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A Magic Lens for Revealing Device Interactions in Smart Environments

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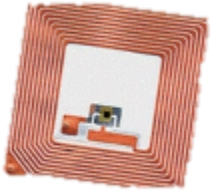
A thousand **interacting devices** at home…











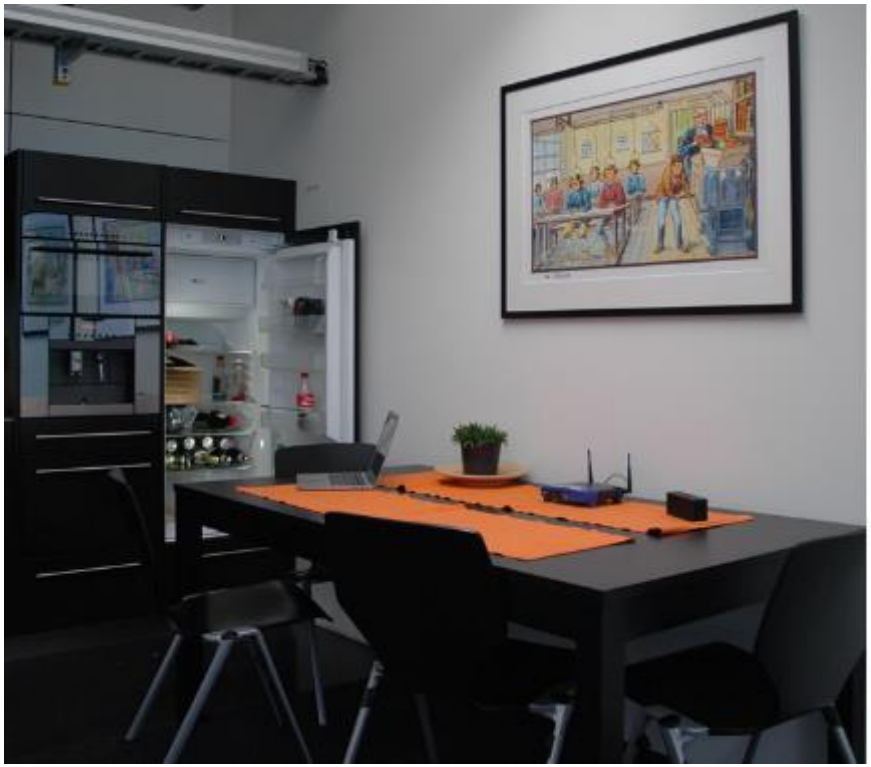


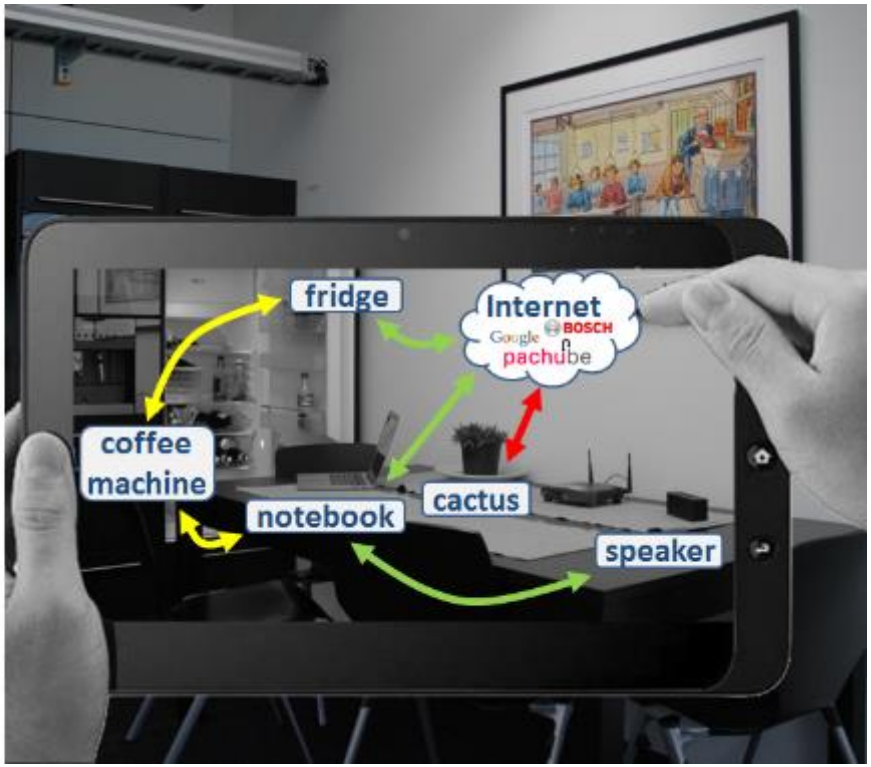





…humans should stay in control!

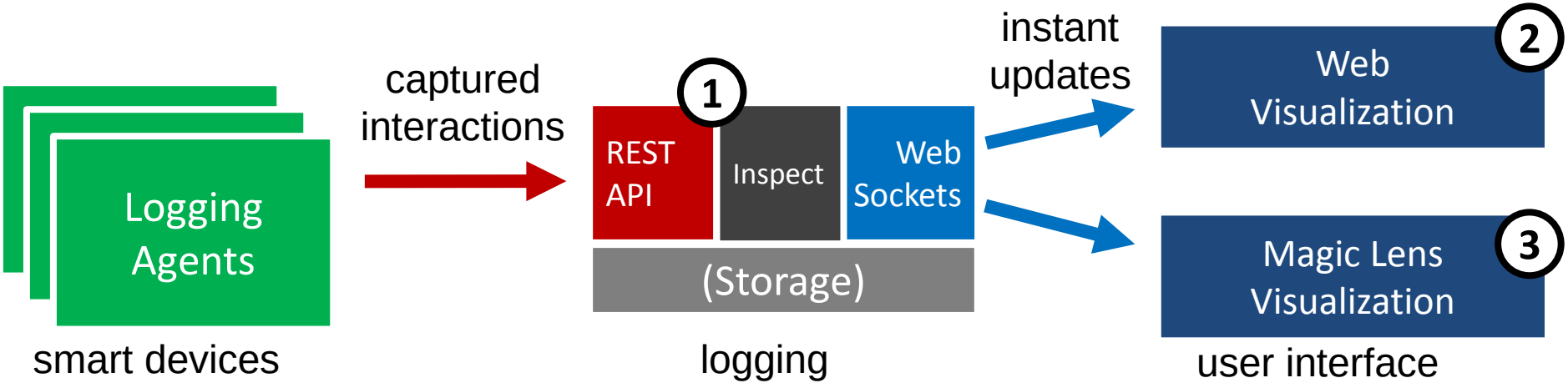
A magic lens for revealing these interactions





