Pervasive Computing, IoT and Smart Buildings

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Pervasive Computing

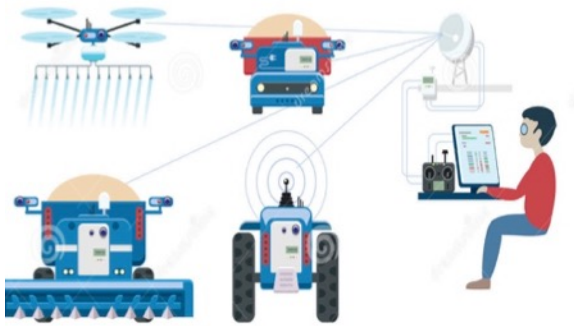
- Computing is becoming increasingly ubiquitous
- Sensing and computing "everywhere"
  - Increasingly part of physical environments
  - Enables many new application domains

Smart Health

Smart Buildings

Smart Transportation

Smart Agriculture



Rise of Pervasive Computing

- Miniaturization of computing
  - Tiny sensors with computing and communication capability
  - MEMS: MicroElectroMechanical Systems
  - Expectation: Moore's law-like growth in MEMS
- Rise of internet of things
  - Network of Physical Devices
  - Ability to network devices and have them communicate
  - Large network of sensors

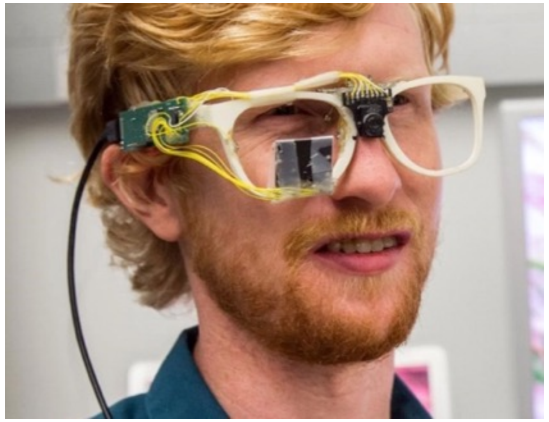
Smart Health

- Early Wearables devices
  - Fitness, exercise tracking
  - Sleep, heart rate, …
- New technologies emerging:


Smart Clothing


On-body monitoring

Smart Glasses

Gaze tracking, fatigue detection

Smart Buildings

- Proliferation of smart devices in homes

Thermostat

Smart Plug

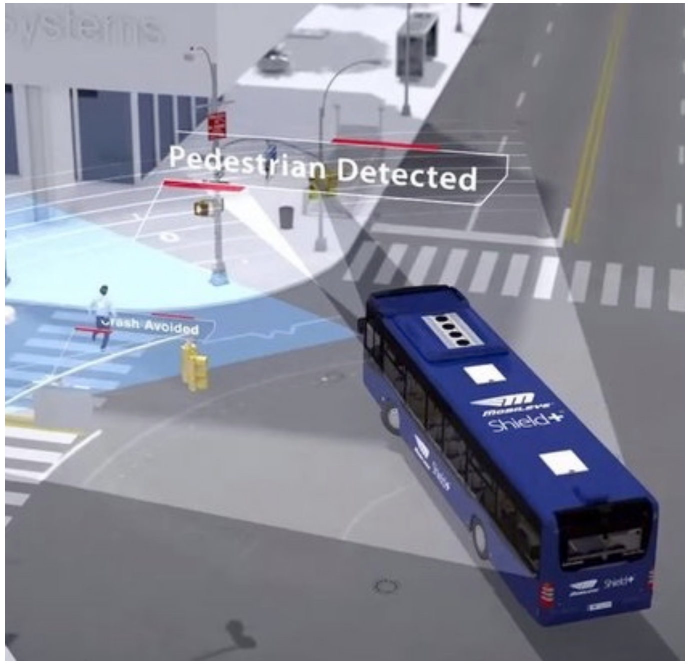
Smart Appliances

Smart Lock

- Phone and voice interfaces:

Smart Transportation

- Smart Roadways
  - Reactive Lights/Dynamic Lanes
  - Road Condition Monitoring
  - Traffic Management
- Connected Cars
  - Accident avoidance
  - Fleet Management
  - Real time public transport alerts



Typical smart app

- Personal device to mobile phone to the cloud
  - Upload data to cloud via a mobile device (or directly)
  - Low-power communication to phone
  - Cloud provides analytics and provides feedback to phone

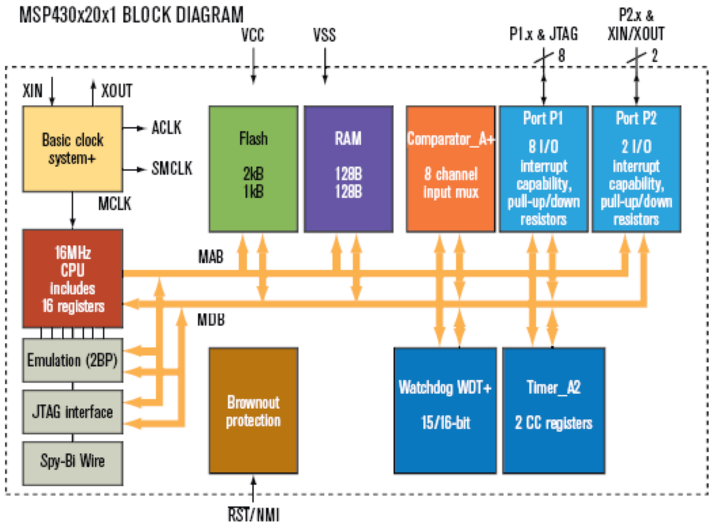
- Environmental sensors to internet to the cloud
  - Internet-enabled sensors
  - Upload to directly to servers / cloud through a router
  - Cloud provides analytics and provides dashboard

Sensor Platform

- Smart devices are a sensor node
- Resource-constrained distributed system
- Typical Sensor platform
    - Small CPUs
        - E.g. 8bit, 4k RAM
    - Low-power radios for communication
        - 10-200kbit/sec
    - Sensors
    - Battery driven or self-powered
    - Flash storage

Small CPUs

- Example: Atmel AVR
  - 8 bit
  - 4 KB RAM
  - 128 KB flash on-chip
  - ~8 mA
- Example: TI MSP430
  - 16 bit
  - 10 KB RAM
  - 48 KB flash
  - 2 mA



Higher-powered processors:

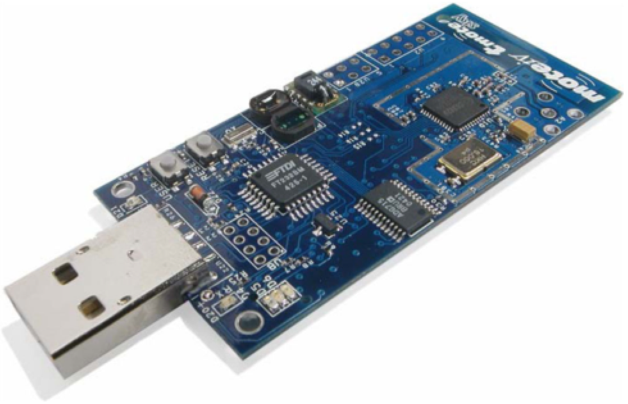
- ARM7 - 32 bit, 50 MHz, >>1MB RAM
- ARM9 - 32 bit, 400 MHz, >>16MB RAM

Low Power Radios

- Industrial, Scientific and Medical (ISM) Band
  - 900 MHz (33 cm), 2400 MHz (Bluetooth)
- Varying modulation and protocol
  - Zigbee (IEEE 802.15.4) – Modulating Phase
  - Bluetooth (IEEE 802.15.1) – Modulating Frequency
- Short range
  - Typically <100 m
- Low power. E.g. Chipcon CC2420:
  - 9-17 mA transmit (depending on output level)
  - 19 mA receive
- Listening can take more energy than transmitting

Battery power

- Example: Mica2 "mote"
  - Total battery capacity: 2500mAH (2 AA cells)
  - System consumption: 25 mA (CPU and radio on)
  - Lifetime: 100 hours (4 days)



- Alternatives:
  - Bigger batteries
  - Energy Harvesting (Solar/Wind/Motion)
  - Duty cycling

Sensors

- Temperature
- Humidity
- Magnetometer
- Vibration
- Acoustic
- Light
- Motion (e.g. passive IR)
- Imaging (cameras)
- Accelerometer
- GPS
- Lots of others…

Self-harvesting Sensors

- Harvest energy from environment to power themselves
    - tiny solar panels,
    - use vibration,
    - thermal,
    - airflow, or
    - wireless energy

Typical Design Issues

- Single node
  - Battery power/how to harvest energy to maximize lifetime
- Inside a network of sensors
  - Data aggregation
  - Duty cycling
  - Localization, Synchronization
  - Routing
- Once data is brought out of the network (server-side processing)
  - "Big data" analytics
  - Derive insights
  - Make recommendations, send alerts
  - Provide active control

Green Computing

- Greening of Computing
  - Sustainable IT
    - How to design energy-efficient hardware, software and systems?

- Computing for Greening
  - Use of IT to make physical infrastructure efficient
    - Homes, offices, buildings, transportation

Historical Overview

- Energy-efficient mobile devices a long standing problem
  - Motivation: better battery life, not green
- Recent growth of data centers
  - More energy-efficient server design
  - Motivation: lower electricity bills
    - Green systems, lower carbon footprint
- Apply "Greening" to other systems
  - IT for Greening

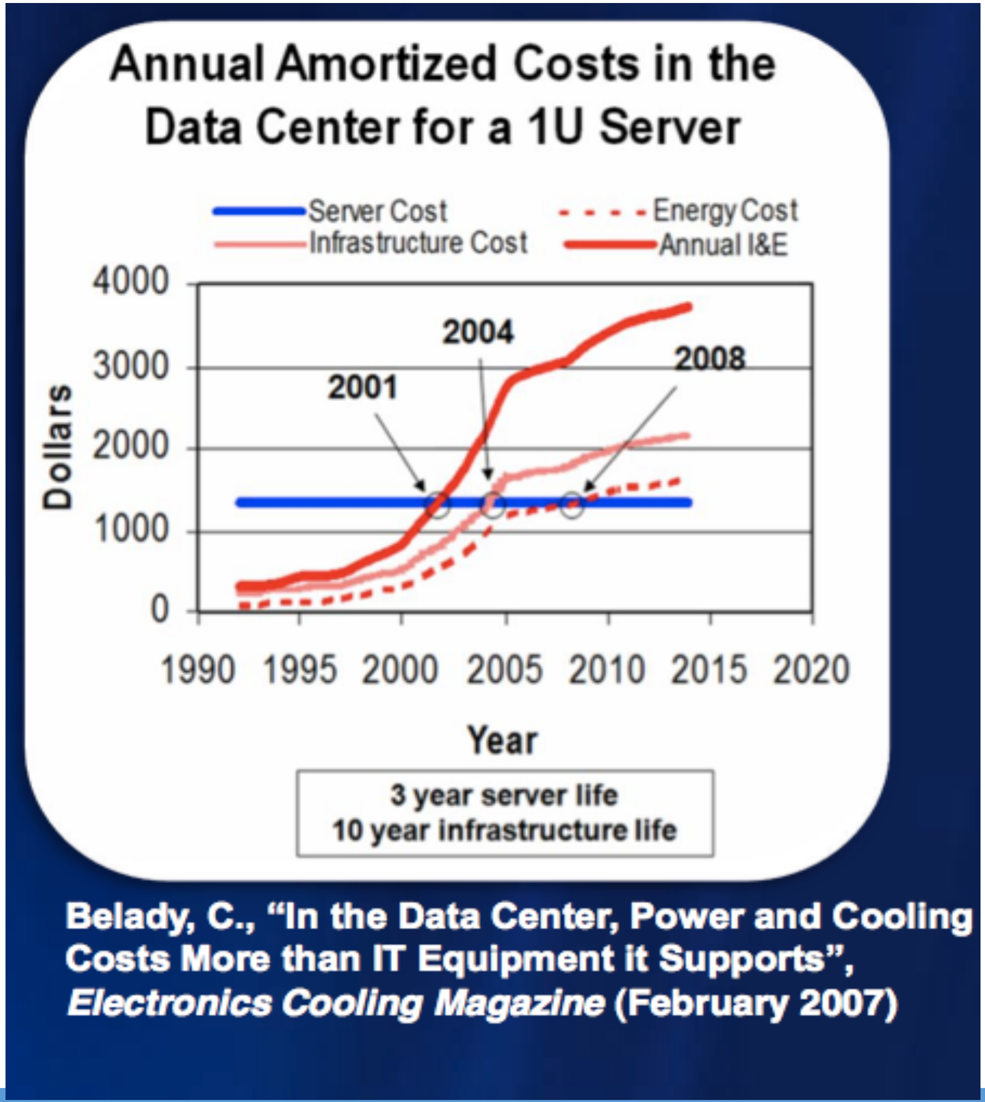
Computing and Power Consumption

- Energy to Compute
  - 20% power usage in office buildings
  - 50-80% at a large college
  - 3% of our carbon footprint and growing
- Data centers are a large fraction of the IT carbon footprint
  - PCs, mobile devices also a significant part

What is a data center?

