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DI TRENTO

Estimating the number of people based on Wi-Fi probe request frames

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Academic year 2019/2020



About this Project

External internship at U-Hopper:

Big Data Analytics

Business Intelligence

Chatbot

IoT solutions

Artificial Intelligence solutions





Problem Statement

Badly handled demand in company that provides services to physical customers can lead to overcrowding and inefficiency of the services

- Inefficient and bad organized service leads to higher costs
- Badly managed overcrowding during this global pandemic period due to COVID-19 leads to long queues and new infections



State of the Art

→ Analysis of different methods to count/estimate people

Infrared sensors, LSE, treadle switch-based systems, Video methods,
Audio methods, Wi-Fi, Bluetooth, BLE, LTE, Radar, RFID approaches

→ Many fields of applicability and different implementations



Why Wi-Fi solution?

High diffusion of Wi-Fi devices

High accuracy using machine learning

Low-cost implementation

Real-time data transmission

User privacy ensured



Standard 802.11 → Management
frames → Probe request frames



Research Statement

Is it possible to continuously estimate the number of people
in a place of interest based on the Wi-Fi probe request frames?

Achievements

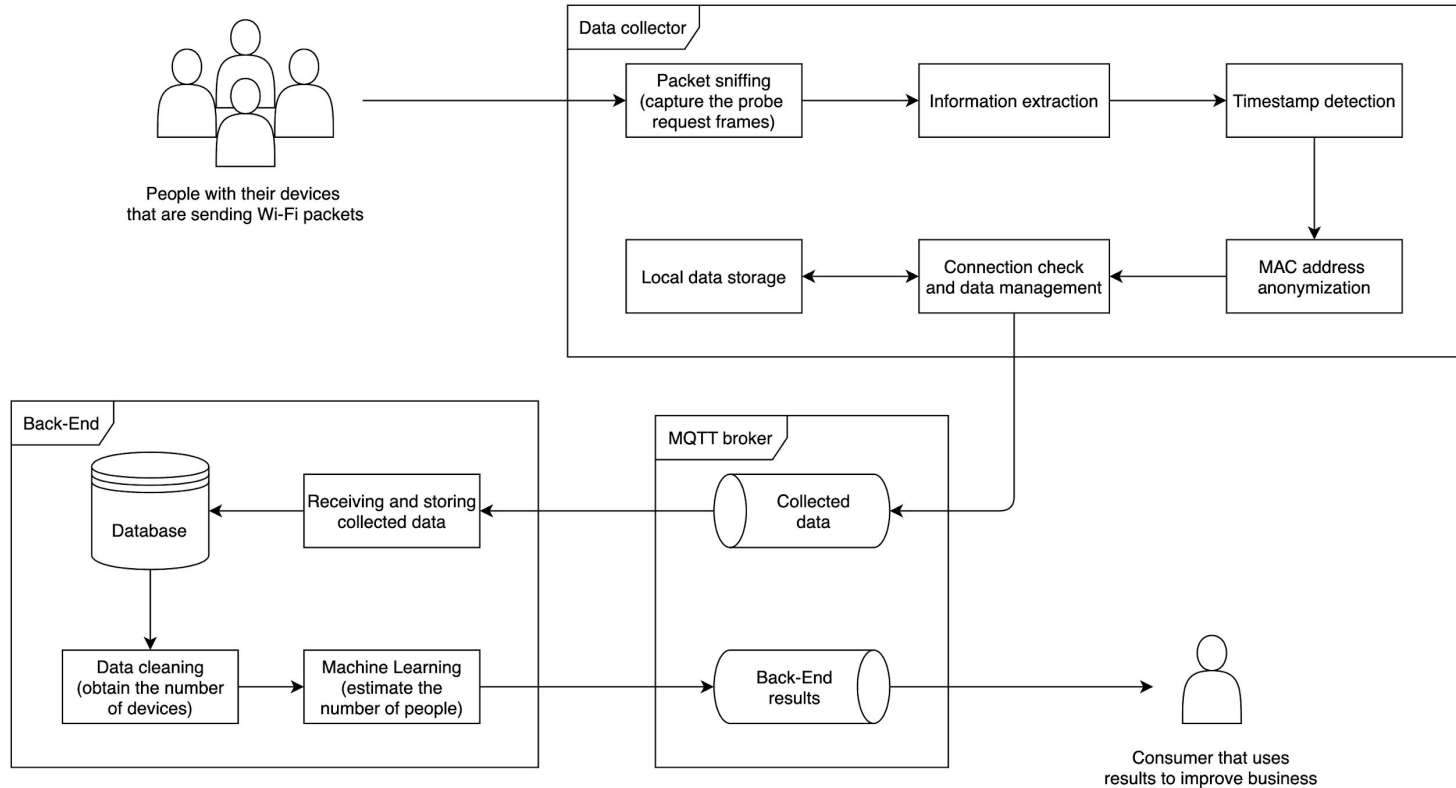
Designed and developed a system for this problem that could work in several context

