UNIVERSITÀ DI TRENTO

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

Department of Information Engineering and Computer Science

Supervisors

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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

→ It is important to avoid generating crowds to reduce the risk of COVID-19 spreading during this global pandemic period

State of the Art

→ Analysis of different methods for estimating crowd density

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

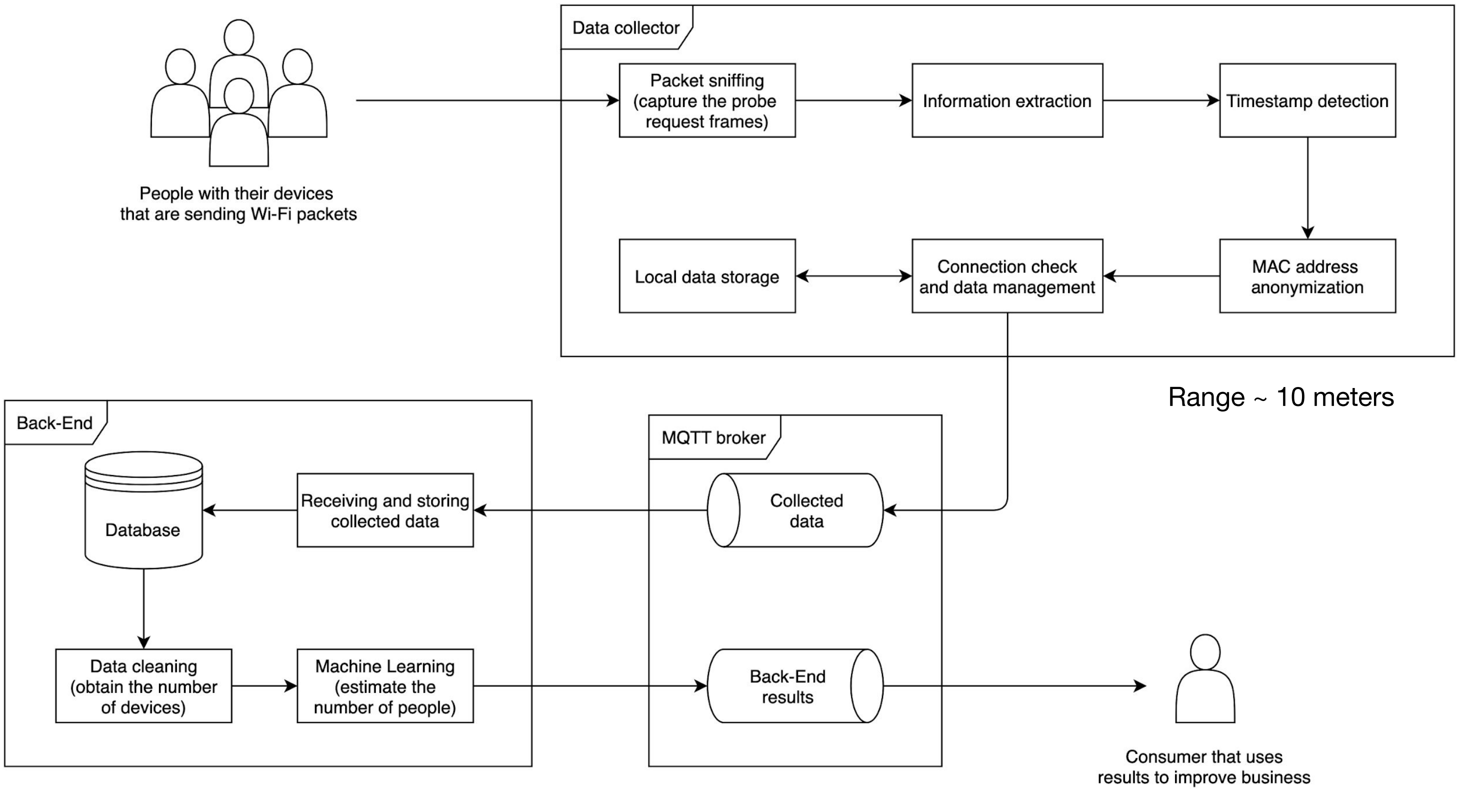
Is it possible to continuously estimate the density of the crowd in a place of interest based on the Wi-Fi probe request frames?

