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DI TRENTO

A system for estimating crowd density based on Wi-Fi probe request frames

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Supervisors

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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 (important avoid generating crowds to reduce risk of spread of covid)

State of the Art

→ Analysis of different methods to estimate occupancy

Infrared sensors, LSE, treadle switch-based systems, Video methods,

Audio methods, Wi-Fi, Bluetooth, BLE, LTE, Radar, RFID approaches

→ Many fields of application and several implementations

Why Wi-Fi solution?

High diffusion of Wi-Fi devices

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 density of the crowd

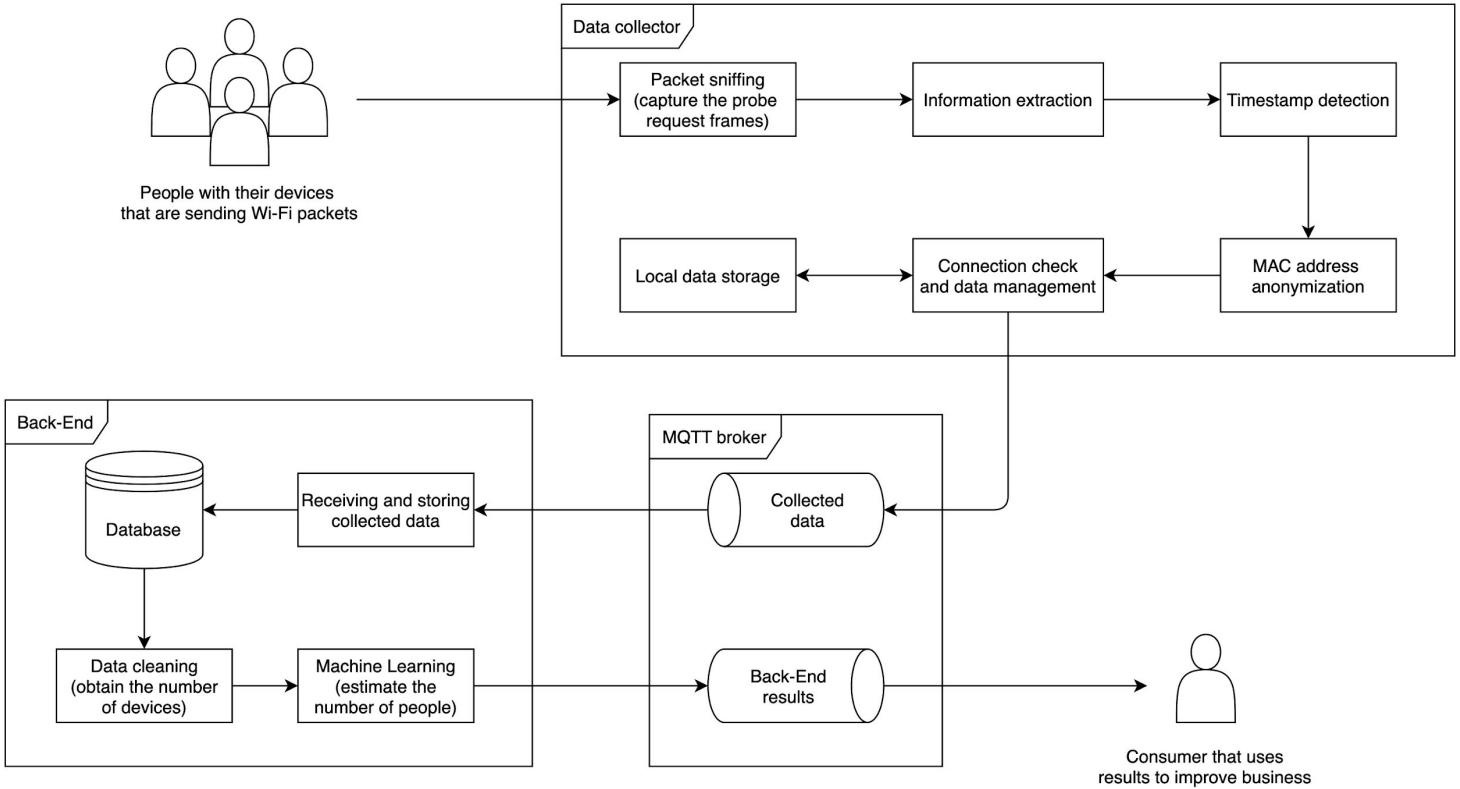
in a place of interest based on the Wi-Fi probe request frames?

