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IM2-046: Artificial Intelligence of Things (AIoT) for Disaster Monitoring using Wireless Mesh Network

Presenter: Mau-Luen THAM

UTAR UNIVERSITI TUNKU ABDUL RAHMAN
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I. Introduction

Background

- The inherent characteristics of Internet of things (IoT) such as low computation power of IoT nodes and transmission reliability of IoT links demand a new paradigm for efficient data processing and dissemination.
- This is especially true for disaster situations with high possibility of communication breakdowns.
- In the traditional IoT framework, these data are transmitted to a remote central cloud platform through the Internet to be processed.
- **Drawback**: There is an issue where the big data transmission process consumes enormous energy, time, cost, and bandwidth.

I. Introduction

Problem Statement

- Edge computing is introduced to process and analyze the valuable information from the raw sensor data at the network edge in real-time.
- The evolution of edge computing technology has driven the smart applications towards the use of artificial intelligence (AI).
- The fusion technology of AI and IoT is referred to as artificial intelligence of things (AIoT).
- **Drawback**: The limited processing capacity constraints of IoT devices present a challenge to integrate AI into AIoT applications.

II. Related Work

Artificial Intelligence of Things (AIoT)

- Several existing works [8]–[10] explored the potential of AIoT for situational awareness and disaster recovery operations.
- The authors in [11] demonstrated how sequence model could predict the flow rates in downstream gauging station based on the flow rate in upstream station.
- The study in [12] utilized signals from fire detection system to predict the potential of house fire and alert the appropriate authorities using IoT networks.
- **Drawback**: These works utilized only machine learning. When using more advanced deep learning (DL) algorithms such as convolutional neural networks (CNN), the computational power of IoT device could become a burden.

II. Related Work

Disaster Classification and Victim Detection

- When disaster events happen, an efficient rescue operation requires the detected disaster type and number of victims.
- Literature on disaster classification often surrounds the dataset since the robustness of disaster monitoring is tightly correlated with the quality and quantity of training data.
- There are five major datasets for disaster classification, which are Artificial Intelligence for Disaster Response (AIDR) [20], Damage Multimodal Dataset (DMD) [21], Damage Assessment Dataset (DAD) [22], CrisisMMD [23] dataset, and Crisis Image Benchmark Datasets (CrisisIBD) [24].
- **Drawback**: For victim detection task, there is a lack of a proper benchmark dataset possibly due to privacy concerns.

II. Related Work

Multi-task Learning

- **Drawback**: There are limited works in disaster response domain that address multiple tasks together.
- Research work in [28] was the first to address the need of MTL model for (i) disaster classification, (ii) informativeness, (iii) humanitarian categories, and (iv) damage severity assessment on a given input image.
- On the other hand, our previous work [6] is the first to propose a MTL model for joint disaster classification and victim detection, as shown in Figure 1.

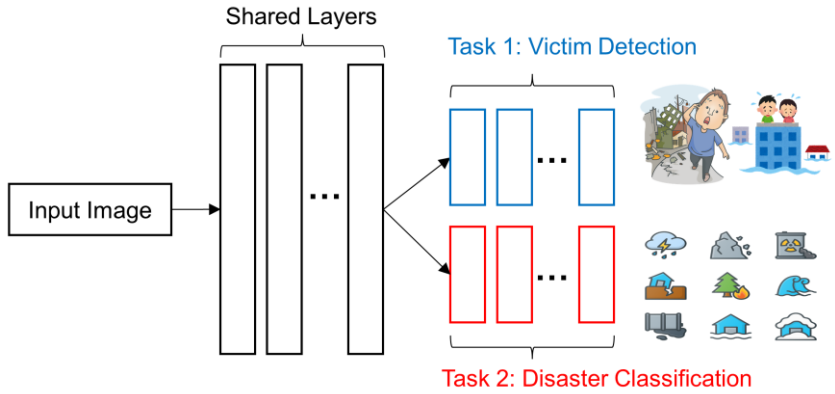


Figure 1: Proposed multi-task learning model.

