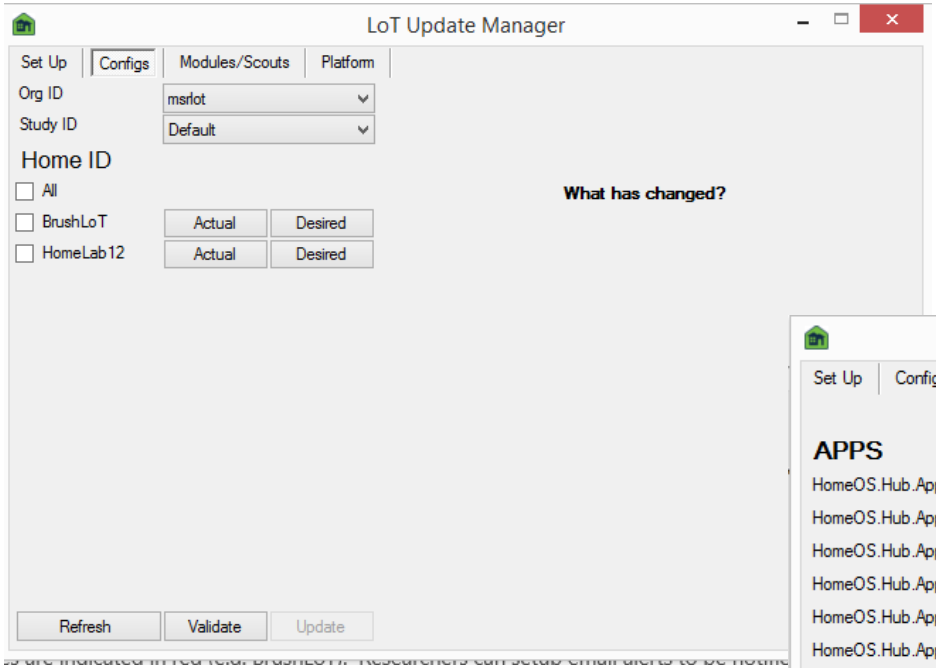
DG #2: Monitoring & Updating

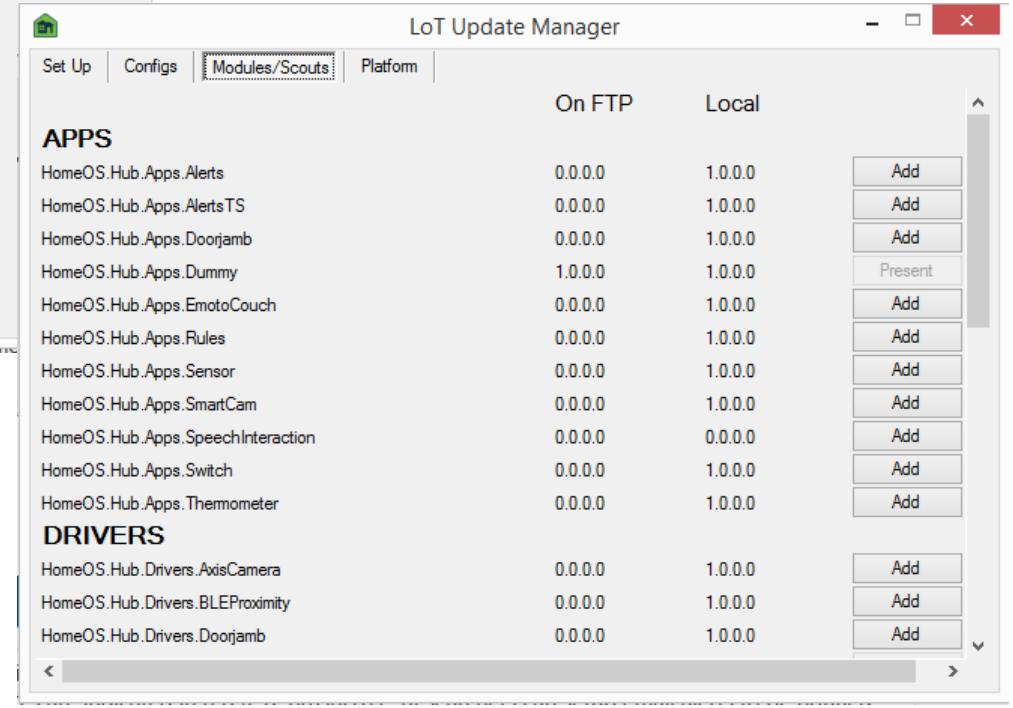


- Hub sends a heartbeat