Achievements

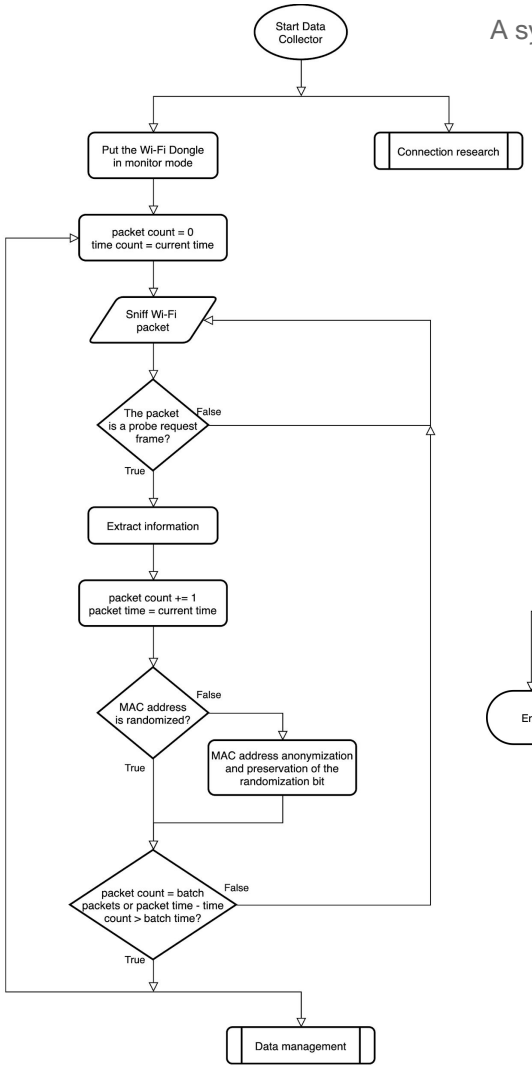
Designed and developed a system for this problem that could work in several context

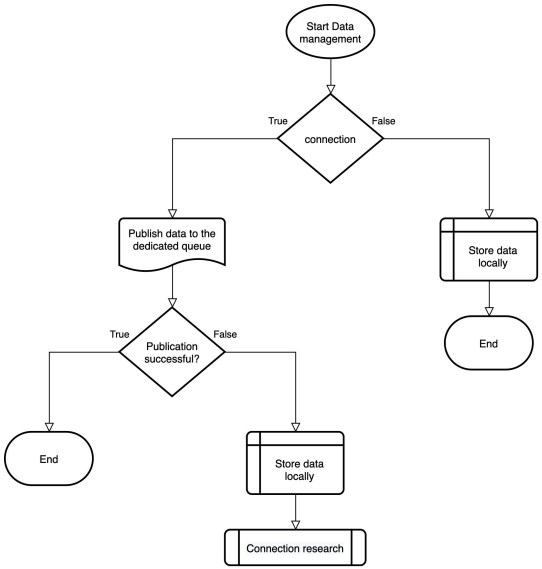
Tested the system in a Cafe and collected 4 weeks of data and manually-annotated ground truth