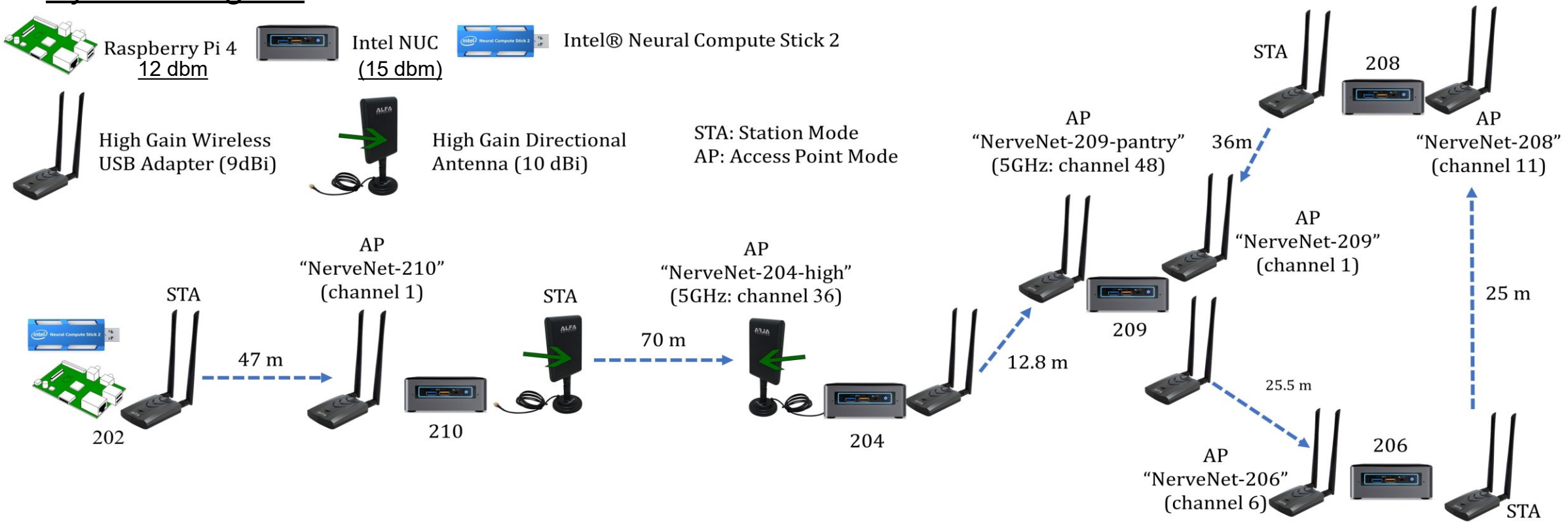
II. Related Work

NerveNet

- NerveNet is a resilient network developed by Japan's National Institute of Information and Communications Technology (NICT).
- NerveNet is a specially developed mesh network for the regional area to provide reliable network access and a stable, resilient information-sharing platform in emergencies, even if the base station is destroyed in a disaster.
- NerveNet has the feature of database synchronisation. It uses a hearsay daemon to synchronize the database of every node within the NerveNet network.
- We utilize NerveNet to increase the transmission reliability of AIoT.

III. AIOT IMPLEMENTATION

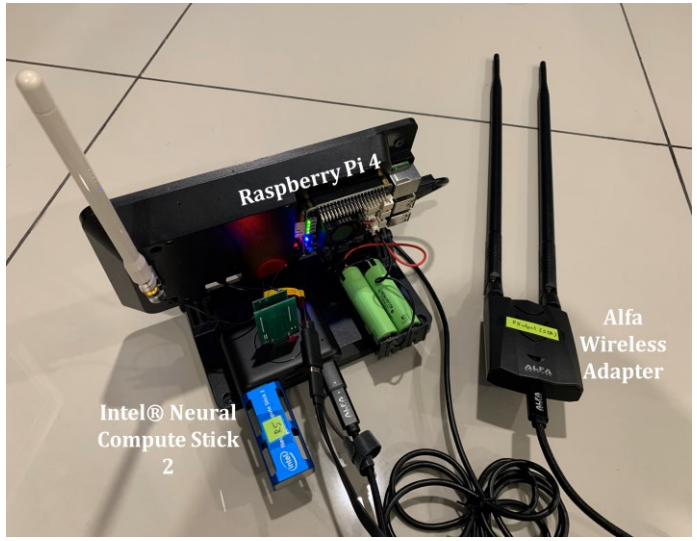
System Diagram



III. AIOT IMPLEMENTATION

Testbed

(b)