- Get alerts

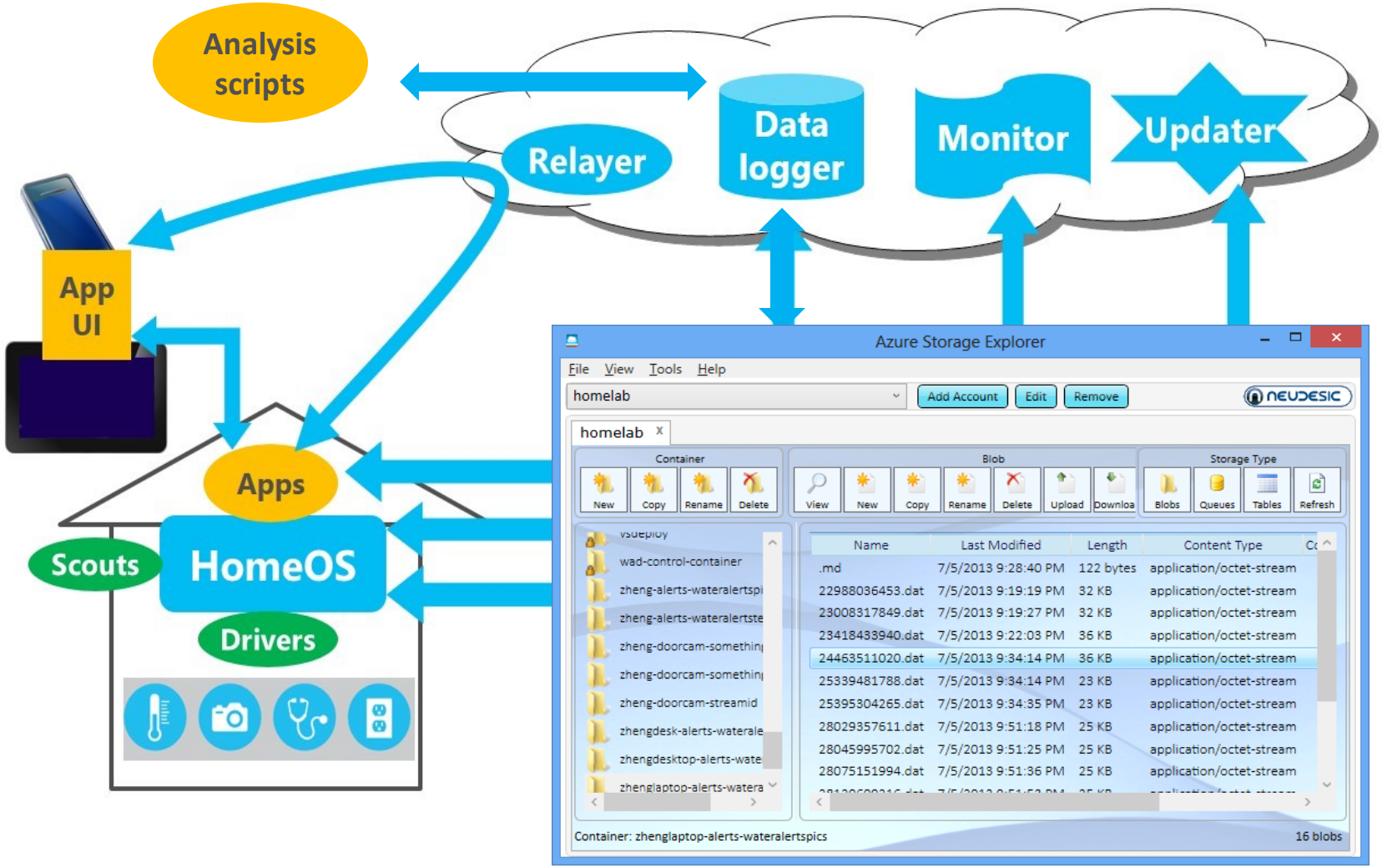
- SS1 problems:
  - Hub not on wireless
  - Hub not sending heartbeats