Tested the system in a Cafe and
collected 4 weeks of data and
manually-annotated ground truth



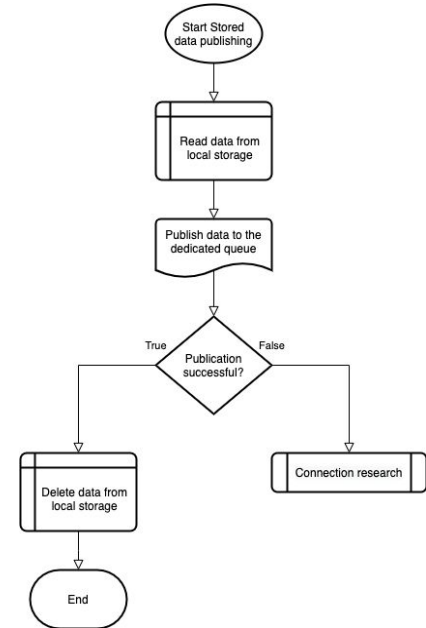
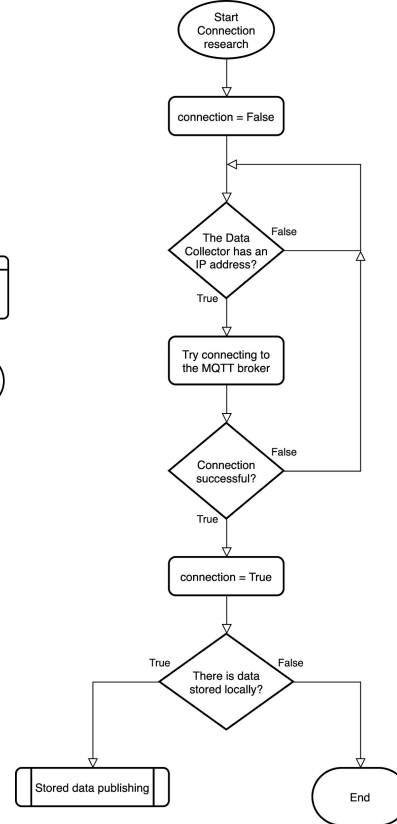
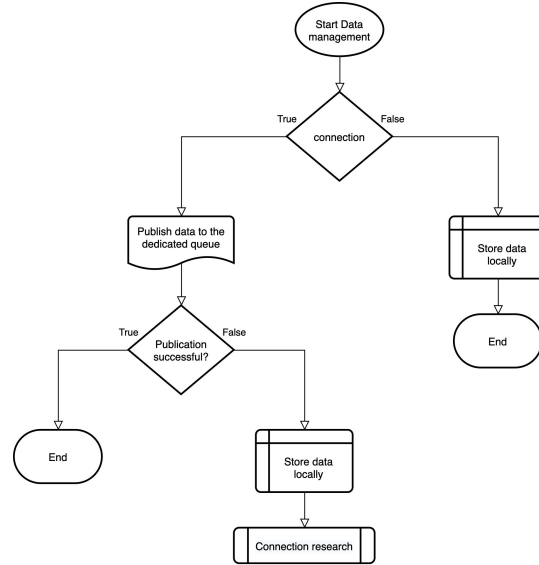
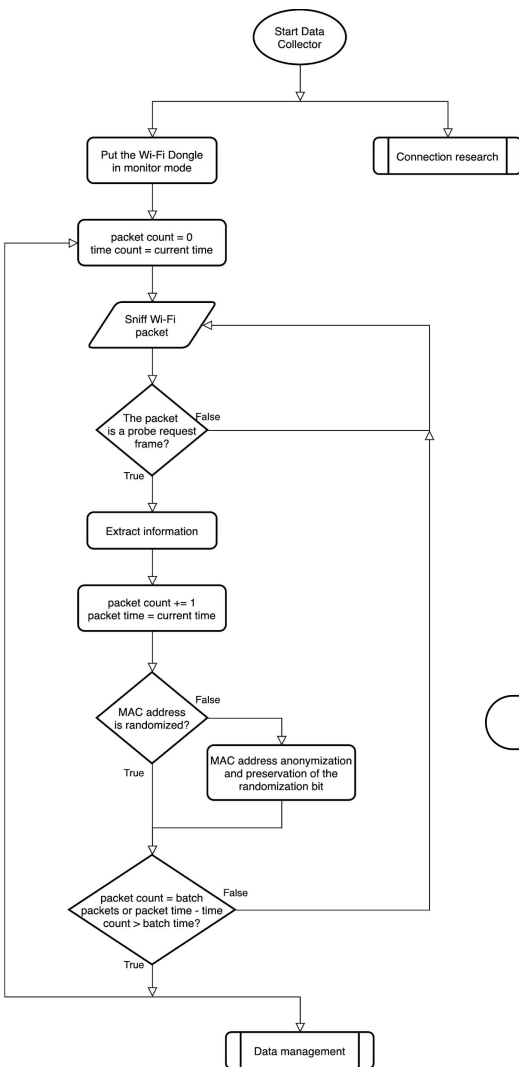


