
Lab of Things: A Platform for Conducting Studies with Connected Devices in Multiple Homes

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Abstract

Researchers who develop new home technologies using connected devices often want to conduct large-scale field studies in homes to evaluate their technology, but conducting such studies today is extremely challenging. Inspired by the success of PlanetLab, which enabled development and evaluation of global network services, we are developing a shared infrastructure for home environments, called Lab of Things. Our goal is to substantially lower the barrier to developing and evaluating new technologies for the home environment.

Author Keywords

Home automation; smart home; domestic technology

ACM Classification Keywords

H.5.2. User Interfaces. H.1.2. User/Machine systems.

Introduction

Homes are a challenging places to conduct studies and gather data. Researchers who wish to conduct a field deployment in homes, perhaps to understand current behavior or evaluate a new technology in-situ, face a number of challenges including recruiting and managing appropriate households, and ensuring their software and hardware configurations work robustly.

Because of these challenges, individual research groups rarely manage to deploy their prototypes in more than a dozen or so homes concentrated in their geographic area. Such deployments tend to lack the scale and diversity that is needed to confidently answer the research hypothesis. To lower the barriers to conducting field studies, we are building *Lab of Things*, a shared platform for conducting studies in homes.

We first outlined the vision and rationale of Lab of Things¹ in a HomeSys 2012 workshop paper presented at UbiComp 2012 [1]. This demo will show the work we have done over the past year to enable Lab of Things and allow attendees to evaluate whether Lab of Things would be useful for their research and teaching.

We envision Lab of Things to comprise of a large number of homes in various parts of the world, where each home has a Home Hub, on which studies can be run (illustrated in Figure 1). Individual research groups that participate in Lab of Things recruit and manage a dozen or so homes. They can then run their studies on other groups' homes in exchange for letting others run studies in their homes. While our long term goal is a shared test bed of homes, we believe researchers conducting home field deployments will benefit from using Lab of Things even if they initially (or always) conduct studies only in homes they manage.

Lab of Things Design

We define a *Lab of Things study* as a research application (e.g. energy monitoring, occupancy sensing, adaptive heating) running in multiple homes. Lab of Things provides a common framework to write

¹ Lab of Things was previously called HomeLab.

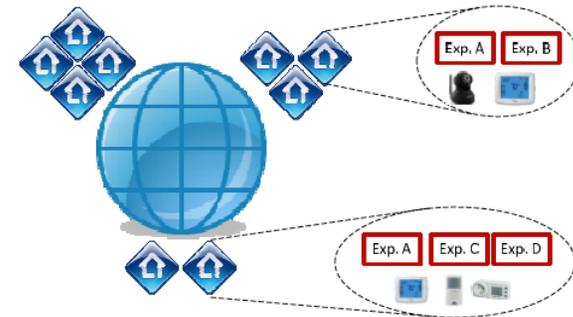


Figure 1: Lab of Things will consist of multiple sites across the world. Each site has multiple homes and is managed by a research group.

applications and has a set of capabilities beneficial to field deployments including logging application data from houses in cloud storage, remote monitoring of system health, and remote updating of applications if needed (e.g. to change to a new phase of the study by enabling new software, or to fix bugs).

Lab of Things builds on top of HomeOS [2]. HomeOS provides a PC-like abstraction for in-home hardware and simplifies the tasks of writing applications and managing sensors. Each household in Lab of Things runs HomeOS on dedicated computer, the Home Hub, which interacts with the in-home sensors and hosts the applications needed for the study (or studies) in which the household is participating.

In the demo we will show the following capabilities of Lab of Things:

- **Extensible support for devices:** Lab of Things supports a wide range of off-the-shelf devices (e.g., many Zwave sensors, IP cameras) as in-home sensors, as well as custom devices built using .NET Gadgeteer [4]. The platform provides mechanisms for additional devices or prototypes to be added and shared amongst the research community. Research groups that have been using HomeOS over the past year (see [3] for examples) have already contributed drivers to support several devices (see <http://homeos.codeplex.com/>).
- **Simple application development:** Lab of Things maintains the benefits that HomeOS offers to application developers. In particular, HomeOS decouples application logic from device specifics. For instance, an application can collect energy consumption data using various types of sensors while being agnostic to sensor-specific protocols (e.g., Zwave, Zigbee, or WiFi).
- **Simple setup:** Simplifying the often complex and tedious setup of sensors in a home, Lab of Things provides a unified interface for a researcher or participant to setup and configure in-home hardware. This setup interface is extensible to support additional devices as needed.
- **Data storage and access:** Lab of Things incorporates a Home Data Store which provides seamless transfer of application data to the cloud, and handles scarce in-home storage and intermittent network connectivity. As a result, researchers get reliable, low-latency access to their data, conducive for data analysis.
- **User security and privacy:** Studies involving end-user applications can easily incorporate robust user authentication and authorization. For instance, researchers do not need to re-design parental control,



Figure 2. Example in-home deployment

guest access, out-of-home access to applications, or DoS prevention components in their applications.

Figure 2 shows an example Lab of Things deployment setup. The netbook serves as the Home Hub and runs our in-home framework (HomeOS) which interacts with sensors including a Foscam IP camera, Aeon Zwave door-latch, water-leaks sensors and power switch. Cloud services run on Microsoft Azure, to provide remote access for home user and experiment management for researchers.

Conclusion

By reducing the effort required for researchers to conduct home field deployments, we believe that Lab of Things has the potential to change the scale and pace of research on connected devices in homes. We invite any interested researchers and practitioners to use Lab of Things to conduct studies and join us in continuing the development of the platform.

Acknowledgements

We thank all the people that have worked on HomeOS and Lab of Things.

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