Overview

- 1. Logging Communication Traces
  - Record application-layer (HTTP) communication
  - Collect and causally order messages
- 2. Web Visualization
  - Network topology
  - Timeline view and graph view
- 3. Magic Lens Visualization
  - Recognize (multiple) devices
  - AR View



1. Logging Communication Traces

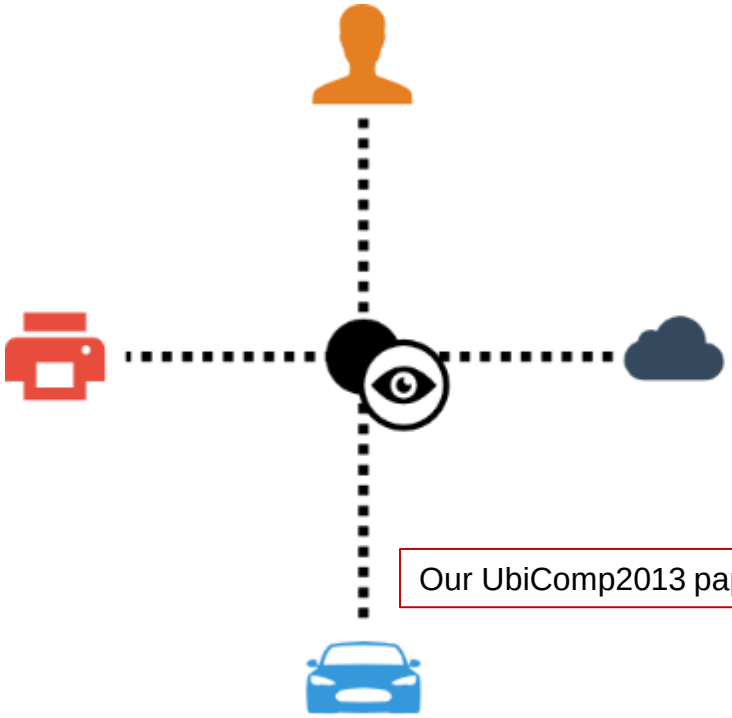
2. Web Visualization

3. Magic Lens Visualization

Web of Things

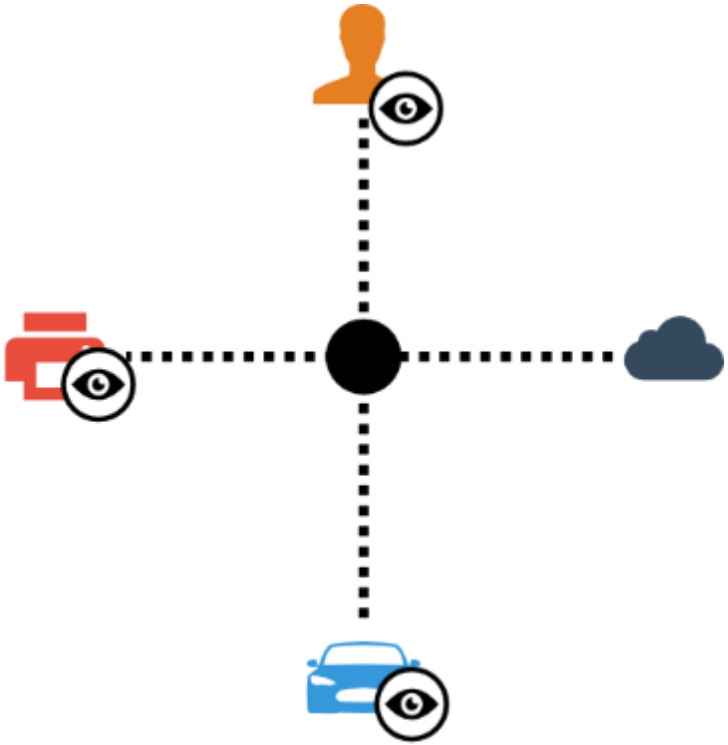
- **Internet of Things**: Focus on **Connectivity**
- **Web of Things**: Focus on **Interoperability**
  - “Everything is a Web Resource”
  - Inherit **desirable properties** of the Web: scalability, caching, addressing, security, etc.
  - **Simpler usage** (and debugging) for humans: the Web browser
  - **Simpler interaction** with other devices: Internet Media Types and Content Negotiation
- In this paper: Every device runs an embedded Web server
  - Grizzly server, based on the Java Non-Blocking IO
  - REST APIs: Idealized Web Architecture

Recording Device Interactions



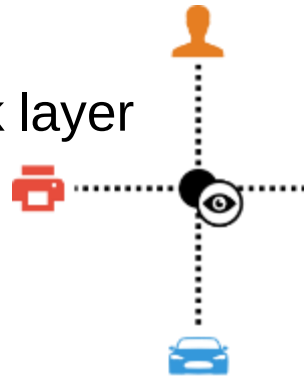
Our UbiComp2013 paper

Non-Intrusive

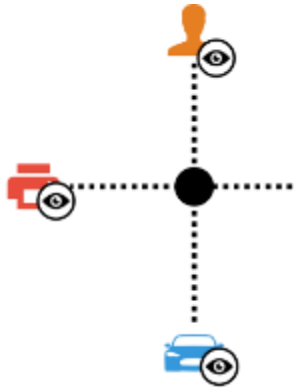


Intrusive

HTTP packet inspection



- (Non-intrusive) **sniffing** on router: Information on the network layer
  - Only IP-addresses and headers
  - Or even restricted to layer 2 frames (L2-Switching for WLAN-WLAN)
- (Intrusive) **logging** on clients: **Full application-layer information**
  - Content + Media Type (e.g., display transmitted images)
  - Inspect encrypted traffic (we log after the decryption step)
  - Use HTTP to piggy-back management information (e.g., vector clocks)
  - Full URLs: Ability to distinguish devices behind a translation gateway and differentiate HTTP endpoints (e.g., robot.org/motor2 vs. robot.org/sensor4)
- Drawback: Install the logging agent on every device

