2024-1 Introduction to Internet of Things

: Progress Report

Team 6
201931322 김재영 - jykim7568@gachon.ac.kr
202031415 임형섭 - gudtjqdkwk@naver.com
202033502 강현준 - kanghj1537@gachon.ac.kr
202034909 김주혜 - epnjh0807@gachon.ac.kr

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>> Brief Description

Develop a system using Wi-Fi sensing technology on Raspberry Pi to identify human activities or states in indoor environments

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Project Overview

Part 1 >> Project Overview

Project objectives and needs

Part 1 >> Project Overview - Raspberry Pi os

Debian-based OS

Created for Raspberry Pi computers

Hardware Optimization

Pre-installed with various software packages

Active Community Support

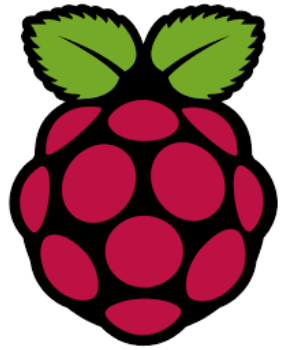
Ongoing development & collaborative problem-solving

Lightweight & Efficient

Suitable for diverse projects

Educational Use

Supports multiple programming languages & widely used in schools



Part 1 >> **Project Overview** - Nexmon

nexmon

Wi-Fi & Bluetooth

Handles communications

Community Project

continuously expand capabilities.

Raspberry Pi Compatible

Ideal for experimental & development purposes

Patches

Modifies & extends Bluetooth communication.

Software Framework

advanced wireless features for embedded system

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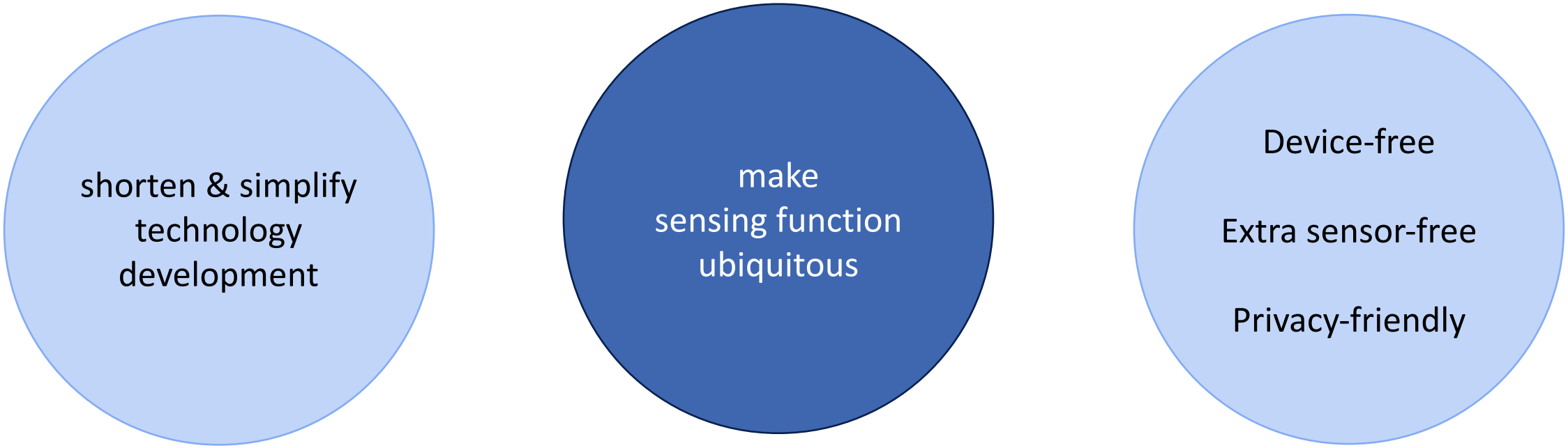
Technical Background

Part 2 >> # Technical Background

Wi-Fi Sensing

Using existing standardized 802.11-based protocols to sense and track changes in the environment such as presence, range, angle, and velocity of non transceiver objects.

Advantages of Wi-Fi Sensing



Part 2 >> **Technical Background**

Channel State Information (CSI)

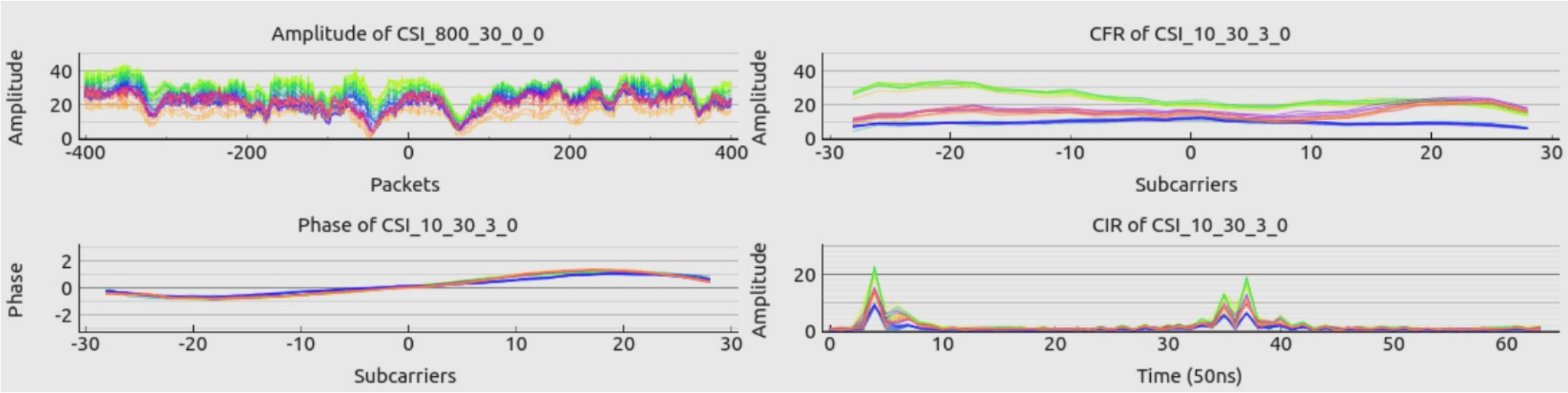
- the channel characteristics of communication links

adjust the **transmission** to the current channel conditions to **achieve reliable communication and high data rates**

characterizes the **propagation of radio signals** from transmitter to receiver at specific frequencies

Part 2 >> # Technical Background

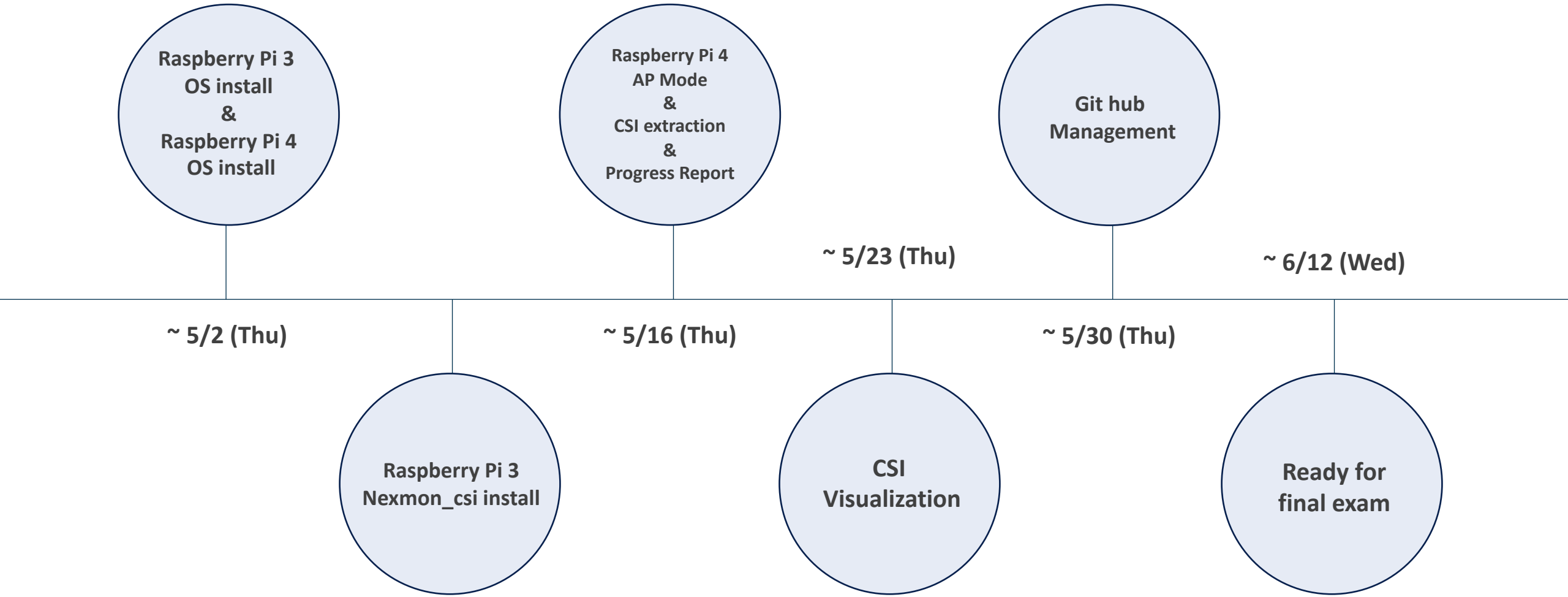
information can be used to **estimate the location of Wi-Fi devices**, which is done by **analyzing how signals propagate through space.**



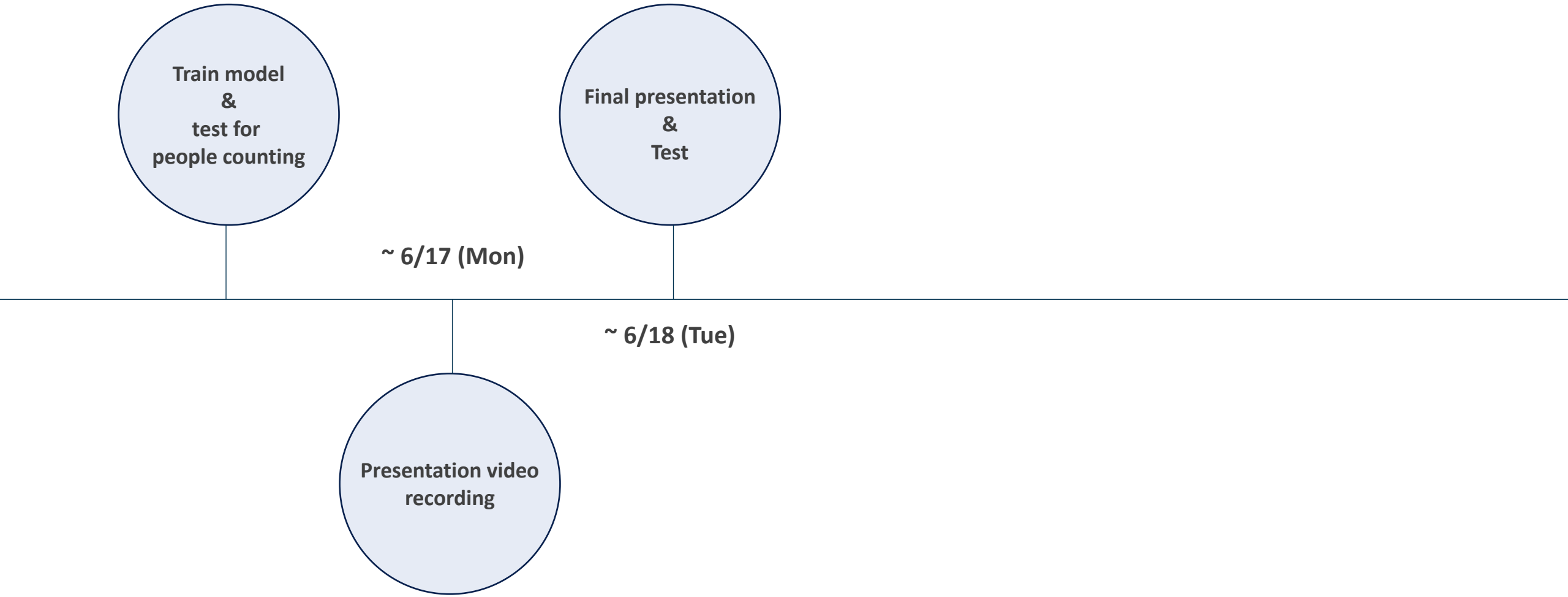
3

Project Progress

Part 3 >> # Project Progress



Part 3 >> # Project Progress



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Setup and Data Collection

Part 4 >> # Setup and Data Collection

Raspberry Pi OS install

STEP 1

Download Raspberry Pi Imager

https://www.raspberrypi.com/software/

>
>

STEP 2

Search and download compatible Raspberry Pi OS img file

Our version: 2022-01-28-raspios-bullseye-armhf.img

https://downloads.raspberrypi.com/

>
>

STEP 3

Select user custom OS file and proper Raspberry Pi model & SD card

>
>

STEP 4

Insert SD card to Raspberry pi model

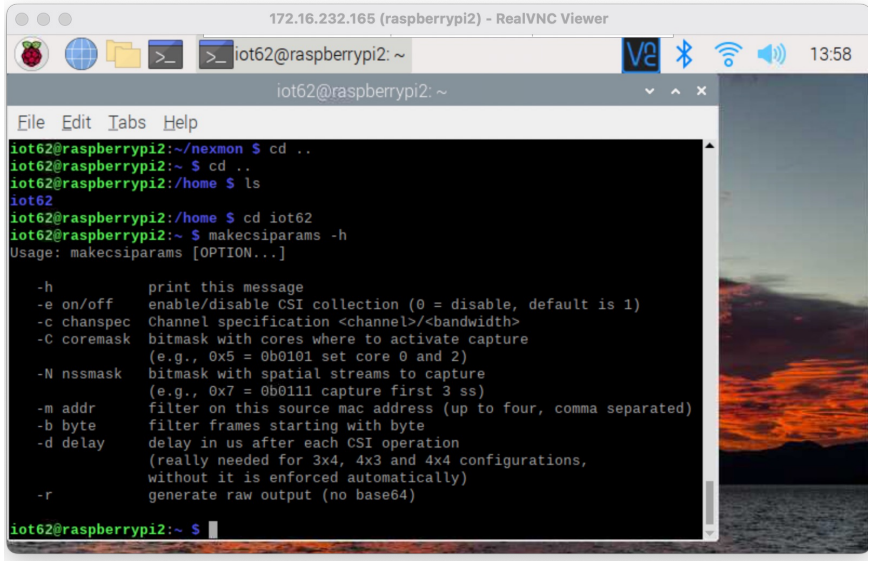
Part 4 >> # Setup and Data Collection

Nexmon & Nexmon CSI install

STEP 1	STEP 2	STEP 3	STEP 4
Dependency & Kernel header setting	Git clone Nexmon https://github.com/seemoo-lab/nexmon	Git clone Nemon_CSI https://github.com/seemoo-lab/nexmon_csi	Check install completed properly $makecsiparams -h

> >

Nexmon CSI install



* more documents on ch 7.

