Is Anybody Home? Inferring Activity from Smart Home Network Traffic

Bogdan Copos Matt Bishop Karl Levitt Jeff Rowe

University of California, Davis

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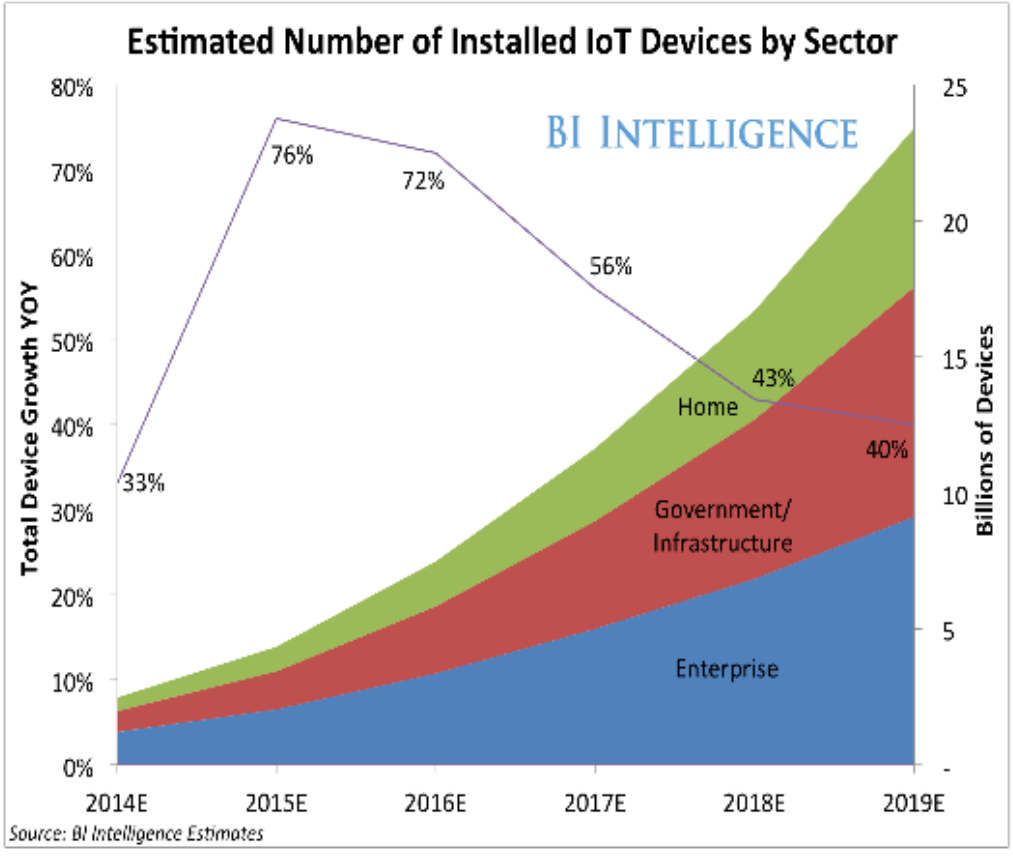
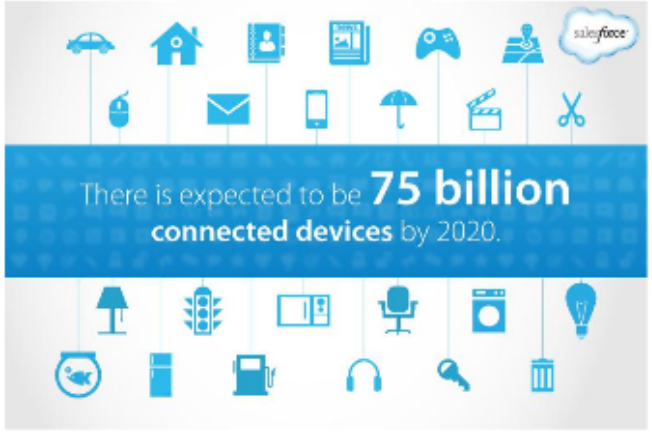

Estimated Number of Installed IoT Devices by Sector
BI INTELLIGENCE
Total Device Growth YOY
Billions of Devices
80%
70%
60%
50%
40%
30%
20%
10%
0%
25
20
15
10
5
-
76%
72%
56%
43%
40%
33%
Home
Government/
Infrastructure
Enterprise
2014E
2015E
2016E
2017E
2018E
2019E
Source: BI Intelligence Estimates


There is expected to be 75 billion
connected devices by 2020.