- Facility for housing a large number of servers and data storage
- Google data center (Dalles, OR)
  - 12 football fields in size
  - ~ 100K servers
- 100 MW of power
  - Enough for a small city

Data Center Energy Cost



Energy Bill of a Google Data Center

- Assume 100,000 servers
- Monthly cost of 1 server
  - 500W server
  - Cost=(Watts X Hours / 1000) * cost per KWH
  - Always-on server monthly cost = $50
- Monthly bill for 100K servers = $5M
- What about cost of cooling?
  - Use PUE (power usage efficiency)
  - PUE =2 => cost doubles
  - Google PUE of 1.2 => 20% extra on 5M (~ $6M)

How to design green data centers

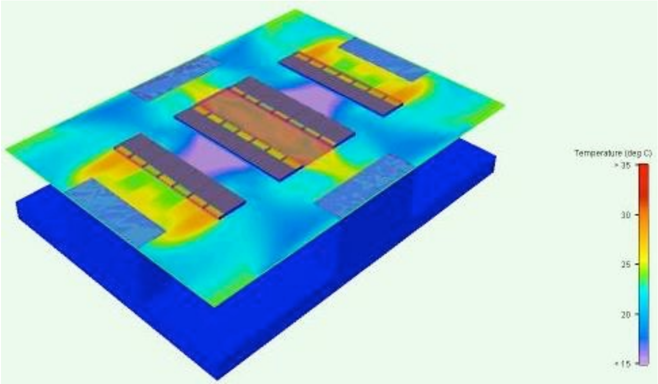
- A green data center will
  - Reduce the cost of running servers
  - Cut cooling costs
  - Employ green best practices for infrastructure

Reducing server cost

- Buy / design energy-efficient servers
  - Better hardware, better power supplies
  - DC is more energy-efficient than AC
- Manage your servers better!
  - Intelligent power management
  - Turn off servers when not in use
  - Virtualization => can move apps around

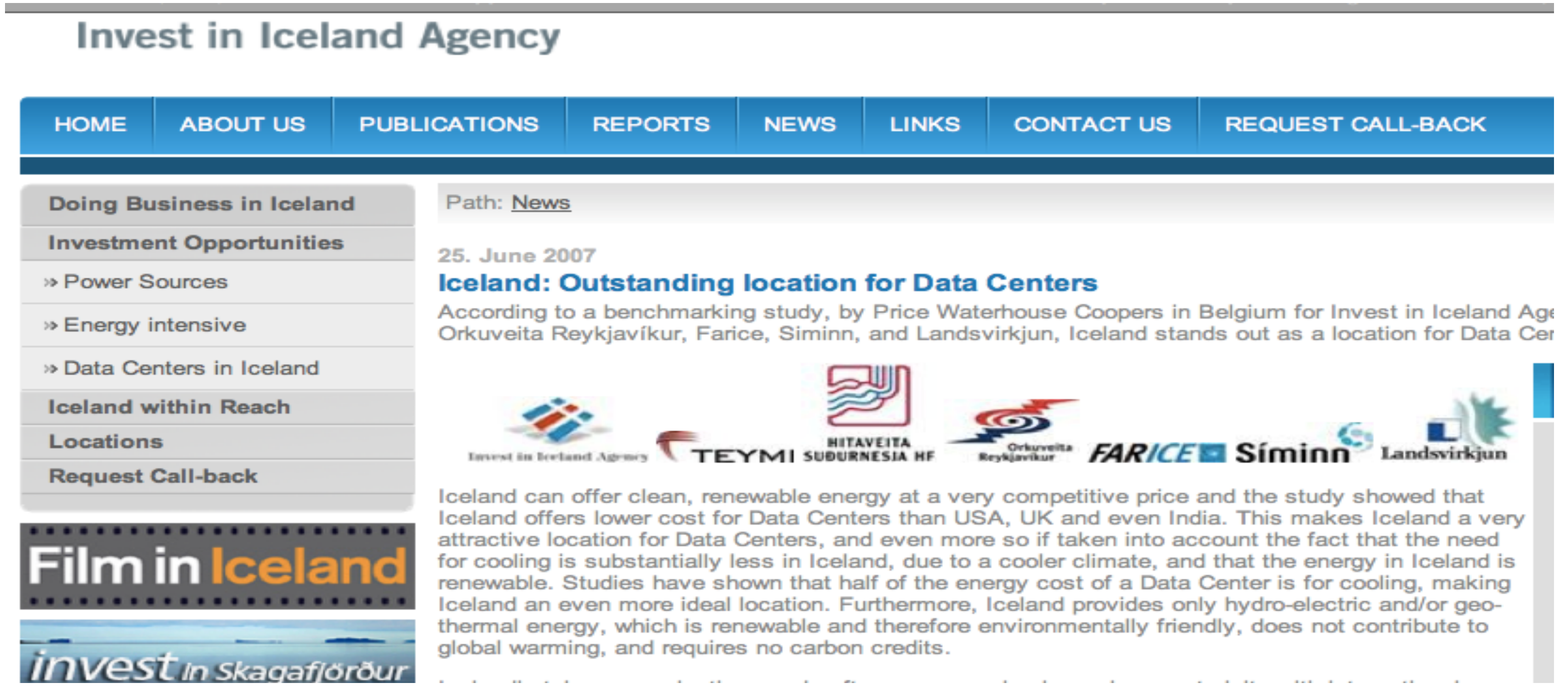
Reducing cooling cost

- Better air conditioning
  - Thermal engineering / better airflow
  - Move work to cooler regions
- Newer cooling
  - Naturally cooled data centers
  - Underground bunkers



Build them in Iceland

- Free cooling-based data centers


Invest in Iceland Agency

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Path: News

25. June 2007

Iceland: Outstanding location for Data Centers

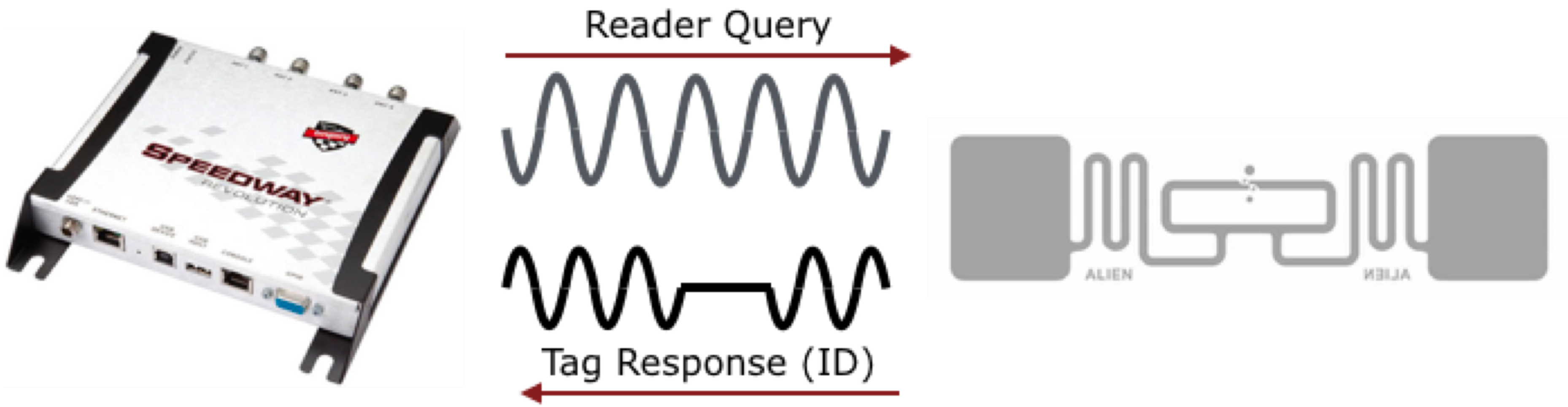
According to a benchmarking study, by Price Waterhouse Coopers in Belgium for Invest in Iceland Age
Orkuveita Reykjavíkur, Farice, Siminn, and Landsvirkjun, Iceland stands out as a location for Data Cer