Achievements

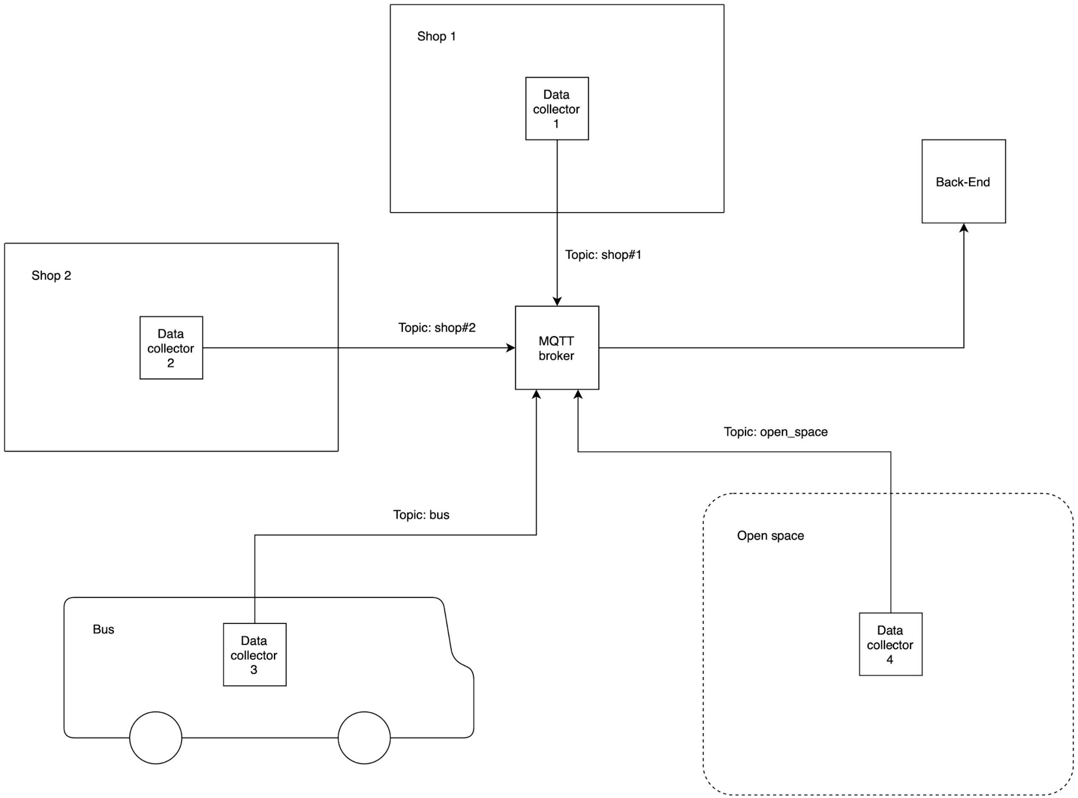
Designed and developed a system for this problem that could work in several context

