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# Estimation of the number of people in a place of interest based on Wi-Fi probe request frames

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# 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

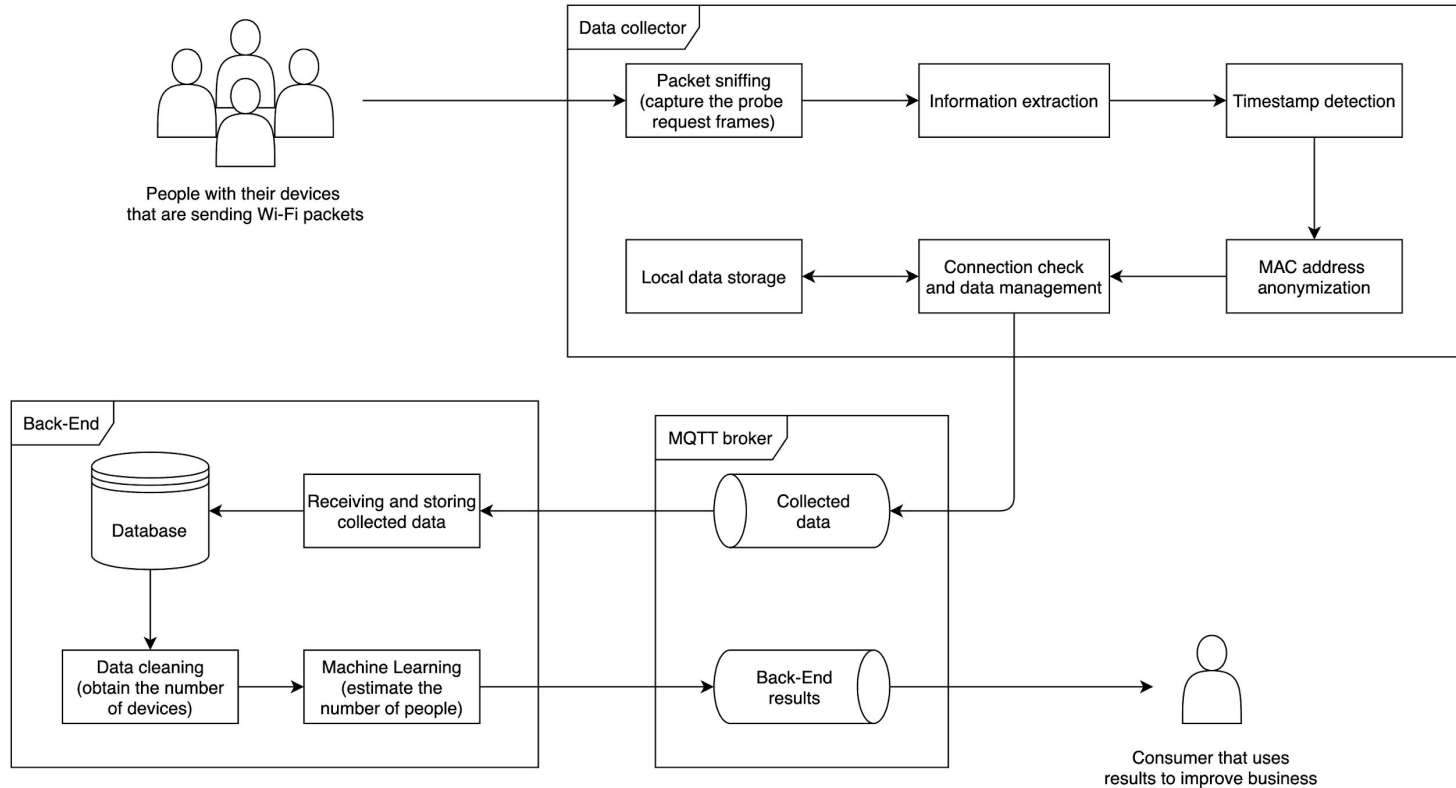
Designed and developed a system for this problem that could work in several context