U.S. Unit Sales of
Smart Home Devices*
MILLIONS OF UNITS
40
20
0
2014
2015
2016
2017
* Smart thermostats, networked cameras, smart door locks, smart water leak detectors, smart smoke detectors, smart carbon monoxide detectors, and smart light bulbs, smart light switches, smart plugs and outlets, and smart power strips
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Samsung Smart Home flaws let hackers make keys to front door

Don't rely on SmartThings for anything security related, researchers warn.

by **Dan Goodin** - May 2, 2016 11:31am PDT

Samsung Smart Home flaws let hackers make keys to front door

Don't rely on Sma

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KIM ZETTER SECURITY 01.05.16 7:00 AM

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For The First Time, Hackers Have Used A Refrigerator To Attack Businesses

Julie Bort

Jan. 16, 2014, 1:36 PM 197,861 39

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DEAN TAKAHASHI AUGUST 10, 2014 8:00 AM


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Report: Thieves Can Hack and Disable Your Home Alarm System | WIRED

POSTED BY: PAUL JULY 23, 2014 10:16 COMMENTS OFF ON REPORT: THIEVES CAN HACK AND DISABLE YOUR HOME ALARM SYSTEM | WIRED

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Security

Many things can go wrong...

- malicious firmware

  e.g. Nest hack presented at BlackHat '14

- poor authentication

  e.g. Rapid7 report on baby monitors hacks

- communication hack

  e.g. Xfinity Home Security System jamming hack

- compromised cloud

  nothing yet?

- **data inference**

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Traffic Analysis

The process of analyzing network traffic for inferring information about the device and its state

- packet/connection size
- protocol
- source/destination address
- timing information
- burstiness

Background

Traffic Analysis:

- Web Browsing
- Marketing
- Reconfiguring Networks
- Monitoring

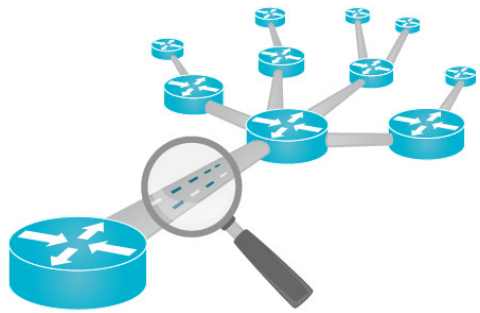
IoT/Smart Home Devices:

- "**Extrapolation and prediction of user behaviour from wireless home automation communication**"

  F. Mollers et al (WiSec '14)
- "**Smart Nest Thermostat: A Smart Spy in Your Home**"

  G. Hernandez (BlackHat '14)
- "**Security Analysis of Emerging Smart Home Applications**"

  E. Fernandes et. al. (S&P '16)



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Devices

- Nest Thermostat 2nd Generation
  - remotely control temperature
  - motion detector
  - self-learning schedule
  - interface for settings and usage logs
  - 802.15.4 radio
- Nest Protect 2nd Generation
  - motion detector
  - Pathlight
  - Nest Interconnect
  - 802.15.4 radios

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Problem Statement

What does network traffic tell us about the devices (and their state)?

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Can network traffic be used to infer state of building?

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Events of Interest

1. Nest Thermostat mode
   - Home
   - Auto-Away

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2. Nest Protect Pathlight Activation

Events of Interest

1. Nest Thermostat mode
   - Home
   - Auto-Away
2. Nest Protect Pathlight Activation
3. Nest Protect Smoke Alarm

Setup

HP netbook

Network interface in monitor mode

dumpcap with MAC address based filter

Approximately 1 month of pcaps

Convert pcaps to connection logs using *Bro*

User Activity

User activity during time of packet captures varies:

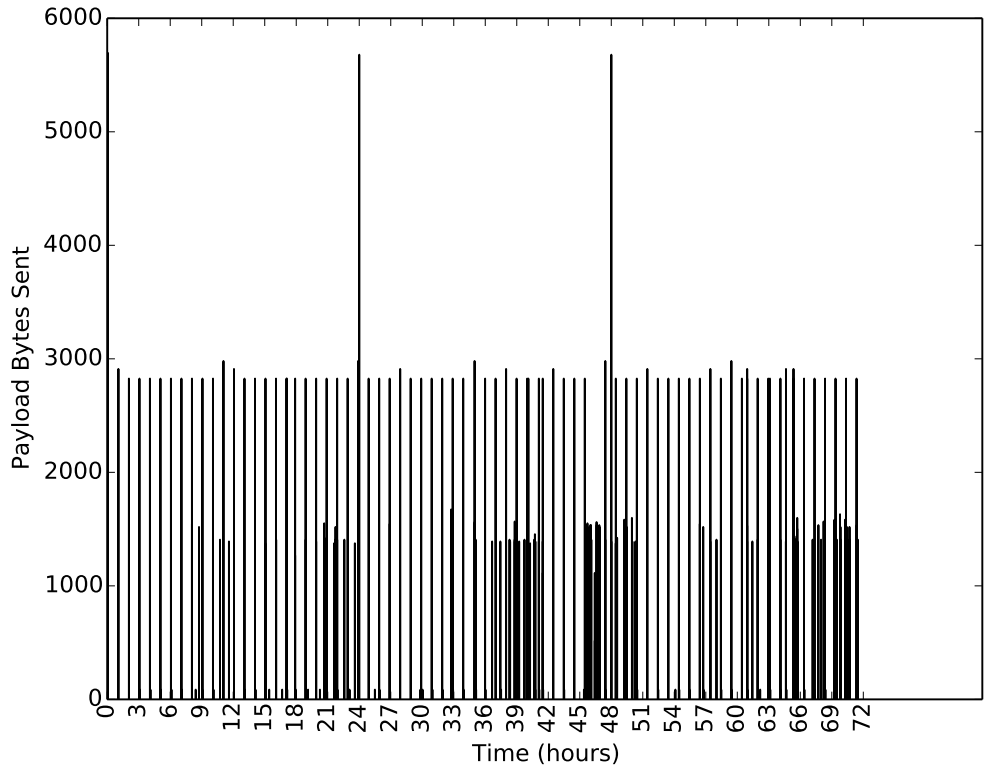
- time of arrival
- time of departure
- number of arrivals & departures

Traffic Overview

Nest Thermostat

- 14 hosts
- HTTP, **NTP**, DNS, SSL/TLS

HTTP used to obtain weather data



Correlation Analysis

Supervised correlation analysis to identify connections (up to set of three connections) which occur only during the time of an event.

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1. Extract time of events (i.e. *ground-truth*)
2. Parse *connection logs* and extract connections
3. For each type of event, generate frequency count per connection
4. Identify connections with high correlations

