IOTTB

An Automation Testbed for IoT Devices

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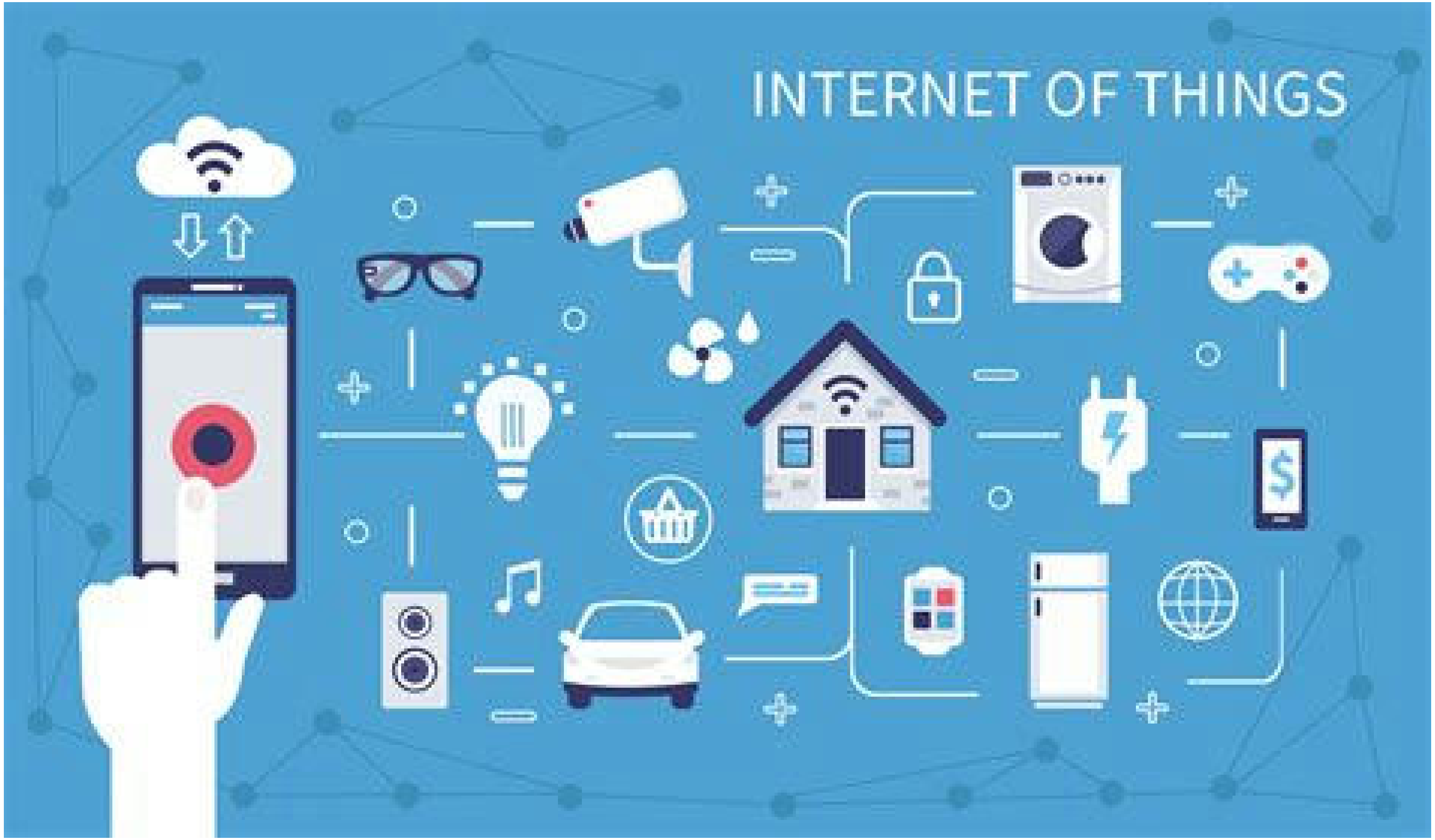
Outline



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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`

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]).