DG #2: Monitoring & Updating





DG #3: Ongoing Data Collection

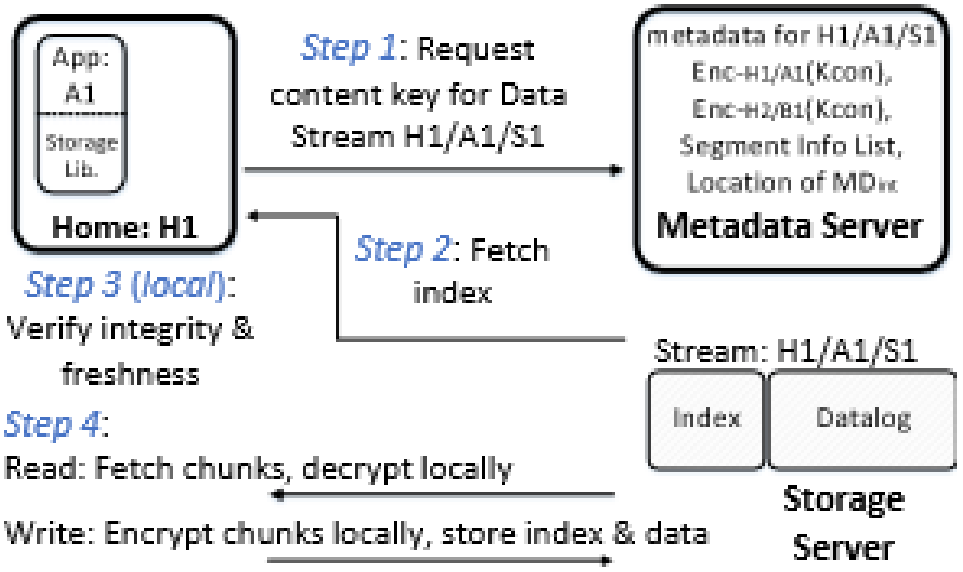


Data management using Bolt

Simple storage abstraction: stream of time-tag-value records.

Specify where you want data stored. Encrypt data if you don't trust the storage providers.

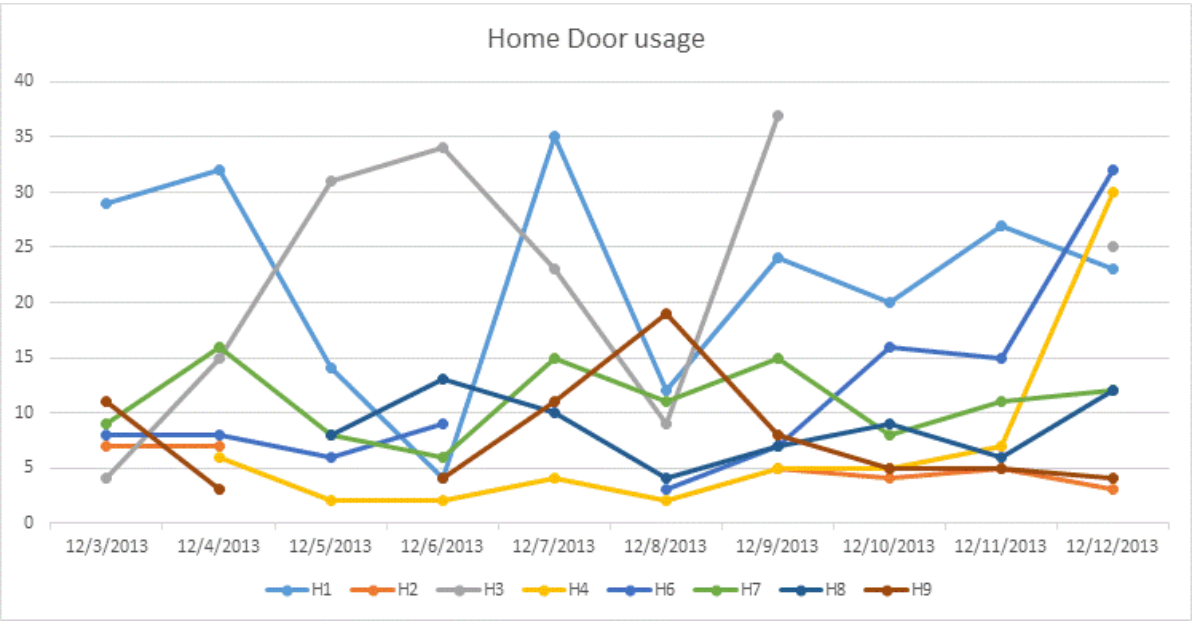
Efficiently ***share*** data across applications and homes.