System Architecture



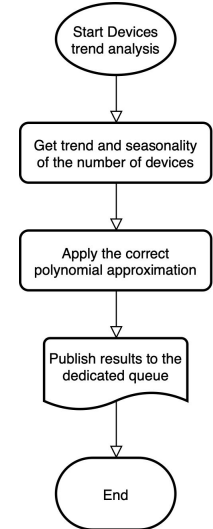
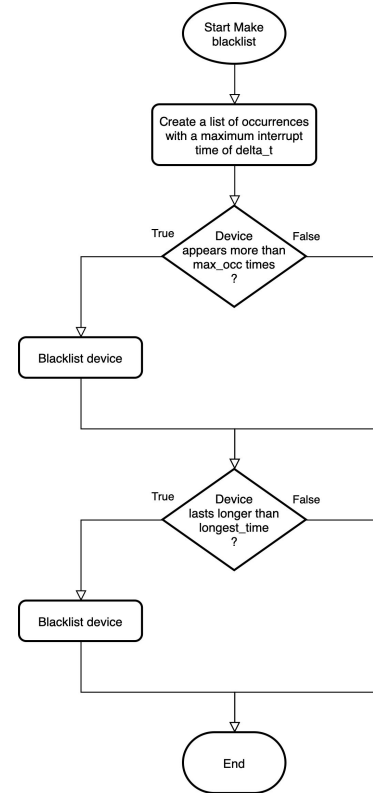
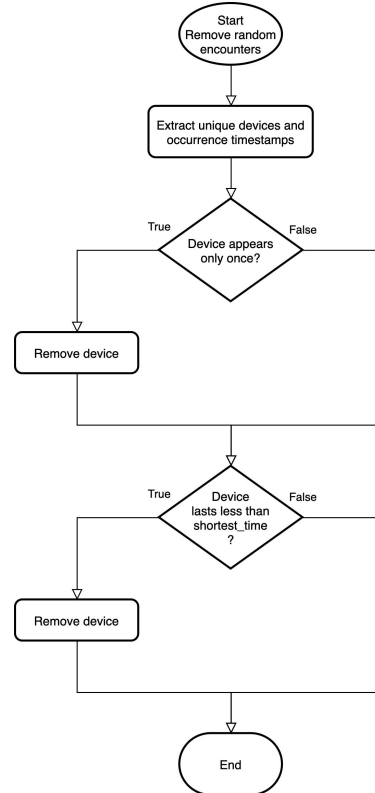
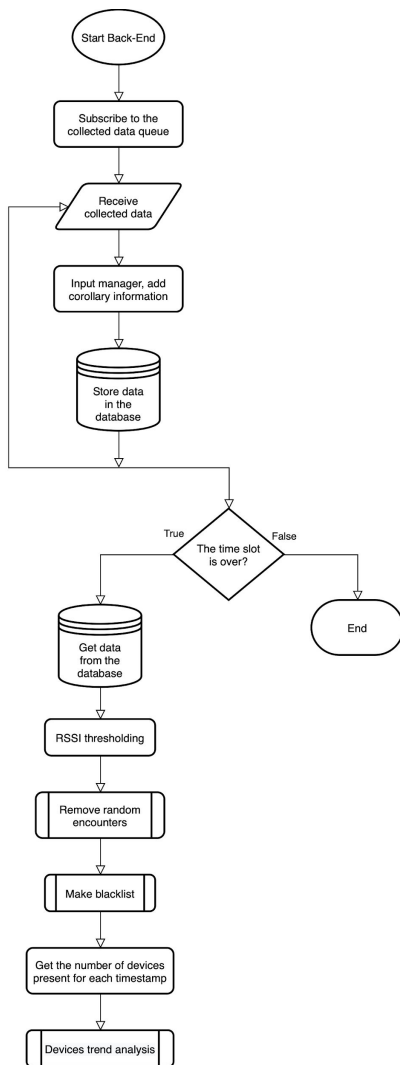


