IOTTB

An Automation Testbed for IoT Devices

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Outline

Introduction

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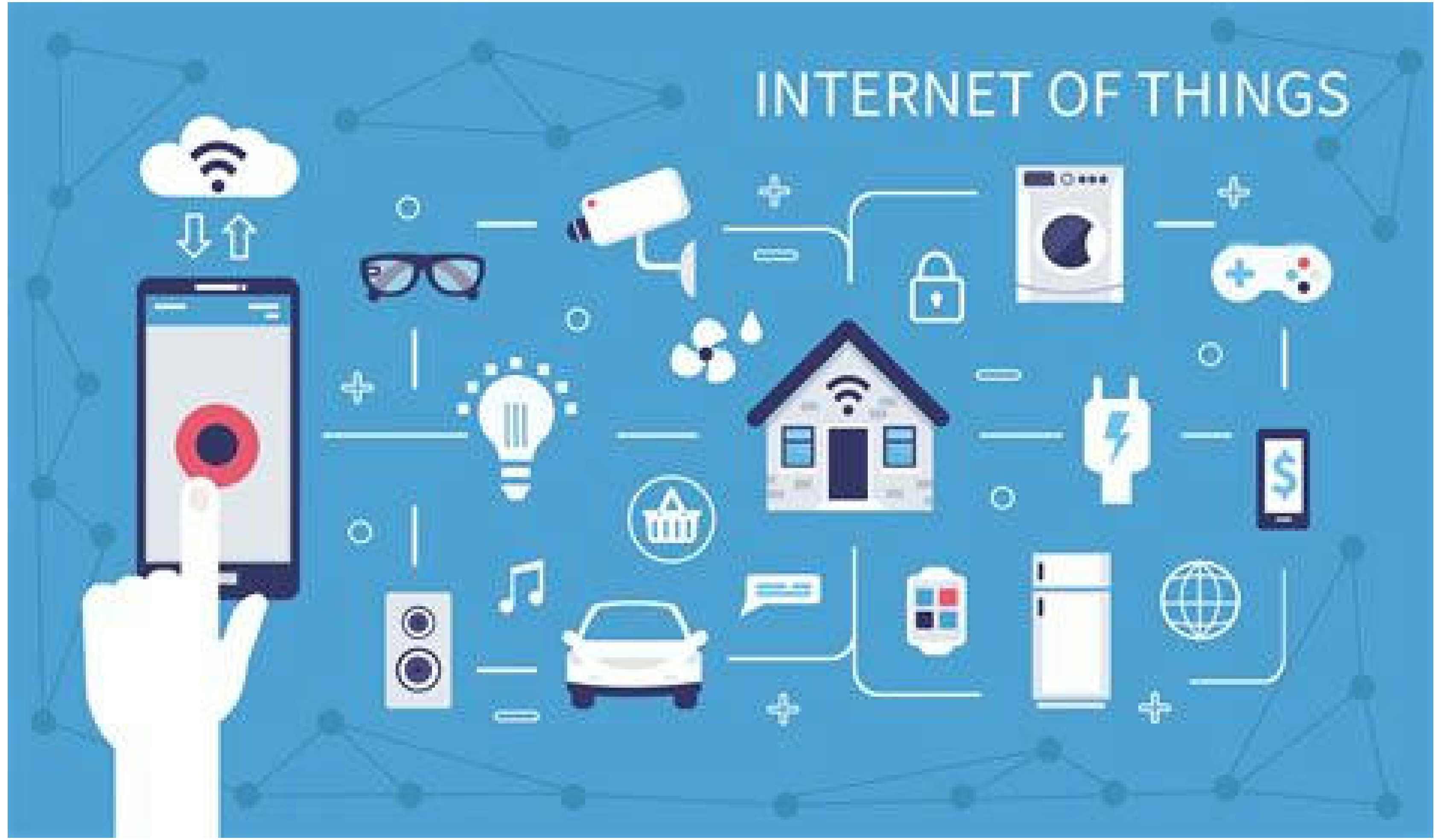

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Introduction
— Why are we here?

Project Description

To study the privacy and security aspects of IoT devices

- *systematically* and
- *reproducibly*,

we need an easy-to-use

- *testbed*

that

- *automates*

(some aspects of) the process of experimenting with IoT devices.

In this presentation I describe an implementation of such a testbed: `IOTTB`

Introduction
— Why are we here?

- *systematically*: standardization,
- *reproducible*: a systematic approach promises more reproducible experiments, and thus better verifiable results.
- *testbed*: and environment which fixes certain parameters
- *automates*: beyond reproducibility, the level of manual involvement influences feasibility w.r.t. reproduction

Objectives

Key objectives:

1. *Automation recipes* [1] for repeated execution of experiments, including data collection and analysis.
2. *FAIR* data storage (Findable, Accessible, Interoperable, Reusable) (see [2], [3] and [4]).