Bolt is up to 40 times faster than OpenTSDB, a popular time-series database system, while requiring 3–5 times less storage space.

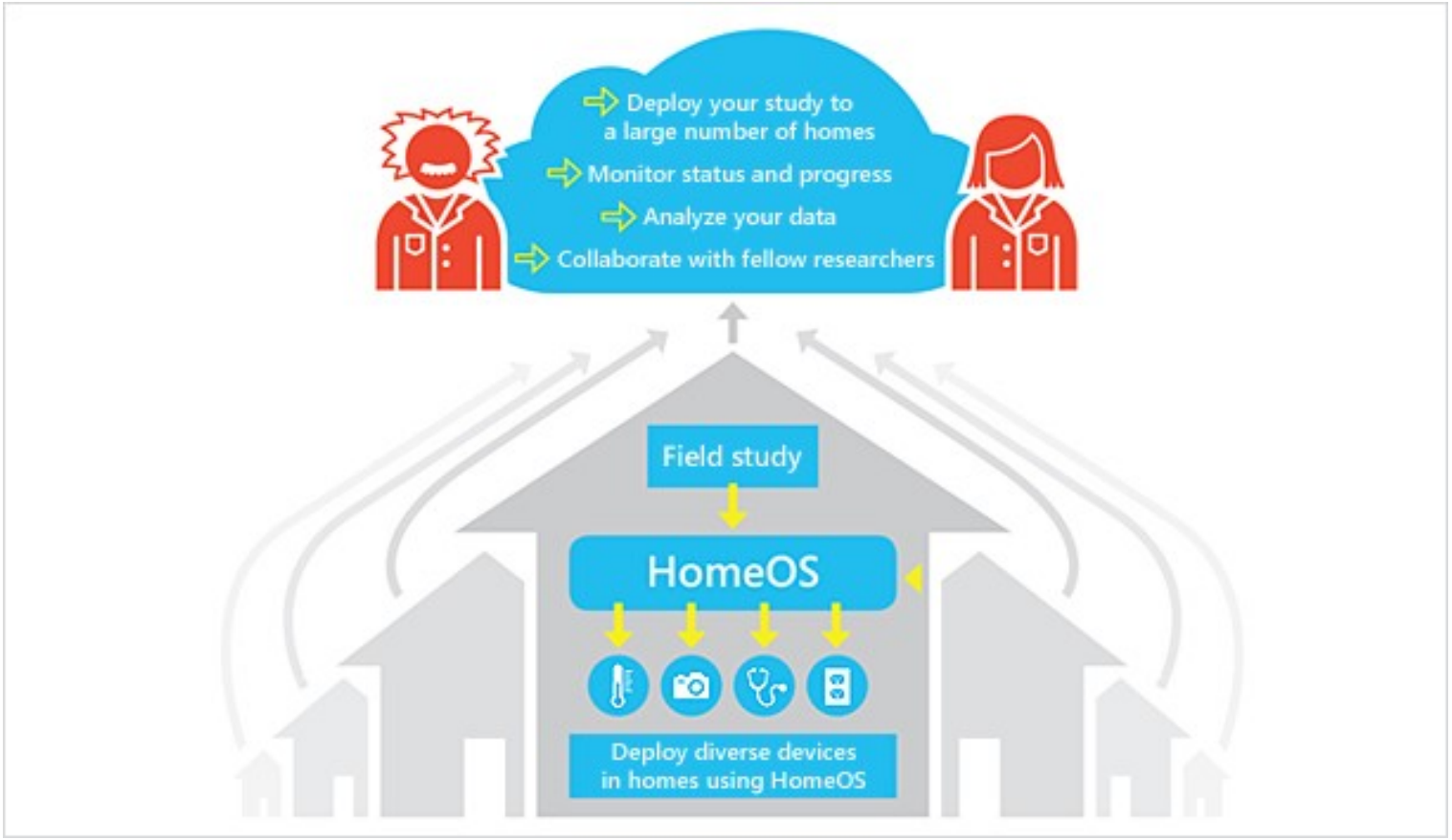
Gupta, Singh, Phanishayee, Jung, and Mahajan, Bolt: Data management for connected homes, To appear in NSDI 2014

How often do you use your main door?