Data Collector Logic



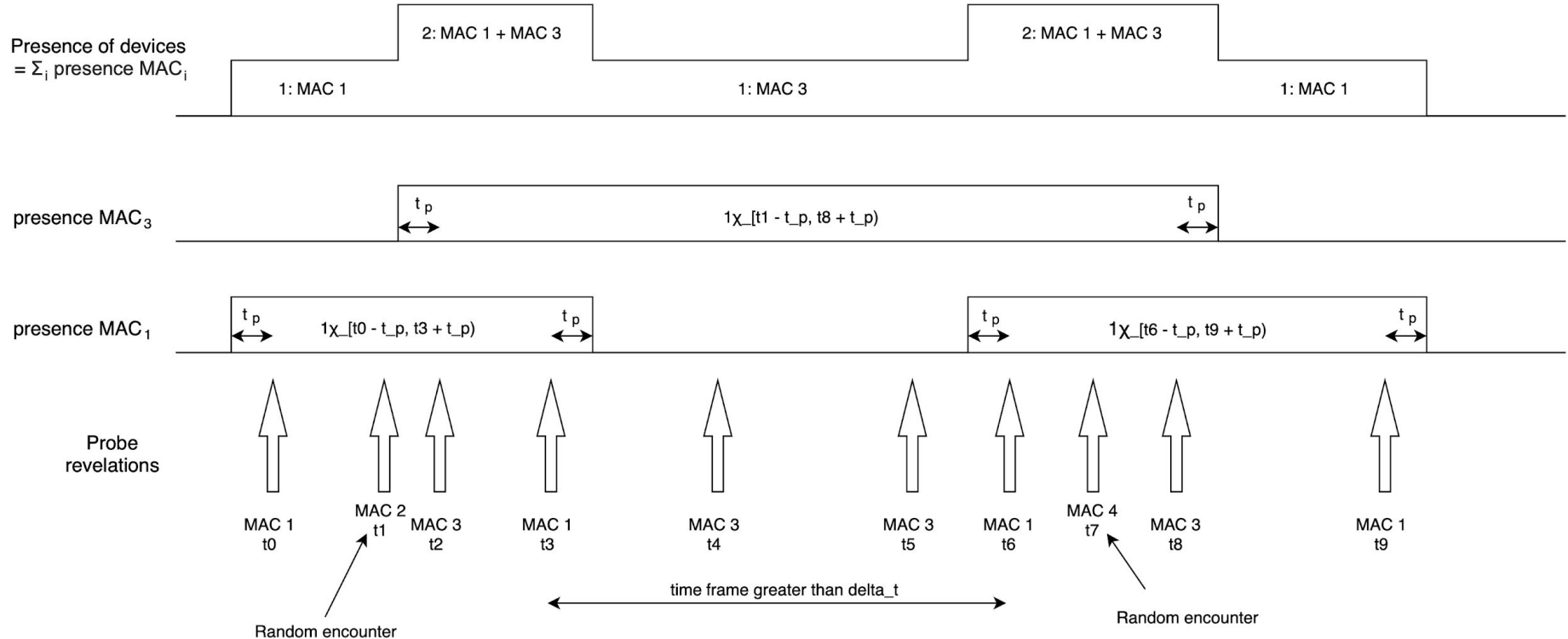


Back-End Logic

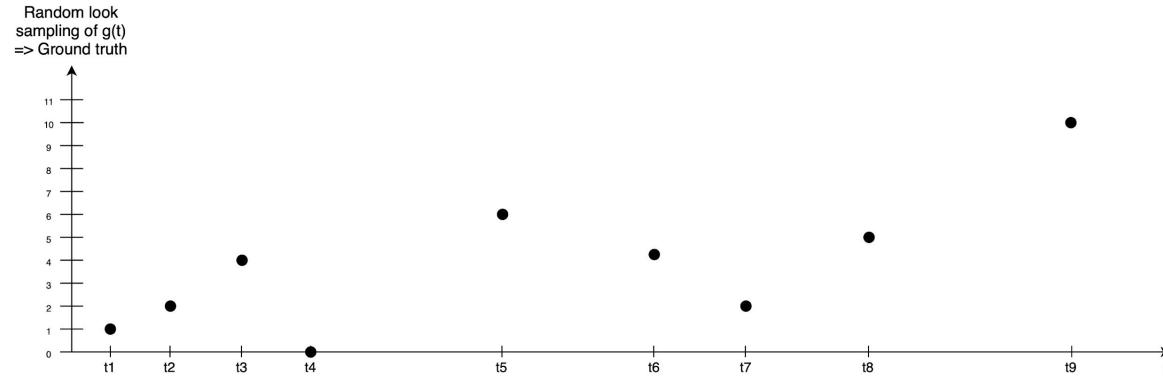