More detail about install nexmon_csi
https://pio-ji.notion.site/Nexmon-CSI-2653217c26644723a5f91e45f37b8a5a

Part 4 >> # Setup and Data Collection

Wi-Fi CSI Extraction

STEP 1

Make one Raspberry Pi as AP Mode and activate it

https://limjunhogithub.io/2020/08/25/Raspberry-Pi-AP%EB%A7%8C%EB%93%A4%EA%B8%B0.html

>>

STEP 2

Extract CSI using

$makecsiparams -c 40/20/ -C 1 –N 1 –m 88:36:6c:c7:95:fe

* channel/band width & MAC address

>>

STEP 3

Set to monitor mode

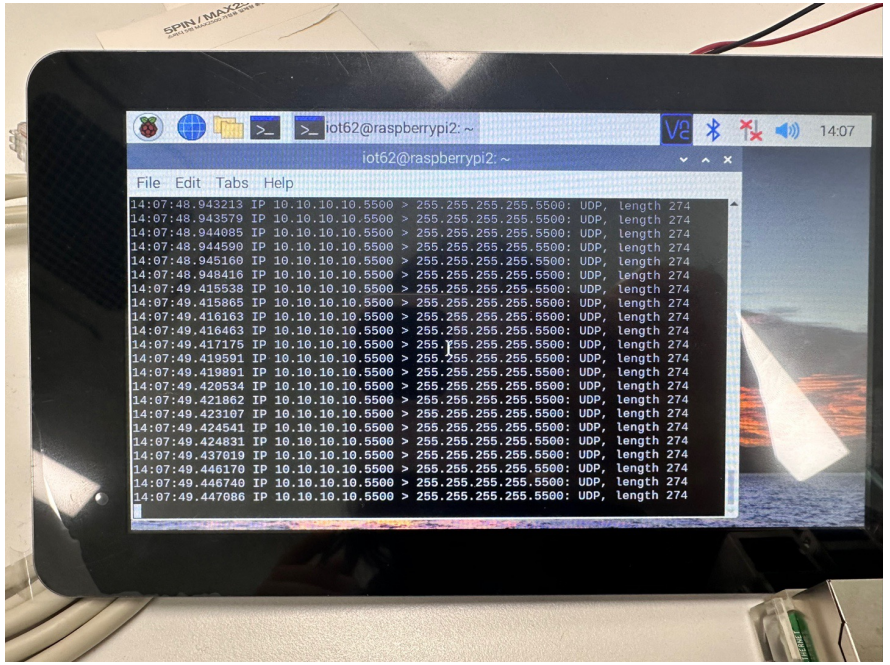
>>

STEP 4

Store the CSI extraction

$tcpdump –I wlan0 dst port 5500 –w –w outputpcap –c 1000 outputpcap

CSI Extract



* more documents on ch 7.

More detail about CSI extraction
https://pio-ji.notion.site/CSI-3ddf719f41934575bddda406732b2ccf

Part 4 >> Setup and Data Collection

pcap to CSV: milestone1 (updated page 27)

STEP 1

Move pcap file in RPI to laptop for easier progress

>
>

STEP 2

Use 'gigasheet' to convert the file to CSV

https://www.gigasheet.com/

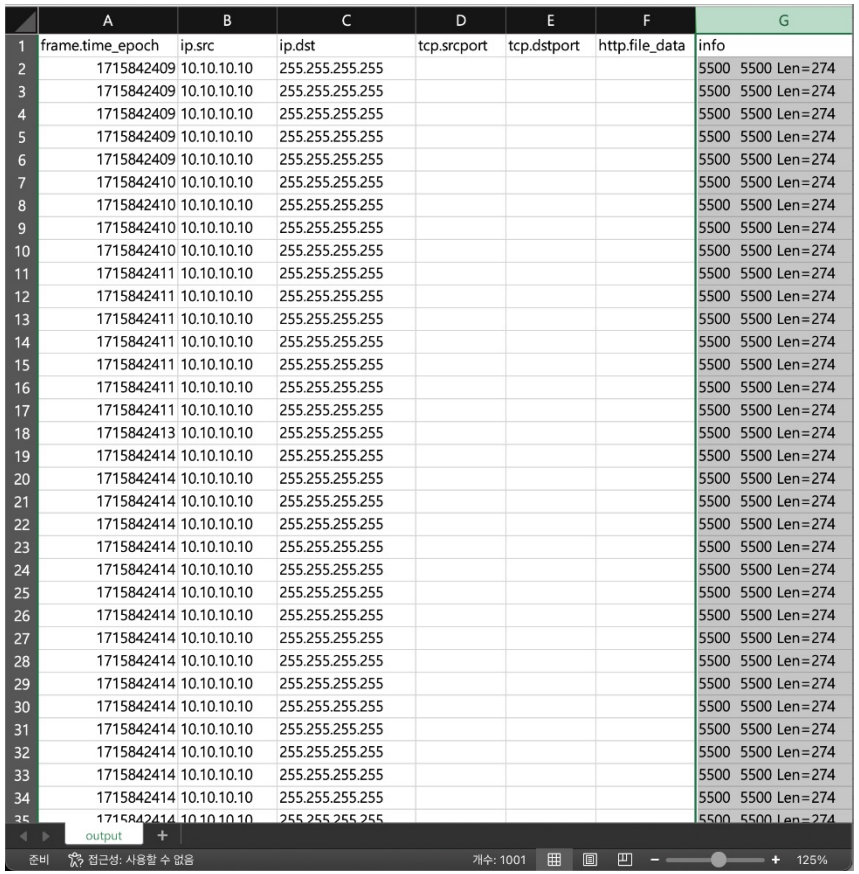
>
>

STEP 3

Check if the packet has stored thoroughly

we tried to use the module given by TA, but somehow it didn't work

CSI.CSV



	A	B	C	D	E	F	G
1	frame.time_epoch	ip.src	ip.dst	tcp.srcport	tcp.dstport	http.file_data	info
2	1715842409	10.10.10.10	255.255.255.255				5500 5500 Len=274
3	1715842409	10.10.10.10	255.255.255.255				5500 5500 Len=274
4	1715842409	10.10.10.10	255.255.255.255				5500 5500 Len=274
5	1715842409	10.10.10.10	255.255.255.255				5500 5500 Len=274
6	1715842409	10.10.10.10	255.255.255.255				5500 5500 Len=274
7	1715842410	10.10.10.10	255.255.255.255				5500 5500 Len=274
8	1715842410	10.10.10.10	255.255.255.255				5500 5500 Len=274
9	1715842410	10.10.10.10	255.255.255.255				5500 5500 Len=274
10	1715842410	10.10.10.10	255.255.255.255				5500 5500 Len=274
11	1715842411	10.10.10.10	255.255.255.255				5500 5500 Len=274
12	1715842411	10.10.10.10	255.255.255.255				5500 5500 Len=274
13	1715842411	10.10.10.10	255.255.255.255				5500 5500 Len=274
14	1715842411	10.10.10.10	255.255.255.255				5500 5500 Len=274
15	1715842411	10.10.10.10	255.255.255.255				5500 5500 Len=274
16	1715842411	10.10.10.10	255.255.255.255				5500 5500 Len=274
17	1715842411	10.10.10.10	255.255.255.255				5500 5500 Len=274
18	1715842413	10.10.10.10	255.255.255.255				5500 5500 Len=274
19	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
20	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
21	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
22	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
23	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
24	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
25	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
26	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
27	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
28	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
29	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
30	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
31	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
32	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
33	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
34	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274
35	1715842414	10.10.10.10	255.255.255.255				5500 5500 Len=274

output

준비 접근성: 사용할 수 없음 개수: 1001 125%

There was no obstacle between AP and the client, which has resulted 255.255.255.255 I guess

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Discussion and Future Plans

Part 5 >> Discussion and Future Plans: milestone1

Problems

Problem 1

Tried to set constant IP to use VNC server, however it ended up with 'wlan0 not associated'

Problem 2

When rebooting RPI after installing CSI, the wlan interface kept shutting down and never come back

Problem 3

'pcap' -> 'csv' doesn't work with the given module from TA.

>>

>>

Solutions

Solution 1

We googled a lot and also asked to TA. The solution was simply reformatting the RPI.

Solution 2

We found out website that does the task 'pcap' -> 'csv'.

Part 5 >> Discussion and Future Plans: milestone2

Problems

Problem 1

CSI real time visualization python model 'pcap' import error

Problem 2

real-time graphs not being updated and disconnected from 100 packets

>>

Solutions

Solution 1

Install 'pypcap' not 'pcap'.

Solution 2

Uninstall the 'matplotlib' library and re-install with version '3.8.2'

Part 5 >> Discussion and Future Plans: milestone3

Problems

Problem 1

Model can't classify 'empty state'.

Problem 2

OSError: [Errno 99] Cannot assign requested address

>>

Solutions

Solution 1

There was imbalance in time series dataset.
We collected additional empty state.

Solution 2

Changed IP address value with 0.0.0.0

Part 5 >> # Discussion and Future Plans

WLAN connection issue is quite difficult in Raspberry Pi's os, not only in our team, but also in other teams.

For a stable development environment, it is necessary to find a way to resolve errors related to the Wi-Fi interface.

Activity recognition and people count are both **classification task.**

Therefore, we will **change the label** of the activity recognition model and **apply it to the people counting task.**

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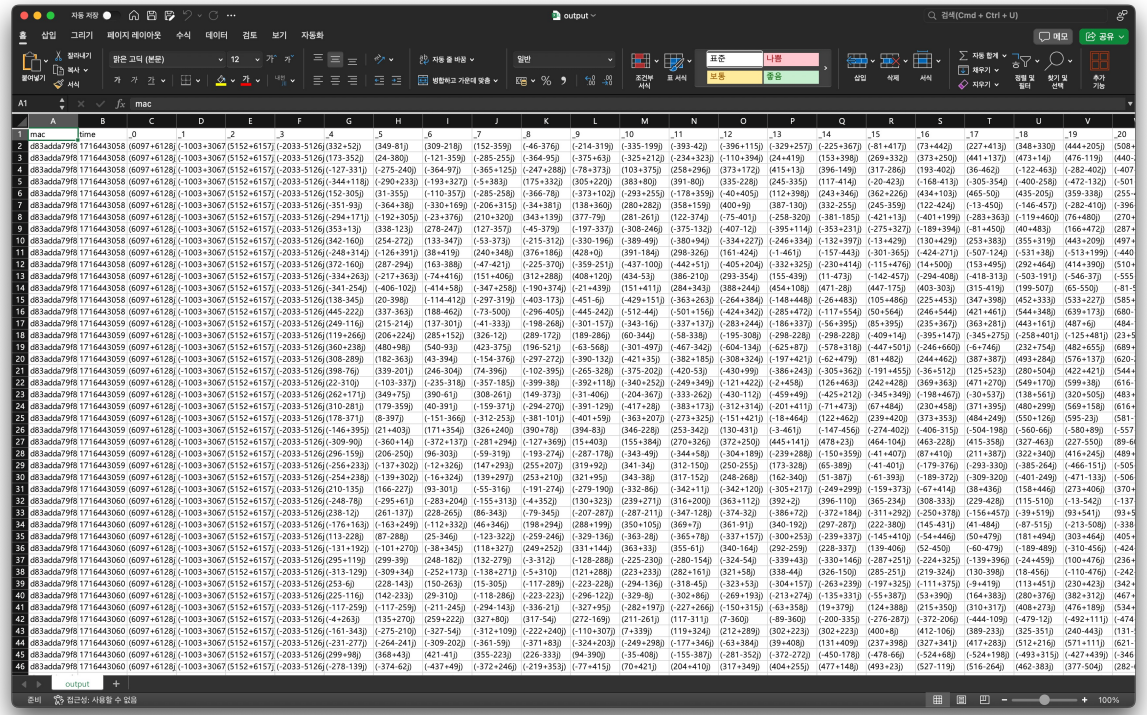
Data Collection and System Implementation

Part 6 >> Data Collection and System Implementation

pcap to CSV

```
~/Desktop/pcap-to-csv | main !1 ?1 ──────────── 19:25:18
❯ python create_dataset.py
WARNING: No IPv4 address found on anpi1 !
WARNING: No IPv4 address found on anpi0 !
WARNING: more No IPv4 address found on en3 !
Save output.csv
```

CSI.CSV



More detail about pcap to csv

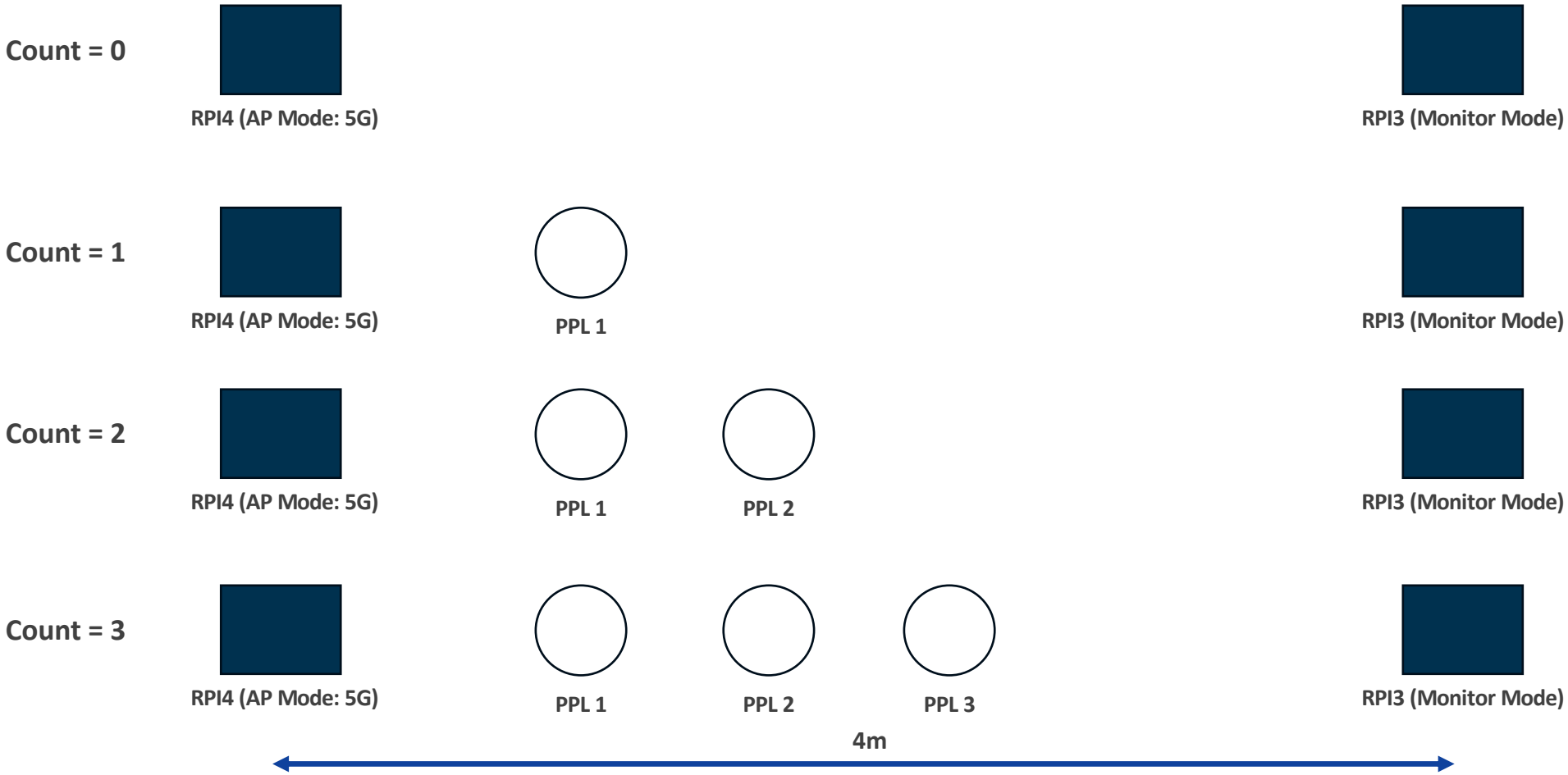
https://github.com/cheeseBG/pcap-to-csv

Part 6 >>

Data Collection and System Implementation

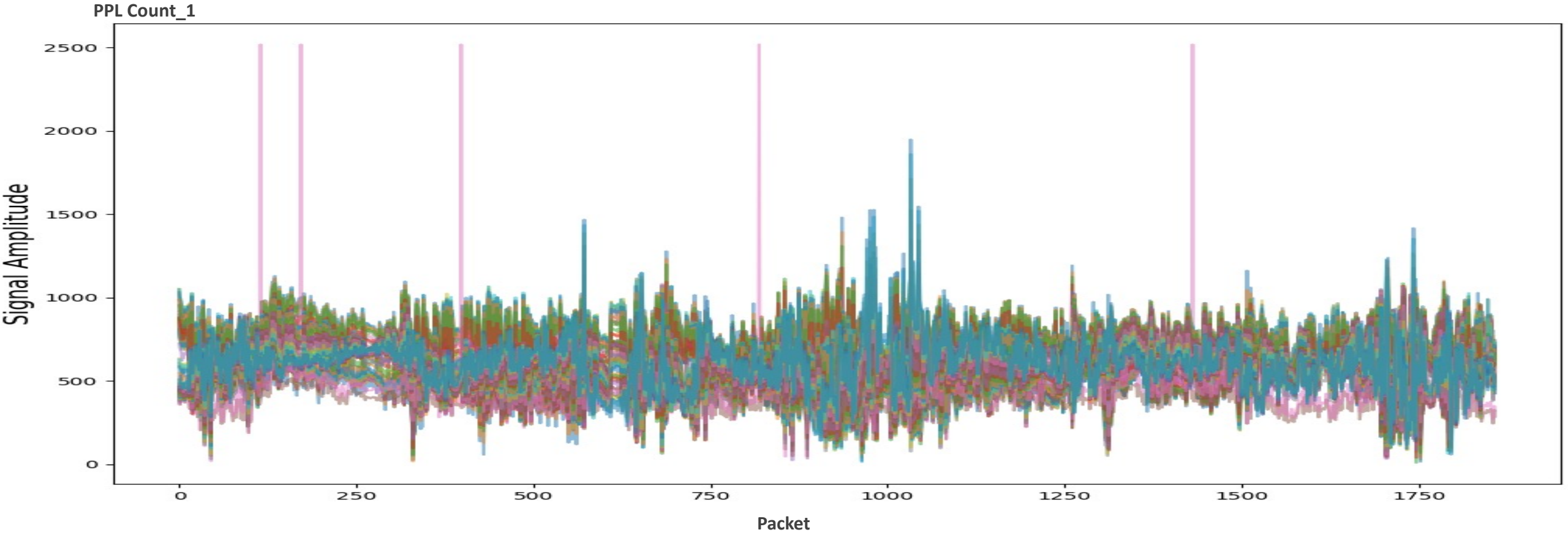
Data Collection: People Count 1 – Vertical Direction