	People	Median per day
H4	1	5
H9	1	5
H2	2	5
H7	2	11
H8	2	8.5
H1	4	23.5
H3	4	24
H6	4	8

DG #4: Scale & Diversity



Focus on the aspect that is interesting to you.

Lab of Things Usage

More than 6,000 code downloads
156 OrgIds registered (37 academic)

Teaching:
Used by 80+ student developers
Several classes taught

Research:
Ongoing academic research deployments

Project title: Lab of Things Analytics Engine
PI: Dean Mohamedally, University College London
URL: Lab of Things Analytics Engine CodePlex site
Blog: Students develop analytics engine for the Lab of Things

Project title: SoftUPS: Virtualizing the home UPS solution to enable efficient peak load sharing in developing world
PI: Affan Syed, FAST-NUCES, Pakistan
URL: http://www.sysnet.org.pk/w/SoftUPS

Project title: SOLACE (Supporting Older Low-ses Adults and their Caregivers Electronically) deployment using Lab of Things
PI: Kay Connelly, Indiana University
URL: http://phitlab.org/

Project title: Supporting User Control of Intelligent Home Systems
PI: Mark Newman, University of Michigan
URL: http://mwnewman.people.si.umich.edu/projects.html

Project title: Evaluating Smart Home Sensor Technology and the use of HomeOS for Monitoring Mobility Among Community-Dwelling Older Adults
PI: George Demiris, University of Washington

Project title: Wearable Multi-Sensor Gesture Recognition in Assistive Devices for Paralysis Patients
PI: Nilanjan Banerjee, University of Maryland
URL: Mobile, Pervasive and Sensor Systems Laboratory
Course: CMSC 691: Systems for Smart Home Automation

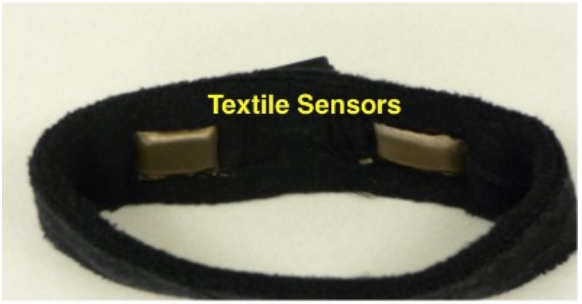
Project title: Scalable Radiator Valve Control for HomeOS
PI: Mike Hazas, Lancaster University
URL: Project Webpage

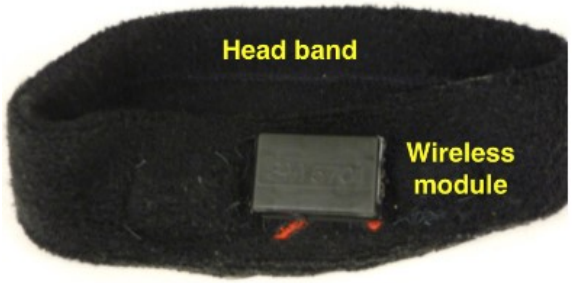
Project title: Intelligent Agents for Home Energy Management
PI: Alex Rogers, Southampton University
URL: Project Webpage