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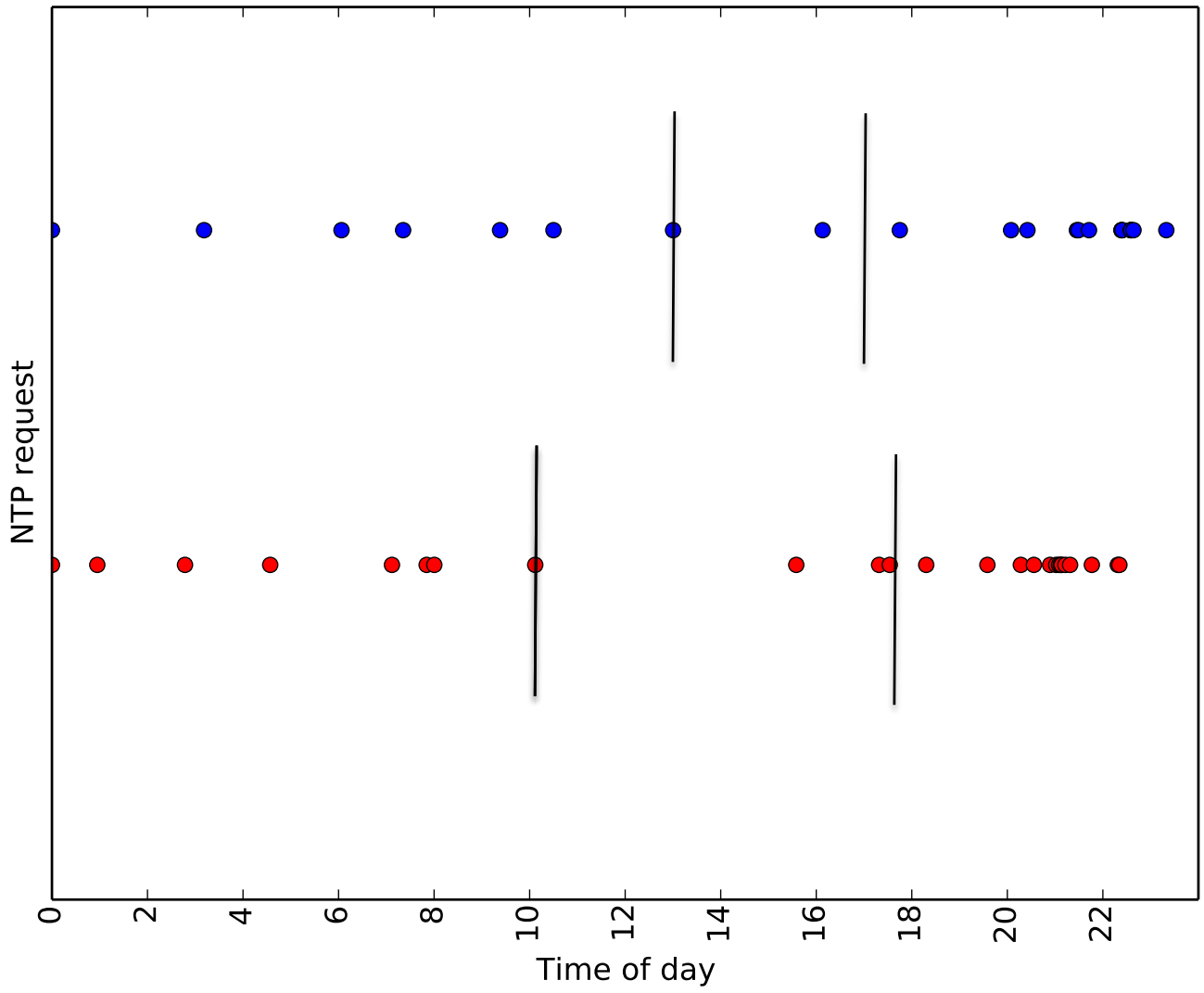
Findings

- Mode Transition
  - *Home* $->$ *Auto-Away*: set of 3 connections
  - *Auto-Away* $->$ *Home*: single connection
  - NTP requests
- Pathlight Activation
- Smoke Alarm
  - set of 2 connections

NTP Traffic



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Evaluation

- **Mode Transition**
  Home $->$ *Auto-Away*: 67% accuracy, 0 False Positives
  Auto-Away $->$ *Home*: 88% accuracy, 0 False Positives
- **NTP Requests**
  simple SVM approach (features = number of NTP requests per hour period)
  81% accuracy
- **Pathlight Activation**
  50% accuracy (100% sensitivity), 0 False Negative
  FP due to repeated connections after 30 minutes
- **Smoke Alarm**
  100% accuracy

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Limitations

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- lack of flexibility for connection sizes
- time dependency
- no WPA/WEP encryption
- source of False Positives and False Negatives

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What can be done?

Previously proposed countermeasures include:

- Morphing
- Injecting Bogus Traffic
- Padding

BUT... **must** consider that IoT devices have limited resources

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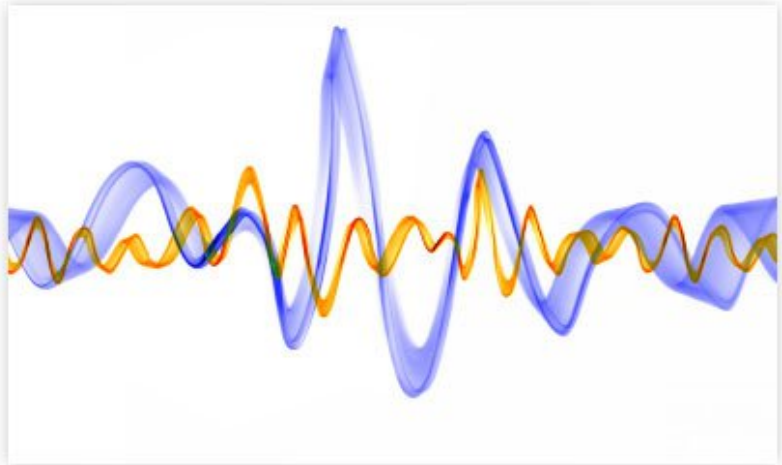
Future Work

- Apply signal processing techniques to model state of devices
- Study defense mechanisms



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Thank you!

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