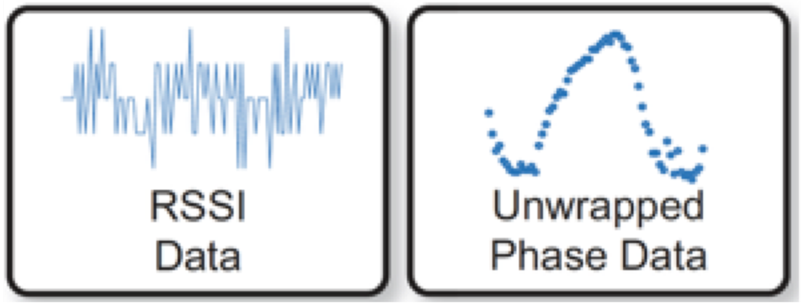
TEYMI HITAVEITA SUÐURNESJA HF Orkuveita Reykjavíkur FARICE Síminn Landsvirkjun

Iceland can offer clean, renewable energy at a very competitive price and the study showed that Iceland offers lower cost for Data Centers than USA, UK and even India. This makes Iceland a very attractive location for Data Centers, and even more so if taken into account the fact that the need for cooling is substantially less in Iceland, due to a cooler climate, and that the energy in Iceland is renewable. Studies have shown that half of the energy cost of a Data Center is for cooling, making Iceland an even more ideal location. Furthermore, Iceland provides only hydro-electric and/or geo-thermal energy, which is renewable and therefore environmentally friendly, does not contribute to global warming, and requires no carbon credits.

Battery-Free IoT

RFID Sensing:





Read rate:
~50 samples / second

Ubiquitous RFID Challenges

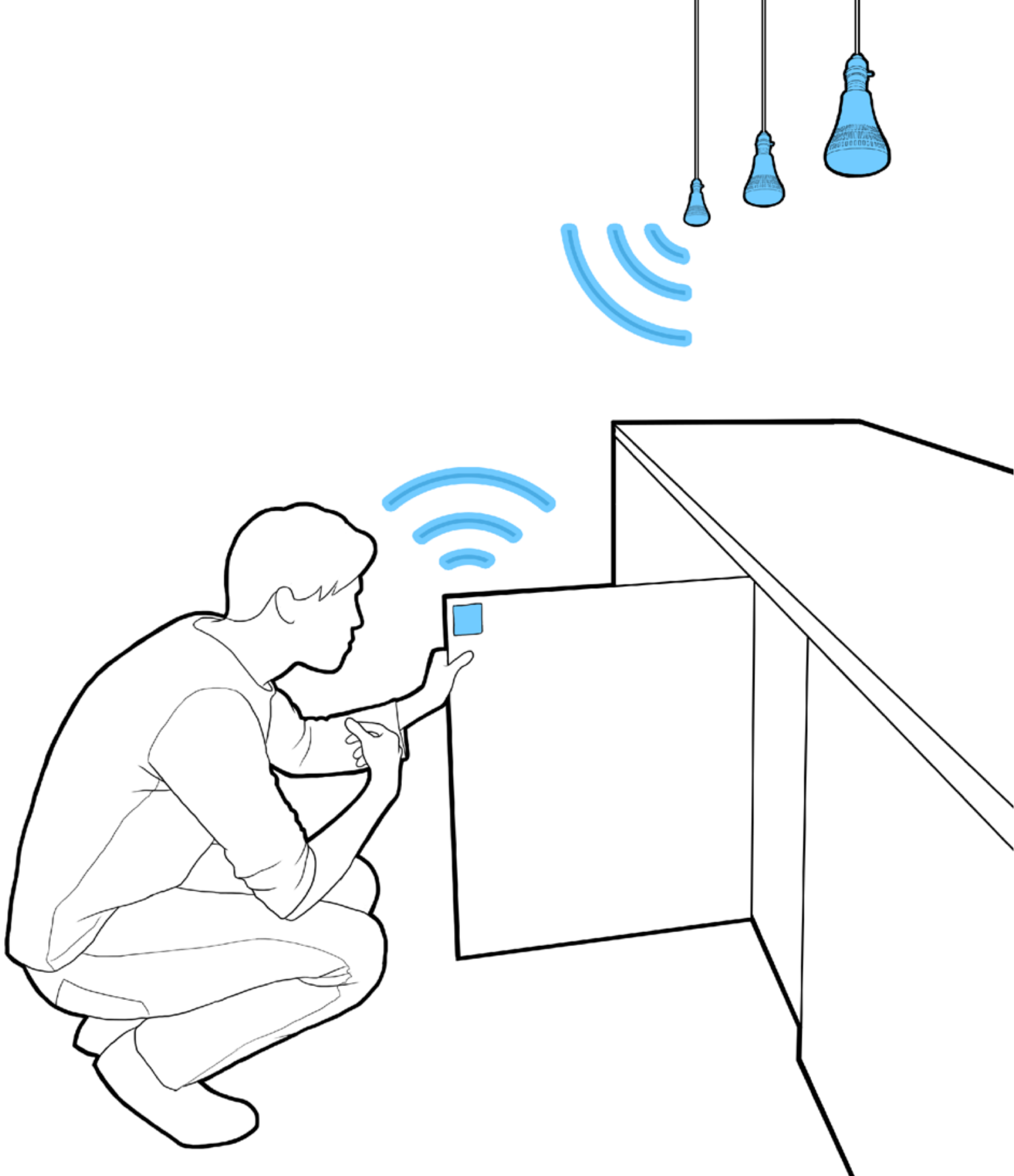
1. Routing power and communications to readers is challenging