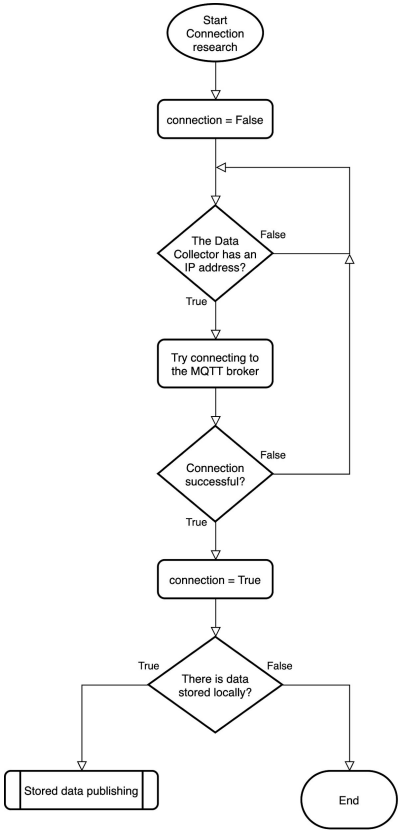
System Architecture

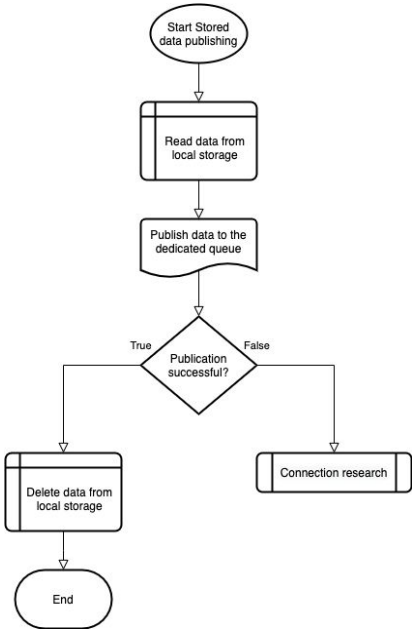


Data Collector Logic

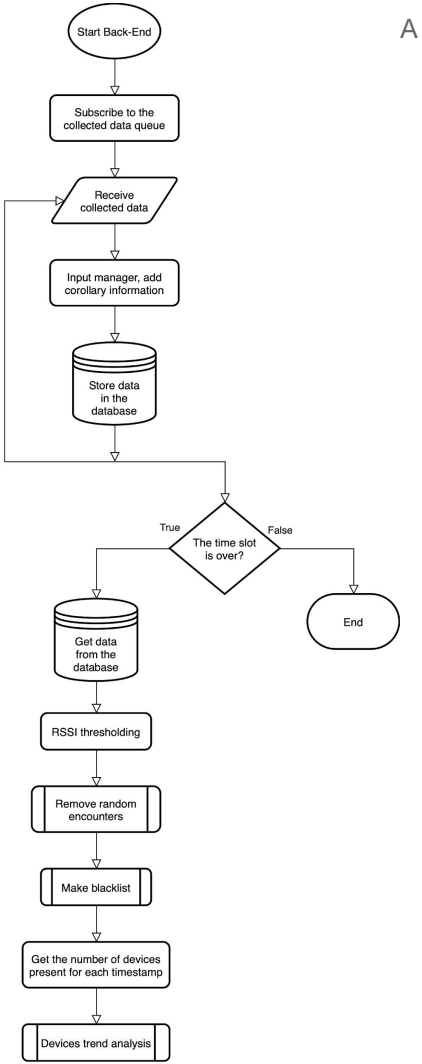


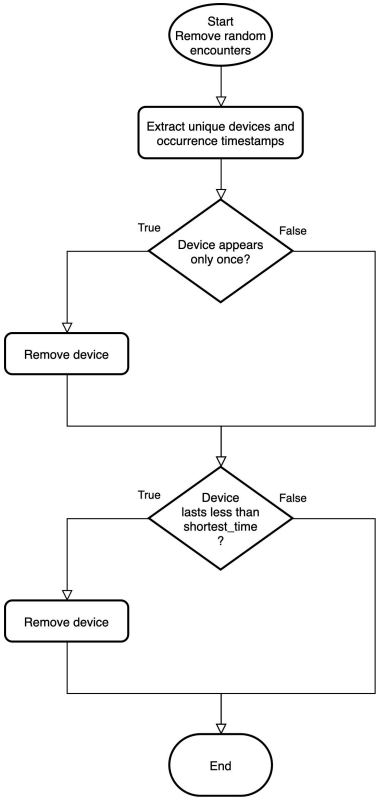


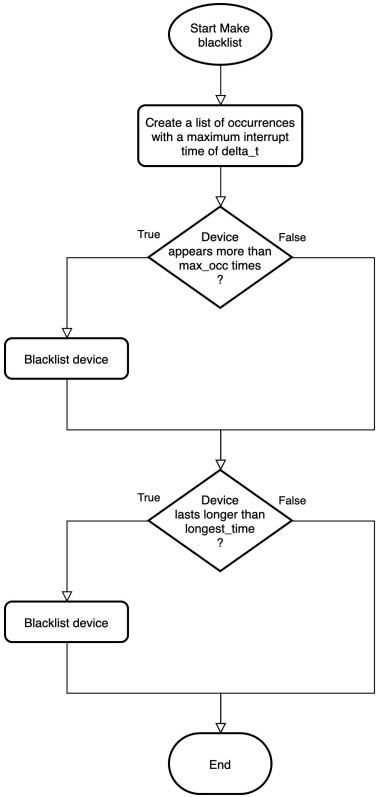