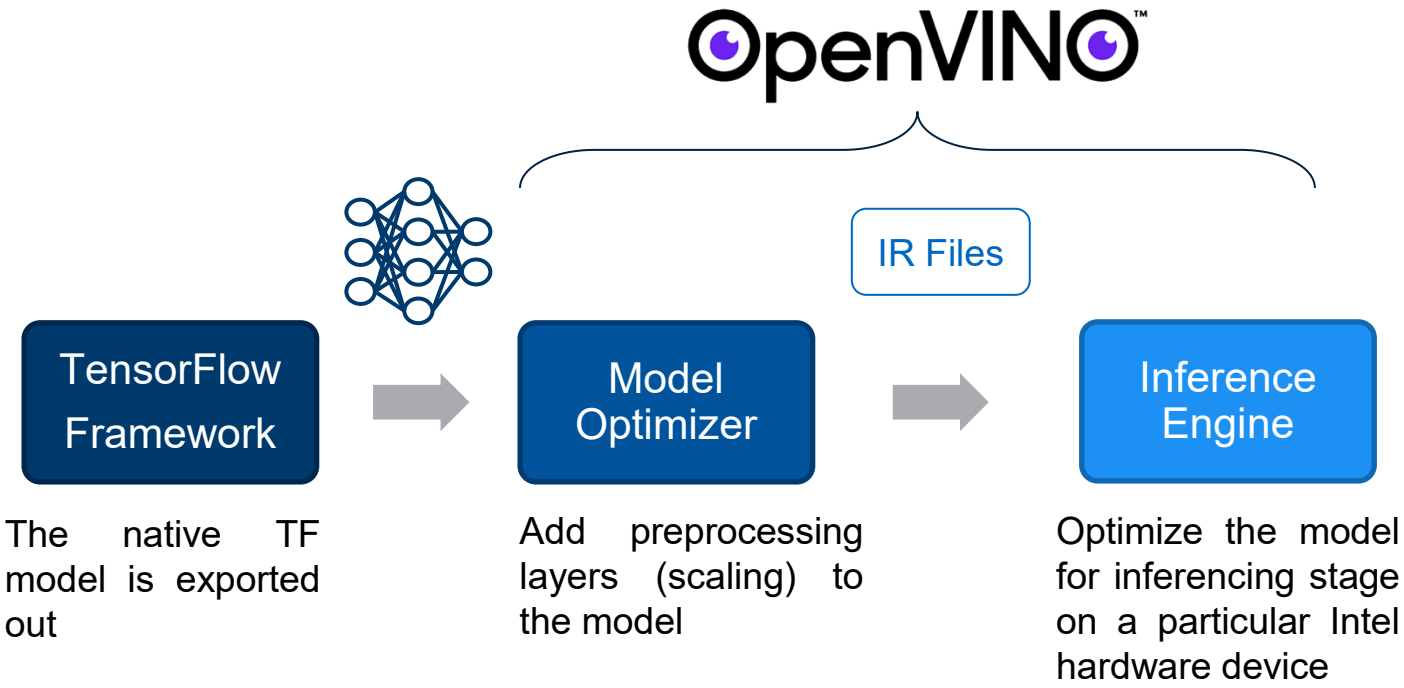
(c)

(d)

Figure 2: (b) NerveNet monitoring node (front view). (c) NerveNet monitoring node (rear view). (d) NerveNet base station node.