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

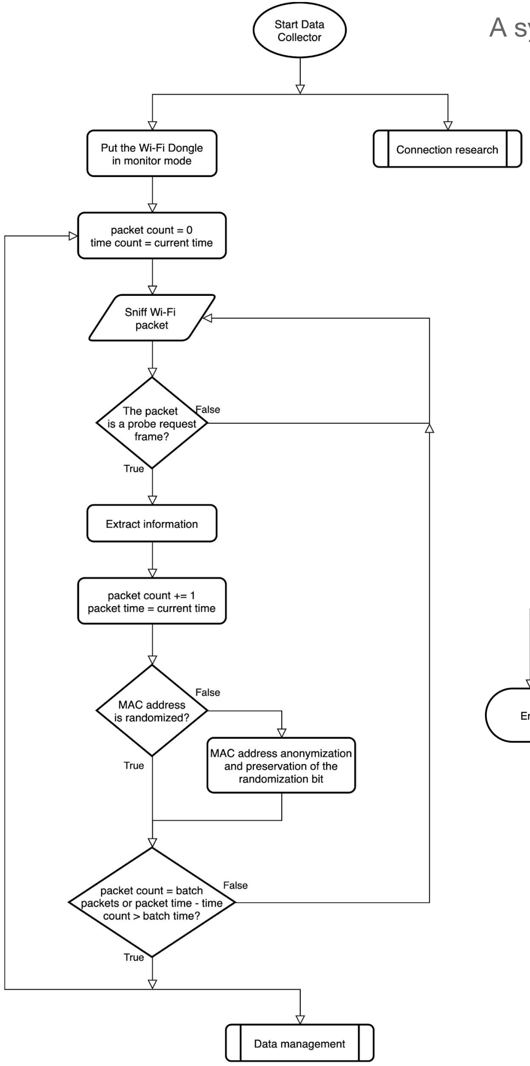
System Architecture

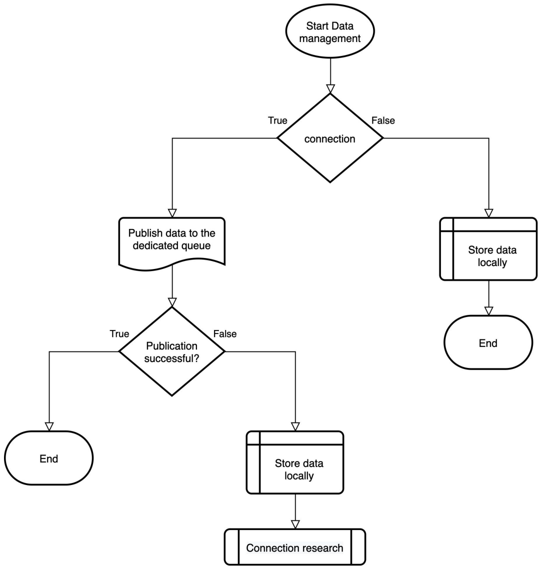


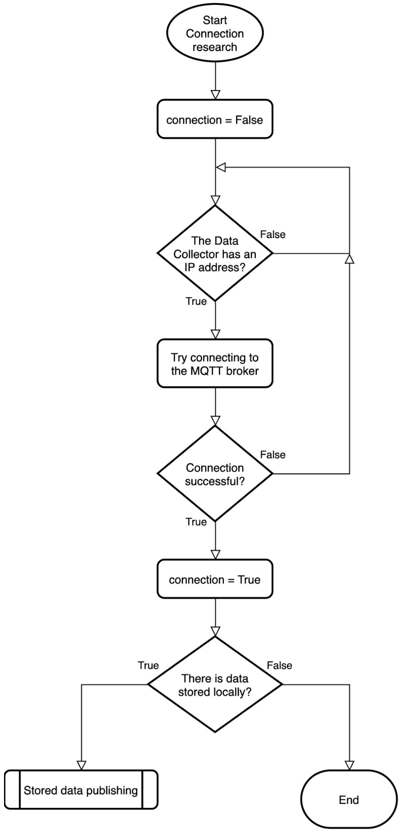
Scalable Architecture