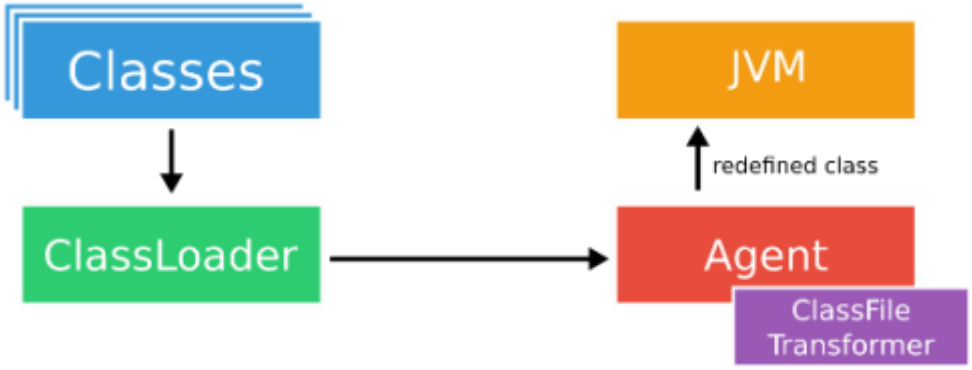


Logging Agents

- Java Agents **modify the bytecode** of the classes loaded by the JVM at runtime without changing its source code

```
java -javaagent:LoggingClient.jar -jar WoTDevice.jar
```

- Adds logging code to the Java classes `URLConnection` and `HttpServer`

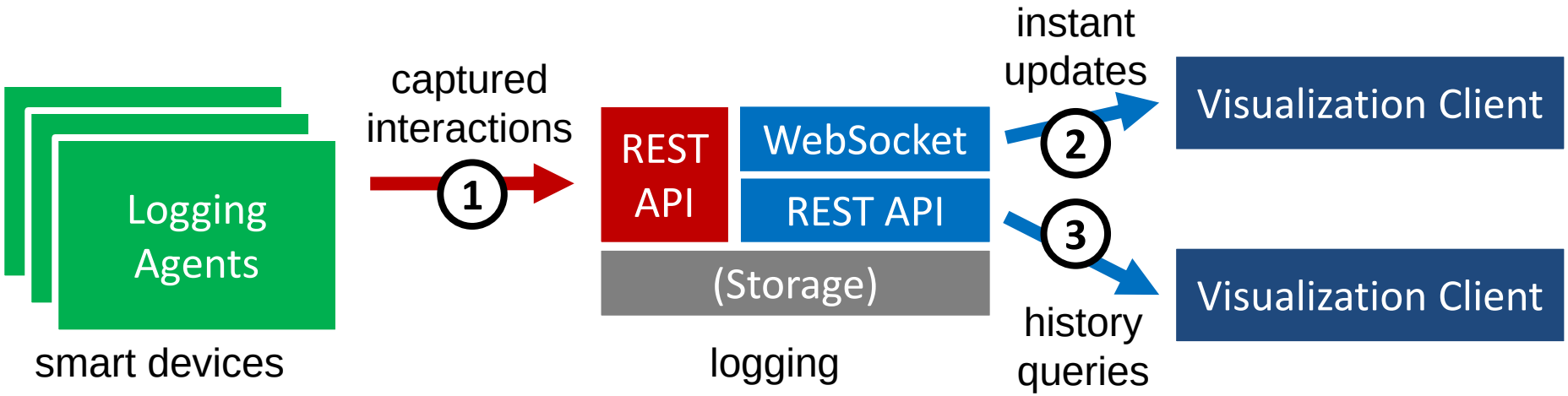


- Information about recorded packets is sent to the logging server
- The server can be any connected device with enough computing resources

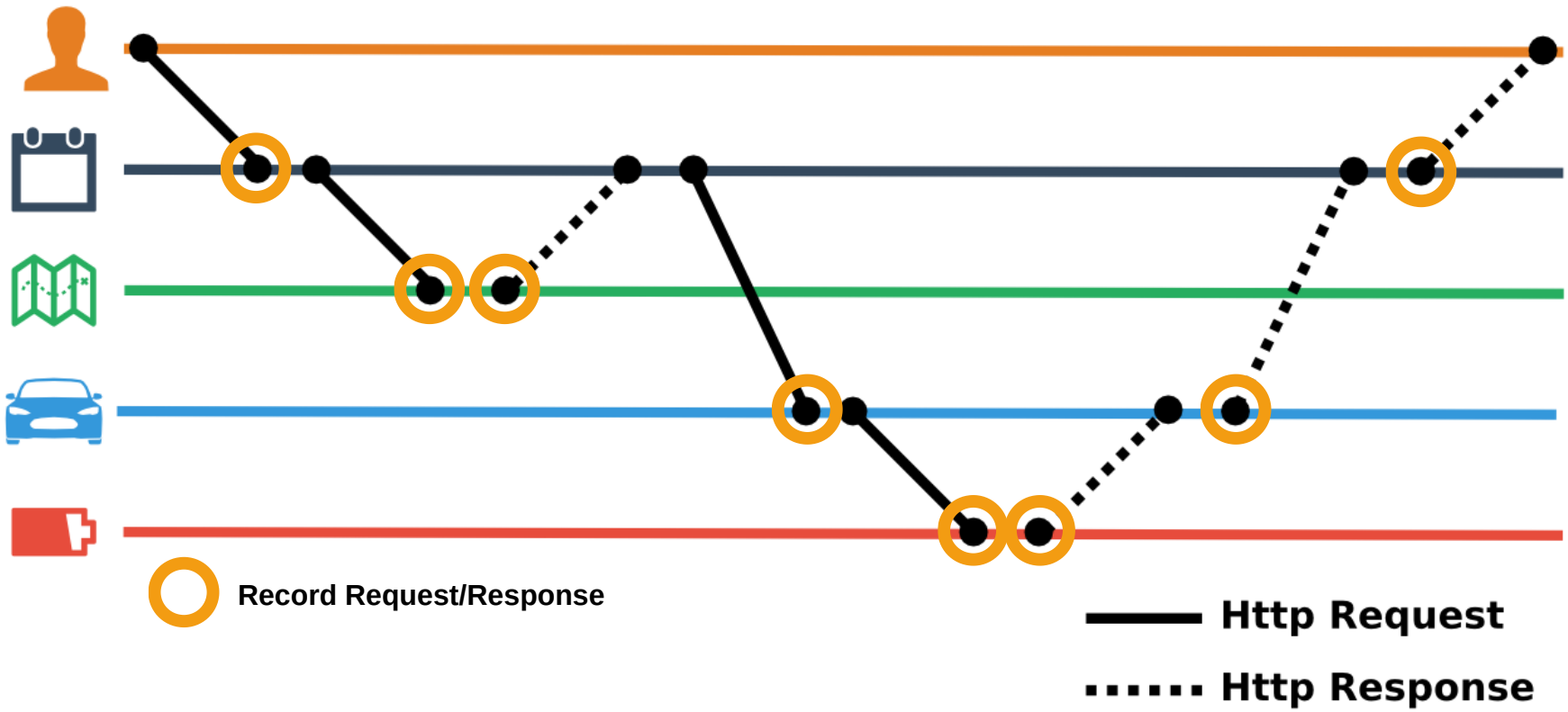
Logging Server

- Logging agents report through a REST API (1)
- Updates are pushed to subscribers using HTML5 WebSockets (2)
- History can be queried through another REST API (3)