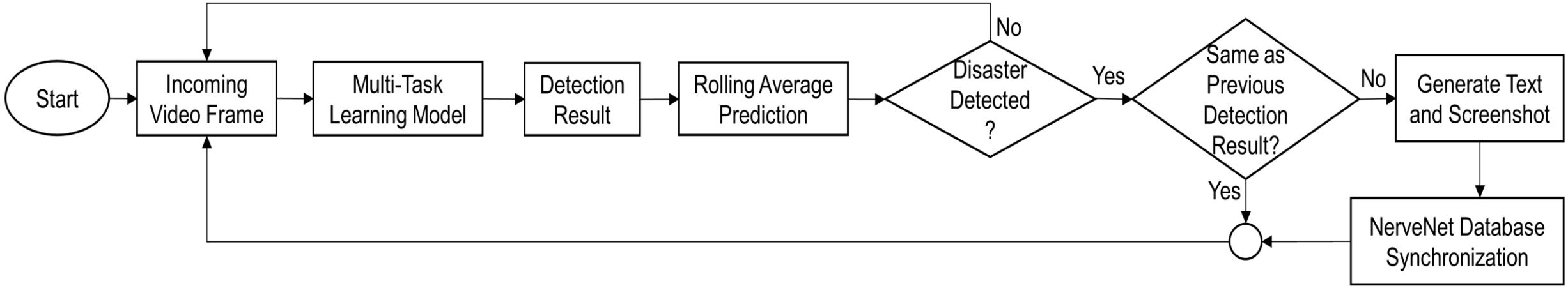
III. AIOT IMPLEMENTATION

Open Visual Inference and Neural Network Optimization (OpenVINO)