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





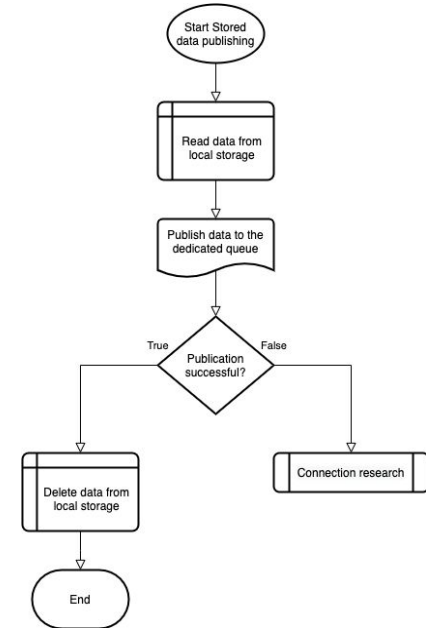
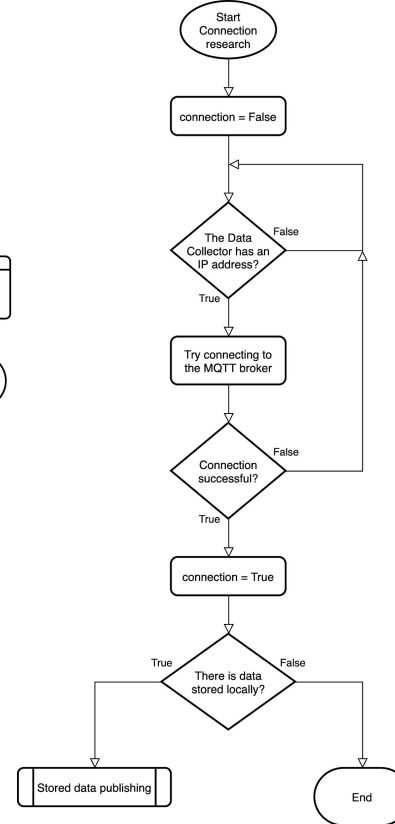
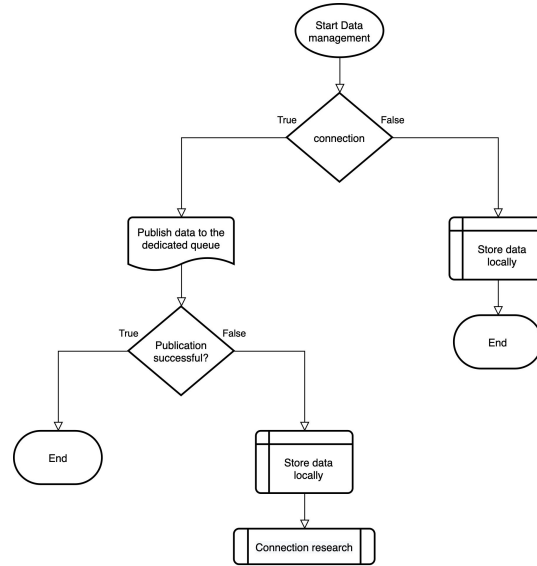
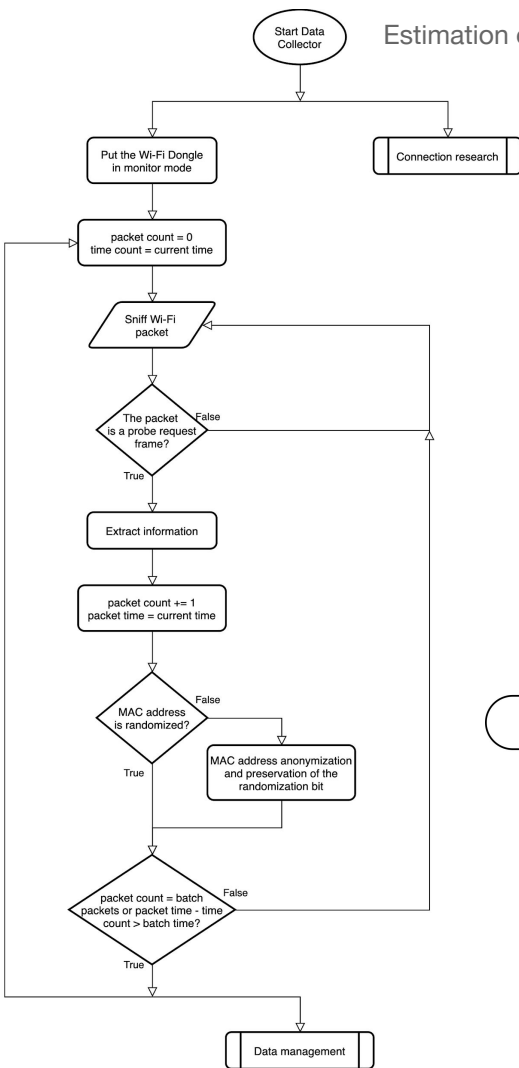
# System Architecture