- The server **orders** incoming messages causally and identifies **interaction chains**



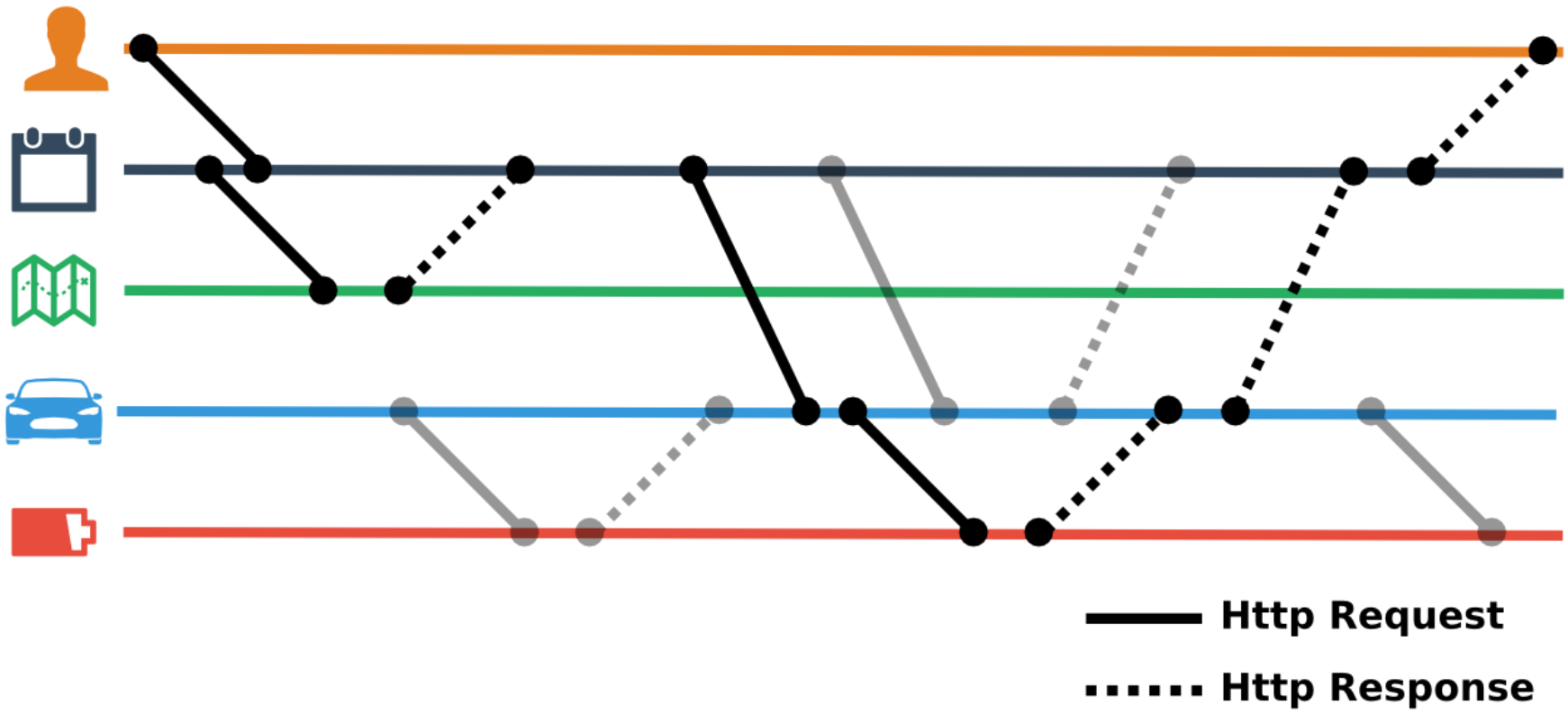
Causal ordering: messages



An interaction chain is a set of interactions in which all requests and responses are the consequence of an initial HTTP request.

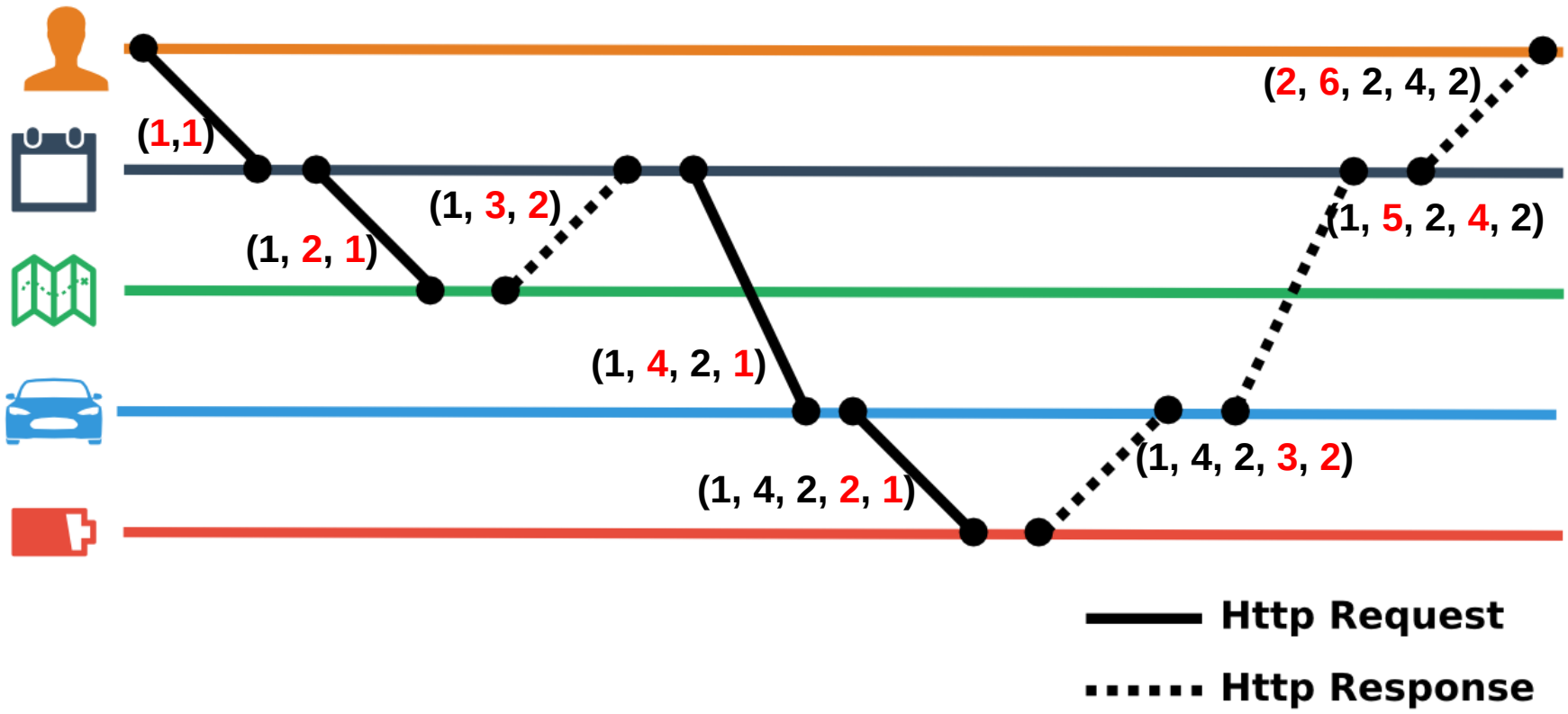
Send/Receive events are logged and reported to the server