III. AIOT IMPLEMENTATION

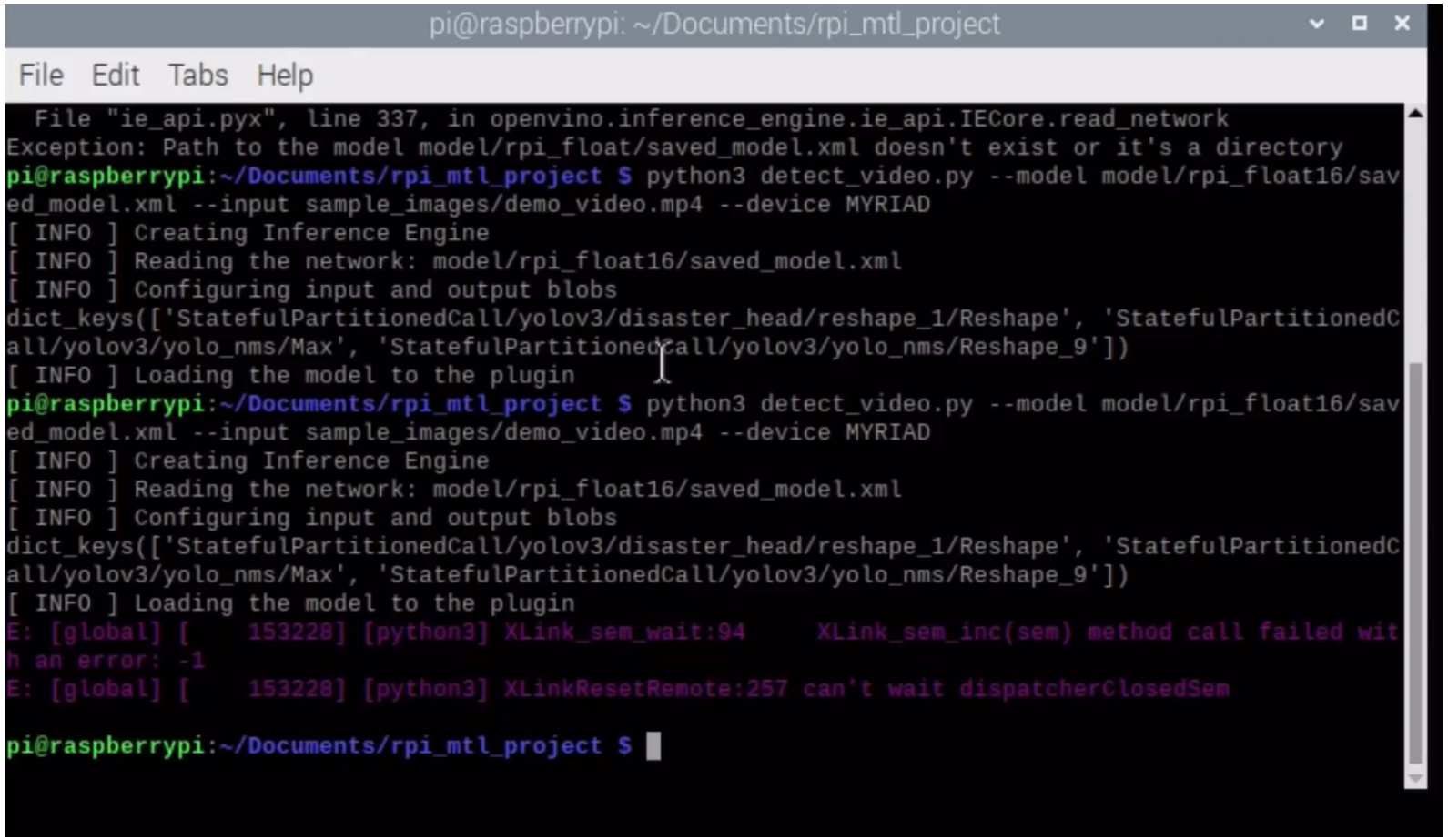
Working Flow



IV. PERFORMANCE EVALUATION

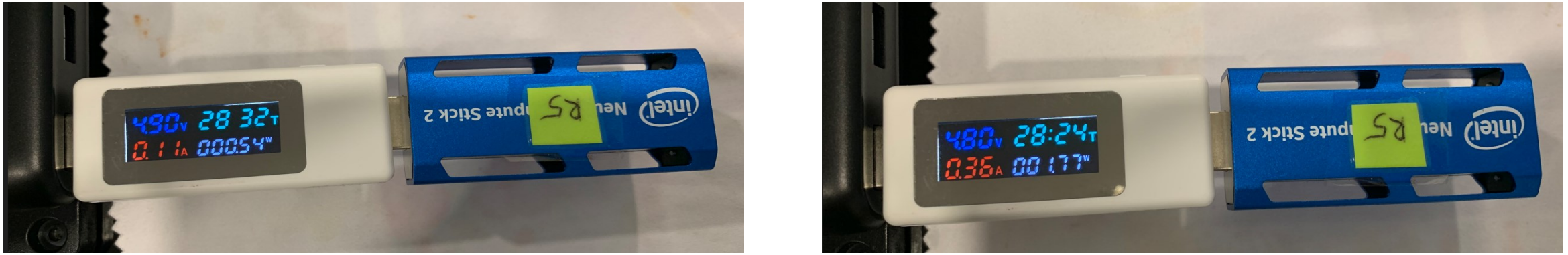
Disaster Monitoring (Frames per second)

2 FPS



IV. PERFORMANCE EVALUATION

Disaster Monitoring (Power Consumption)



(a) (b)

1.23 W

Figure 5: Power Measurement. (a) Idle time. (b) Execution time.

IV. PERFORMANCE EVALUATION

NerveNet Database Synchronization (Text)

```
MariaDB [db_donut]> select * from application_disaster;
+--------------------+--------------+----------------+------------+---------------+---------------+---------------------+--------------+
| disaster_detected  | flag_invalid | id_node_update | id_record  | time_discard  | time_update   | timestamp_sync      | victim_count |
+--------------------+--------------+----------------+------------+---------------+---------------+---------------------+--------------+
| wildfire           |         NULL | BS202          | 202-W-1    | 1671005184900 | 1670918784900 | 2022-12-13 08:23:44 |            0 |
| flood              |         NULL | BS202          | 202-W-2    | 1671005252170 | 1670918852170 | 2022-12-13 08:23:44 |            0 |
| earthquake         |         NULL | BS202          | 202-W-3    | 1671005312069 | 1670918912069 | 2022-12-13 08:23:44 |            5 |
| flood              |         NULL | BS202          | 202-W-4    | 1671005313689 | 1670918913689 | 2022-12-13 08:23:44 |            5 |
| wildfire           |         NULL | BS202          | 202-W-5    | 1671005322759 | 1670918922759 | 2022-12-13 08:23:44 |            1 |
| other              |         NULL | BS202          | 202-W-6    | 1671005399168 | 1670918999168 | 2022-12-13 08:23:44 |            2 |
| wildfire           |         NULL | BS202          | 202-W-7    | 1671005406078 | 1670919006078 | 2022-12-13 08:23:44 |            3 |
| earthquake         |         NULL | BS202          | 202-W-8    | 1671005416478 | 1670919016478 | 2022-12-13 08:23:44 |            3 |
| landslide          |         NULL | BS202          | 202-W-9    | 1671005445368 | 1670919045368 | 2022-12-13 08:23:44 |            0 |
| other              |         NULL | BS202          | 202-W-10   | 1671005601817 | 1670919201817 | 2022-12-13 08:23:44 |            2 |
| earthquake         |         NULL | BS202          | 202-W-11   | 1671005609557 | 1670919209557 | 2022-12-13 08:23:44 |            1 |
| wildfire           |         NULL | BS202          | 202-W-12   | 1671005692526 | 1670919292526 | 2022-12-13 08:23:44 |            2 |
| earthquake         |         NULL | BS202          | 202-W-13   | 1671005694106 | 1670919294106 | 2022-12-13 08:23:44 |            2 |
| wildfire           |         NULL | BS202          | 202-W-14   | 1671005696126 | 1670919296126 | 2022-12-13 08:23:44 |            2 |
+--------------------+--------------+----------------+------------+---------------+---------------+---------------------+--------------+
```