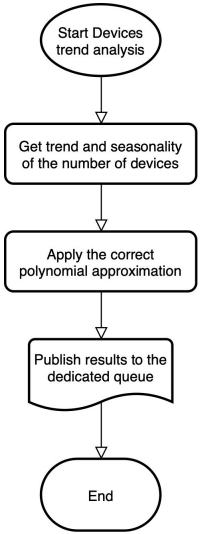


Back-End Logic

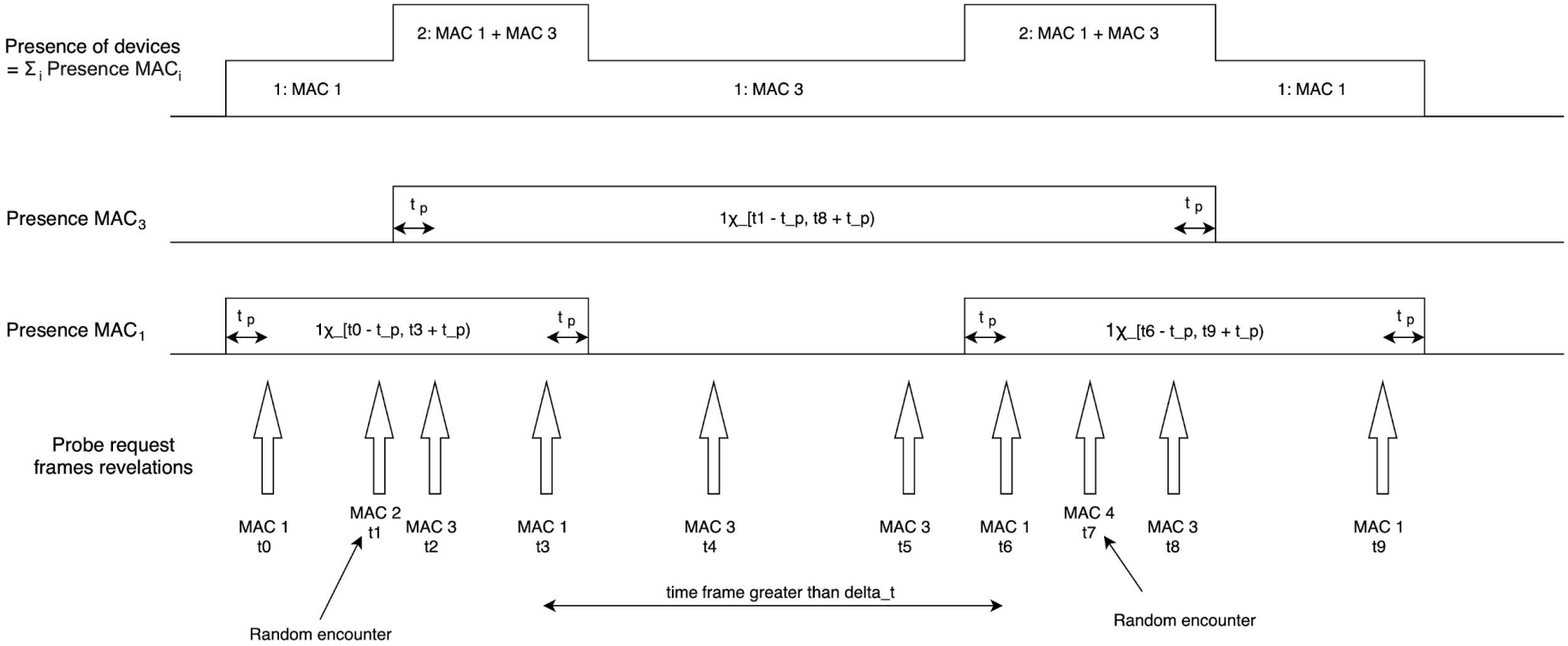








Presence of devices



Feasibility Test at Home

Tests at home before validation

3 days of data collection