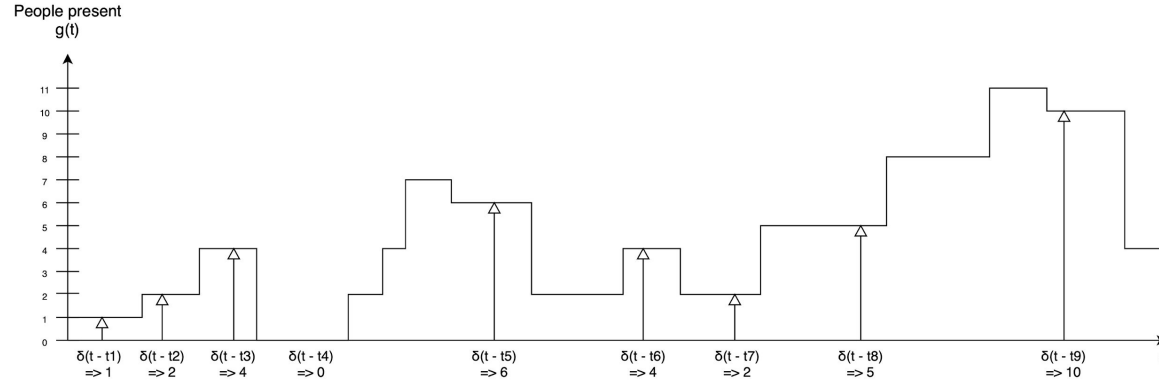
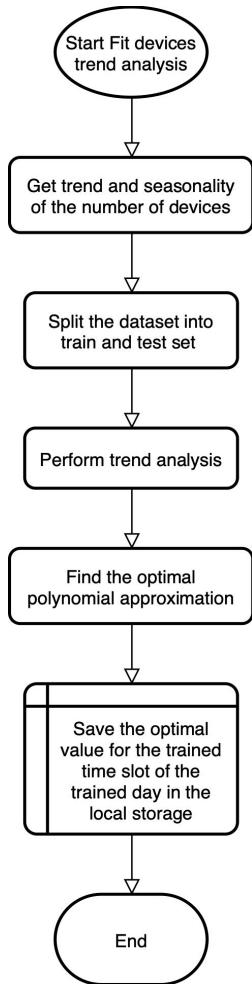