Date: 2024.05.27 (Mon) 11:00 ~ 13:00
@: AI Building Room 405



Part 6 >> Data Collection and System Implementation

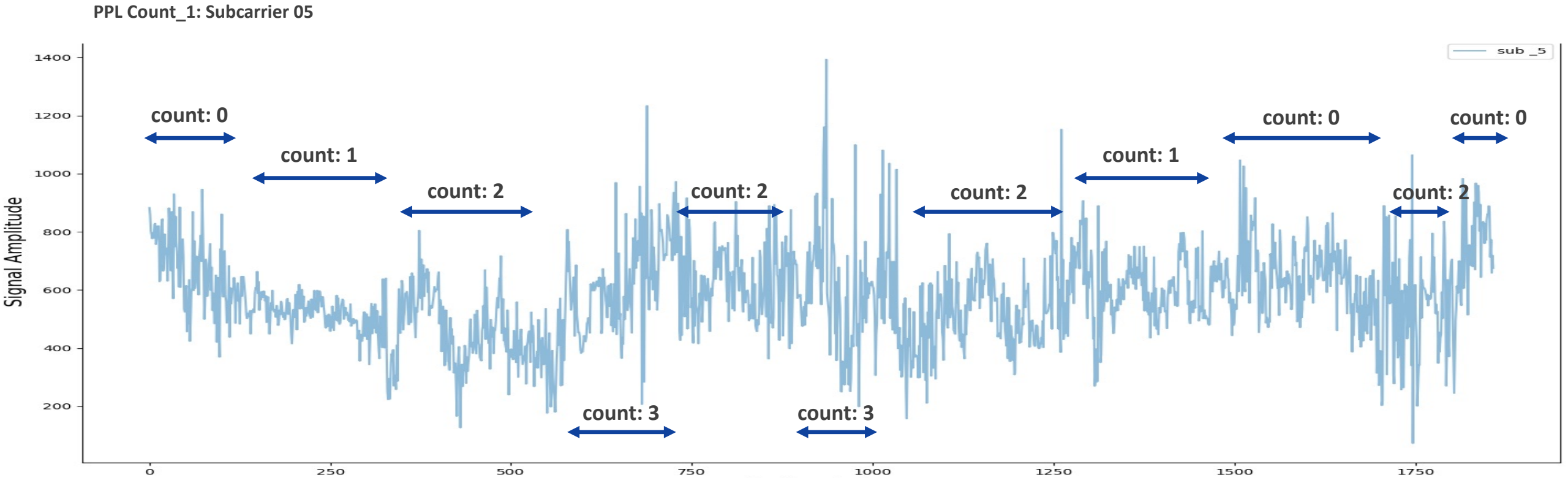
CSI visualization: People Count 1 – Vertical Direction



More detail about CSI visualization
https://github.com/cheeseBG/csi-visualization

Part 6 >> Data Collection and System Implementation

CSI visualization: People Count 1 – Vertical Direction



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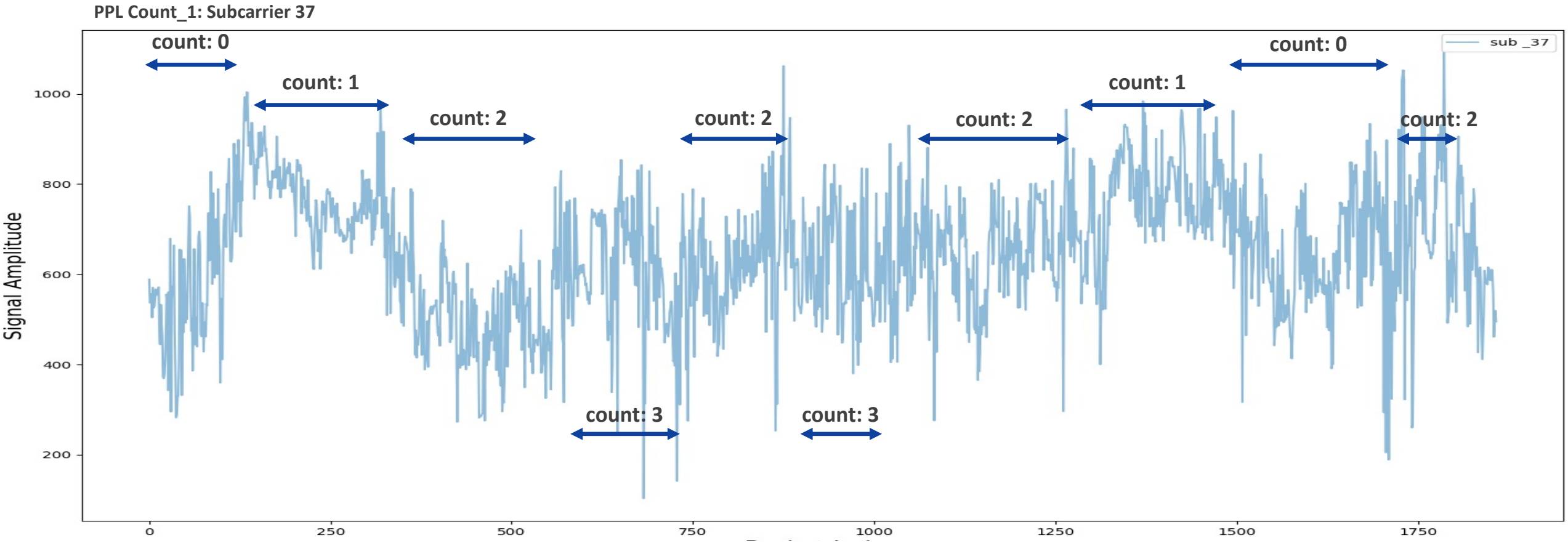
Part 6 >> Data Collection and System Implementation

CSI visualization: People Count 1 – Vertical Direction



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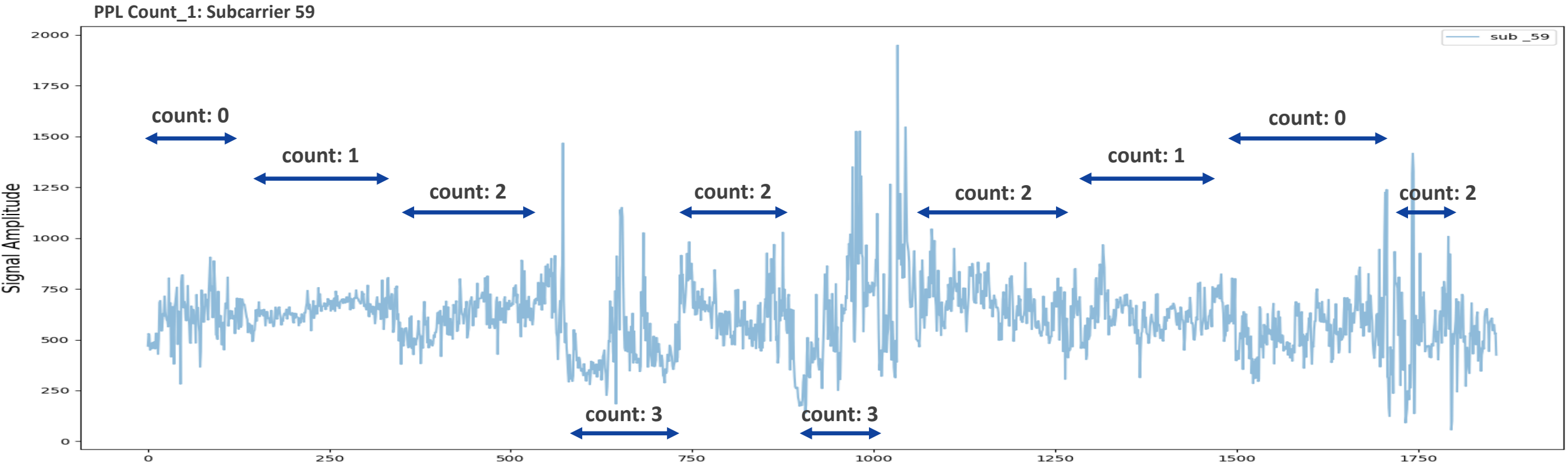
Part 6 >> # Data Collection and System Implementation

CSI visualization: People Count 1 – Vertical Direction

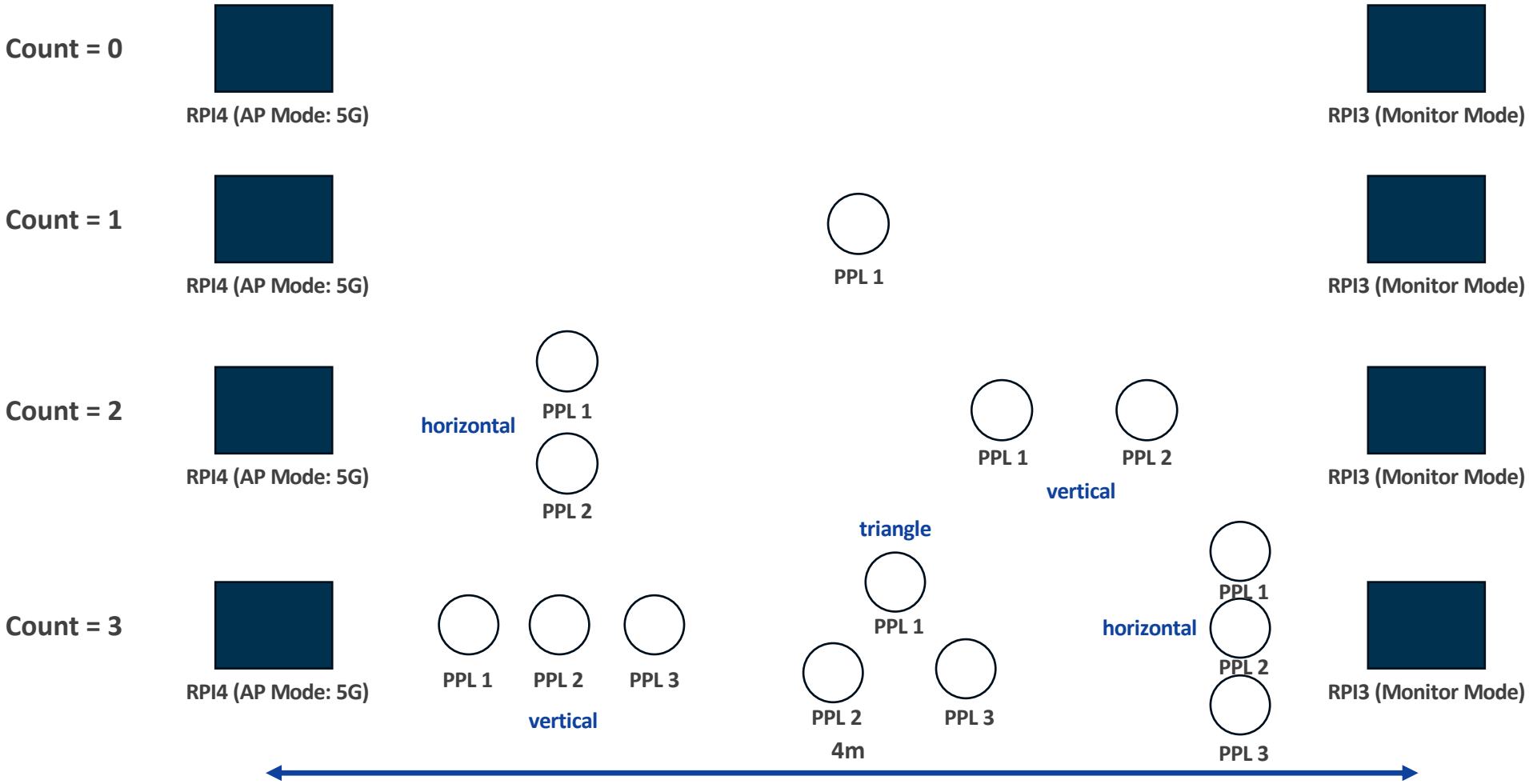


More detail about CSI visualization
https://github.com/cheeseBG/csi-visualization

Part 6 >> # Data Collection and System Implementation

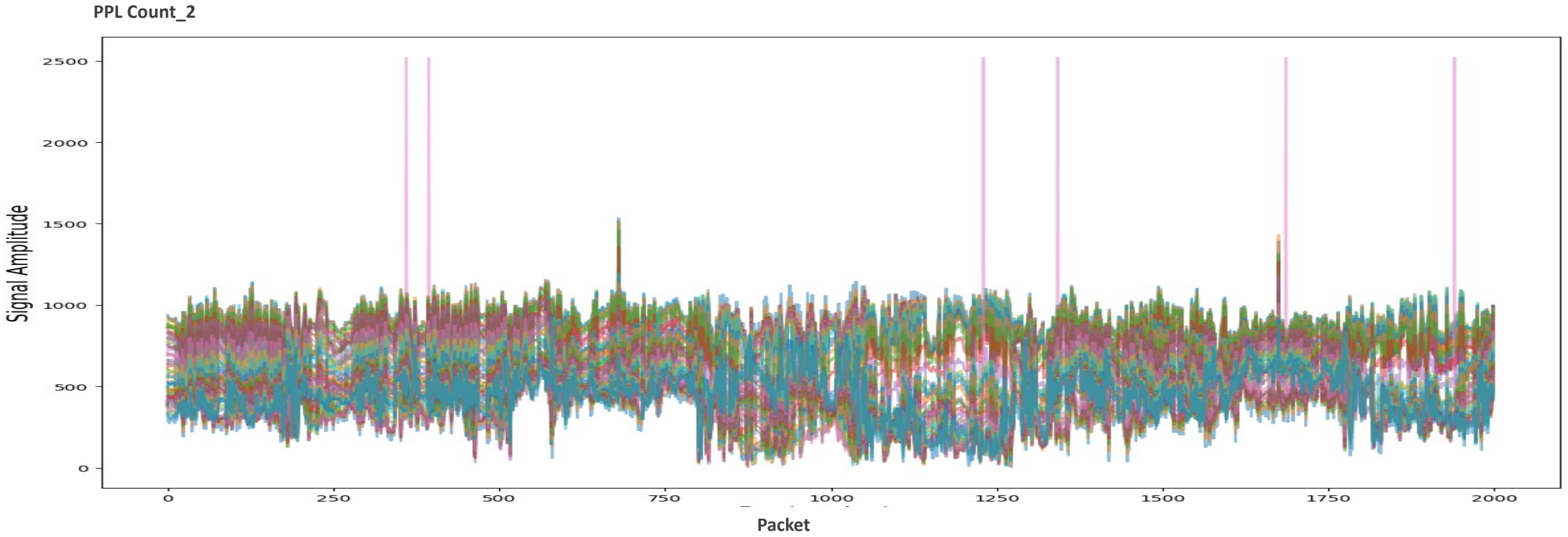
Data Collection: People Count 2 – Free Direction