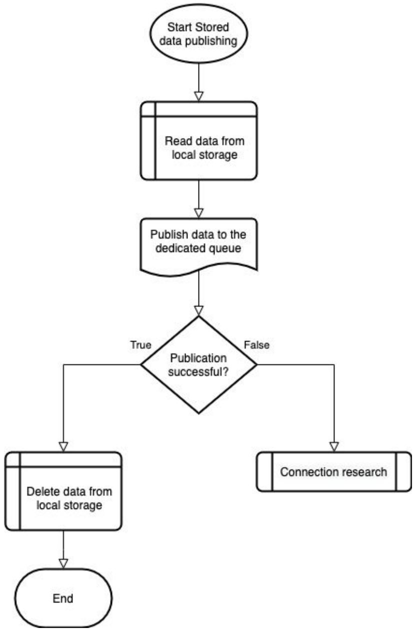


Data Collector Logic

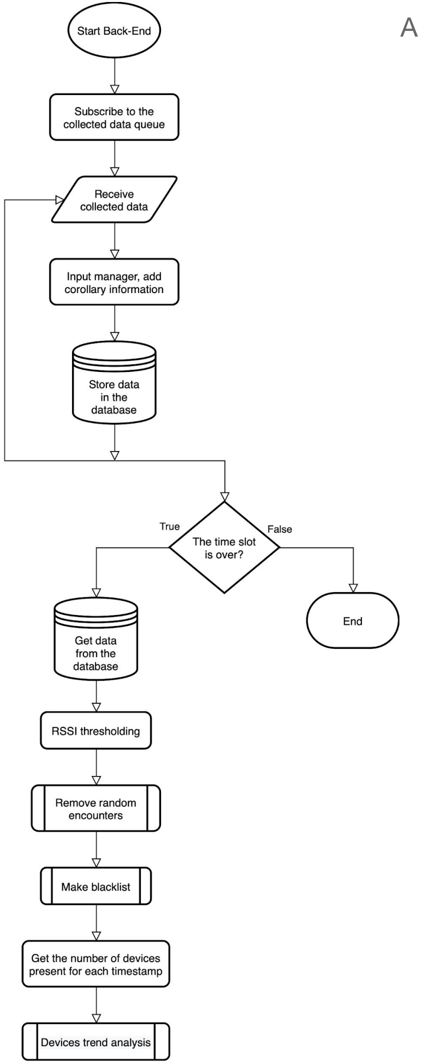


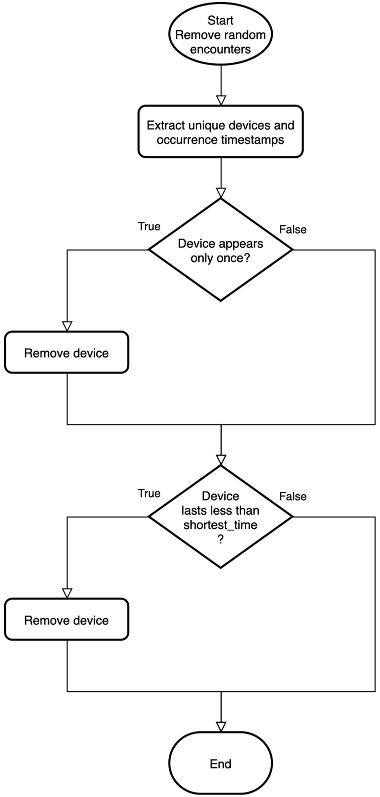


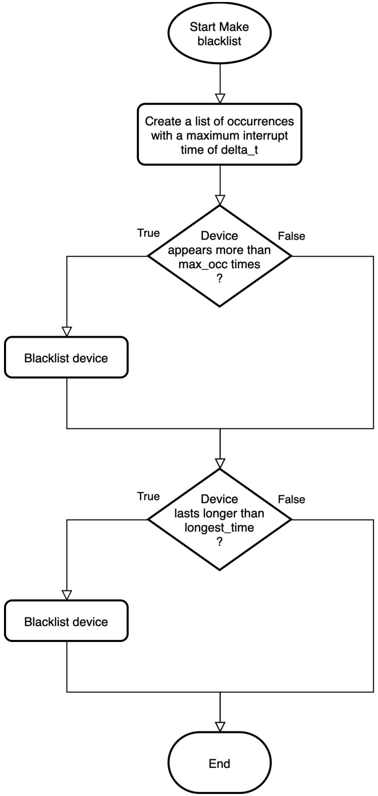


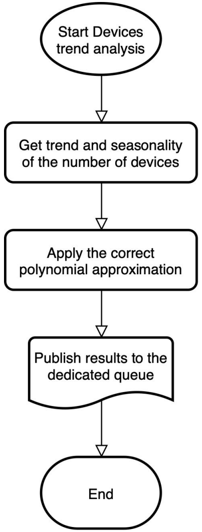