Presence of devices



Ground Truth Collection





Feasibility Test at Home

Tests at home before validation

3 days of data collection

65928 probe request frames captured

12 home devices revealed

2 main range of RSSI $-71 \div -91$ not in the kitchen, $-35 \div -69$ in the kitchen

→ Feasibility of the method for detecting devices in the area



Validation

- Raspberry Pi in a Cafe where I annotate manually the ground truth
- Eclipse Mosquitto Broker MQTT of U-Hopper on their server
- MQTT receiver and MongoDB on U-Hopper server
- Analyzer and Estimator on my pc to use on the data + collected ground truth to test accuracy and reliability of the proposed system



Results

4 weeks of data collection

1022 manual annotation of ground truth

580673 probe request frames captured

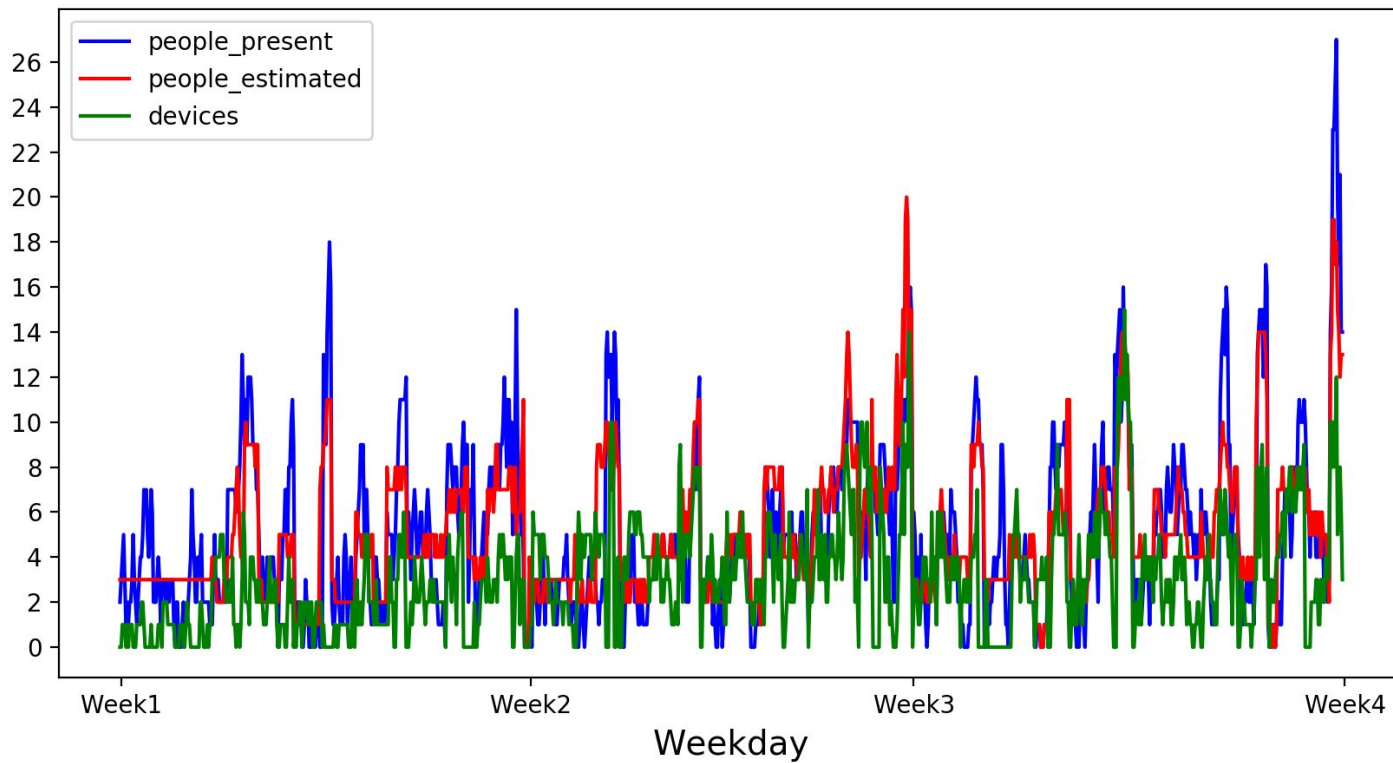
26567 MAC addresses revealed

Mean Absolute Error = 1.656

Mean Squared Error = 5.310

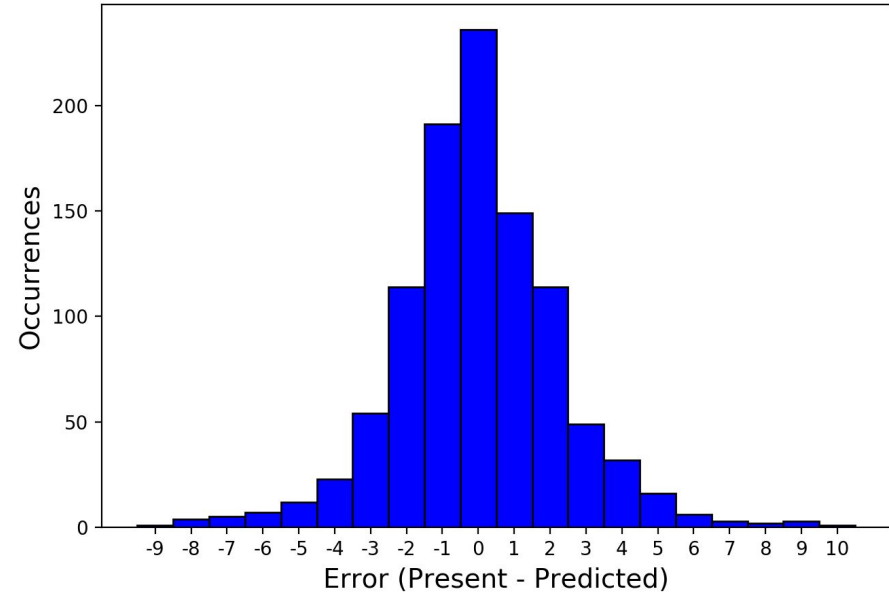
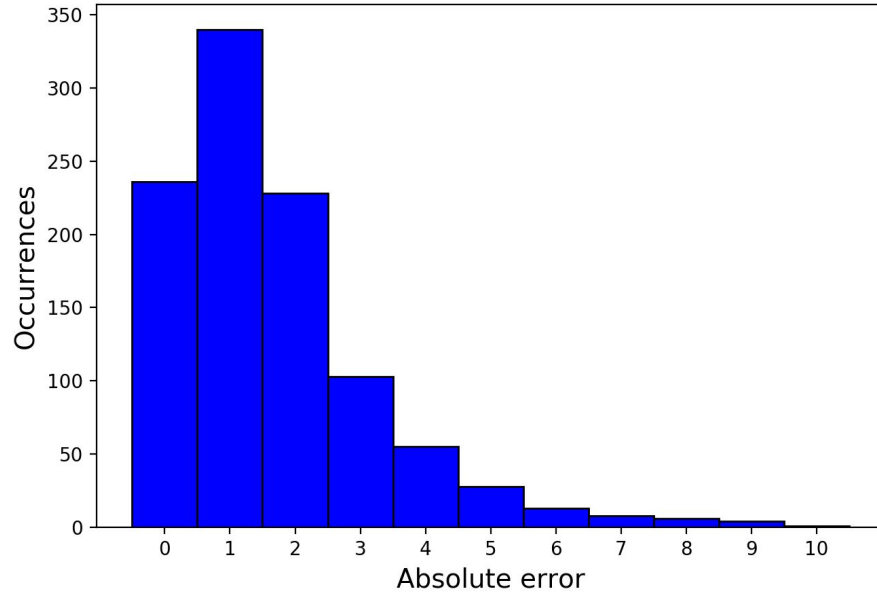