Date: 2024.05.27 (Mon) 11:00 ~ 13:00
@: AI Building Room 405



Part 6 >> Data Collection and System Implementation

CSI visualization: People Count 2 – Free Direction



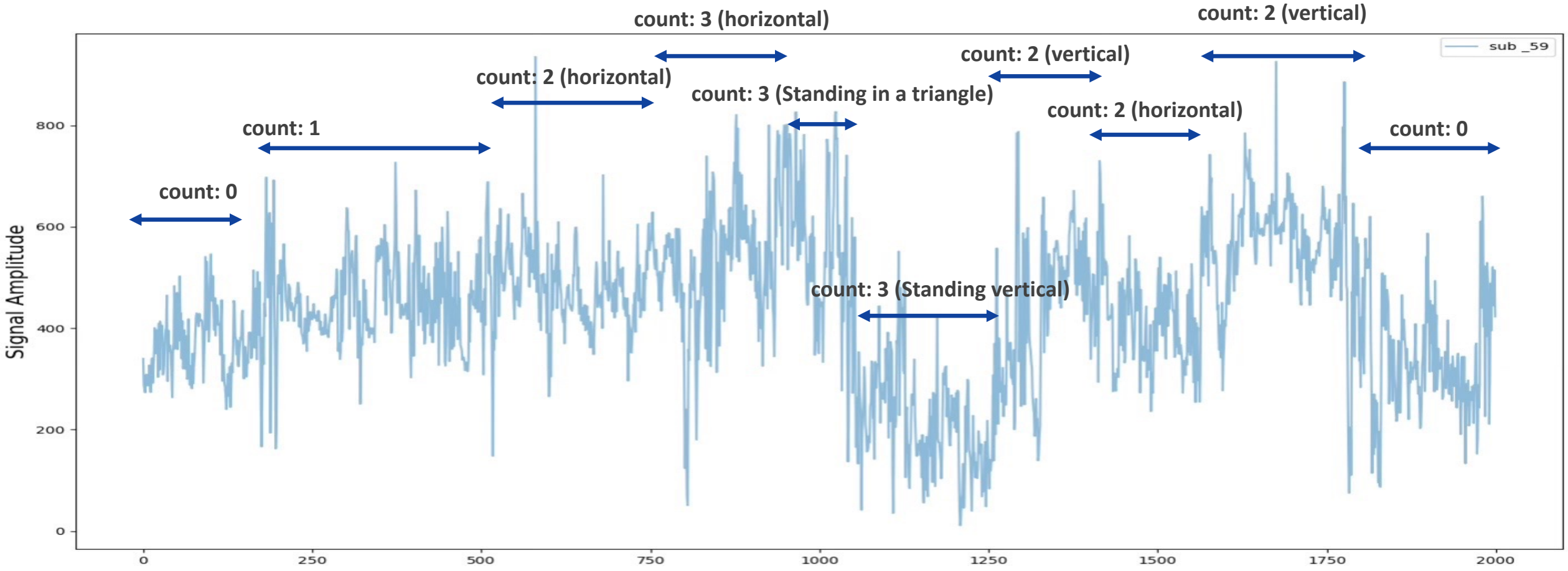
More detail about CSI visualization

https://github.com/cheeseBG/csi-visualization

Part 6 >> # Data Collection and System Implementation

CSI visualization: People Count 2 – Free Direction

PPL Count_2: Subcarrier 05



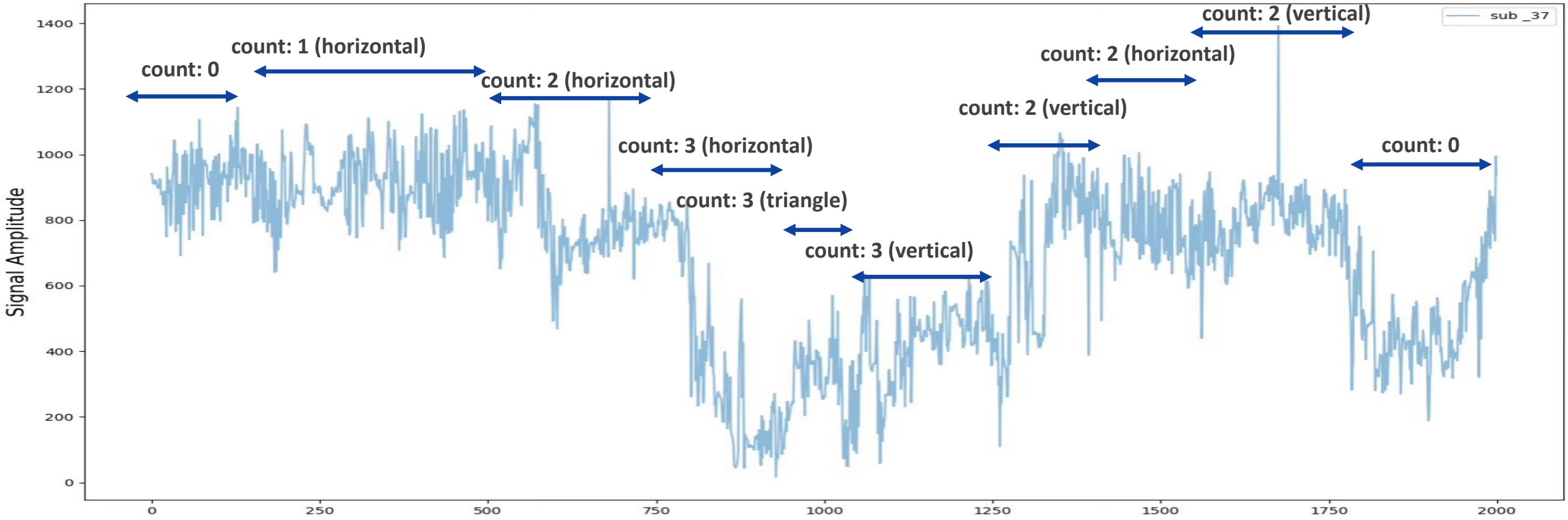
More detail about CSI visualization

https://github.com/cheeseBG/csi-visualization

Part 6 >> # Data Collection and System Implementation

CSI visualization: People Count 2 – Free Direction

PPL Count_2: Subcarrier 37



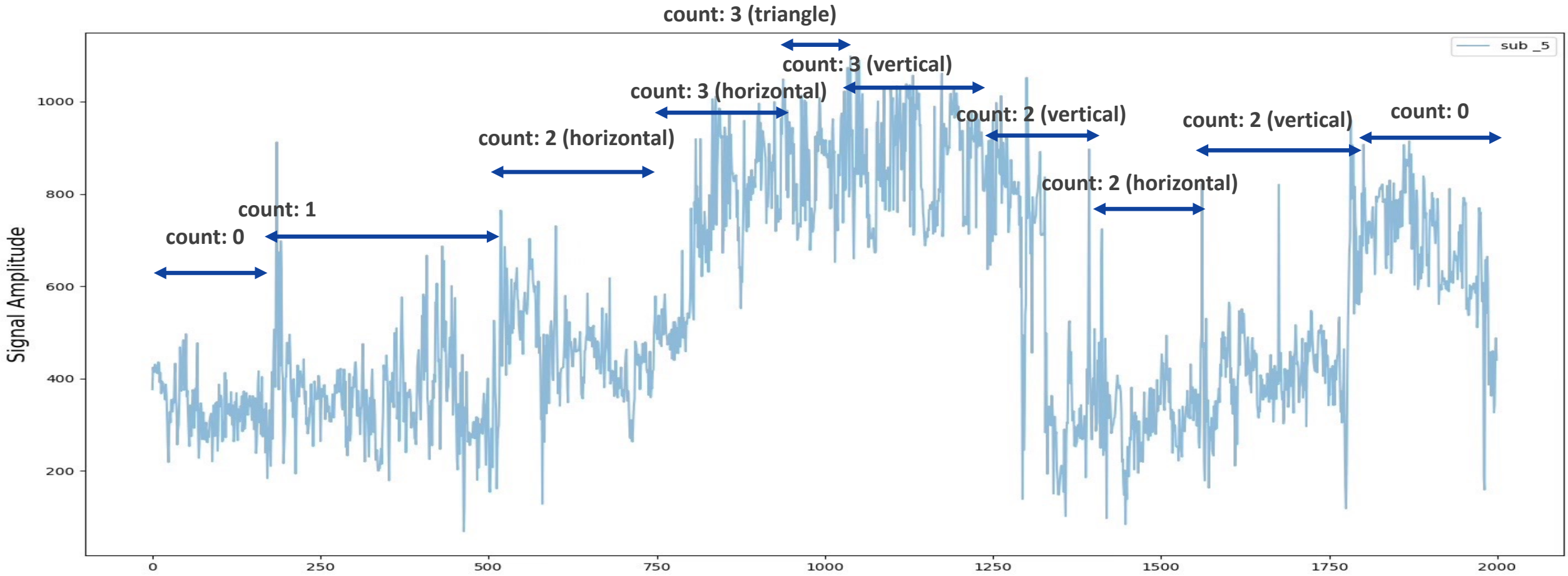
More detail about CSI visualization

https://github.com/cheeseBG/csi-visualization

Part 6 >> Data Collection and System Implementation

CSI visualization: People Count 2 – Free Direction

PPL Count_2: Subcarrier 59



More detail about CSI visualization

https://github.com/cheeseBG/csi-visualization

7

Measuring The Number of People

Part 7 >> # Measuring The Number of People

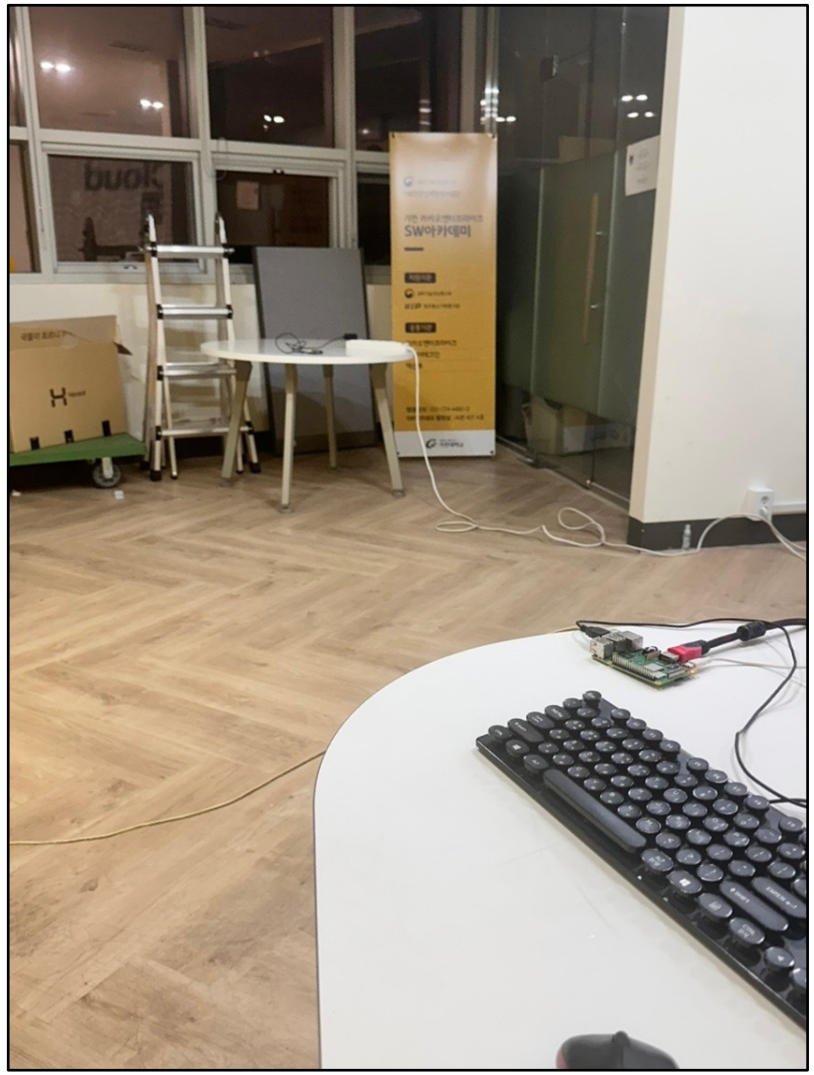
How to make program

STEP 1	>>	STEP 2	>>	STEP 3
use computer as server Raspberry Pi as ap mode & client mode.		Learning by modeling through Numerous pings		Learning how to count people through Data classification

Part 7 >> # Measuring The Number of People

Data Collection: People Count (0~4)

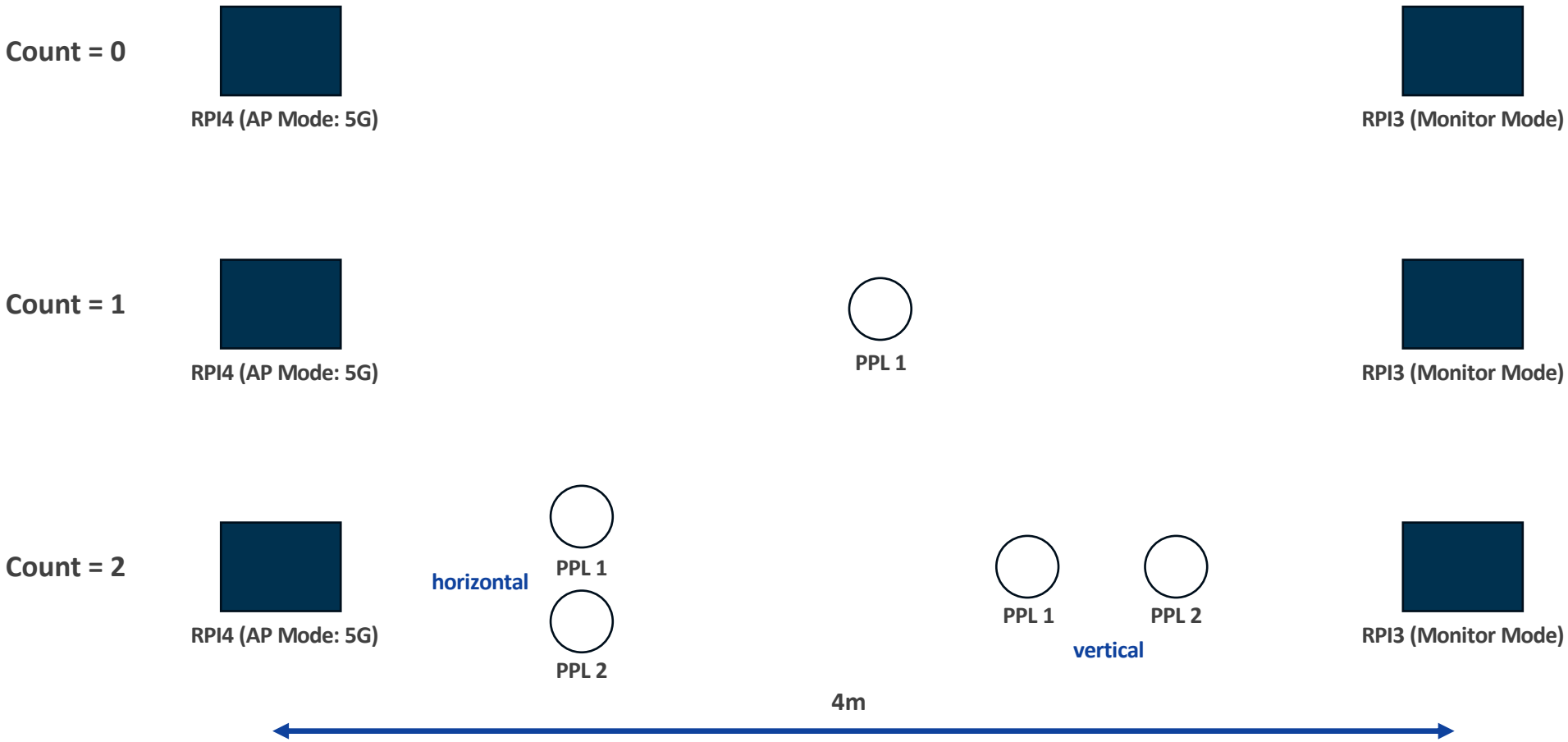
Date: 2024.06.17 (Mon) 23:00 ~ 01:00
@: AI Building Room 407-a