2. Antennas need to be large to achieve good coverage

3. Antennas need line of sight to tags

Idea: Reuse Existing Home Infrastructure

Our Solution: The RFID Light Bulb



Our Solution: The RFID Light Bulb

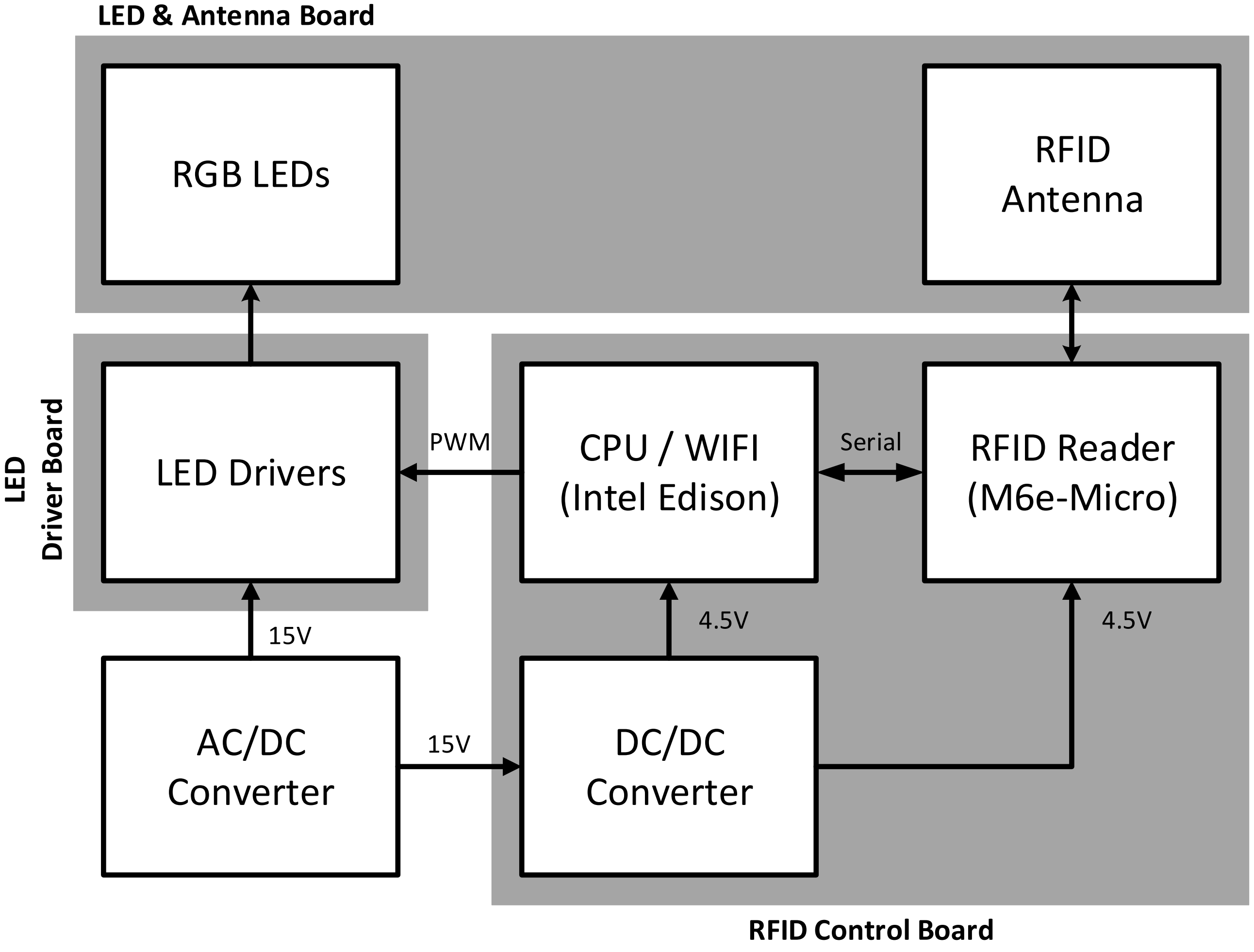
Technical Overview

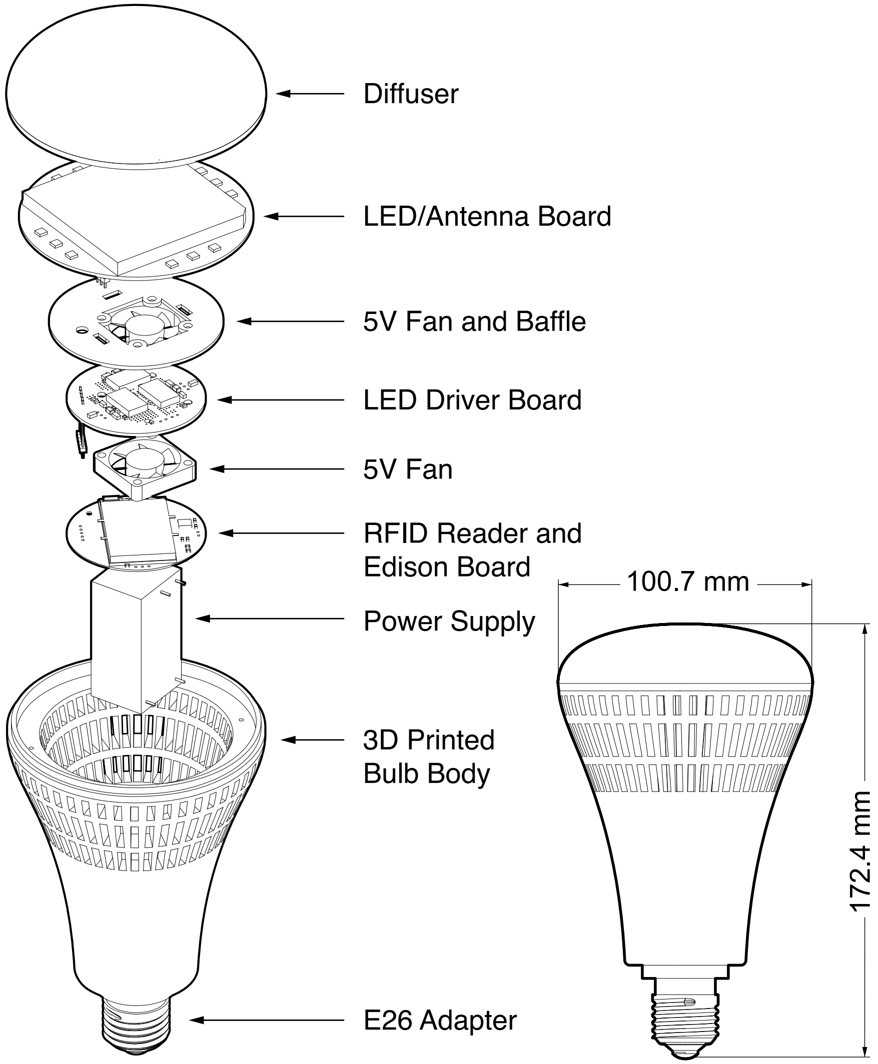
1. Install light bulbs, associate with WiFi APs

