Extrapolation and Prediction of User Behaviour from Wireless Home Automation Communication

Frederik Möllers

Sebastian Seitz

Andreas Hellmann

Christoph Sorge

juris-Stiftungsprofessur für Rechtsinformatik
Universität des Saarlandes

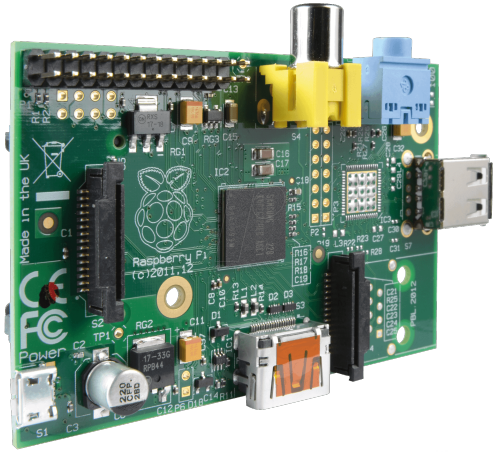
(Wireless) Home Automation

- System performs everyday tasks
  - Locking doors, regulating heating and lighting, controlling blinds …

  - Remote control and full automation
- Increasingly popular: Wireless systems
  - Benefits: Low installation effort/cost, no structural changes required
  - But: Wireless network – everyone can listen and send
  - Do state-of-the art systems use encryption / authentication?
  - Are there problems that persist?

Our Experiment

- 2 volunteers
- HomeMatic systems (default: no encryption, authentication only for door locks)
- Setup (placed inside the property)
  - Raspberry Pi
  - CC1101 USB Lite with culfw firmware
- 36 and 24 days of capturing data
- Analysis with custom software
  - 3 modules
    - Sniffer: Record data
    - Cleaner: Remove unnecessary data and organize the rest
    - Analyzer: Display data in human-readable form