Part 7 >> # Measuring The Number of People

Data Collection: People Count (0~4)

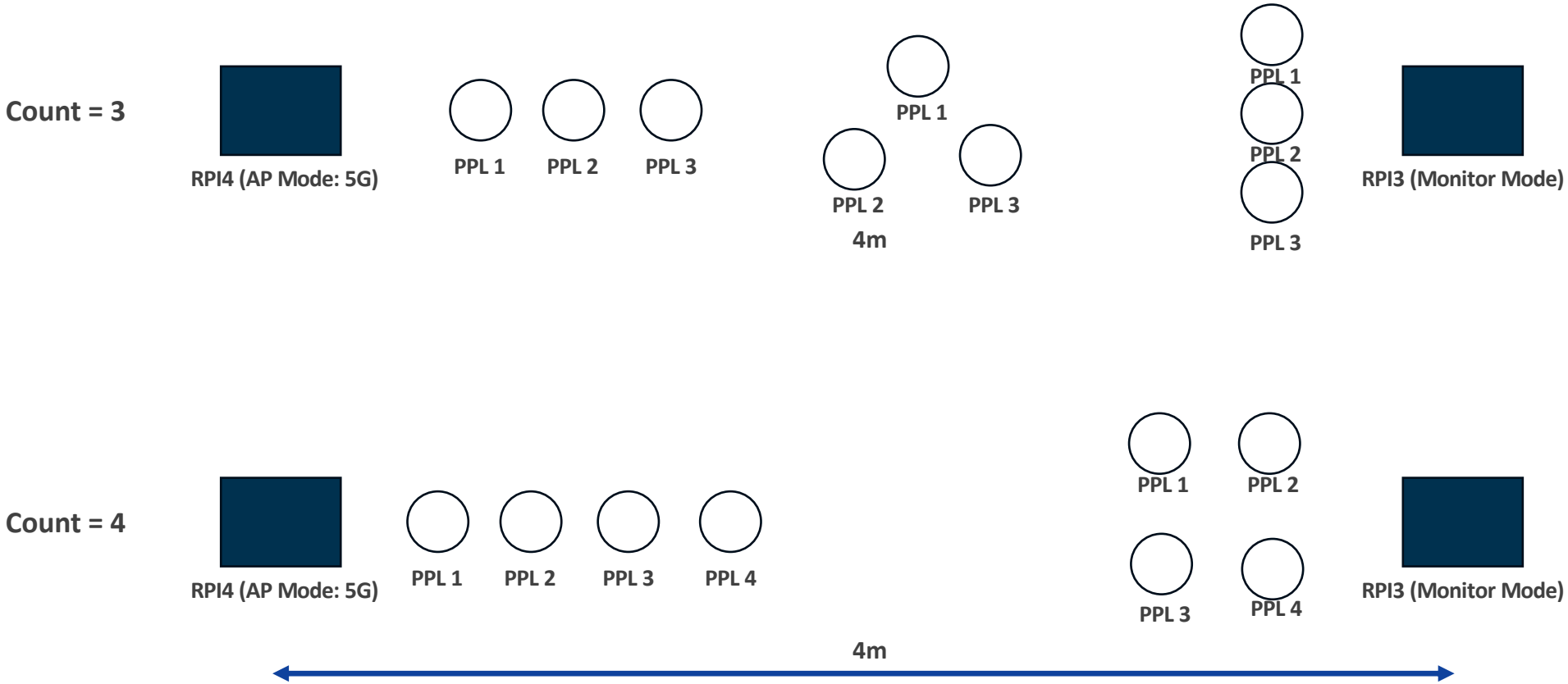
Date: 2024.06.18 (Mon) 23:00 ~ 01:00
@: AI Building Room 407-a



Part 7 >> # Measuring The Number of People

Data Collection: People Count (0~4)

Date: 2024.06.18 (Mon) 23:00 ~ 01:00
@: AI Building Room 407-a



Part 7 >> # Measuring The Number of People

Model training: People Count (0~4)

```
2024-06-18 00:56:07,316 - Start supervised learning (main.py:33)
Cuda:  False
Load Train Dataset.. # window_size:10
Epoch 1/50
----------
100%|| 2080/2080 [00:36<00:00, 57.49it/s]
Epoch 1 -- Loss: 2.1134 Acc: 0.1779
saved at ./checkpoint/svl_vit/0.tar
Epoch 2/50
----------
100%|| 2080/2080 [00:35<00:00, 58.84it/s]
Epoch 2 -- Loss: 1.5704 Acc: 0.2928
saved at ./checkpoint/svl_vit/1.tar
Epoch 3/50
----------
100%|| 2080/2080 [00:35<00:00, 58.32it/s]
Epoch 3 -- Loss: 1.4551 Acc: 0.3548
saved at ./checkpoint/svl_vit/2.tar
Epoch 4/50
----------
100%|| 2080/2080 [00:37<00:00, 55.36it/s]
Epoch 4 -- Loss: 1.4056 Acc: 0.3841
saved at ./checkpoint/svl_vit/3.tar
Epoch 5/50
----------
100%|| 2080/2080 [00:38<00:00, 54.00it/s]
Epoch 5 -- Loss: 1.2507 Acc: 0.4351
saved at ./checkpoint/svl_vit/4.tar
Epoch 6/50
----------
100%|| 2080/2080 [00:35<00:00, 58.22it/s]
Epoch 6 -- Loss: 1.1216 Acc: 0.5178
saved at ./checkpoint/svl_vit/5.tar
Epoch 7/50
----------
100%|| 2080/2080 [00:34<00:00, 59.49it/s]
Epoch 7 -- Loss: 0.9808 Acc: 0.5962
saved at ./checkpoint/svl_vit/6.tar
Epoch 8/50
----------
100%|| 2080/2080 [00:35<00:00, 59.14it/s]
Epoch 8 -- Loss: 0.8844 Acc: 0.6322
saved at ./checkpoint/svl_vit/7.tar
Epoch 9/50
----------
100%|| 2080/2080 [00:36<00:00, 56.34it/s]
Epoch 9 -- Loss: 0.8316 Acc: 0.6553
saved at ./checkpoint/svl_vit/8.tar
Epoch 10/50
----------
```

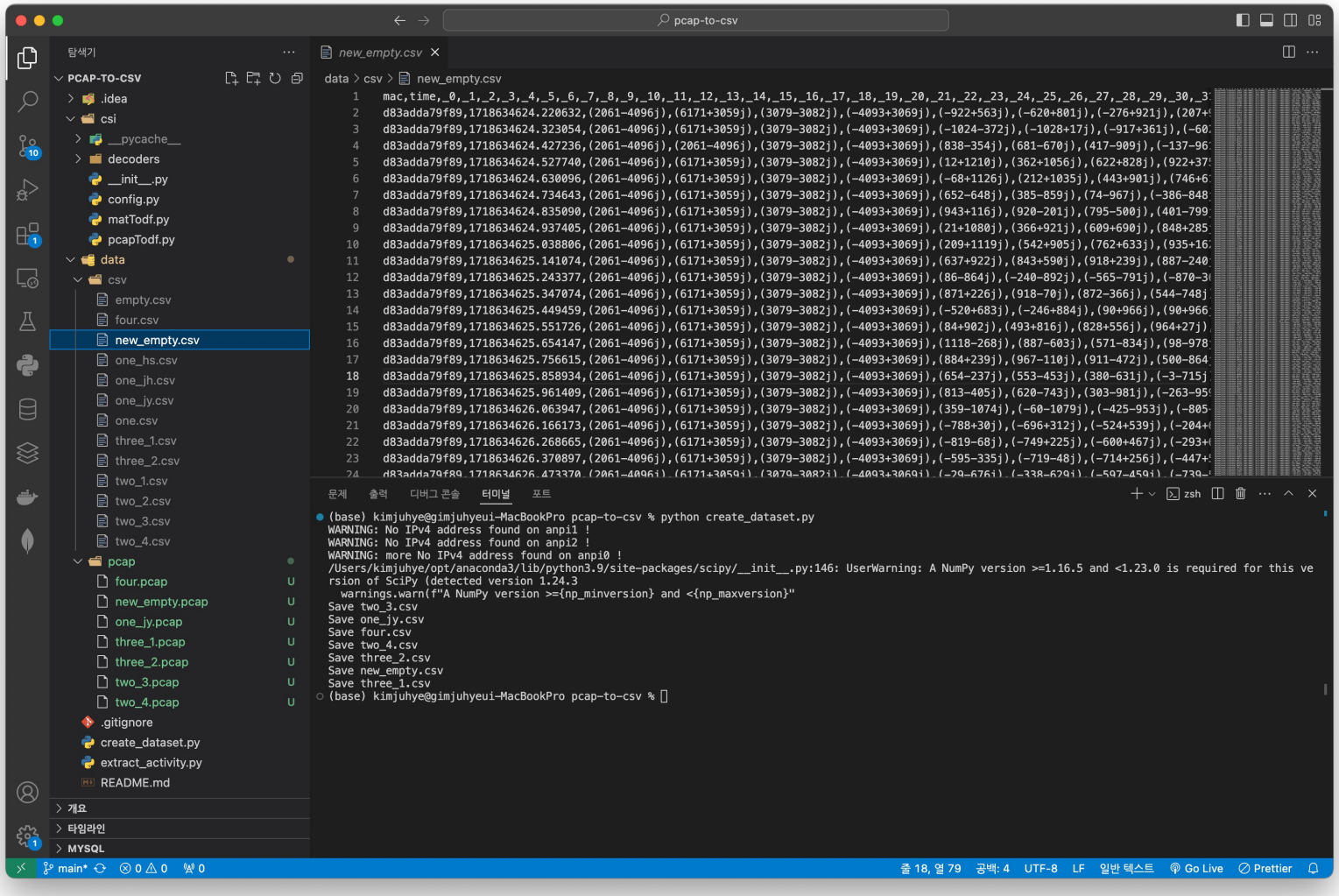
dataset
train_proportion: 0.8
window_size: 10
bandwidth: 20MHz
labels: empty, one, two, three, four

train
epoch: 50
batch_size: 1
lr: 001
step_size: 10
gamma: 0.9

loss & accuracy
loss: 0.53
accuracy: 0.80

Part 7 >> # Measuring The Number of People

Data Collection: People Count (0~4)



pcap to csv

Empty: 10,000 packets

One person: 10,000 packets (four different people)

Two people: 10,000 packets (vertical & horizontal)

Three people: 10,000 packets (vertical & triangle)

Four people: 10,000 packets (vertical & rectangle)

Part 7 >> # Measuring The Number of People

our strategy

"Learn Raspberry Pi through open source, apply machine learning algorithms, and proceed with the classification process to implement a program that recognizes the number of people through classification, rather than detecting human behavior as existing open source code does."

Reference materials used

https://github.com/oss-inc/mowa-wifi-sensing

8

Idea Proposal Exploiting Wi-Fi Sensing

:Treatment of insomnia

Part 8 >>

Idea Proposal Exploiting Wi-Fi Sensing

: treatment of insomnia

The number of **insomniacs is constantly increasing**,
so we're trying to find a way to prevent and solve it through
Wi-Fi sensing.

Part 8 >>

Idea Proposal Exploiting Wi-Fi Sensing

: treatment of insomnia

Recent findings indicate that approximately 22% of adults in the United States experience insomnia every single night. Additionally, over half of US adults encounter insomnia at least once a month (Helsestart).

Prevalence Among US Adults

The number of insomnia patients has increased by 96 % in the last 10 years, and at least 15 %of the total population suffers from chronic insomnia.(BMJopen)

Korea's exponentially growing number of insomniacs

Part 8 >>

Idea Proposal Exploiting Wi-Fi Sensing

: treatment of insomnia

Function

- notify to create a good sleep feedback or appropriate environment
- diagnosing movement or sleep time that interferes sleep using Wi-Fi sensing

Expectation Effectiveness

improves the quality of sleep, helps you recover physically and mentally,
and helps you start a more productive day

Part 8 >>

Idea Proposal Exploiting Wi-Fi Sensing

: treatment of insomnia

Target Marketing	Customer Experience Stories	Experience program	Partenership
• targeting office workers, students, and the elderly who often suffer from insomnia • our idea is a solution that can solve their lifestyles and sleep problems	• Increase credibility by promoting real user success stories. • Highlighting how much the quality of daily life has improved after improving insomnia.	• Run a free experience program so that we can directly experience the effects of the product. • Induce users who experience the effect of improving sleep during the experience period to purchase.	• Partnerships with sleep care hospitals, clinics, and wellness centers