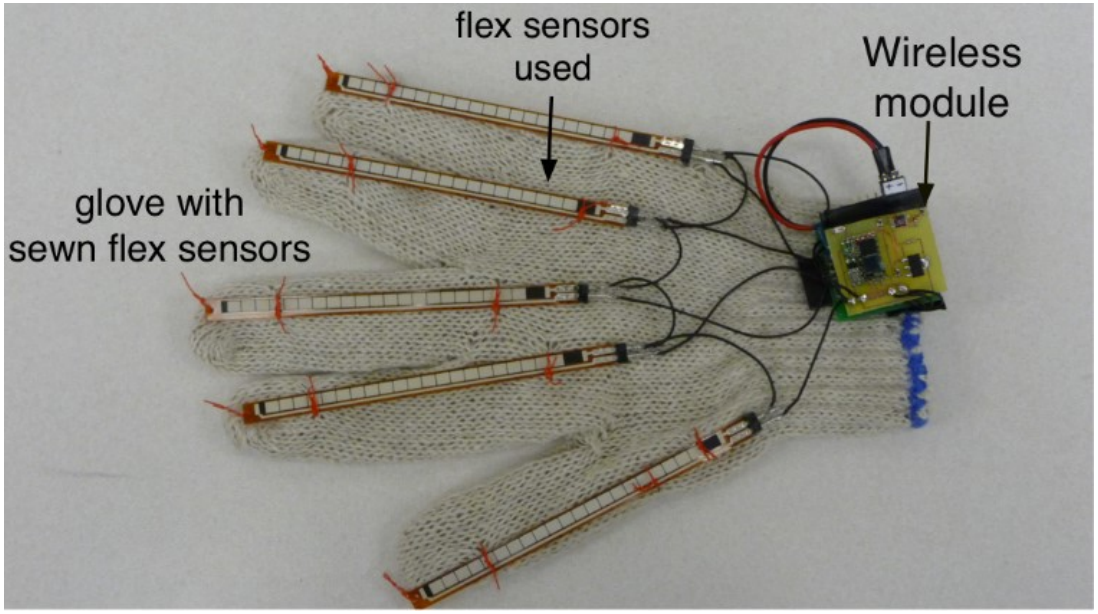
Project title: Intelligent and Scalable Monitoring/Control Platform for Home Energy Management
PI: Lanshun Nie, Harbin Institute of Technology

http://www.lab-of-things.com/community.html

Case Study 1: Allowing paralysis patients to control their environment



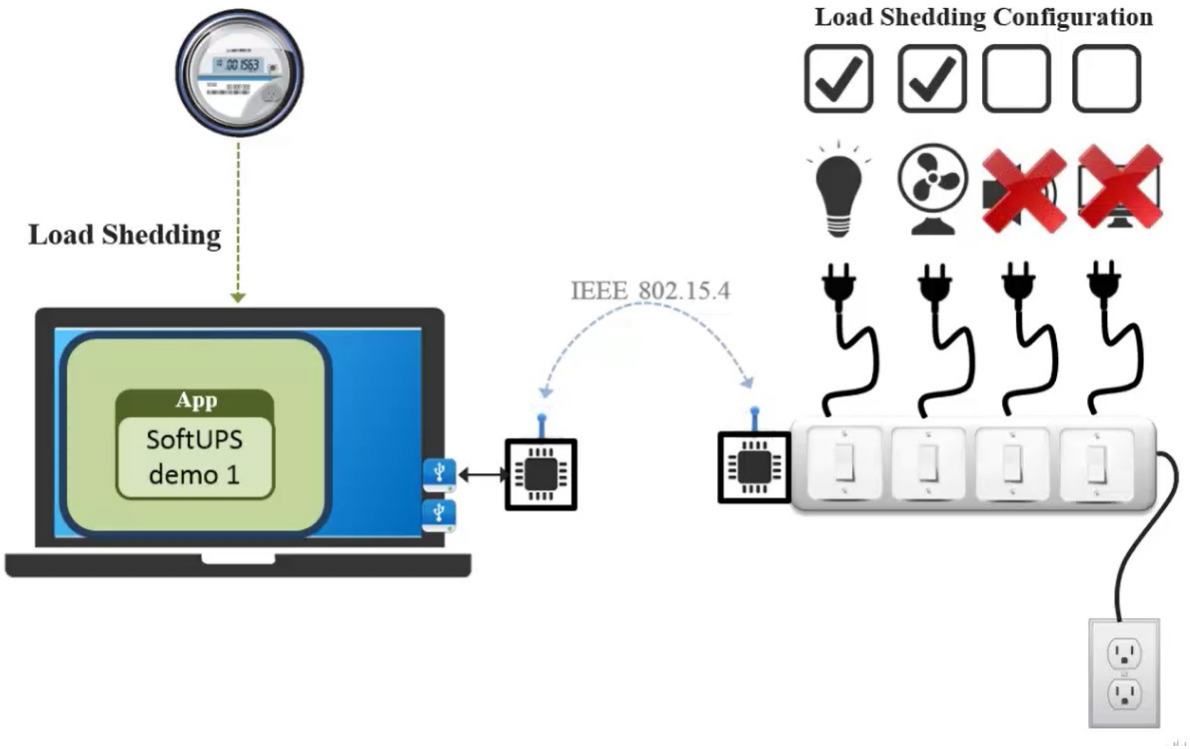




Nelson, A., Shyamkumar, P., Wilkins, W., Lachut, D., Banerjee, N., Rollins, S., Parkerson, J., Varadan, V., (2013) "Wearable Multi-Sensor Gesture Recognition for Paralysis Patients," Presented at IEEE Sensors '13, 4-6 November 2013.