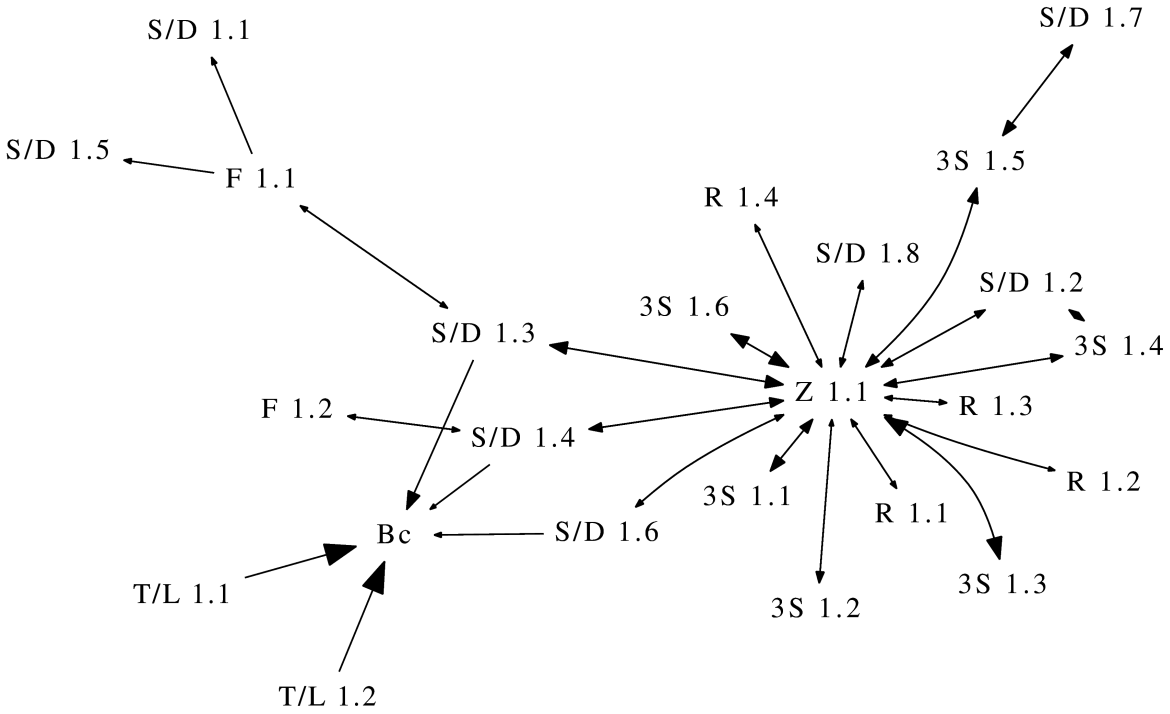


Our Experiment – Methods

- Identifying devices
  - Apply regular expressions to messages
  - Plausibility checks (e.g. temperature values)
- Recognizing patterns
  - Visualization of data
    - Directed graph of connected devices
    - 2D-graphs of statuses / commands over time
- Finding correlations
  - Sliding window (occurrences of message pairs)
- Identifying automation rules
  - Commands sent at approx. the same time (almost) every day