Causal ordering: problem



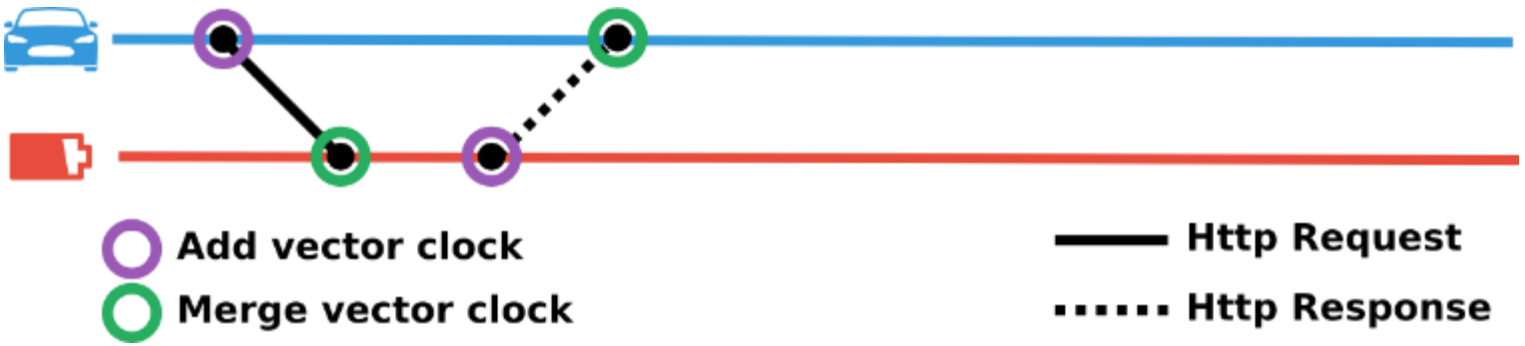
Reports may arrive in a causally incorrect order.
The server must reconstruct the causality chain!

Causal ordering: vector clocks



[Mattern1988] „Virtual Time and Global States of Distributed Systems”

Causal ordering: implementation



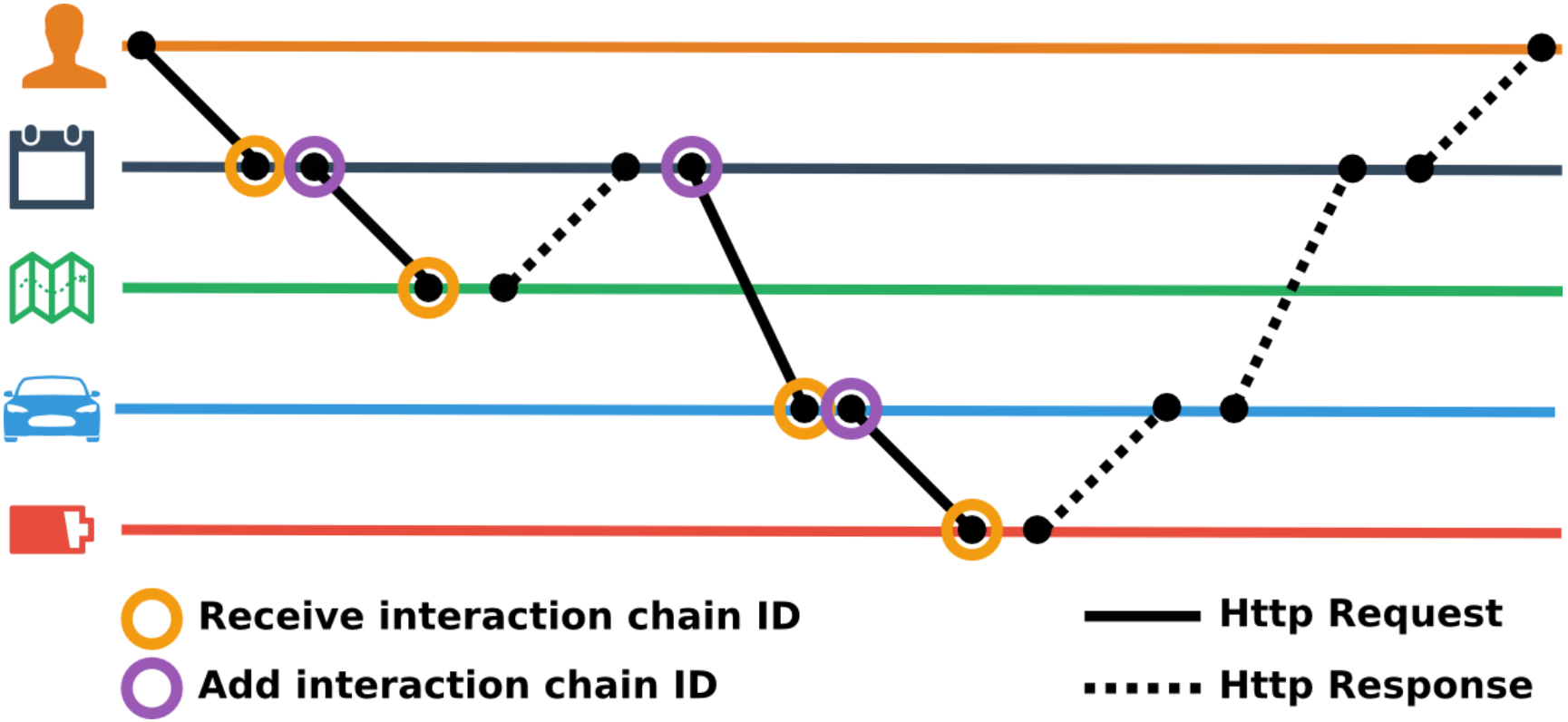
HTTP header information added to outgoing request:

```
GET /volume HTTP/1.1
    Host: 192.168.1.147
    X-Clock-192.168.1.147_9001: 1
```