Nelson, A. , Schmandt, J., Wilkins, W., Parkerson J., and Banerjee, N., (2013b) "System Support for Micro-Harveseter powered Mobile Sensing," Presented at RTSS '13, 3-6 December, 2013

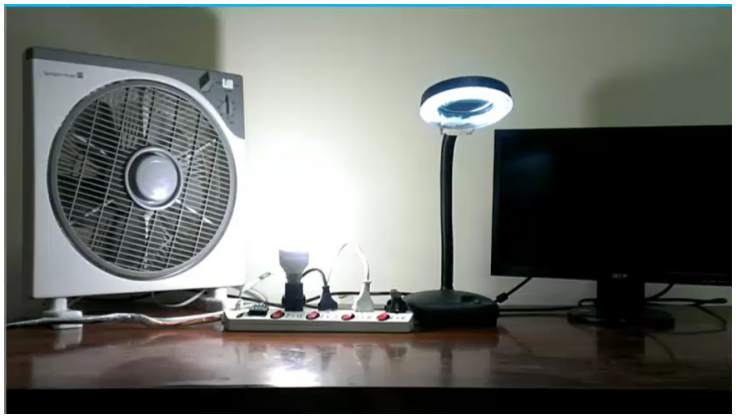
Case Study 2: Peak Load Sharing

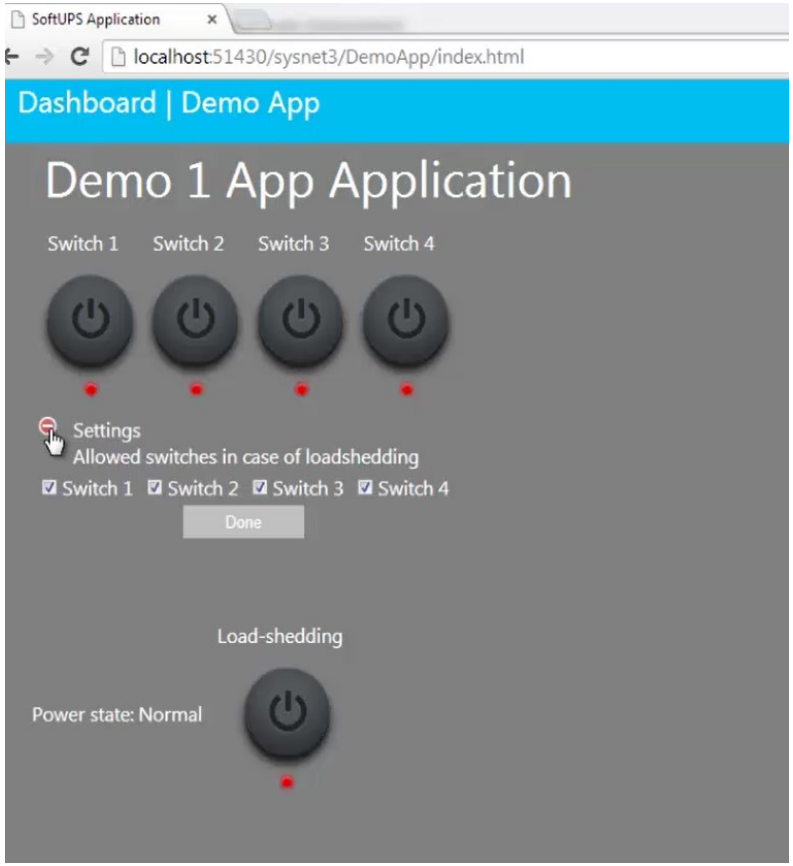


SoftUPS: Virtualizing the home UPS solution to enable efficient peak load sharing in developing world