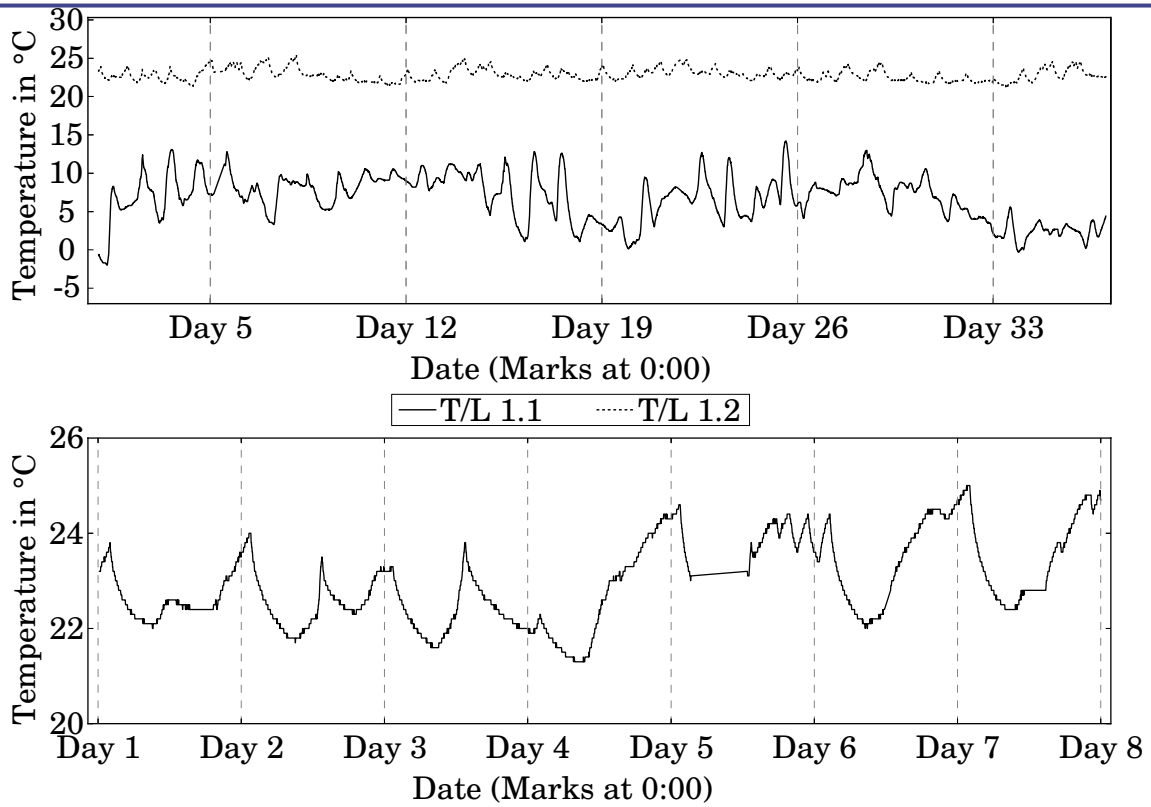
Candidate 1

- Regular home installation
- 45,679 messages from 23 devices



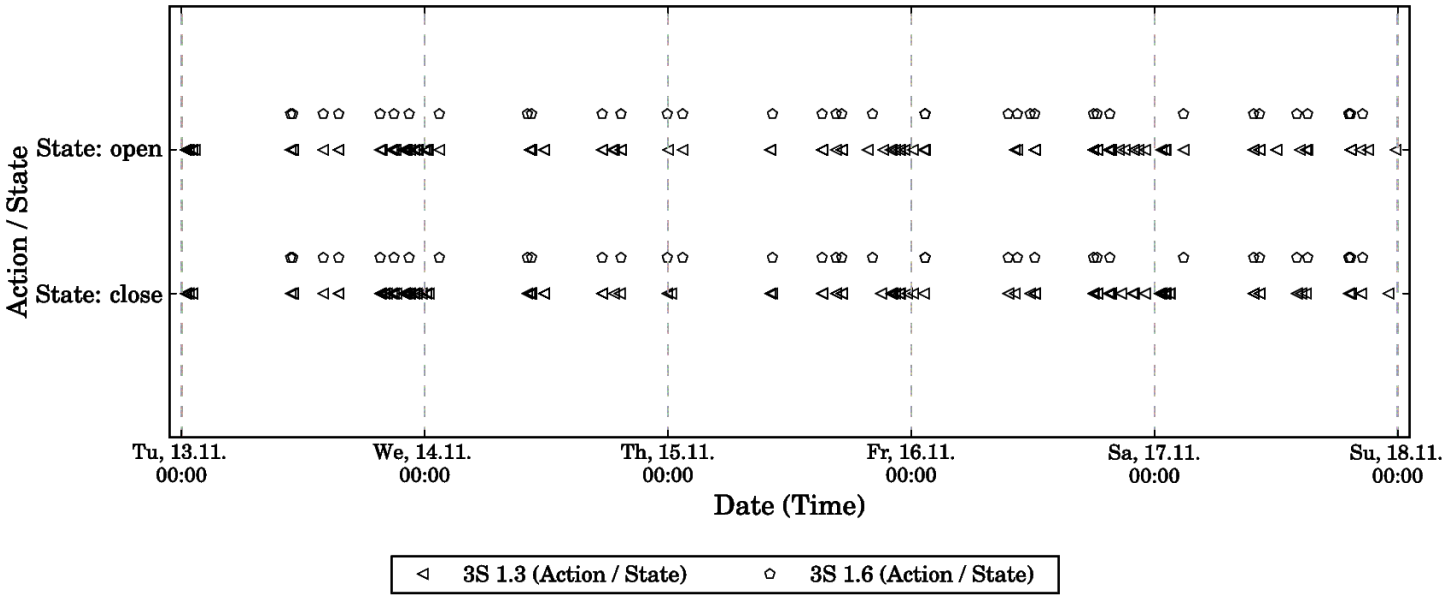
- Some devices are remote controlled
  - Clear user interaction → presence / absence

Candidate 1 – Temperature / Humidity Sensors



- One temperature/humidity sensor outside the house
- Another one in living room
  - Heating controlled manually
  - Seldomly ventilated for more than 10 minutes