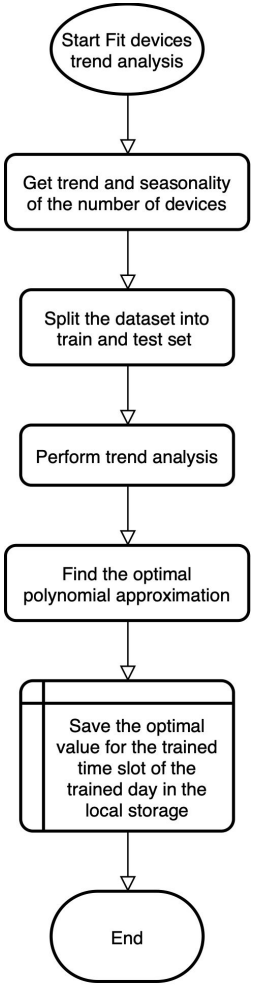
65928 probe request frames captured

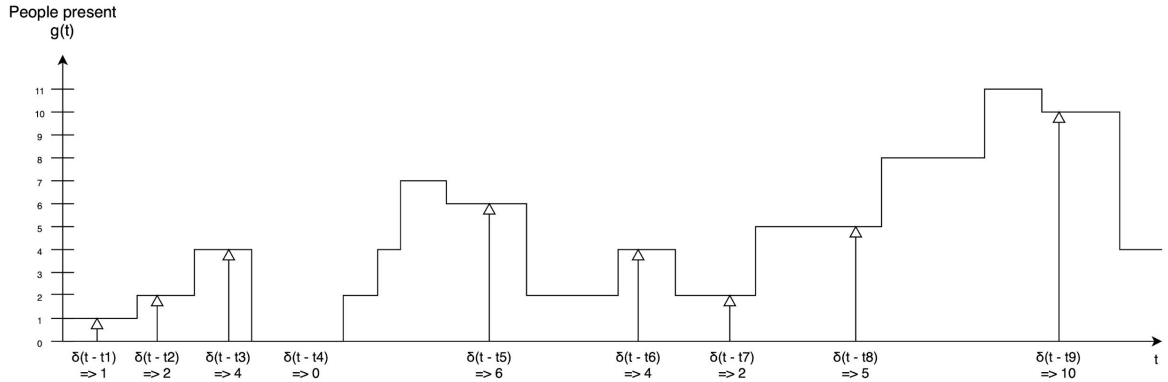
12 home devices revealed

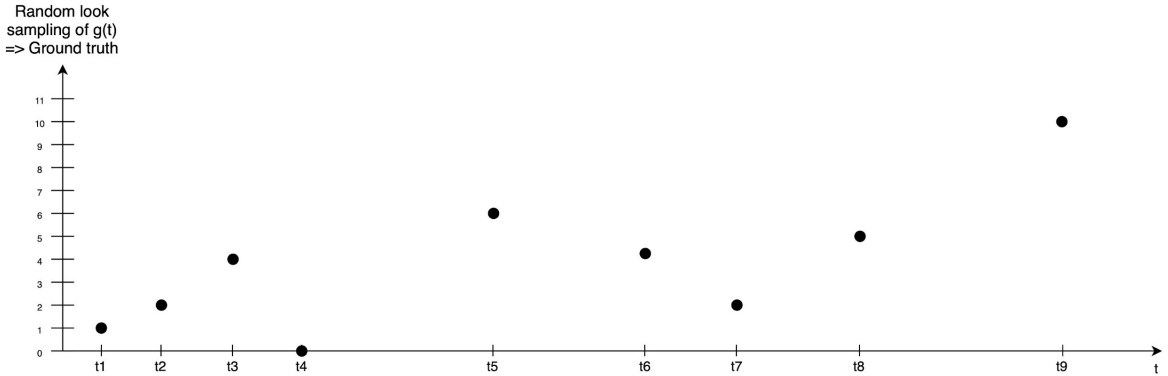
2 main range of RSSI -71 ÷ -91 not in the kitchen, -35 ÷ -69 in the kitchen