Introduction
— Principal Objectives

Outline

Motivation

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1 Manual setup and configuration of tools

- e.g. `tcpdump`, `Wireshark`, `Frida`
- configurations not interoperable between tools

Motivation
— Problem(s)

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- file/artefact naming
- measured/extracted data features
- metadata recorded

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- Difficult to maintain compatibility across projects

5 Onboarding challenges
- New members create ad-hoc solutions
- Perpetuates inefficiency and inconsistency

Motivation
— Problem(s)

Change

- Security researchers' challenges:
  1. Scattered data
  2. Lack of standardized tools
  3. Ad-hoc methods
- Difficulty in:
  1. Producing valid, reproducible results
  2. Reusing scripts across projects

Motivation
— Change

- Problems with current approach:
  1. Inconsistent data collection
  2. Lack of standardized tools and methods
  3. Issues with file naming and data structuring
- Resulting difficulties:
  1. Compatibility across projects
  2. Onboarding new members
  3. Ad-hoc solutions perpetuating inefficiency

Motivation
— Challenges Faced

Outline

Background

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Figure 1: Smart Lighting


Figure 2: Smart Speakers


Figure 3: Home Surveillance Camera


Figure 4: VR Headset

Figure 5: Dall-E Diagram of a Smart Home Network

IoT devices offer **benefits**:
- Home lighting control
- Remote video monitoring
- Automated cleaning

and more! But, they becuase
1. Used in Homes
2. Connected
   - LAN only
   - Internet
     - May lead to information leakage

⟹ Security and privacy **risks**
- Surveillance potential
- Unauthorized data sharing
- Vulnerable to bugs and security failures

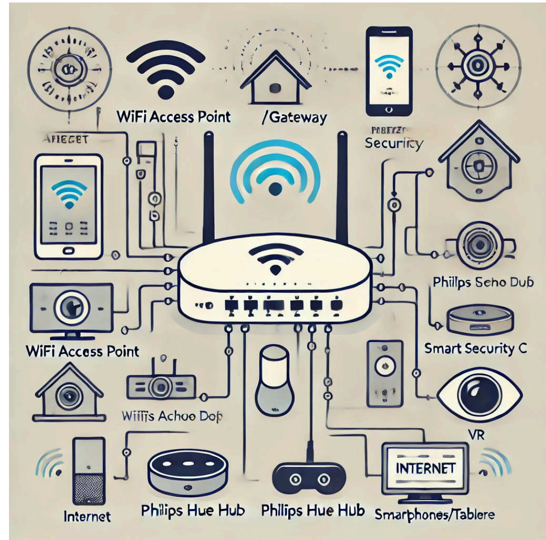

Figure 6: Dall-E Schematic Smart Home Network

Background
— IoT Devices

- **IoT Devices Overview:**
  - Devices connected to the internet (voice assistants, smart watches, smart home gadgets)
  - Embedded with microprocessors and software
- **Examples of IoT Devices:**
  - Security cameras
  - Home lighting systems
  - Children's toys
- **Importance of IoT:**
  - Physical dimension (sensors, controllers)
  - Internet connectivity

Background
— IoT Devices

- **What is a Testbed?**
  - Controlled environment for experiments
  - Ensures reproducibility and standardization
- **Examples of Testbeds:**
  - Industry and Engineering: Platforms for product development
  - Natural Sciences: Laboratories (e.g., climate chambers, wind tunnels, see [5])
  - Computing: Software testing environments (unit tests, IDEs)
  - Interdisciplinary: Complex systems (e.g., smart electric grid testbeds, see [6])

Background
— Testbeds

- **FAIR Data Principles:** [4], [3]
  - **Findability:** Data should be easy to find
  - **Accessibility:** Data should be accessible under well-defined conditions
  - **Interoperability:** Data should be integrated with other data
  - **Reusability:** Data should be reusable for future research
- **Purpose:**
  - Improve reusability of scientific data
  - Guide for designing *data storage* systems

Background
— FAIR Data Principles

Findability:
- Ensuring data is easily locatable and identifiable.
- Use of persistent identifiers like DOIs.
- Metadata should be richly described to enable precise searching.
- **Positive Example:** A dataset with a DOI and comprehensive metadata that is indexed in major search engines.
- **Negative Example:** A dataset stored on a personal computer with no metadata and no persistent identifier.

Accessibility:
- Data should be retrievable by authorized users.
- Use of standardized protocols for data access.
- Clear access conditions and usage licenses.
- **Positive Example:** A dataset available through a well-documented API with clear access guidelines and permissions.
- **Negative Example:** A dataset stored in a proprietary format that requires special software to access, with unclear or restrictive access conditions.