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

- 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

Outline

Figure 1: Smart Lighting

Figure 2: Smart Speakers

Figure 3: Home Surveillance Camera

Figure 4: VR Headset

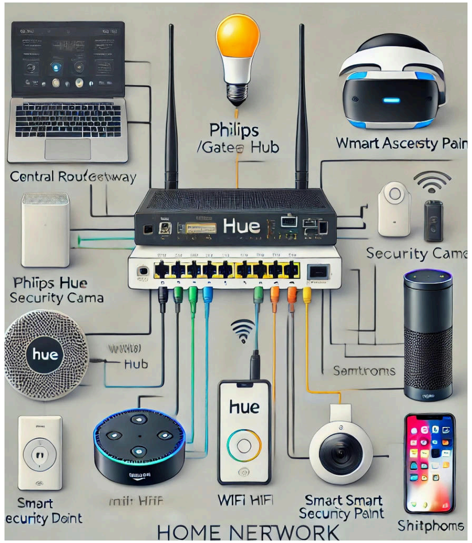

Figure 5: Dall-E Diagram of a Smart Home Network

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

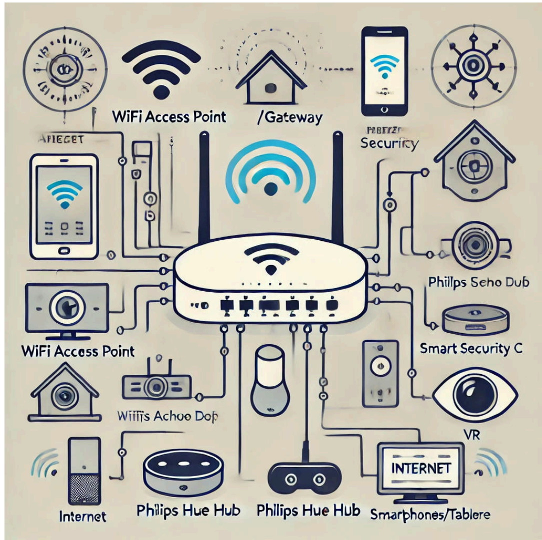

Figure 6: Dall-E Schematic Smart Home Network

- **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

- **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])

- **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

- **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]

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.

- **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

- **Automation Recipes:**
  - Platform agnostic automation
    - e.g., install tool y, retrieve dataset x
  - Integrate with existing scripts/tools
  - Examples in ML
  - *Collective Mind Framework:* [12], [1]
    - Provides reusable recipes for building, running, benchmarking, and optimizing applications
    - Platform-independent or supplemented with user-specific scripts

- **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

- **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

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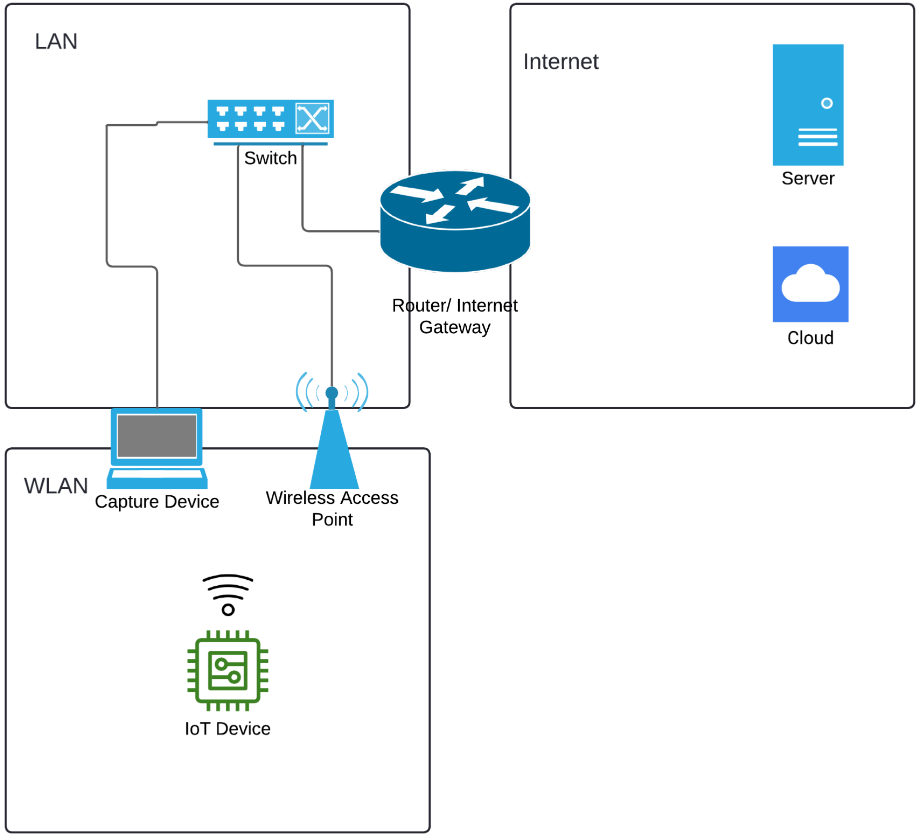