HTTP header information added to the response:

```
HTTP/1.1 200 OK
    Content-Type: text/html
    X-Clock-192.168.1.147_9002: 4
    X-Clock-192.168.1.147_9001: 7
    Content-Length: 0
```

Aggregating interaction chains



HTTP header information added to outgoing requests:

```
GET /volume HTTP/1.1
    Host: 192.168.1.147
    X-Interaction: e989eaa6-2689-4c06-9828-bdda2c4eaf23
```

1. Logging Communication Traces

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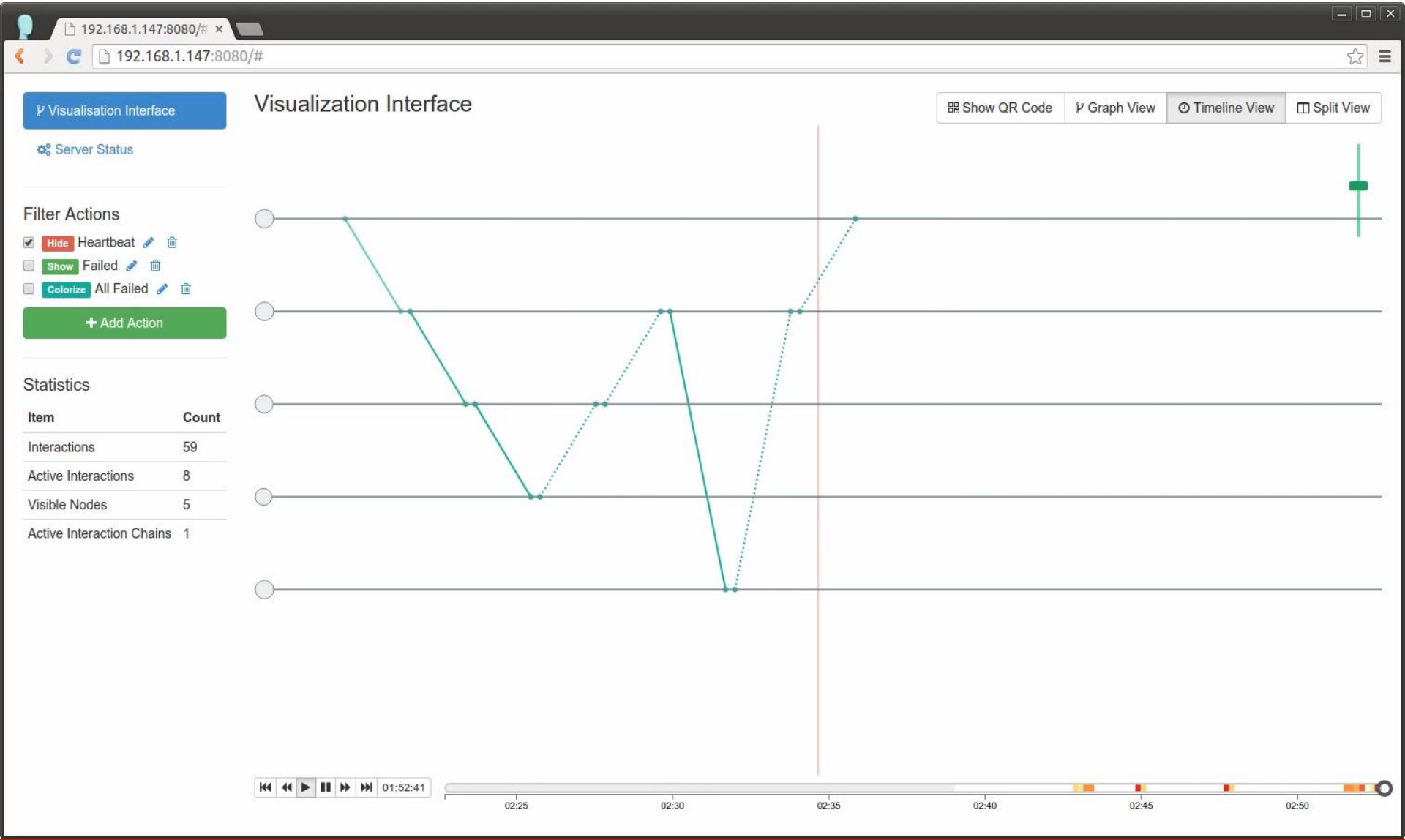
Web Visualization – Graph view

Web Visualization – Timeline View



1. Logging Communication Traces

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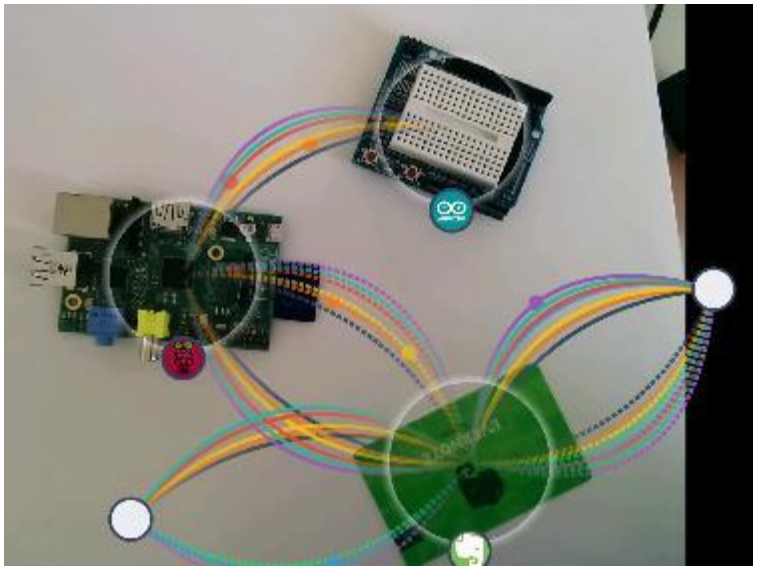
Recognizing Smart Devices

first prototype (non-intrusive sniffing)