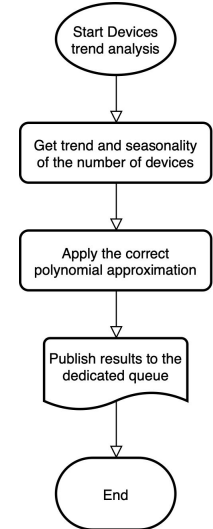
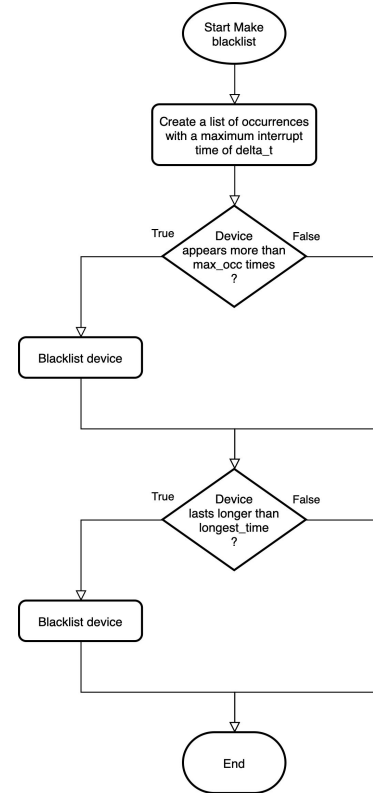
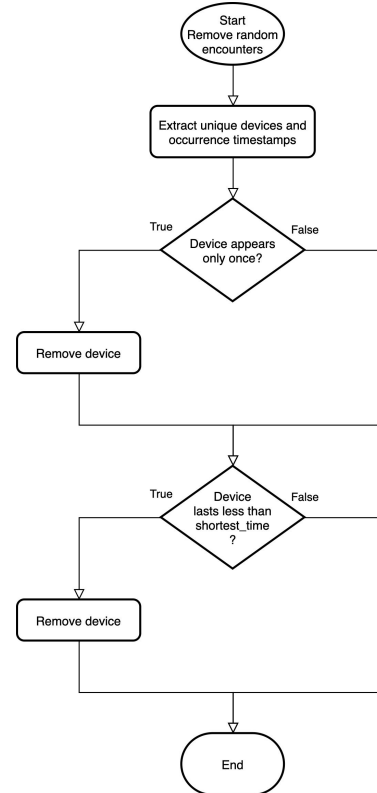
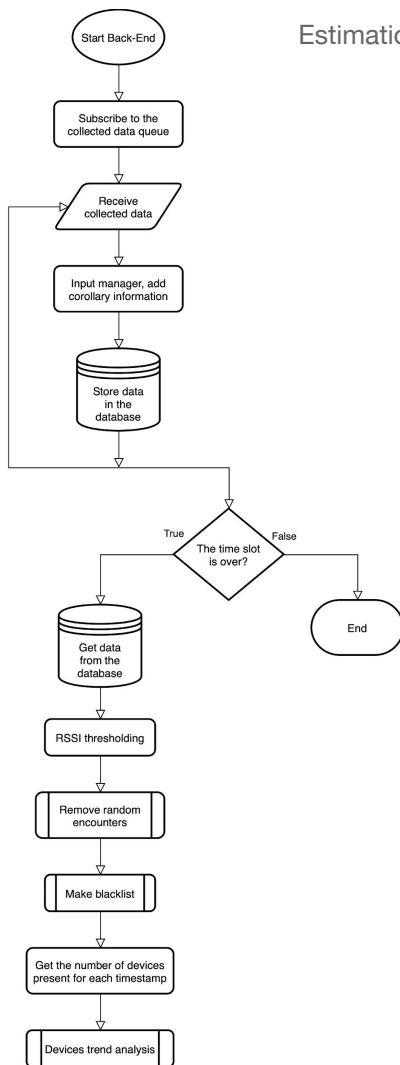