9

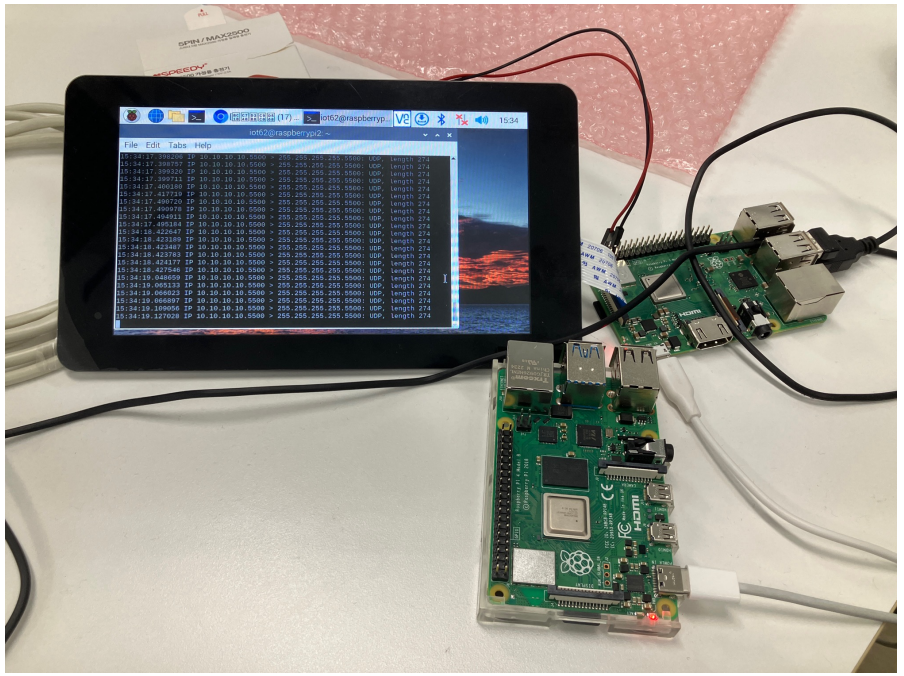
Documents & Contribution

Part 9 >> # Documents

IoT6 Teammates

Lab environment

Ai building, 405

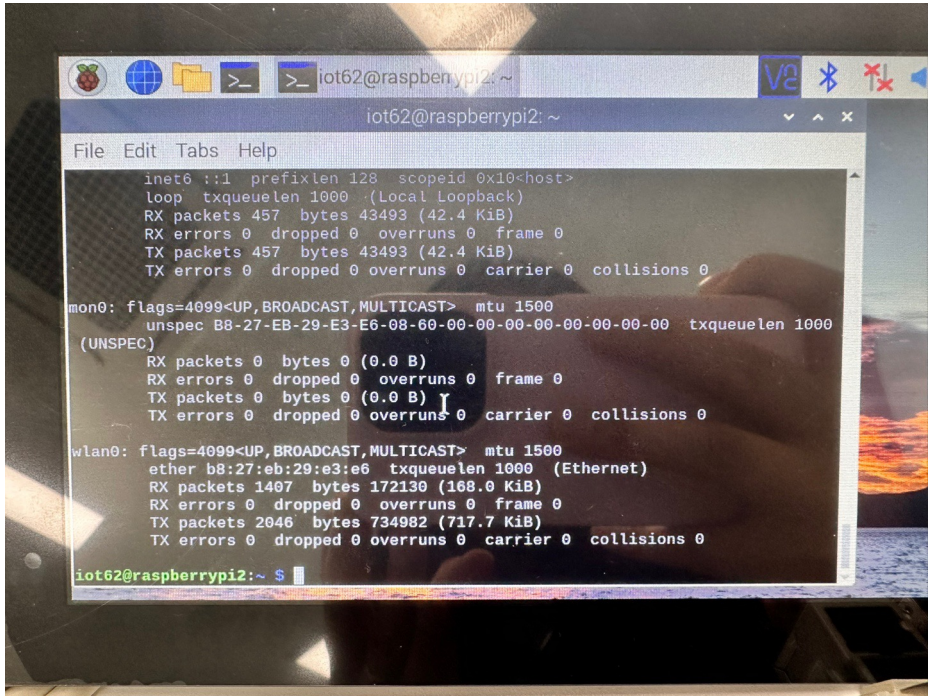


Part 9 >> **Documents**

AP Mode

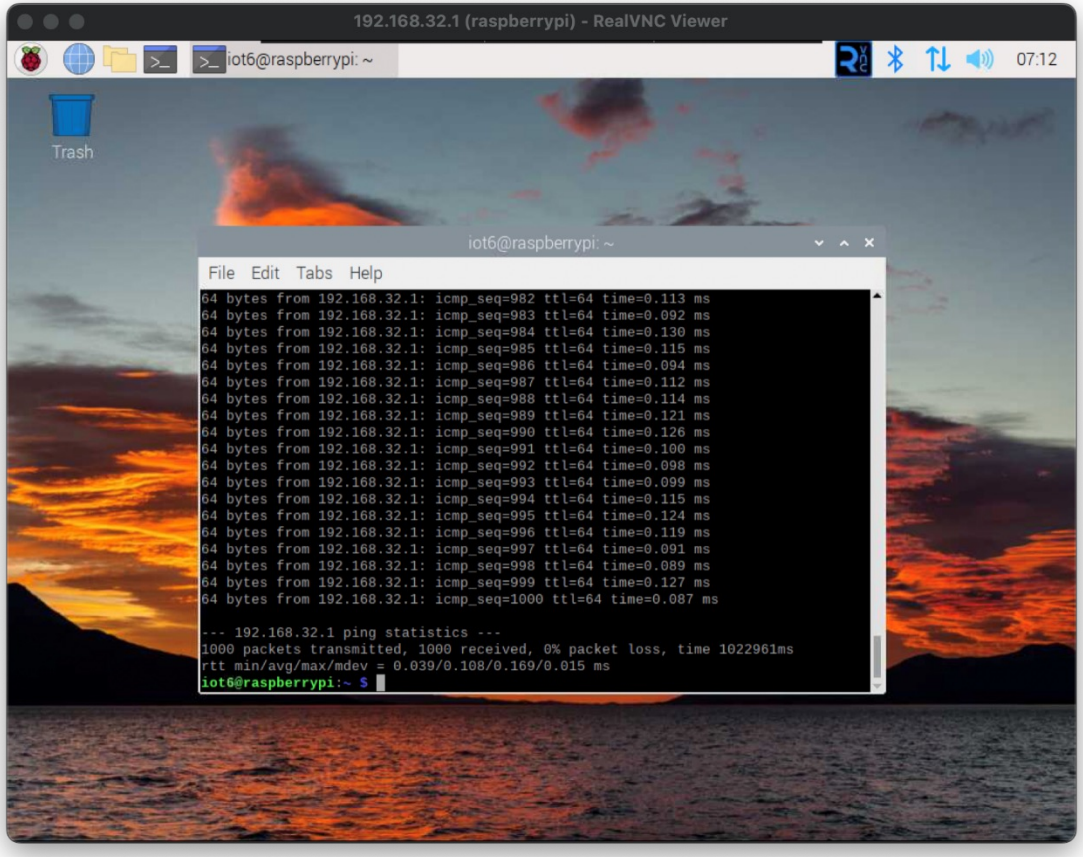
Iot-002-06

nexutil Monitor Mode activation

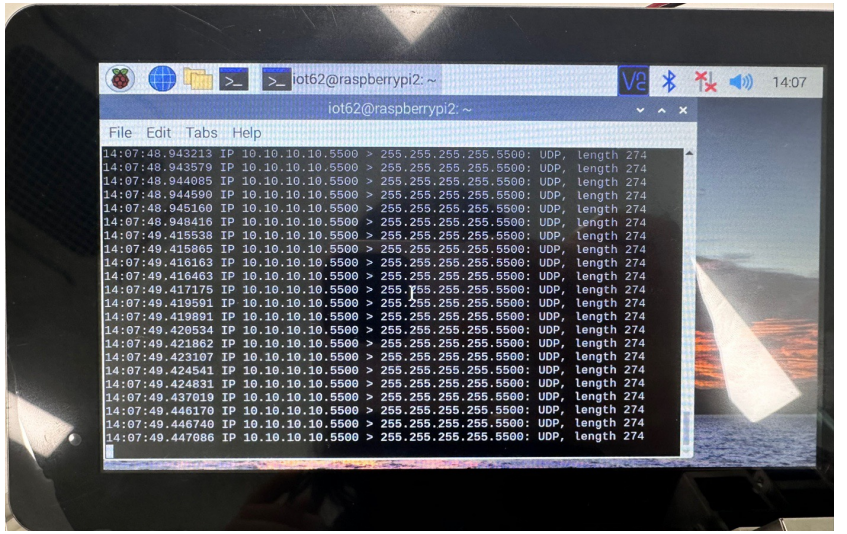


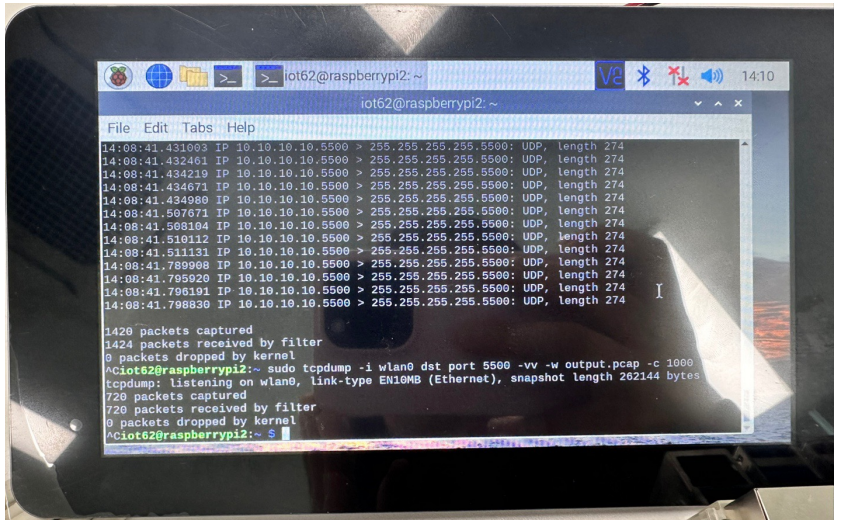
Part 9 >> **Documents**

ping –c 1000



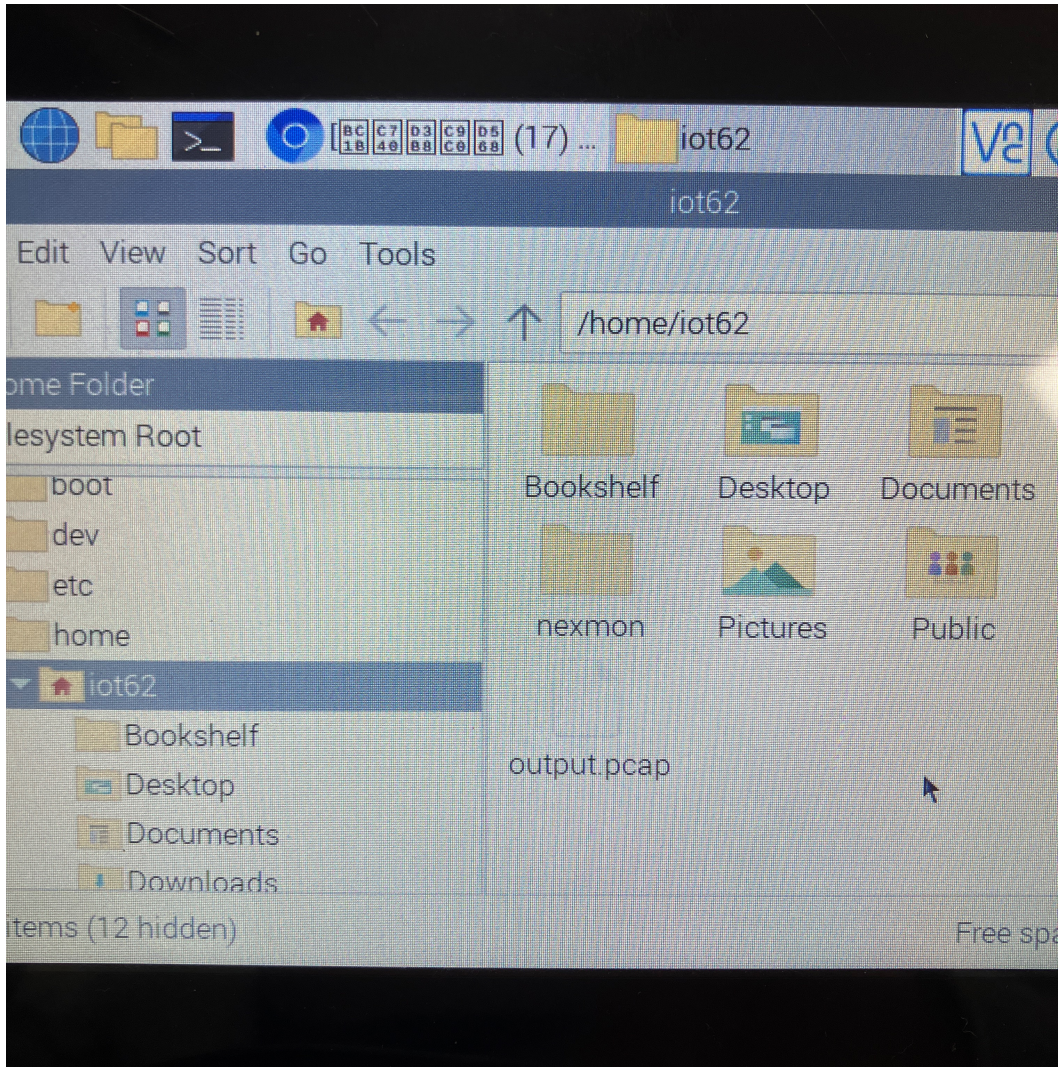
tcpdump Packet Store





Part 9 >> Documents

pcap file store



pcap to CSV

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3	1715842409	10.10.10.10	255.255.255.255				5500 5500 Len=274
4	1715842409	10.10.10.10	255.255.255.255				5500 5500 Len=274
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6	1715842409	10.10.10.10	255.255.255.255				5500 5500 Len=274
7	1715842410	10.10.10.10	255.255.255.255				5500 5500 Len=274
8	1715842410	10.10.10.10	255.255.255.255				5500 5500 Len=274
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output

준비 접근성: 사용할 수 없음 개수: 1001 125%

Part 9 >> Documents

pcap to CSV

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1	mac	time	_0	_1	_2	_3	_4	_5	_6	_7	_8	_9	_10
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4	d83adda79f8	1716443058	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(-127-331j)	(-275-240j)	(-364-97j)	(-365+125j)	(-247+288j)	(-78+373j)	(103+375j)
5	d83adda79f8	1716443058	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(-344+118j)	(-290+233j)	(-193+327j)	(-5+383j)	(175+332j)	(305+220j)	(383+80j)
6	d83adda79f8	1716443058	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(152-305j)	(31-355j)	(-110-357j)	(-285-258j)	(-366-78j)	(-373+102j)	(-293+255j)
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9	d83adda79f8	1716443058	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(353+13j)	(338-123j)	(278-247j)	(127-357j)	(-45-379j)	(-197-337j)	(-308-246j)
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11	d83adda79f8	1716443058	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(-248+314j)	(-126+391j)	(38+419j)	(240+348j)	(376+186j)	(428+0j)	(391-184j)
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13	d83adda79f8	1716443058	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(-334+263j)	(-217+363j)	(-74+416j)	(151+406j)	(312+288j)	(408+120j)	(434-53j)
14	d83adda79f8	1716443058	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(-341-254j)	(-406-102j)	(-414+58j)	(-347+258j)	(-190+374j)	(-21+439j)	(151+411j)
15	d83adda79f8	1716443058	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(138-345j)	(20-398j)	(-114-412j)	(-297-319j)	(-403-173j)	(-451-6j)	(-429+151j)
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23	d83adda79f8	1716443059	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(262+171j)	(349+75j)	(390-61j)	(308-261j)	(149-373j)	(-31-406j)	(-204-367j)
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27	d83adda79f8	1716443059	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(-309-90j)	(-360+14j)	(-372+137j)	(-281+294j)	(-127+369j)	(15+403j)	(155+384j)
28	d83adda79f8	1716443059	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(296-159j)	(206-250j)	(96-303j)	(-59-319j)	(-193-274j)	(-287-178j)	(-343-49j)
29	d83adda79f8	1716443059	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(-256+233j)	(-137+302j)	(-12+326j)	(147+293j)	(255+207j)	(319+92j)	(341-34j)
30	d83adda79f8	1716443059	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(-254+238j)	(-139+302j)	(-16+324j)	(139+297j)	(253+210j)	(321+95j)	(343-38j)
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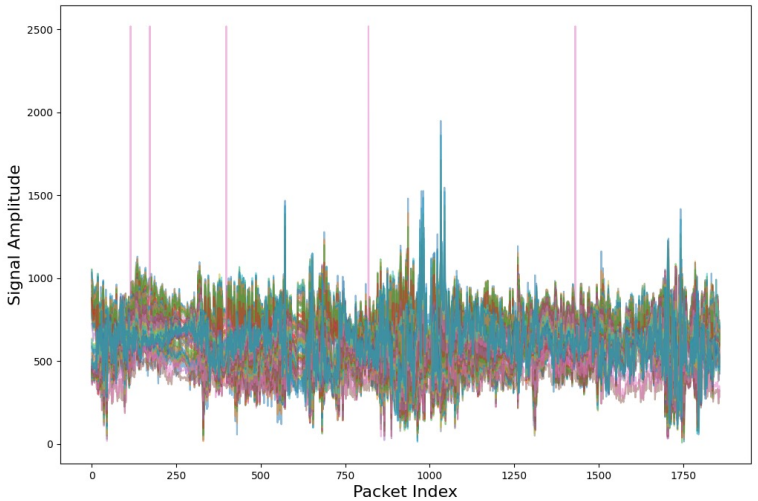
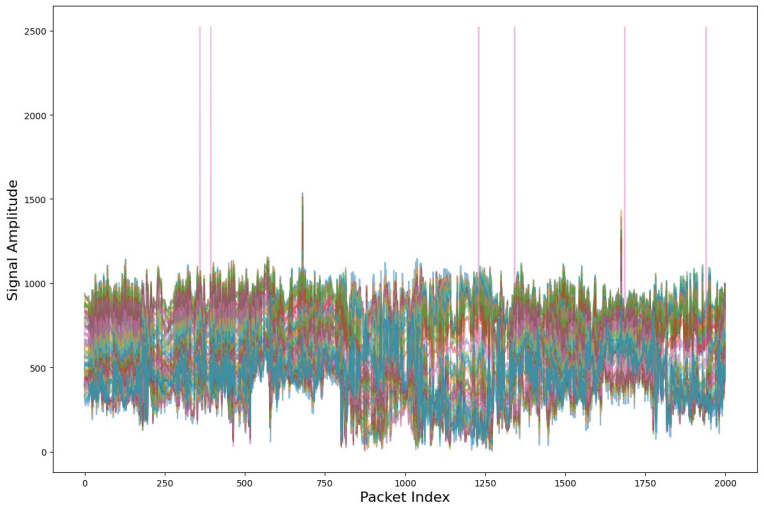
32	d83adda79f8	1716443060	(6097+6128j	(-1003+3067	(5152+6157j	(-2033-5126j	(-248-78j)	(-295+61j)	(-283+204j)	(-155+313j)	(-4+352j)	(130+323j)	(239+271j)