Back-End Logic

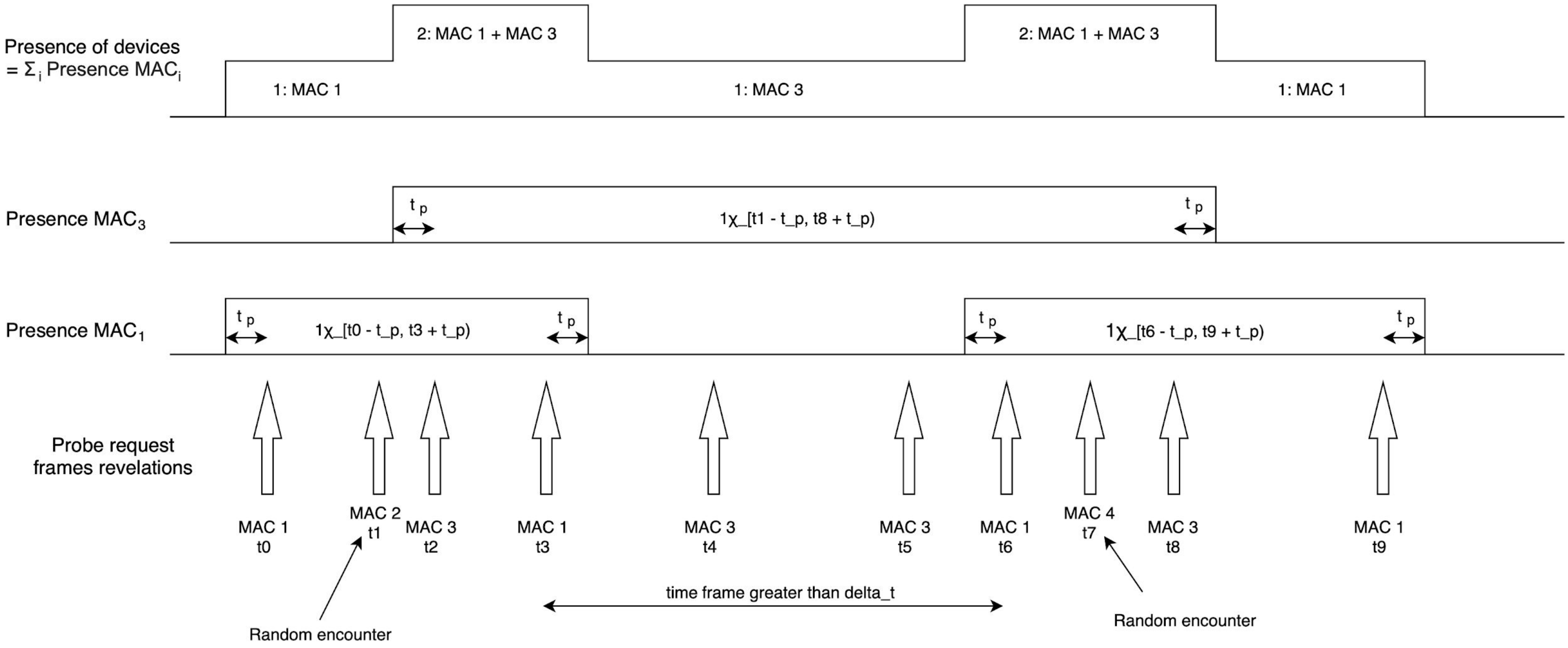








Presence of devices



Feasibility Test at Home

Tests at home before validation

3 days of data collection

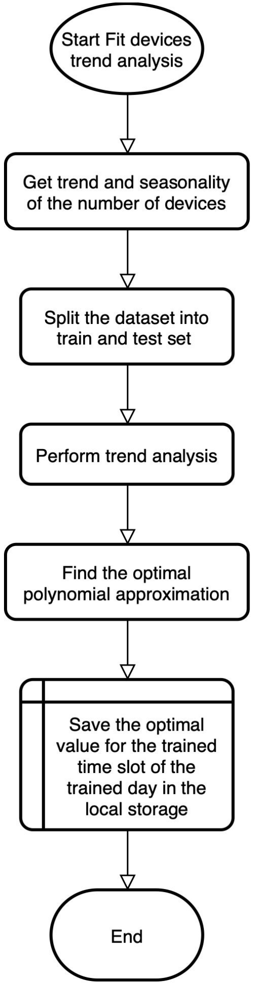