# Data Collector Logic



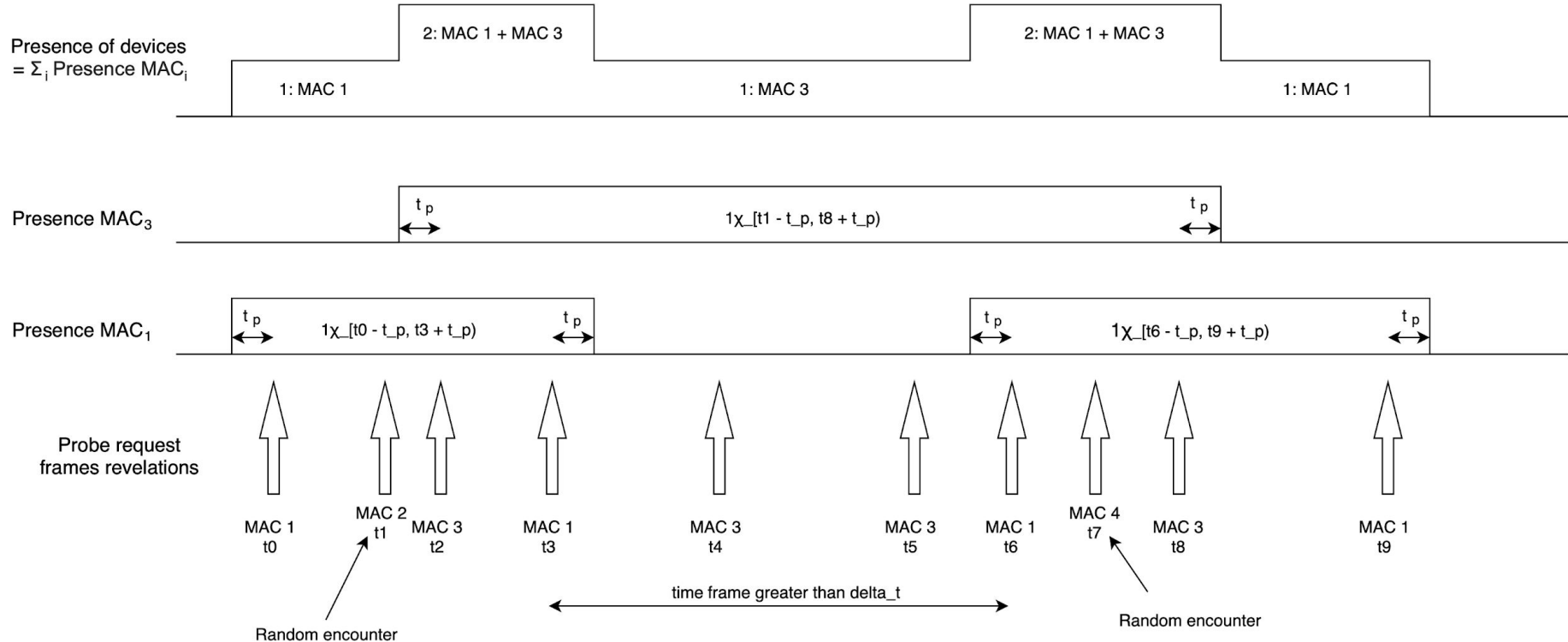


# Back-End Logic



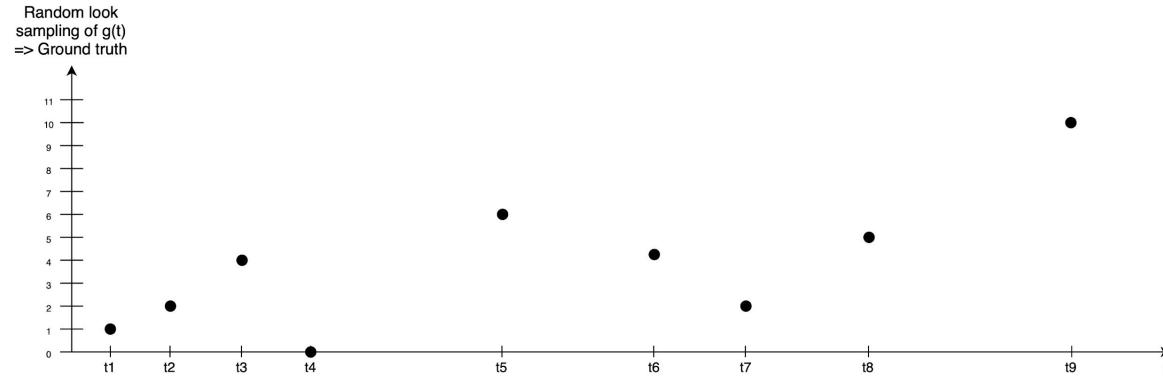
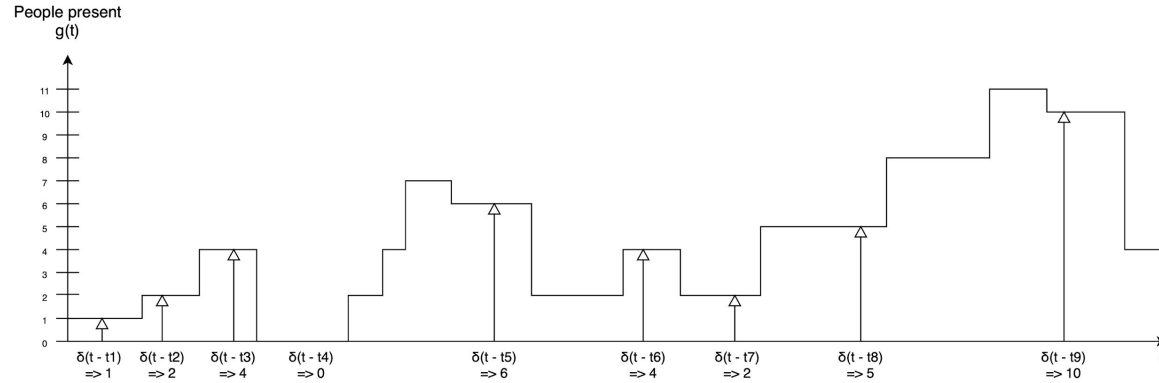
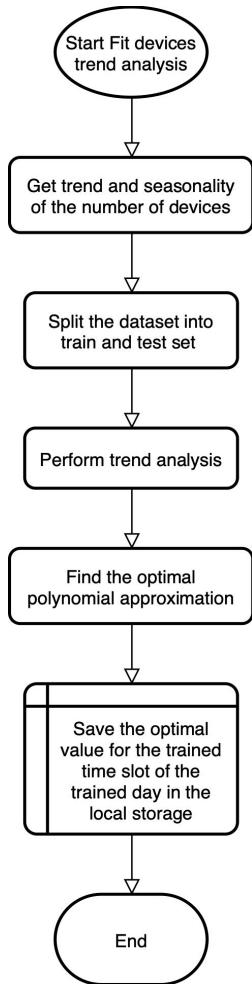