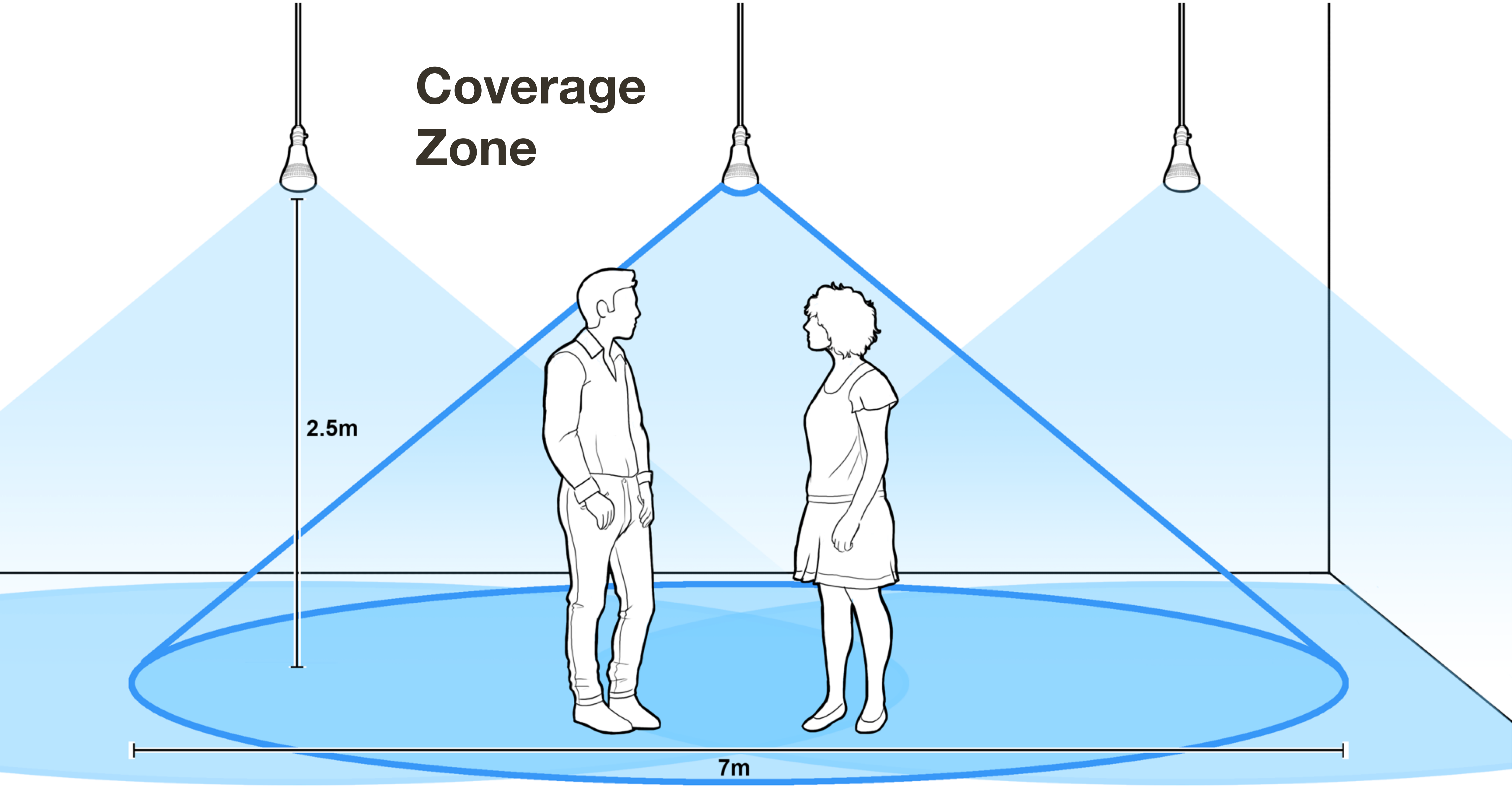
2. Install tags, Register with backend

3. Interpret tag data, Actuate lighting / UI

Hardware Design

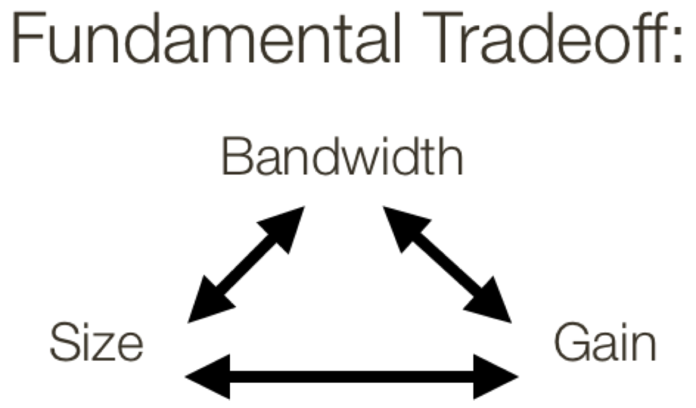


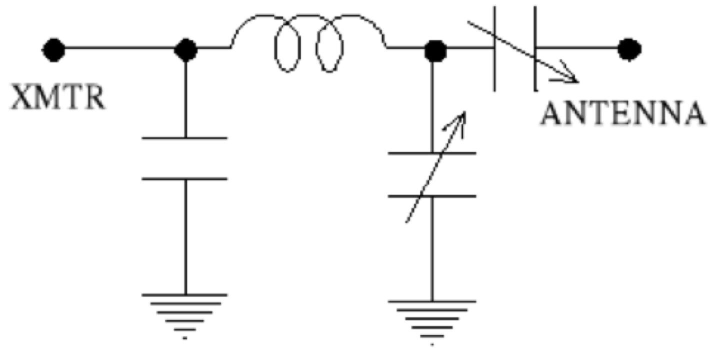


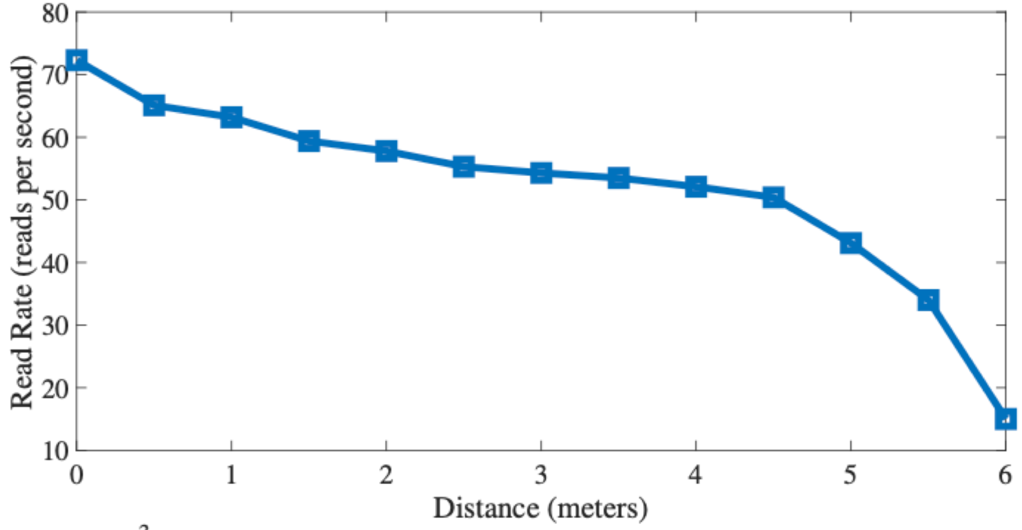