Results



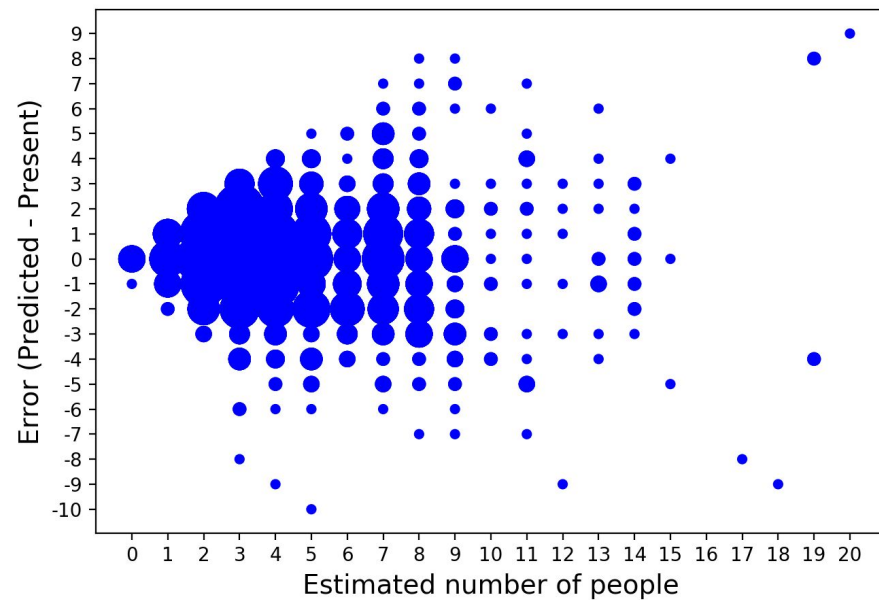
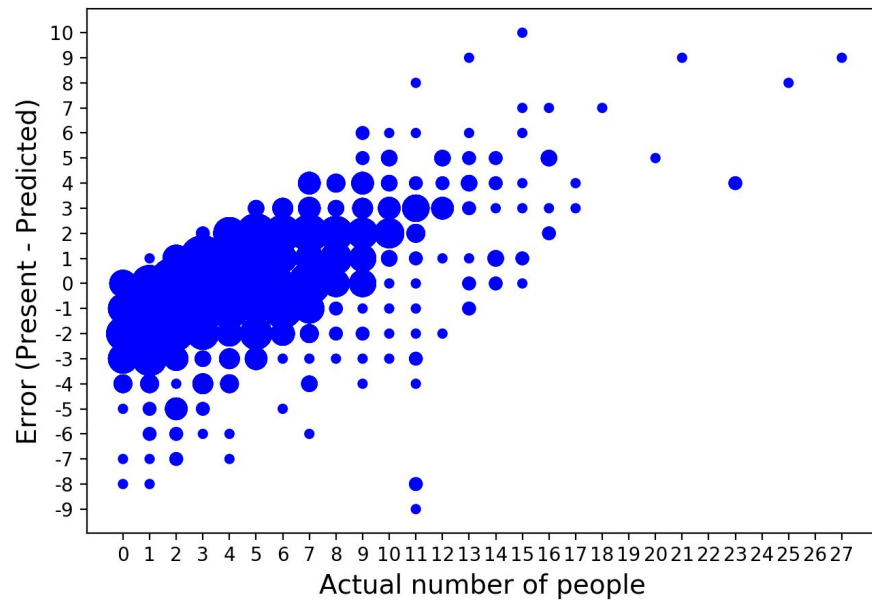


Results





Results





Summary

- It is possible to continuously estimate the number of people in a place of interest based on the Wi-Fi probe request frames
- Designed and developed a system to do that
- Tested the system in a Cafe and collected 4 weeks of data and manually-annotated ground truth



Future Works

- Real-Time integration
- Test the system in different context
- Improve the Machine Learning model