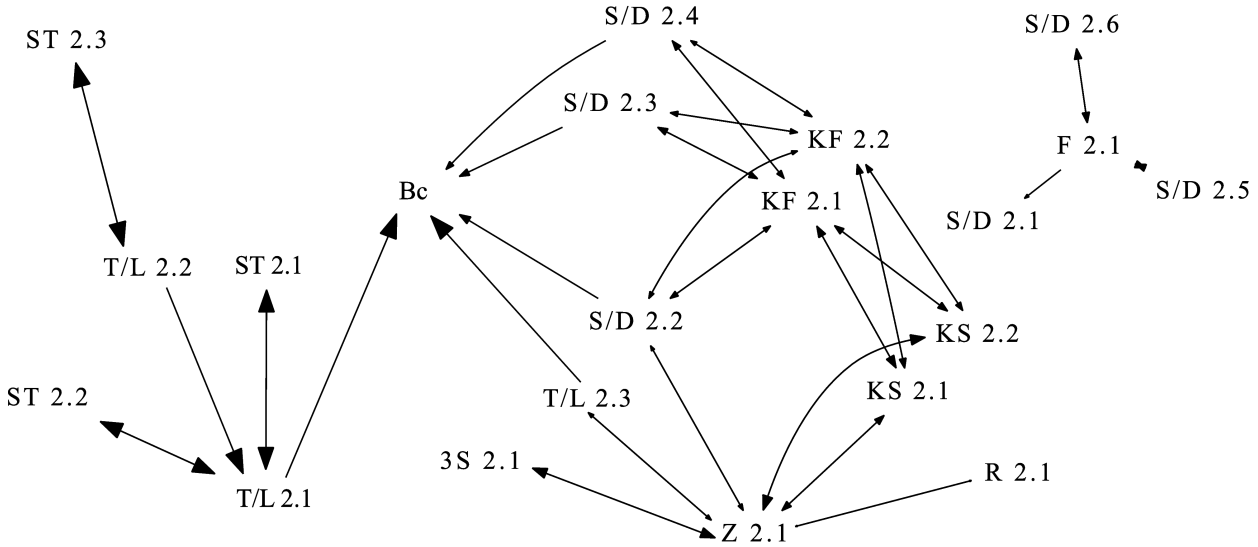
Candidate 1 – Tri-State Sensors



- Tri-state sensor on front door
  - Exact leaving / arrival times!
- Other results
  - Alarm function with bedroom lights
  - Automatic blind control with dawn / dusk times

Candidate 2

- 2 connected installations: Office and home
- 34,707 messages from 20 devices



- More devices are remote controlled or paired
  - Information about automation rules and user interaction
  - Remote control messages only in one location → presence /absence
- Automatic heating control
  - Heating turned off at night and on weekends, on in the morning

Encryption

- We've seen how much information is leaked
- What about encryption?
- Headers not encrypted: Nodes might still be identified
  - Communication partners
  - Frequency of communication
  - Tri-state sensors and locks only report state changes
    - State can be inferred
- Headers encrypted:
  - Amount of communication indicates presence
  - Additional power consumption

Summary / Outlook

- Current systems leak high amount of personal information
- Encryption is important
  - So is authentication – thermostats can be controlled
  - But there is more to do
- Need to hide communication
  - Create dummy traffic
  - How to determine when to send dummy messages?
  - Be energy efficient!

Thank You

Questions?

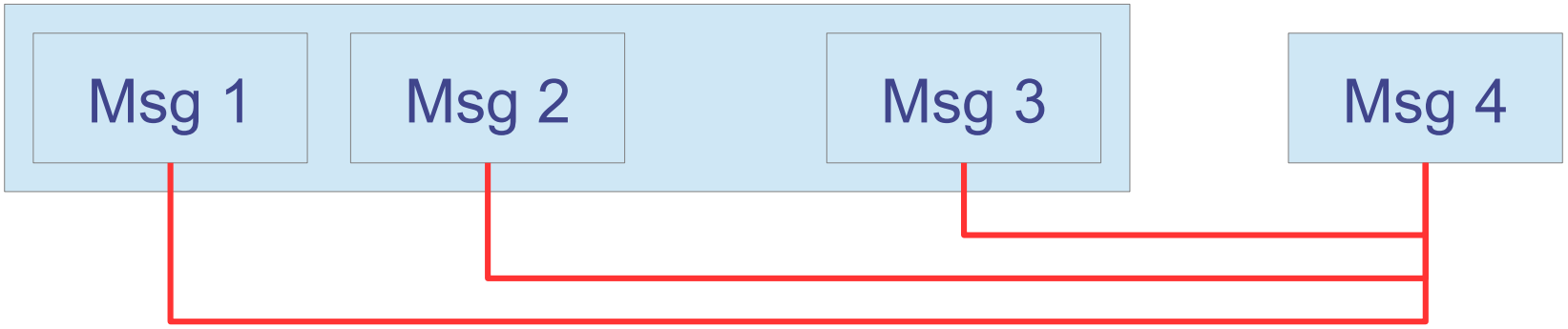
frederik.moellers@uni-saarland.de

BidCos Protocol

- 868,3 MHz
- Layer 0&1: TI CC1100
- Layer 2: BidCos (no higher layers)