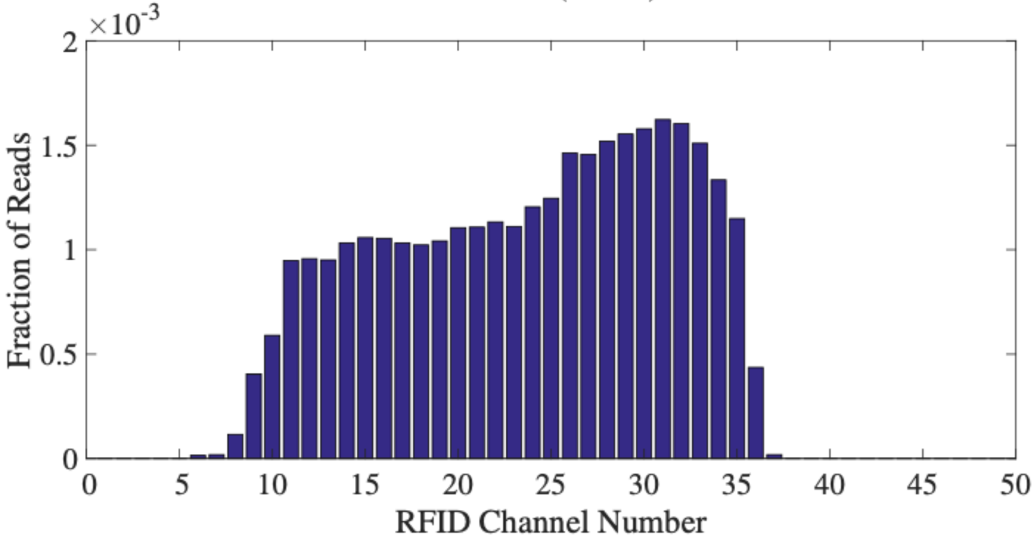
Coverage
Zone
2.5m
7m

Antenna Evaluation

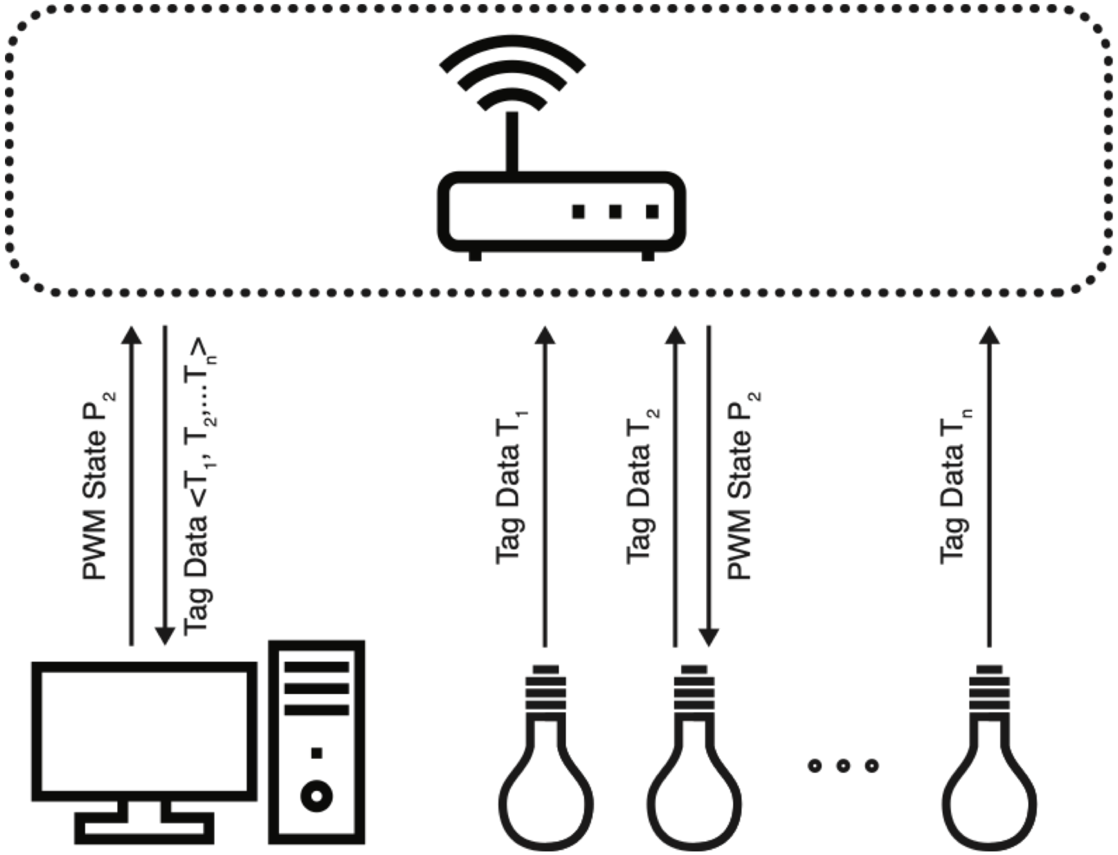








Lightbulb Software



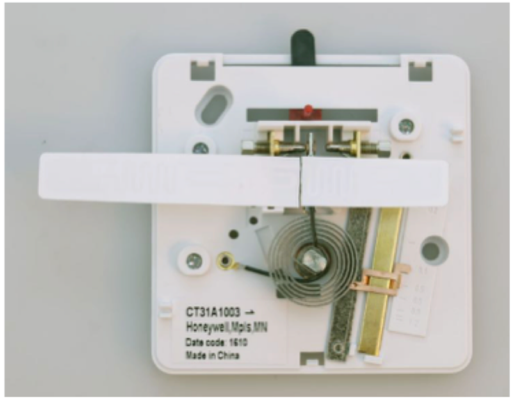
RFID Server:
UDP packet stream including:
<ID, RSSI, Phase, Sensor Value>