AR markers for tracking
QR codes for encoding URLs

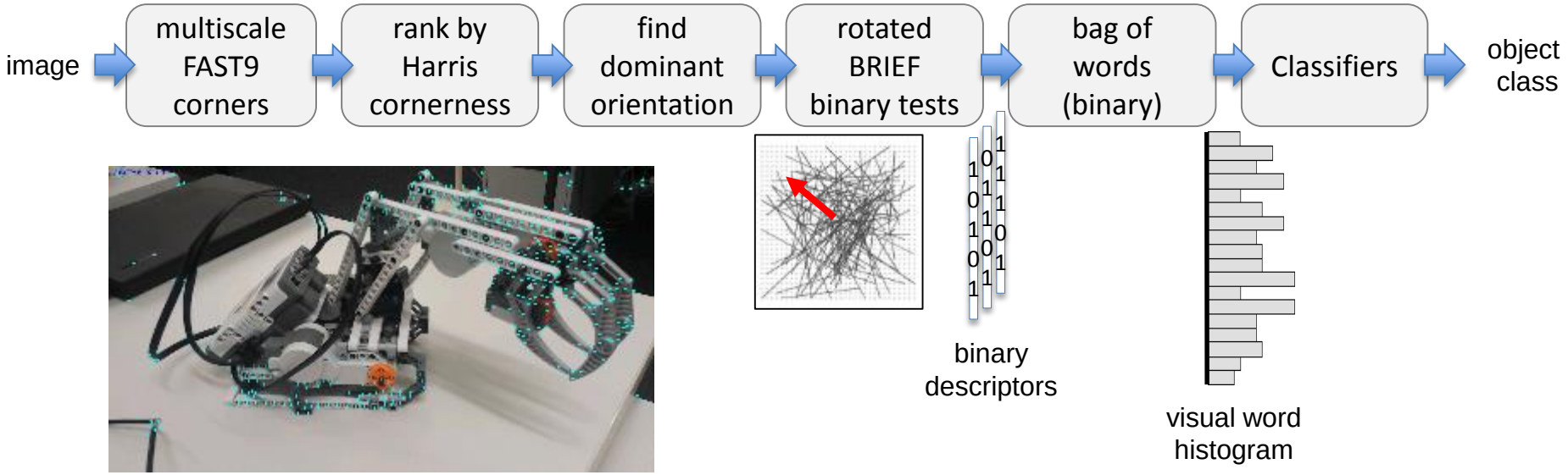


current system (intrusive logging)

Visual features, no markers required
URLs registered manually

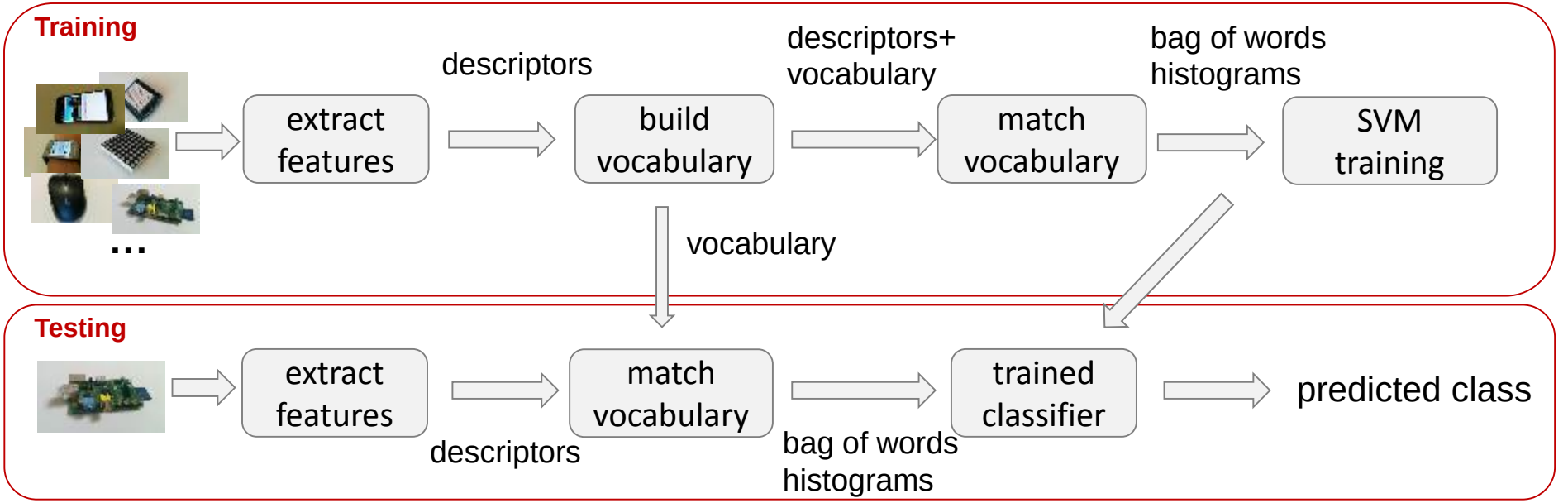
Object Recognition

- ORB Feature Detector and Descriptor
  Oriented FAST (Features from Accelerated Segment Test)
  Rotated **B**RIEF (Binary Robust Independent Elementary Features)
  [Rosten2005] [Calonder 2010] [Rublee 2011]
- Bag of Words (binary version) histograms [Grana 2013]
- One binary SVM per class (10 object classes + noise class)



Training

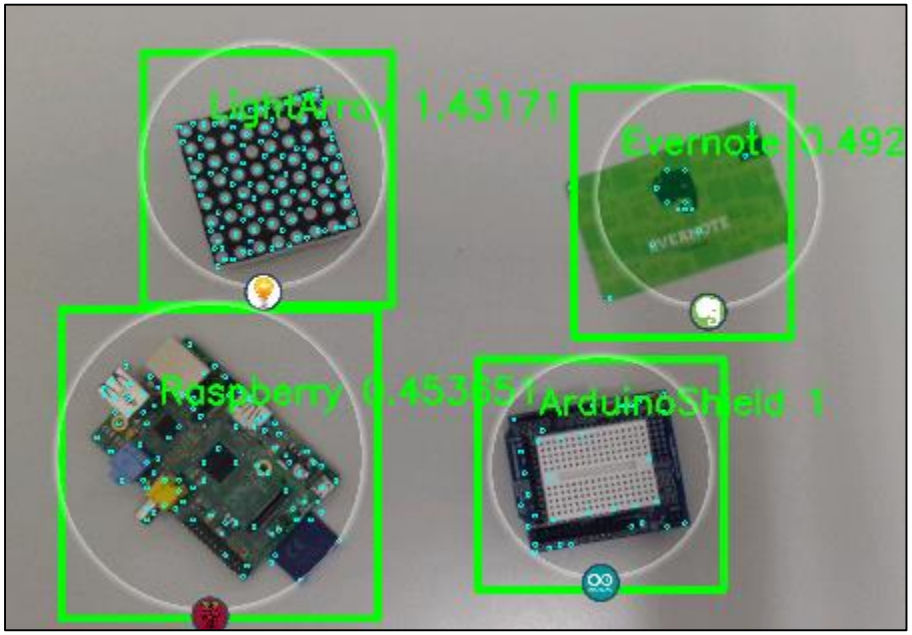
Figure adapted from Carlos Caetano



- Input: 15-30 snapshots of each device
- The method is fast, but limited to the trained objects
  Requires re-training when a new class is added
  What is a representative noise class?