Interoperability:
- Data should integrate with other datasets.
- Use of standardized formats and vocabularies.
- Ensure compatibility with existing data and tools.
- **Positive Example:** A dataset in CSV format using standardized column headers that align with other datasets in the field.
- **Negative Example:** A dataset in a non-standard format with custom jargon that is difficult to merge with other data sources.

Reusability:
- Data should be well-documented to allow future use.
- Include clear licensing for reuse.
- Ensure data quality and provenance are maintained.
- **Positive Example:** A dataset with a clear Creative Commons license, detailed documentation, and a version history.
- **Negative Example:** A dataset with no documentation, unclear provenance, and no stated reuse policy.

- **Importance of Network Traffic in IoT:**
  1. Captures communication patterns (device-to-server (internet), device-to-device (LAN, e.g., companion apps))
  2. Essential for evaluating performance and identifying unauthorized communications
- **Protocol Analysis:**
  1. Understand device operation and communication protocols
  2. Identify compatibility, efficiency, and security issues
- **Flow Monitoring:**
  1. Detect potential security threats (data breaches, unauthorized access, malware)
  2. Monitor for anomalies indicating security incidents or vulnerabilities
- **Information Leakage:**
  1. Adversaries can passively observe traffic and extract sensitive information
  2. Even encrypted traffic can leak information about the smart environment and users

see [7], [8], [9], [7] and [10]

Background
— Network Traffic

Examples:

- **Leakage:** Personal data and device usage patterns. [7]
  - **Details:** The study found that IoT devices often leak personal data and detailed usage patterns to third-party servers.
- **Leakage:** Home device interactions and usage. [8]
  - **Details:** This research revealed that interactions with home devices can be intercepted, providing insights into daily routines and activities.
- **Leakage:** Device/Network communication *patterns*.[9]
  - **Details:** Sniffing tools can capture communications between IoT devices. WiFi packets expose usage patterns regardless of encryption[10]. Those patterns contain features which can be extracted (i.e. leaked) and fed into machine learning models which are capable of exposing more meaningful information (e.g., identifying devices and their functionality) [11].

In the end these are all some aspect of the same issue: even encrypted traffic leaks information which can be valuable to adversaries.

Background
— Findings from Key Studies

- **Network Packet Capture:**
  1. Intercepting and storing data packets on a network
  2. Principal technique for studying device behavior and communication patterns
- **Importance in IoT Security Research:**
  1. Main data collection mechanism
  2. Essential for analyzing network traffic

⟹ Wireshark Example

Background
— Packet Capture

- **Automation Recipes:**
  1. Define a sequence of steps for a process
  2. Used in various fields like machine learning
- **Collective Mind Framework:** [12], [1]
  1. Provides reusable recipes for building, running, benchmarking, and optimizing applications
  2. Platform-independent or supplemented with user-specific scripts
- **Importance of Automation:**
  1. Automates workflows irrespective of underlying tools
  2. Again: enhances reproducibility and efficiency in experiments

Background
— Automation Recipes

- **Key Issues Identified:**
  1. Manual setup and configuration of tools
  2. Ad-hoc decisions in file naming, data features, and metadata
  3. Tailored utilities lacking interoperability
  4. Scattered data and lack of standardization
  5. Onboarding challenges for new members
- **Importance of Addressing These Issues:**
  1. Improve reproducibility and reliability of experiments
  2. Enhance data quality and interoperability
  3. Facilitate easier onboarding and collaboration

Background
— Summary of Key Points

- **How IOTTB Addresses These Issues:**
  1. **Automation Recipes:**
     - Standardize the setup and configuration of tools
     - Ensure consistent data collection and analysis processes
  2. **FAIR Data Storage:**
     - Enhance findability, accessibility, interoperability, and reusability of data
     - Improve data management and sharing practices
  3. **Testbed Design:**
     - Provide a controlled environment for reproducible experiments
     - Simplify onboarding and collaboration through standardized procedures

Background
— Return to …

Outline

Adaptation

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Demo

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Outlook

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Questions

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Appendix

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Introduction[1]

- IoT Network Diagram: https://tse3.mm.bing.net/th?id=OIP.o3AVQNkQCCG_2cmhQzD1zQHaEW&pid=Api
- Figure 2: https://i0.wp.com/thegroyne.com/wp-content/uploads/2018/04/Amazon-Echo-Dot-Altavoces-inteligentes-04.jpeg
- Figure 1: https://www.multimediaplayer.it/wp-content/uploads/kit-philips-hue.jpg
- Figure 3: https://d.otto.de/files/bd42f6e9-ac45-5e1c-8d5f-ac3affcee9d6.pdf[2]

[1]Images licenced for free share and use to the best of my knowledge.

[2]Unclear licence

Appendix
— Images