PWM Server:
TCP Packet Containing:
<Red, Green, Blue, Fadesec>

Interactive RFID Tags

Location

Thermostat



Touch

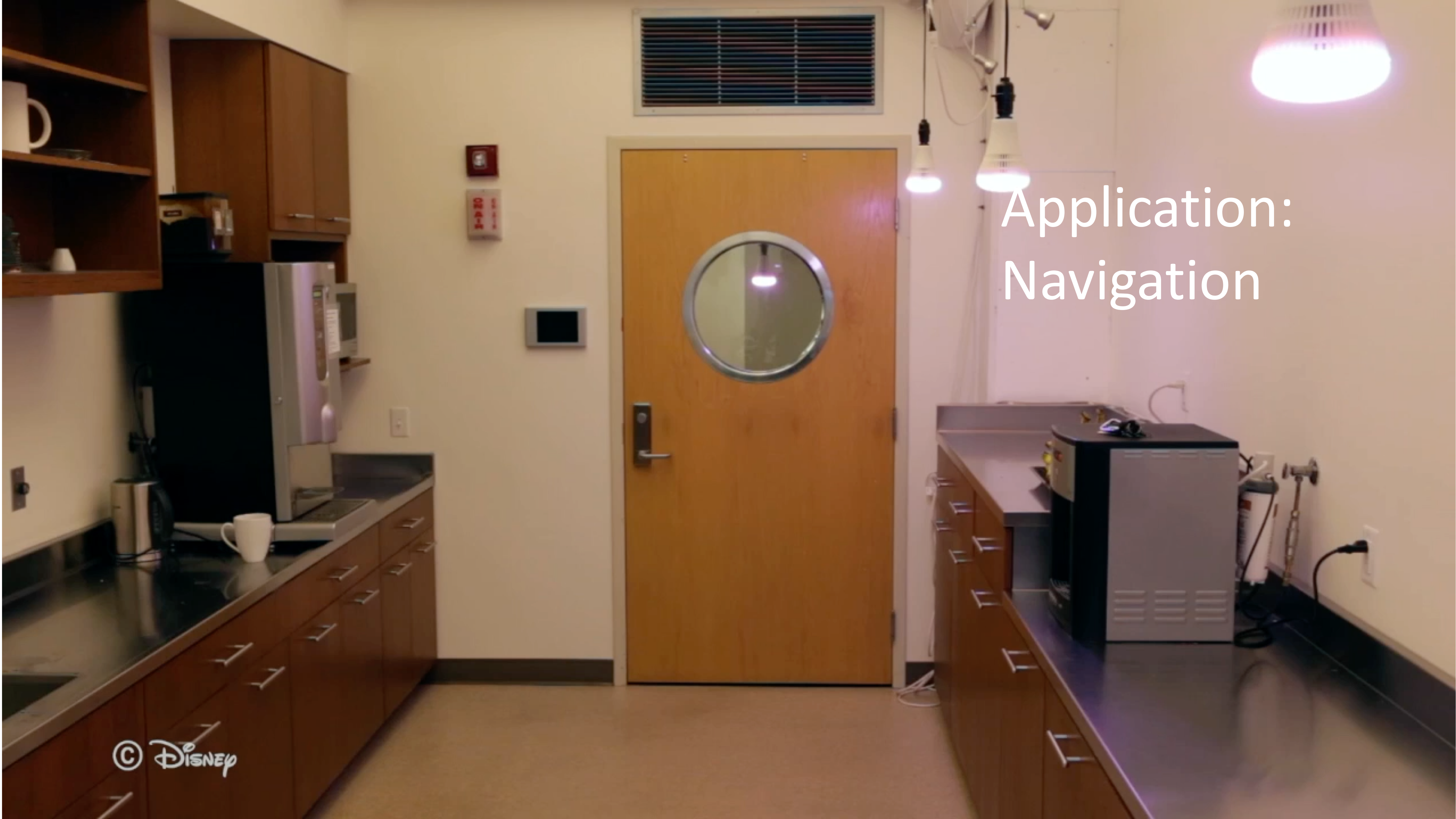
Temperature

Contact Switch

Application Overview

To showcase the applications enabled by networks of RFID light bulbs, we explore three application categories that leverage the scale of coverage and immediate feedback that RFID light bulbs provide:

1. Navigation
2. Infrastructure Monitoring
3. Prepackaged Content


Application:
Navigation
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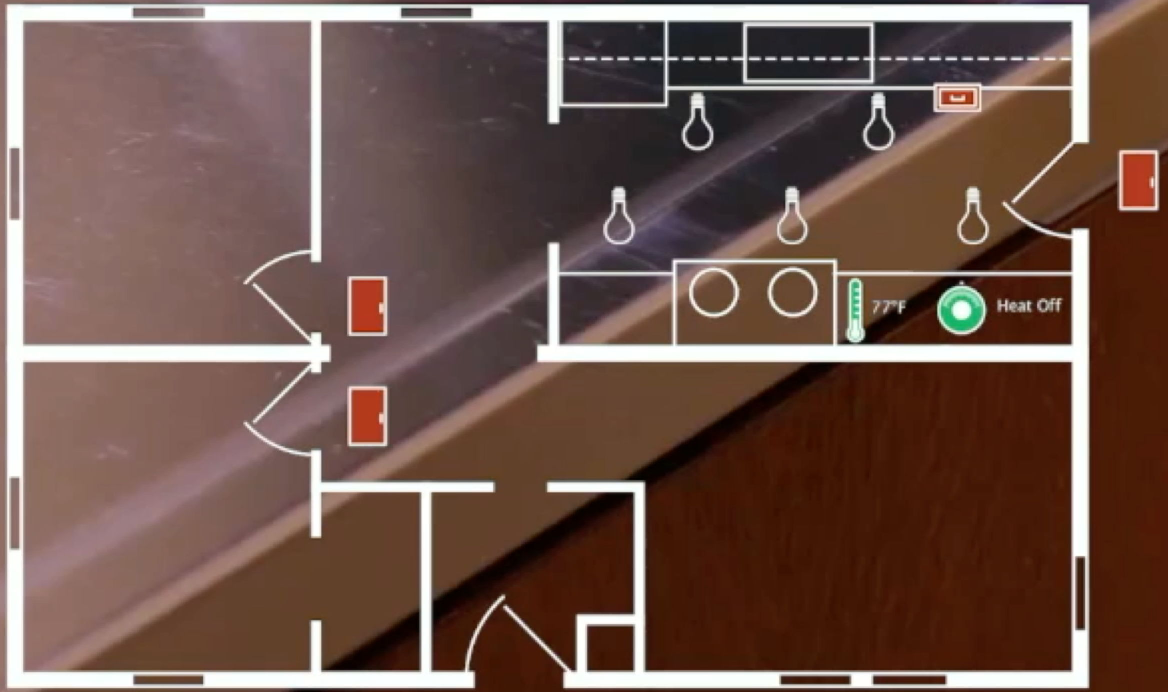

Application: Infrastructure Monitoring

Application: Pre-packaged Content

Summary

- "Greening" of computing for IoT and Health Applications
  - Design of energy-efficient hardware & software

- Computing for greening
  - Use of IT for monitoring, analytics, and control
  - Use of intelligent software for power management
  - Forecasting for renewable energy harvesting

- Emerging IoT Technologies
  - Battery-free Sensing with RFID Sensors