Length	Counter	Control	Type	Sender	Receiver	Data
1	1	1	1	3	3	*$Length*

Corellation Analysis – Sliding Window

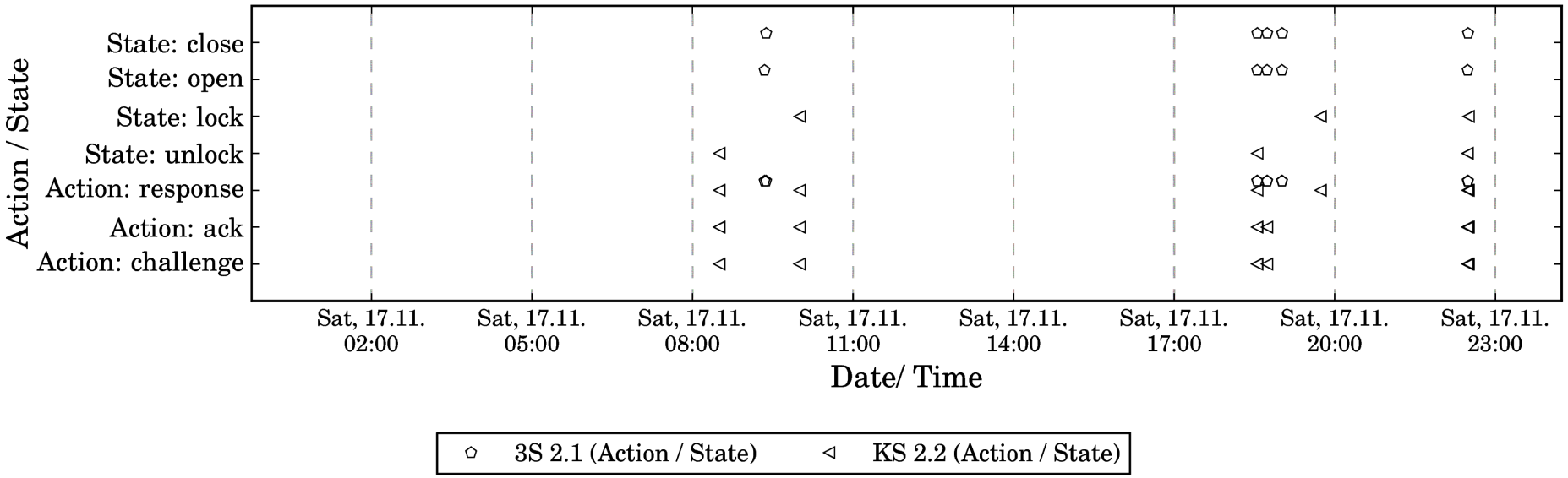


- Configurable parameters:
  - Minimum frequency
    - Number of times a single message (4) occurs
  - Minimum support
    - Number of times a message (4) is preceded by its counterpart (1/2/3)
  - Window size

Identifying Automation Rules

- Steps
  - Collect messages with same content
  - Discard dates (keep times)
  - Sort by time in ascending order
  - Find large number of events at roughly the same time
- Configurable parameters
  - Minimum frequency
    - Number of times the message occurs
  - Maximum deviation from rule
    - Time a message timestamp can deviate from the rule's time
  - Maximum time difference between messages from same rule
    - Should be ≤ max. deviation x 2

Candidate 2 – KeyMatic Door Locks



- KeyMatic door locks
  - Similar to a sensor on the door
  - Tells when door is locked/unlocked
  - Possible DoS targets

External Image Sources

- Slide 2
  - http://www.eq-3.de/produkt-detail-46/items/homematic-funk-fernbedienung-8-tasten.html
  - http://www.ideal-sound.com/home-automation/
- Slide 3
  - http://www.reichelt.com/Programmer-Development-Tools/RASPBERRY-PI-A/3//index.html?ACTION=3&GROUPID=5514&ARTICLE=133473&SHOW=1&OFFSET=16&
  - http://comprise-direkt.de/cc1101-usb-lite-868mhz-cul-antenne.html