65928 probe request frames captured

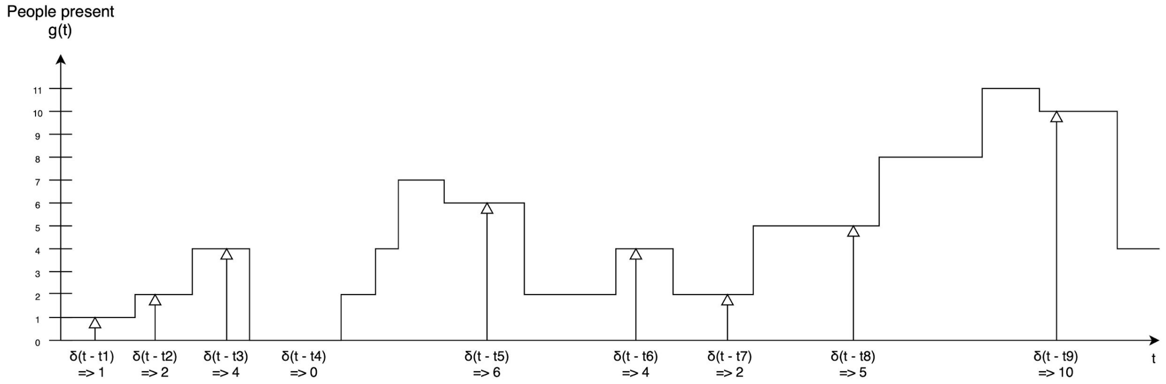
12 home devices revealed

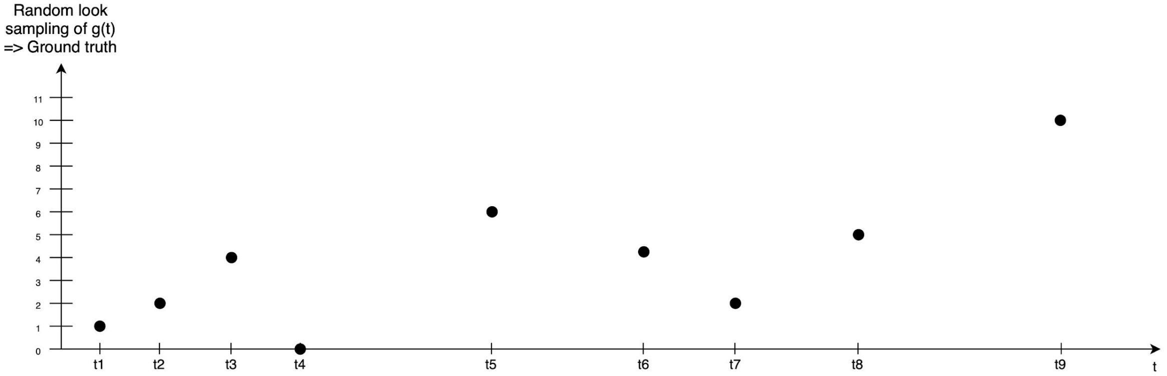
2 main range of RSSI -71 ÷ -91 not in the kitchen, -35 ÷ -69 in the kitchen