→ Feasibility of the method for detecting devices in the area

Ground Truth Collection







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

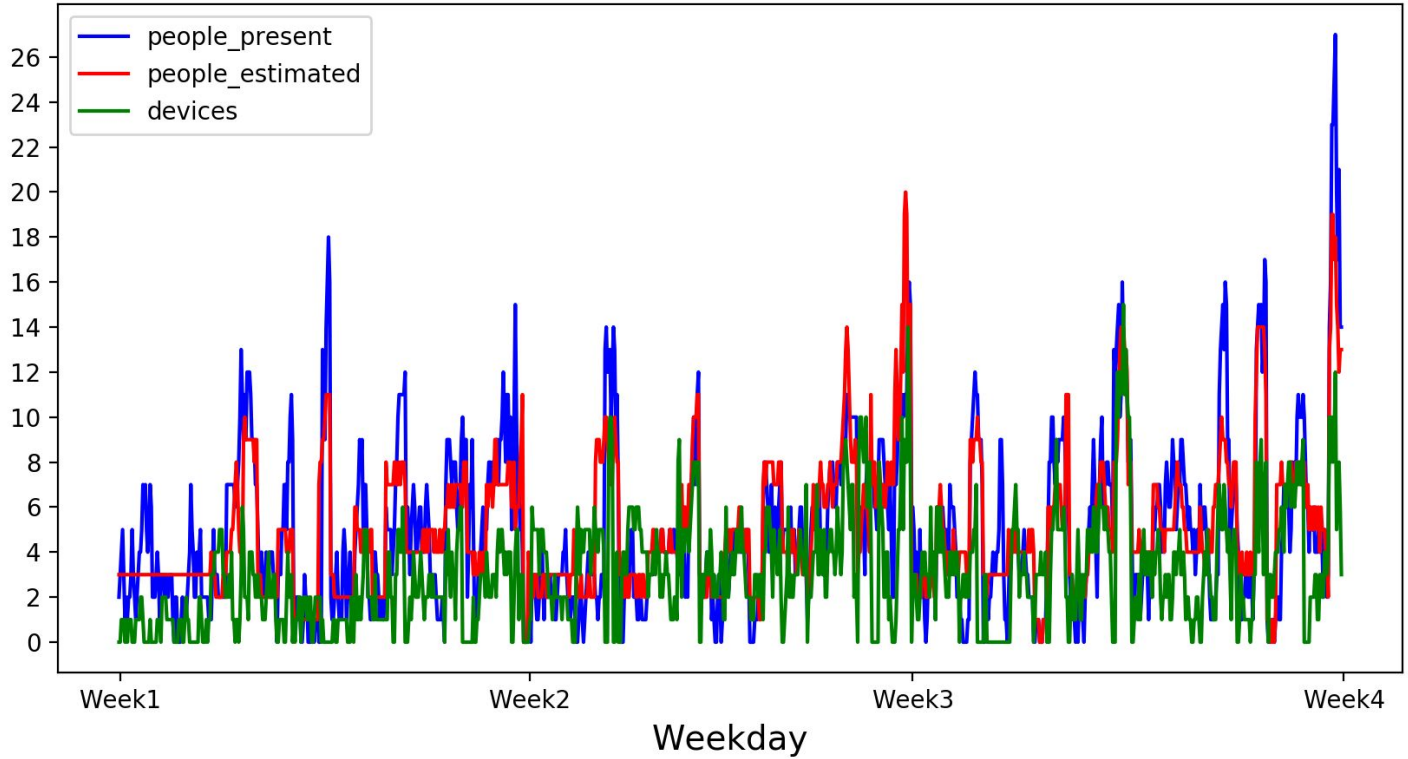
580673 probe request frames captured

26567 MAC addresses revealed