# Presence of devices





# 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

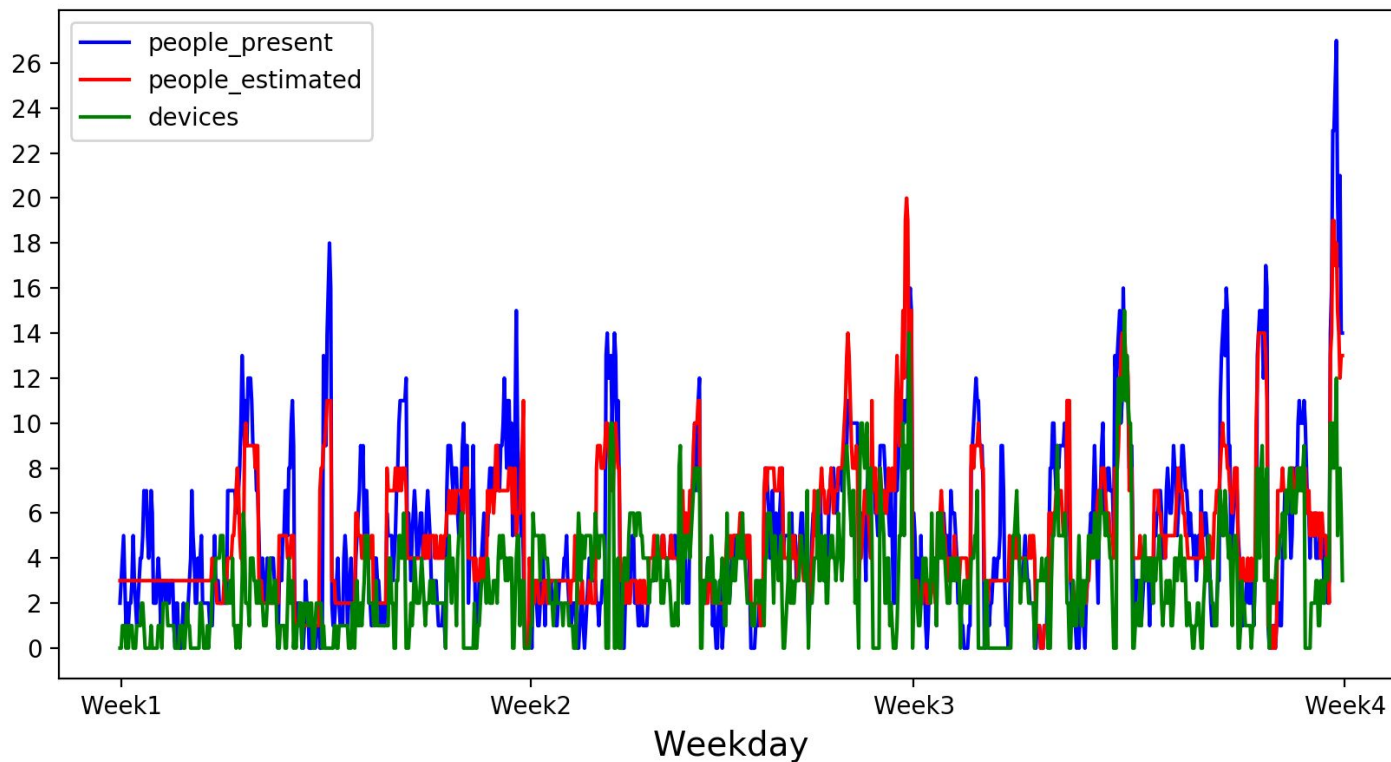
26567 MAC addresses revealed