Figure 7: Common capture setup. Separate AP, switch and capturing device.

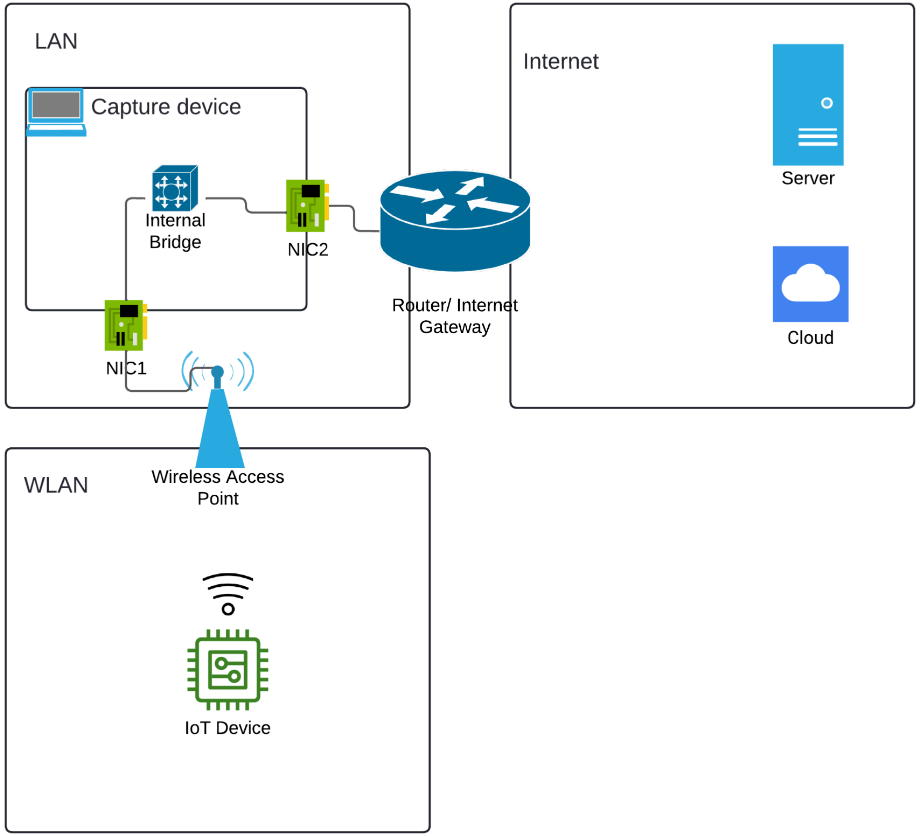

Figure 8: Setup with AP and "Capture Device" on same machine.

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`iottb`:

- Python Package
  - Defines Data Storage (implicit in behaviour)
    - Database is a directory hierarchy in a file system
    - DB is a collection of "device"-folders
    - Devices in turn hold some metadata and can have subfolders containing capture data
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  - Defines a metadata schema for devices, as well as captures
  - Automates collecting of metadata + data

DEMO

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Reusability:

- Used formats support this.
- Data capture tool (`iottb`) can be made available
- + rerun with the same configuration

Automation Recipes?

- `iottb` automates capture
- Metadata should allow repeating experiments
- want: configure capture based on metadata

Outline

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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]

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