→ Feasibility of the method for detecting devices in the area

Ground Truth Collection







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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 (580MB)

1022 manual annotation of ground truth

580673 probe request frames captured

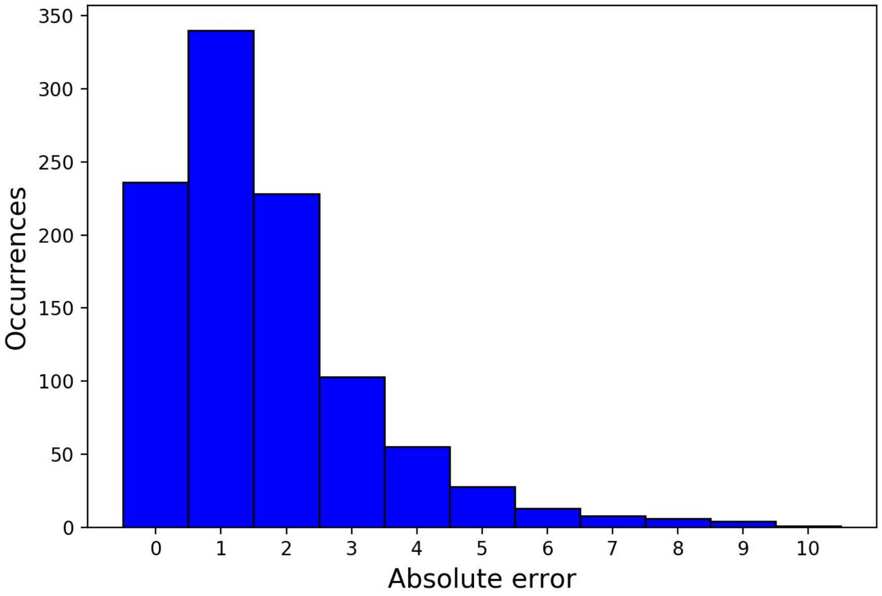
26567 MAC addresses revealed

Mean Absolute Error = 1.656