Mean Absolute Error = 1.656

Mean Squared Error = 5.310



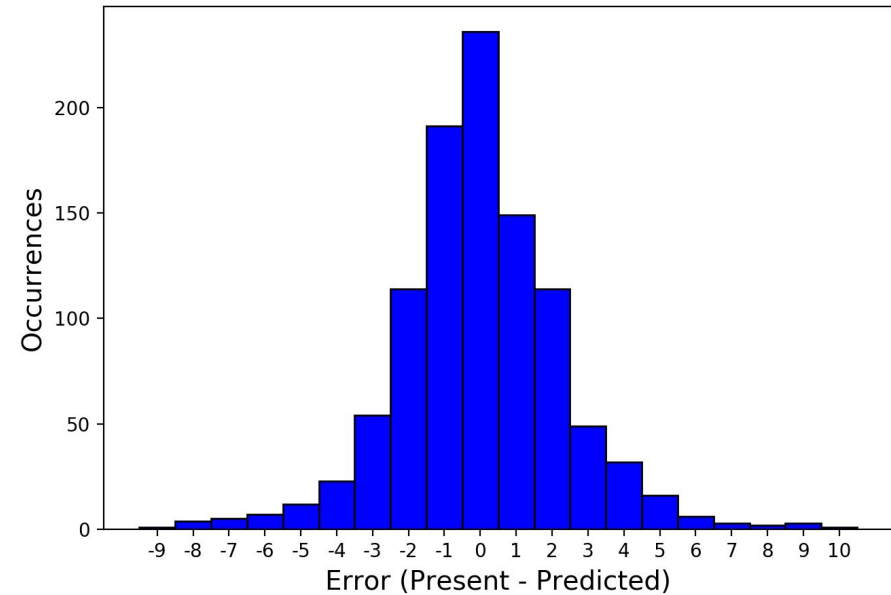
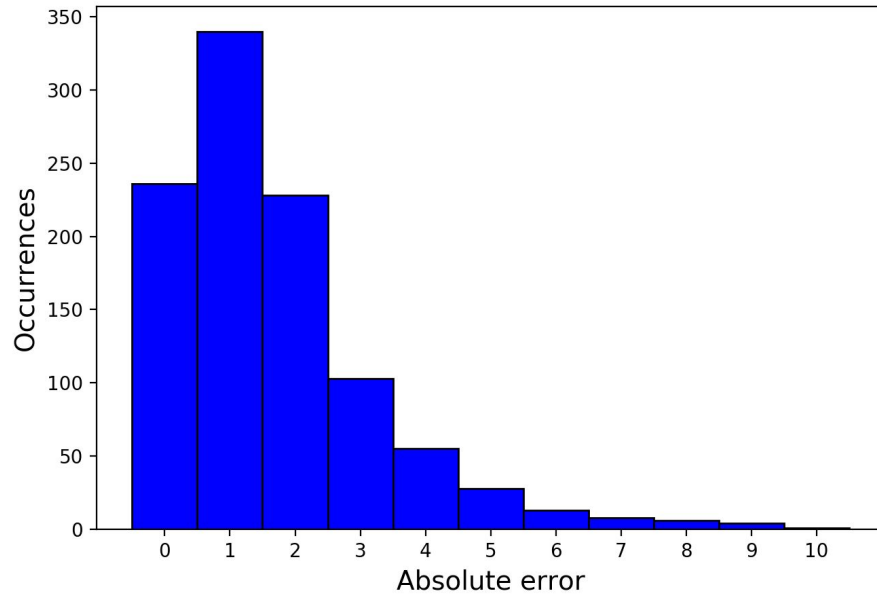
# Results