Mean Absolute Error = 1.656

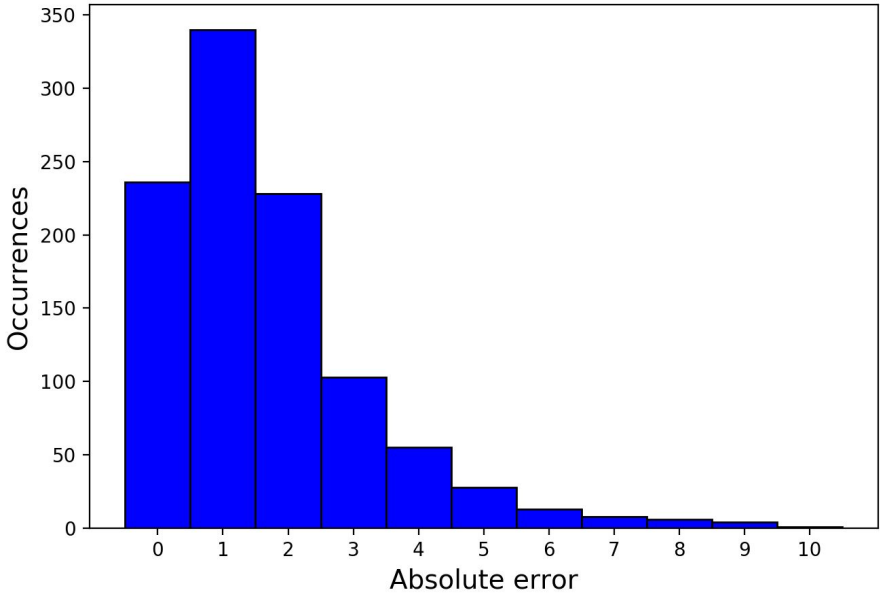
Mean Squared Error = 5.310

Results

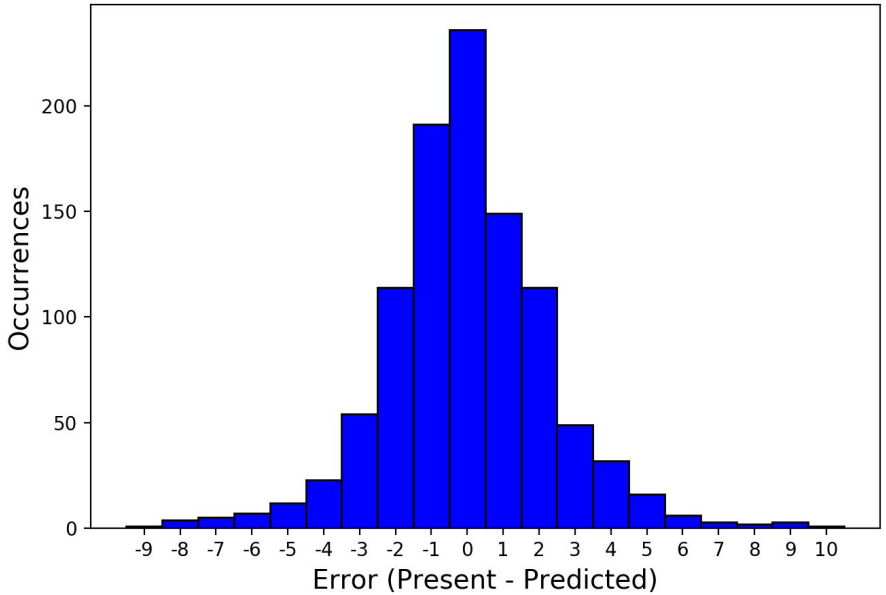

people_present
people_estimated
devices
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Week1
Week2
Week3
Week4
Weekday