CSI Visualization



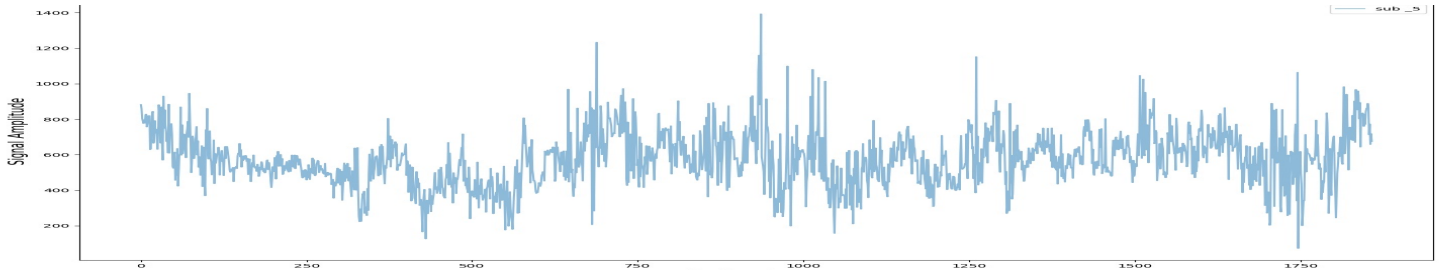
People Count 1: Vertical Direction



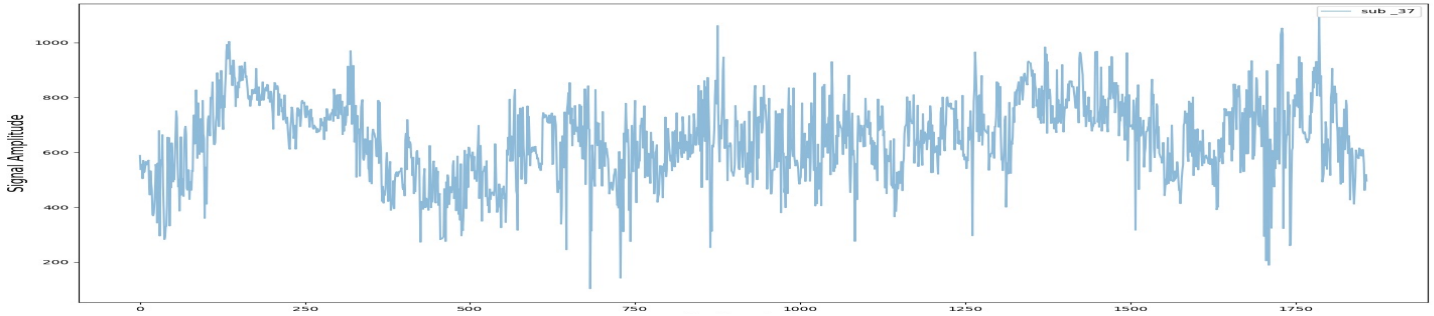
People Count 2: Free Direction

Part 9 >> **Documents**

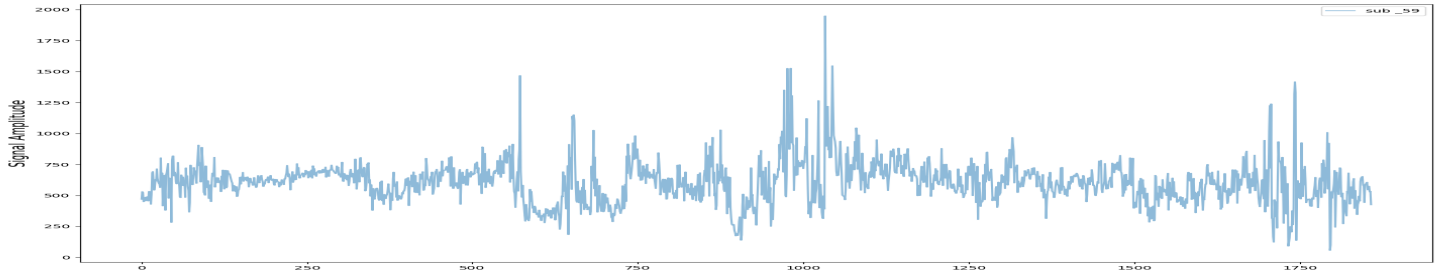
People Count 1 Subcarriers



People Count 1: Sub carrier 05



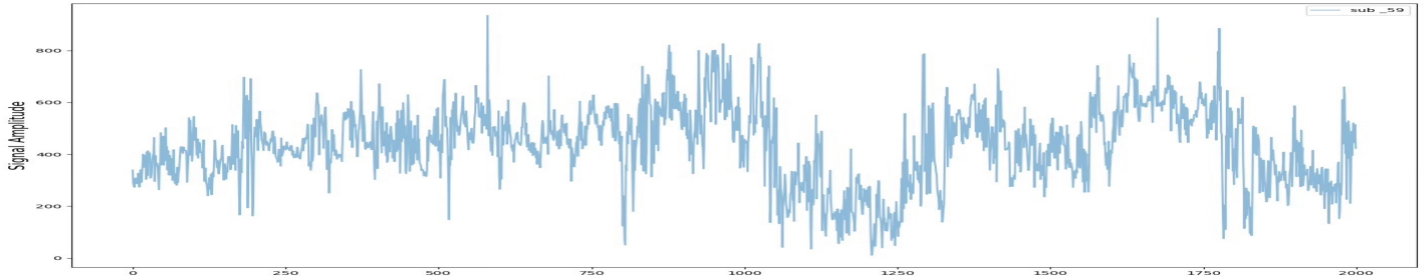
People Count 1: Sub carrier 37



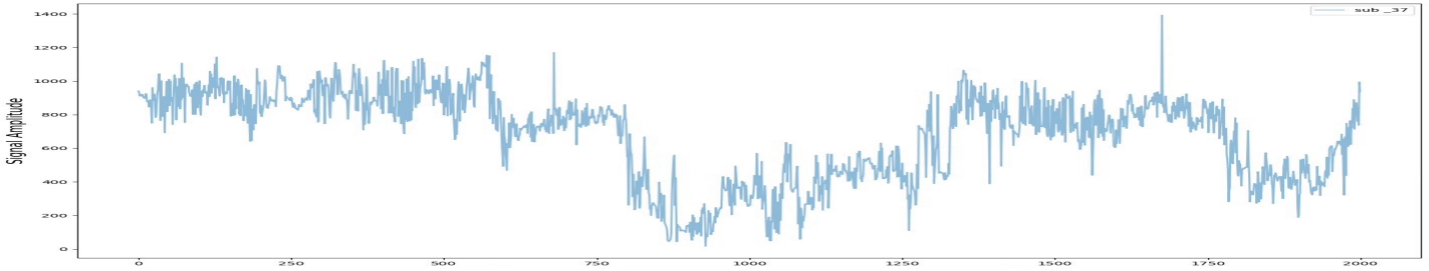
People Count 1: Sub carrier 59

Part 9 >> **Documents**

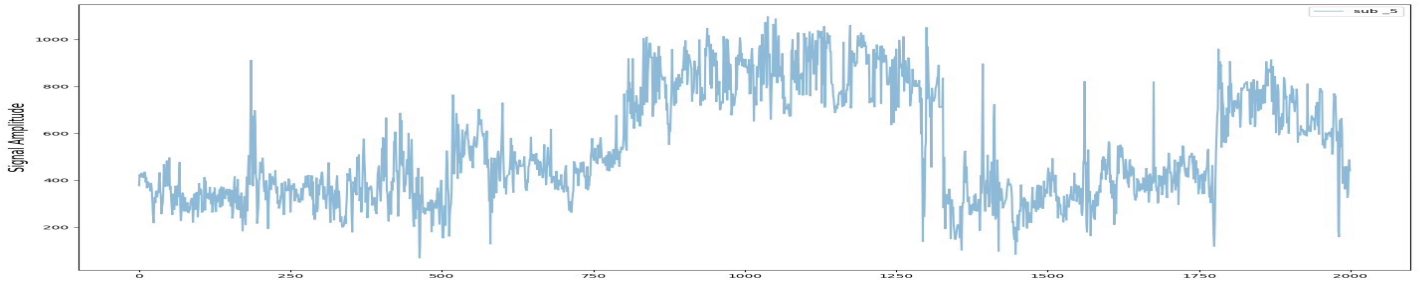
People Count 2 Subcarriers



People Count 2: Sub carrier 05



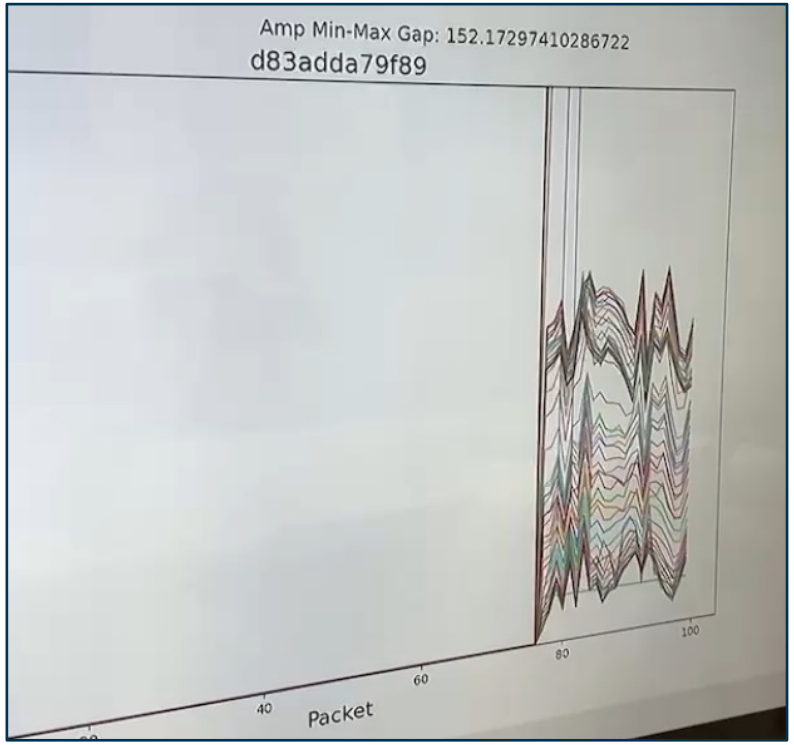
People Count 2: Sub carrier 37

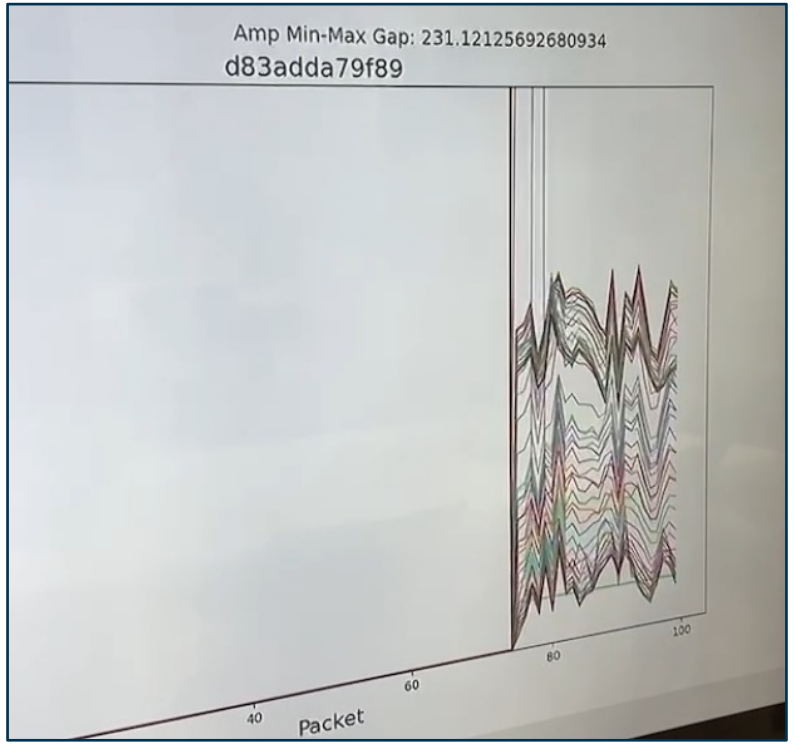


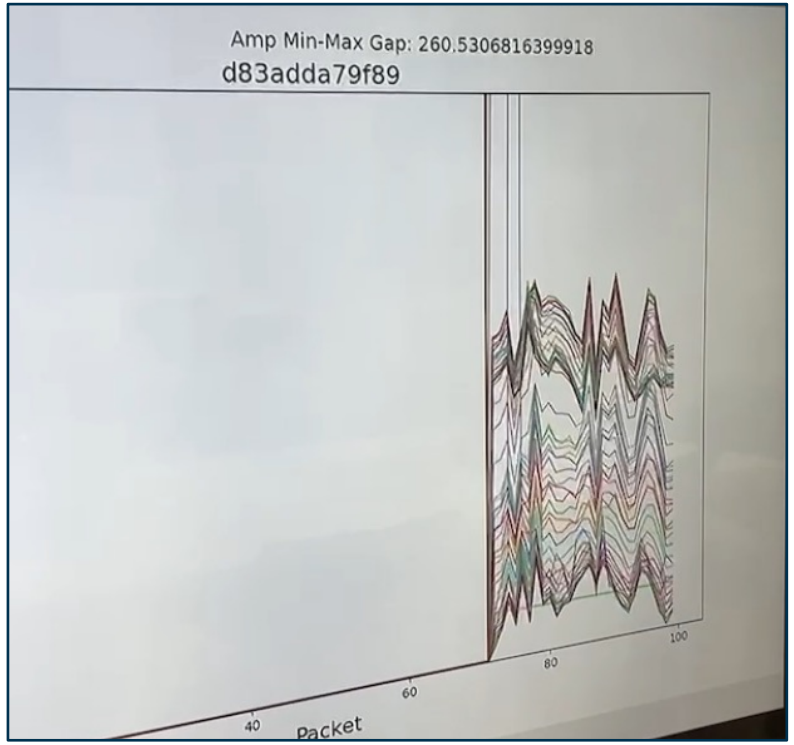
People Count 3: Sub carrier 59

Part 9 >> # Documents

CSI Real time visualization

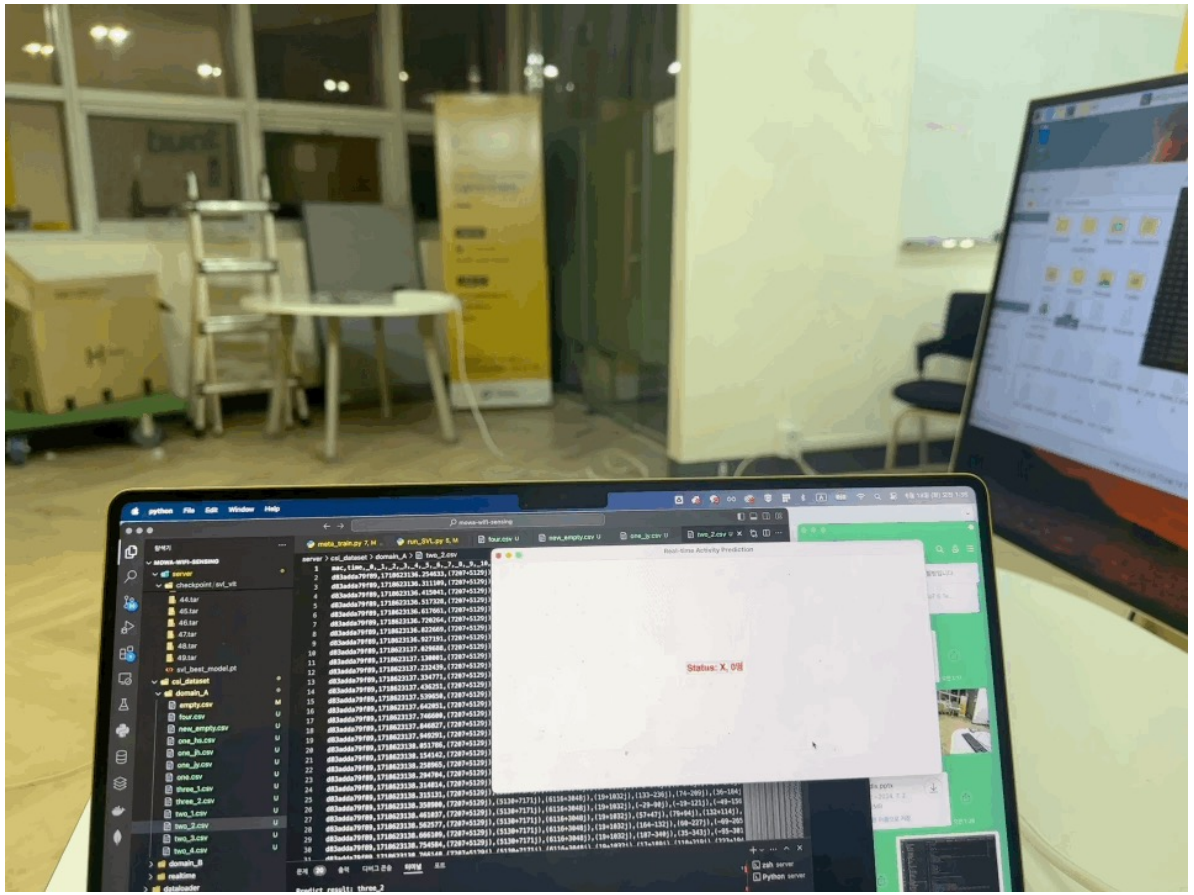