Multiple Object Detection

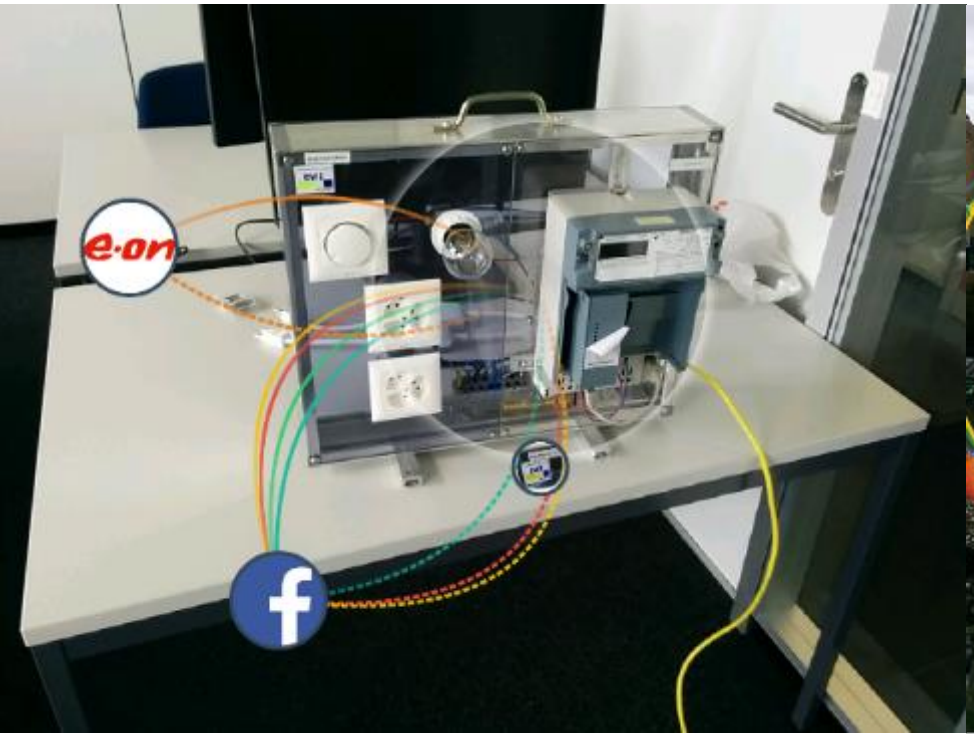
- FAST feature detector
- DBSCAN for spatial clustering
  Density-**B**ased **S**patial **C**lustering of **A**pplications with **N**oise
  number of spatial clusters is not known in advance (as opposed to k-means)
- Kalman filter for object centroid tracking
- Low-pass filter on each class label



The magic lens in action

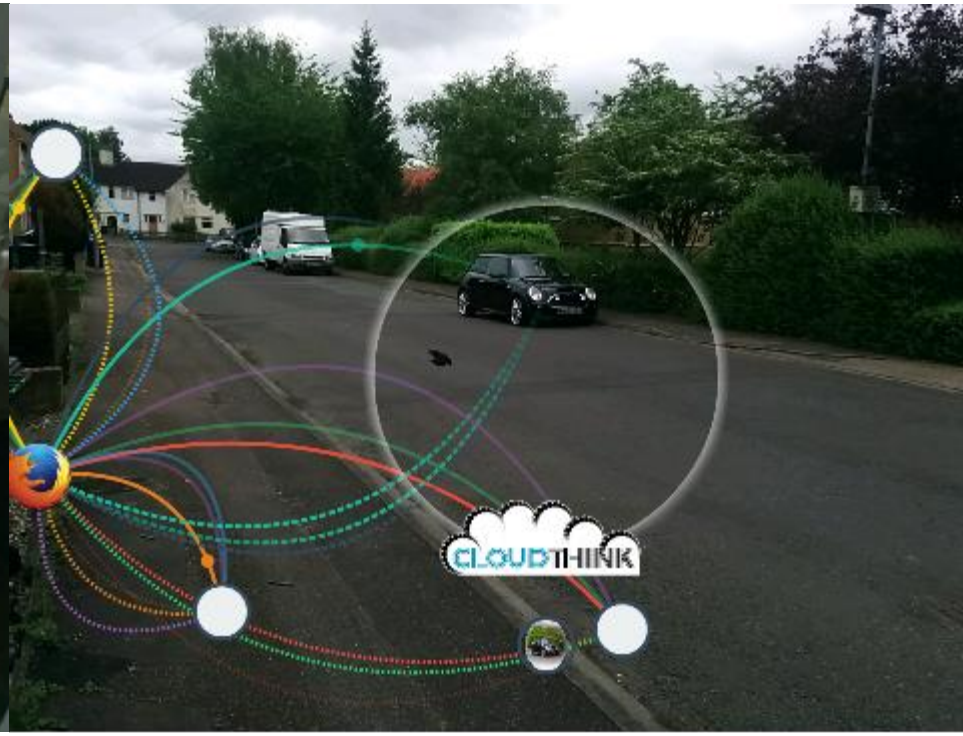
video

Smart electricity meter and smart car



www.bitstoenergy.ch

simulated communication
no Java VM on the smart meter



www.cloud-think.com

real communication
Java VMs in CloudThink

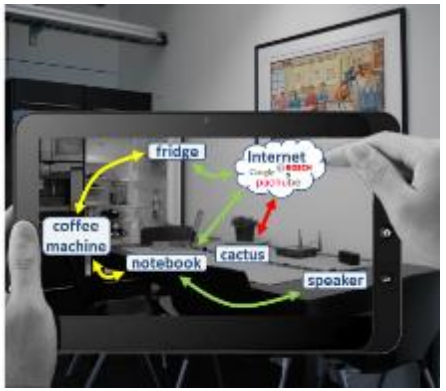
Limitations

- Recognition is relatively fast, but limited to the trained objects
  Need to re-train if a new device is added
- Segmentation requires feature-rich objects and little background clutter
  Use (pointing) **gestures** to select devices?
- Scaling with the number of devices
  Use **context** to limit search space (devices in *this* room)
- Logging client uses Java Agents
  Java-based smart devices only

Summary

Today, our tool

- …**recognizes** smart devices based on their visual features
- …**shows their interactions** in a magic lens view
- …allows users to intuitively **monitor information flows**
- …gives **more control** over the smart home network



Future work should

- …integrate better **object recognition** techniques
- …add **networking** rules by a flick of a finger
- …**categorize** communication (e.g., „Post image to Facebook”, "Download song”)

Simon Mayer

Yassin N. Hassan

Gábor Sörös

Thank You

谢谢

Credits

Markus Schalch
Bram Scheidegger
Claude Barthels
Marian George
Christian Beckel

References

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Image Sources

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