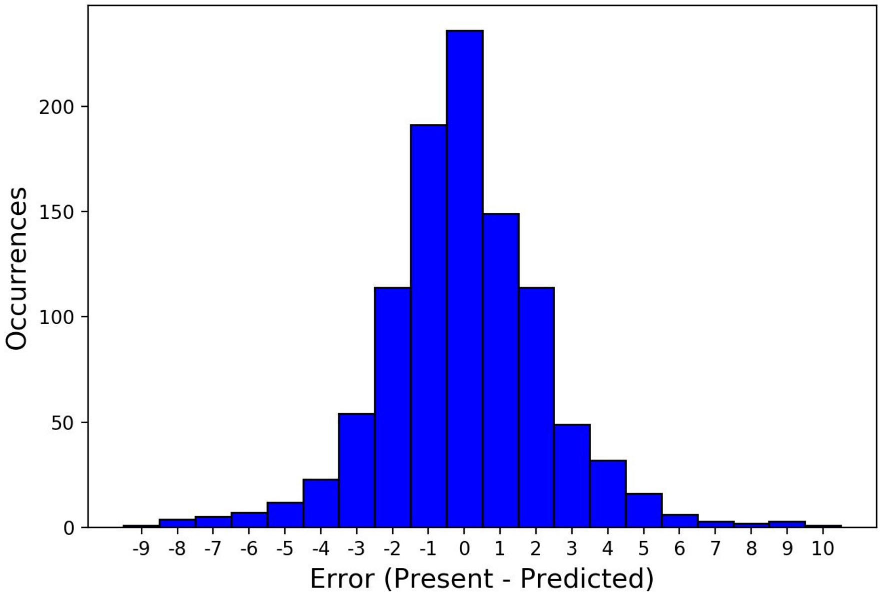
Mean Squared Error = 5.310

Error Distribution

P(absError > 2) = 0.21



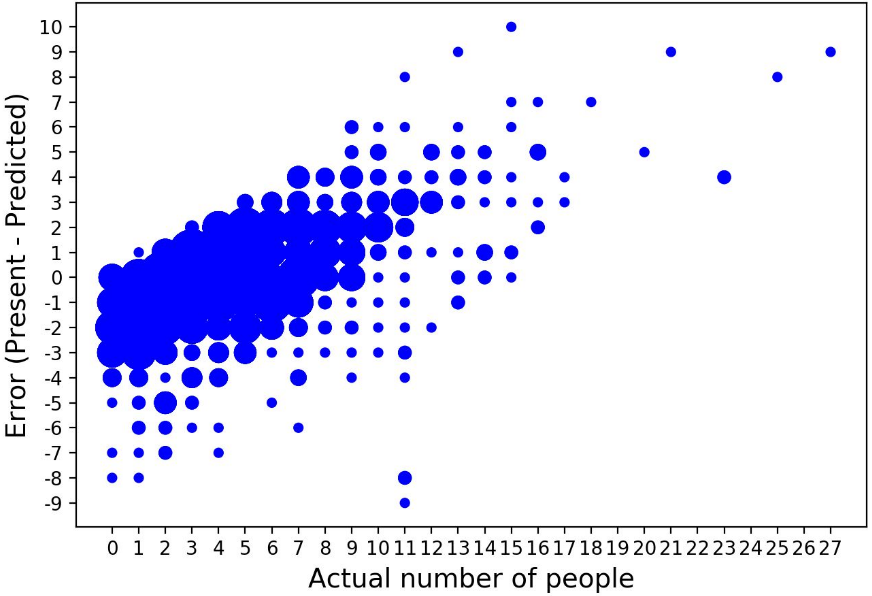
No systematic error

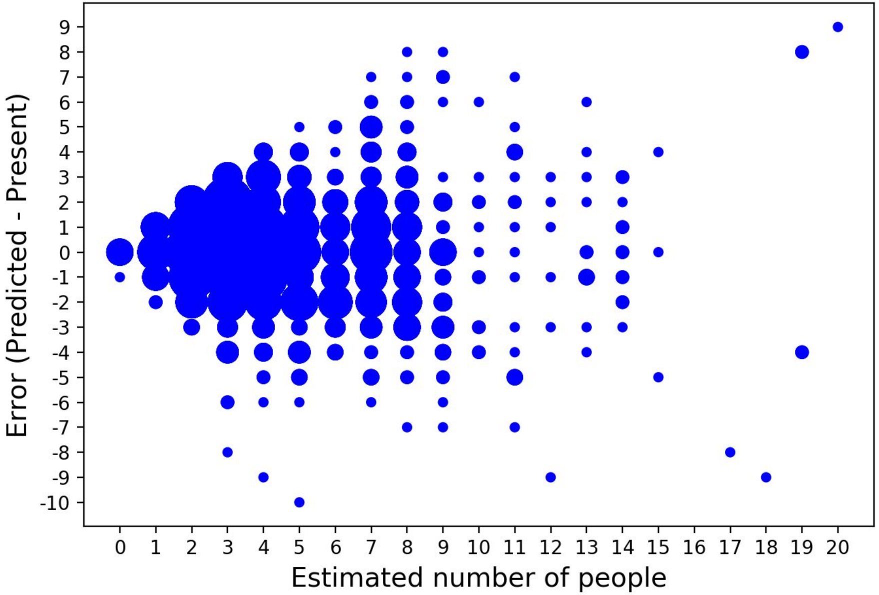


Results

high people, lower predictions

No systematic error





low people, higher predictions

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

Thank you for your attention