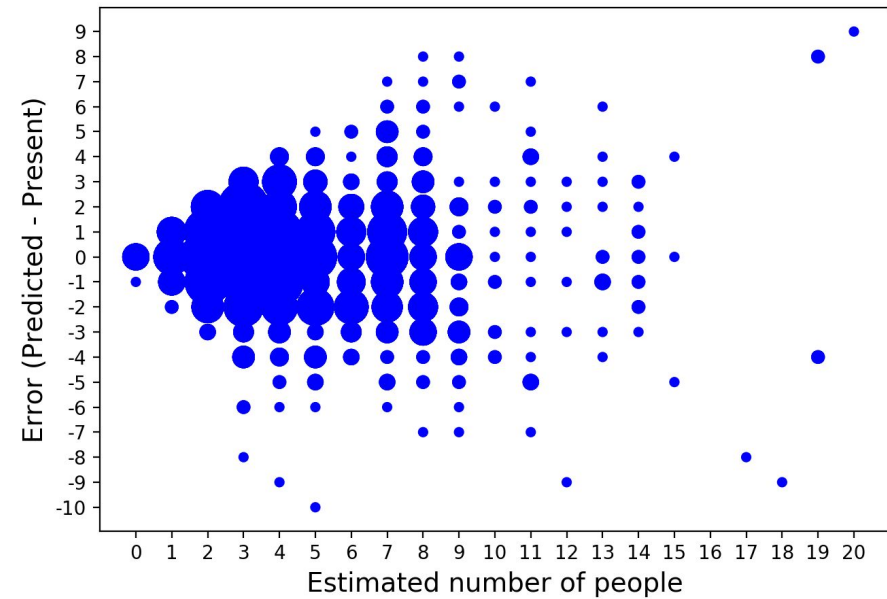
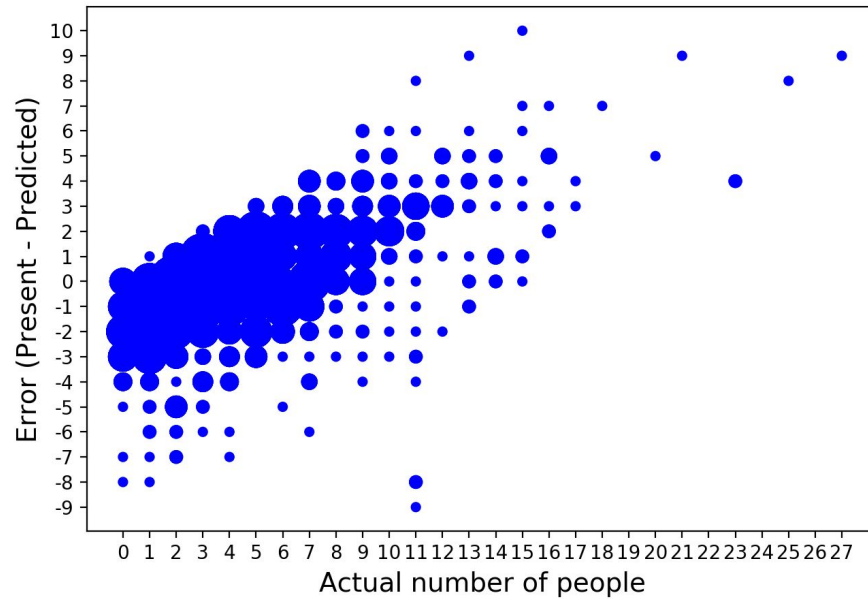


# Results





# 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 execution
- Test the system in different context
- Improve the Machine Learning model