Results

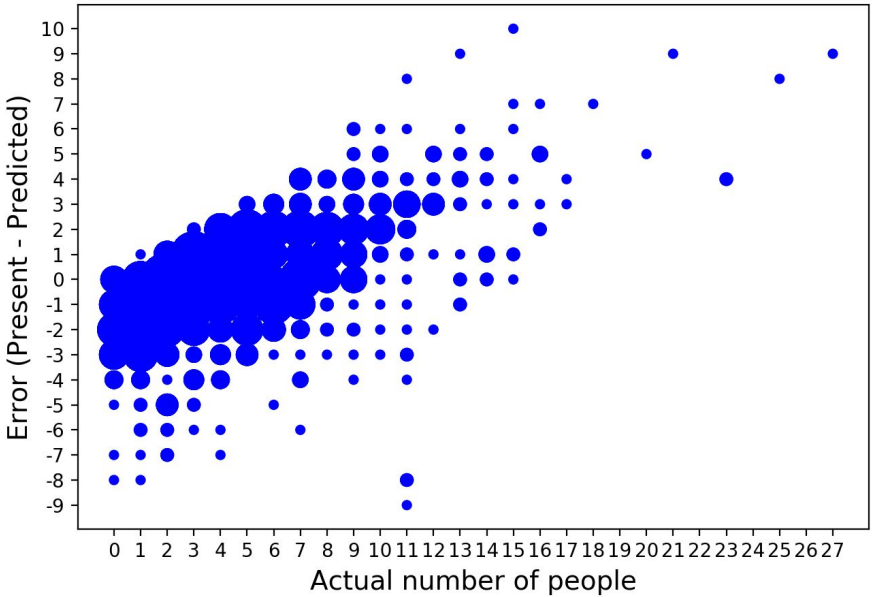
P(absError > 2) = 0.21

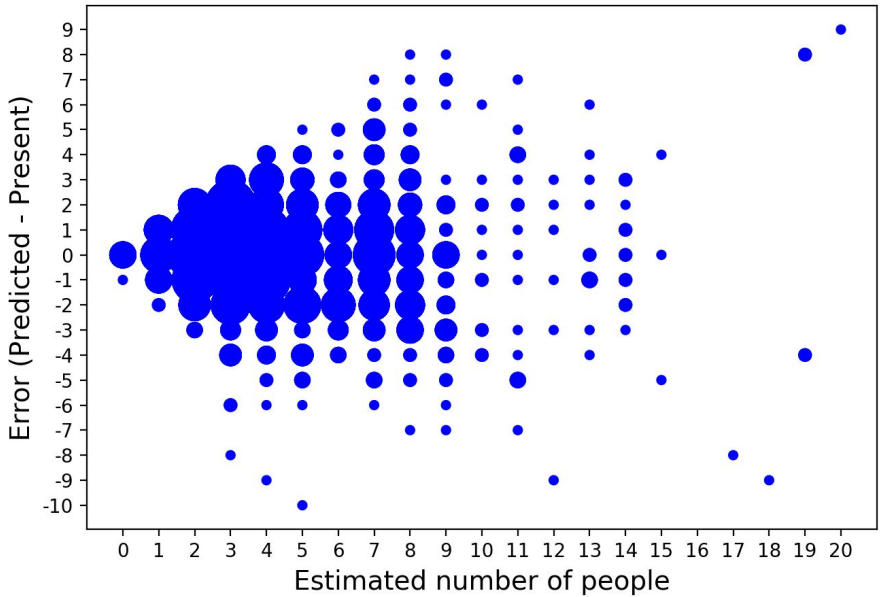


Error Distribution Chart



Results


Error (Present - Predicted)
Actual number of people


Error (Predicted - Present)
Estimated number of people

Summary

→ It is possible to continuously estimate the density of the crowd 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 contexts

→ Improve the Machine Learning model