Affan A. Syed Associate Professor and Director, SysNet Research Lab, National University of Computer and Emerging Sciences (NUCES)

Case Study 2: Peak Load Sharing

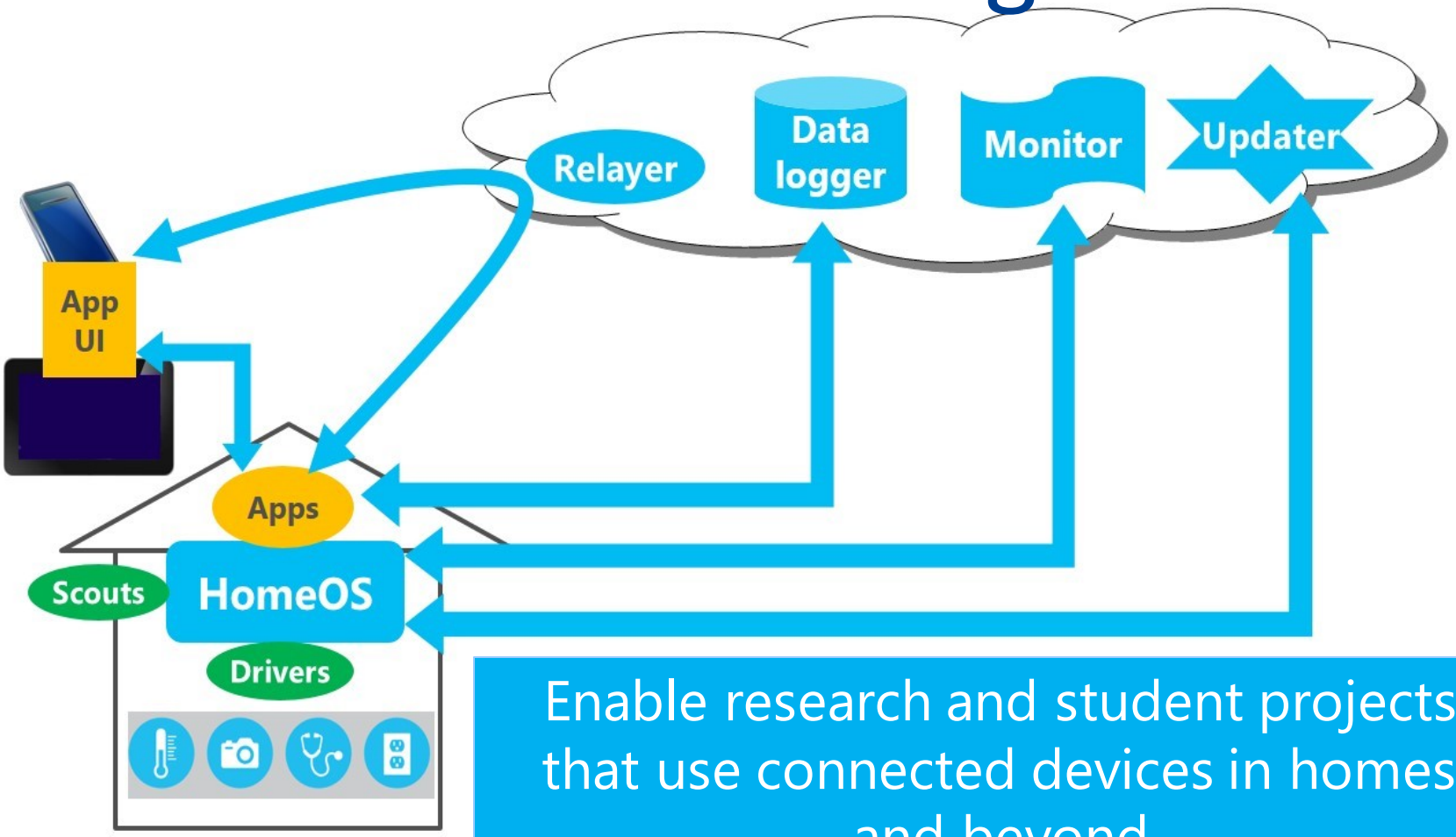




Interactive Furniture

Video not yet publicly available

Lab of Things



Enable research and student projects that use connected devices in homes and beyond

Thanks

More information:

http://research.microsoft.com/~ajbrush

http://www.lab-of-things.com

Join the LoT community!