Part 9 >> **Documents**

Data Detection Experiment



Detection of people : X
Number of people: 0

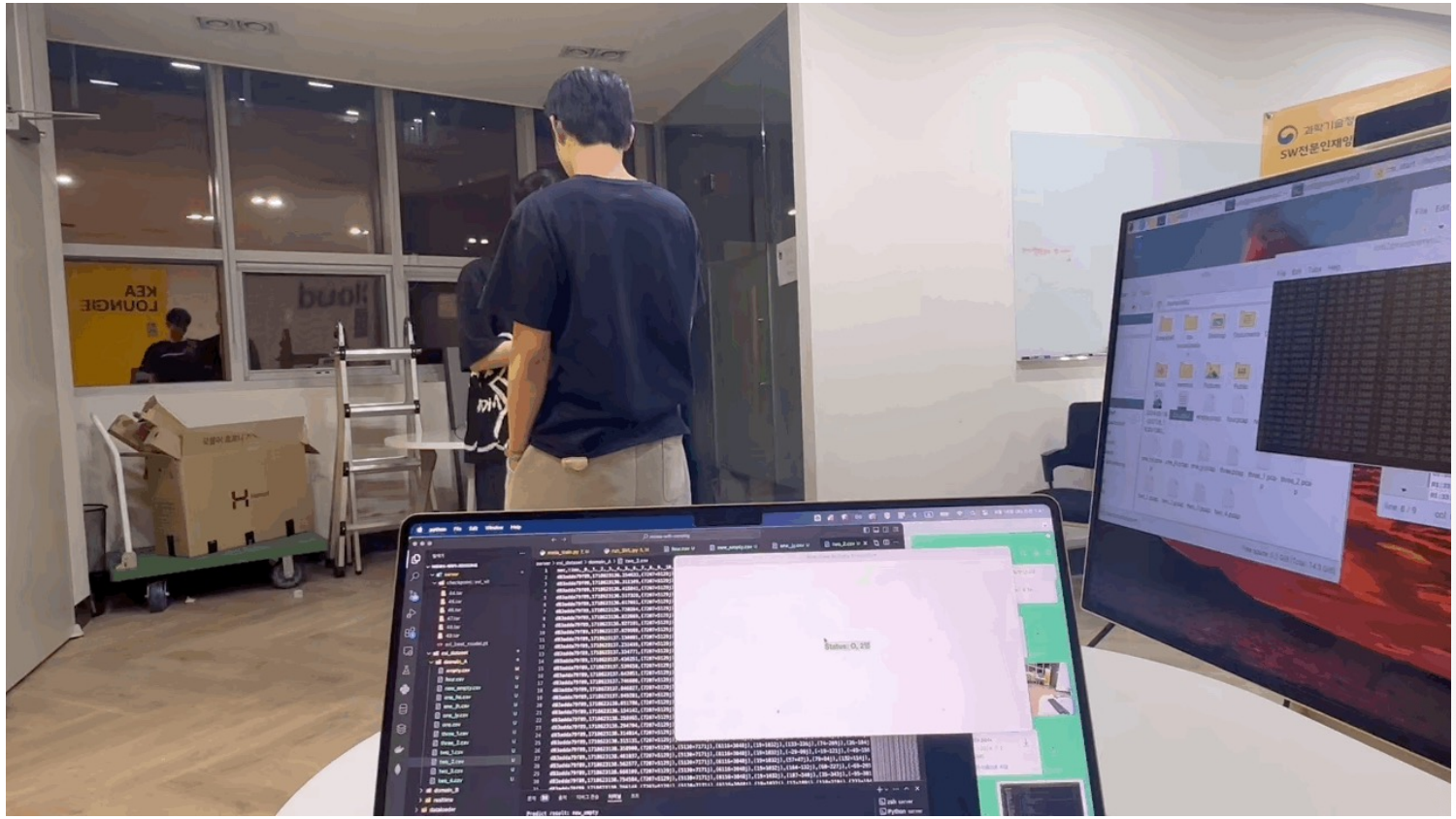
Part 9 >> **Documents**

Data Detection Experiment

Detection of people : O
Number of people: 1

Part 9 >> **Documents**

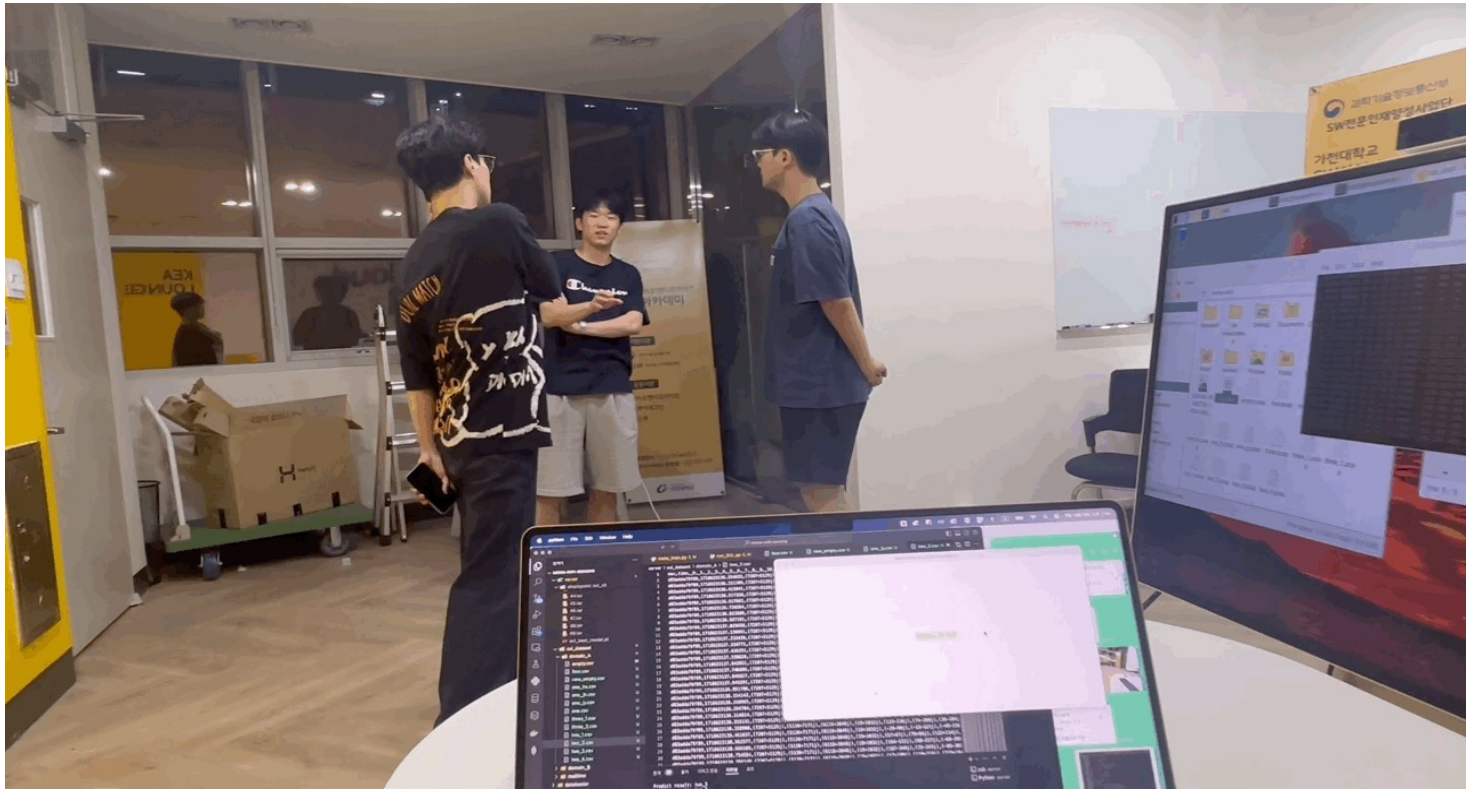
Data Detection Experiment



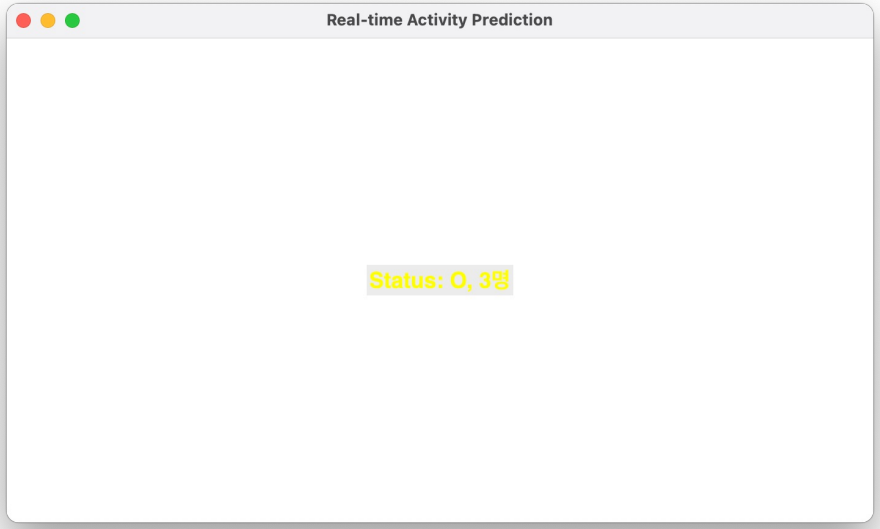
Detection of people : O
Number of people: 2

Part 9 >> **Documents**

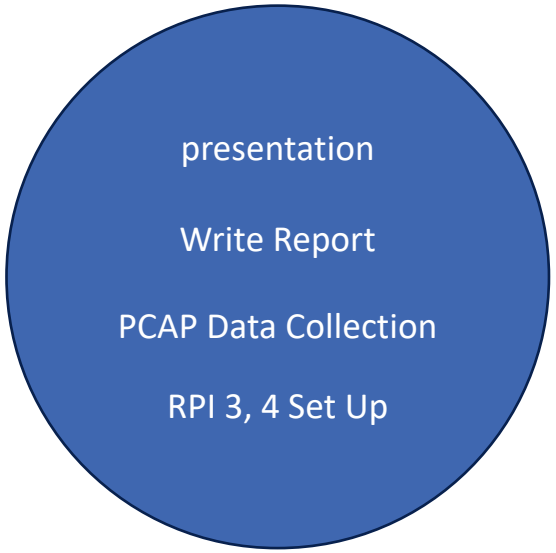
Data Detection Experiment



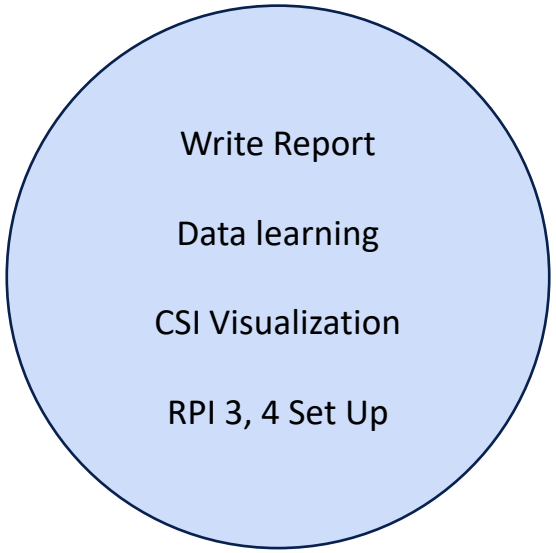
Detection of people : O
Number of people: 3



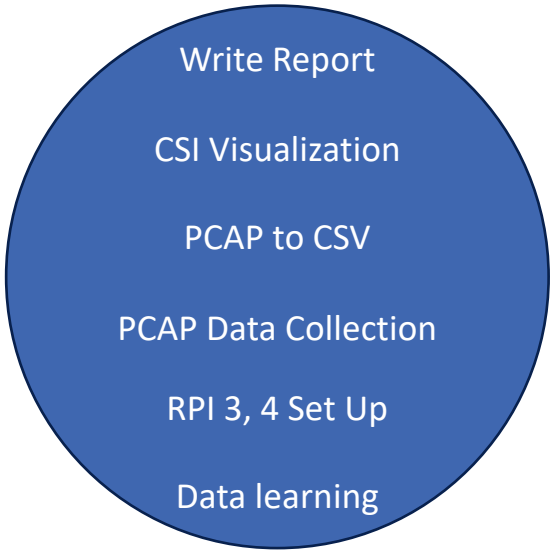
Part 9 >> **Contribution**



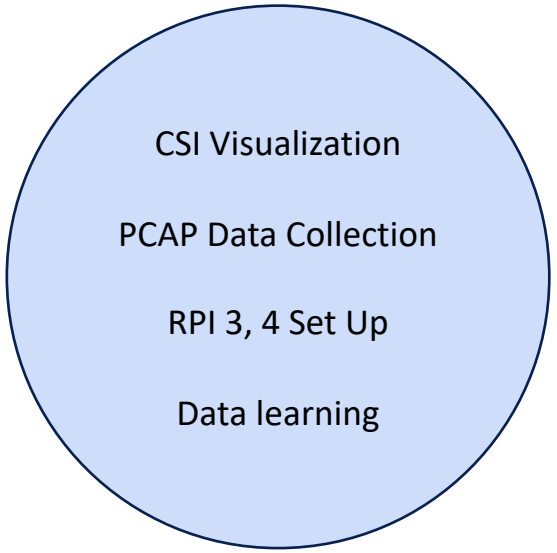
201931322 KimJaeyoung



202031415 LimHyungsub



202033502 KangHyunjoon



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Thank You