IV. PERFORMANCE EVALUATION

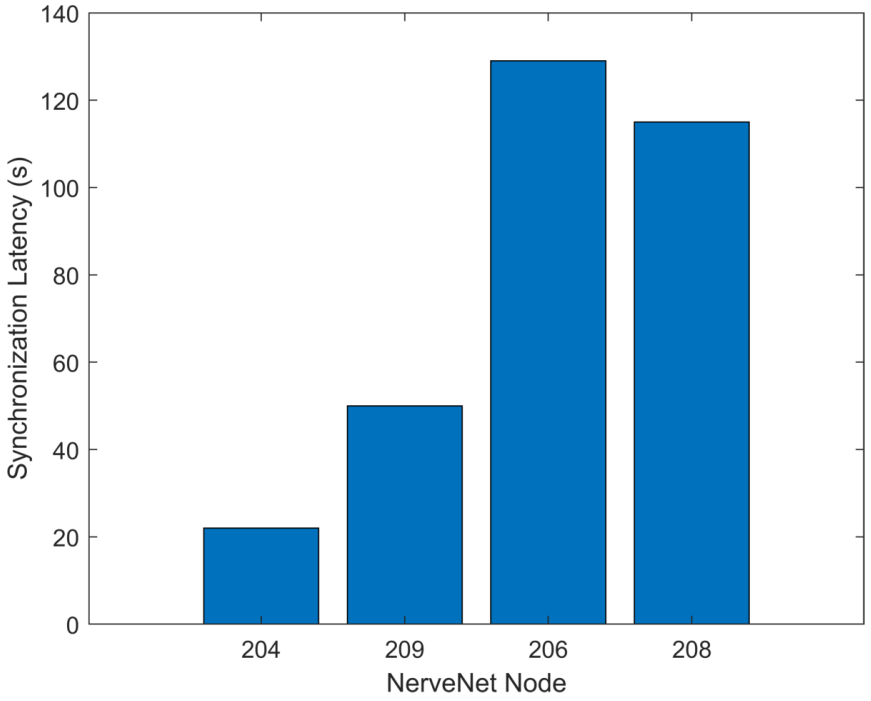
NerveNet Database Synchronization (Image)

```
MariaDB [db_donut]> select * from shbt_boxshare;
+-----------------------------------------------------------+-----------------------------------+-
| attached                                                  | body                              |
+-----------------------------------------------------------+-----------------------------------+-
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d31  | wildfire2022-12-13-16:06:23.jpg   |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d32  | flood2022-12-13-16:07:31.jpg      |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d33  | earthquake2022-12-13-16:08:31.jpg |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d34  | flood2022-12-13-16:08:32.jpg      |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d35  | wildfire2022-12-13-16:08:41.jpg   |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d36  | other2022-12-13-16:09:58.jpg      |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d37  | wildfire2022-12-13-16:10:05.jpg   |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d38  | earthquake2022-12-13-16:10:15.jpg |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d39  | landslide2022-12-13-16:10:44.jpg  |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d3130| other2022-12-13-16:13:20.jpg      |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d3131| earthquake2022-12-13-16:13:28.jpg |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d3132| wildfire2022-12-13-16:14:51.jpg   |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d3133| earthquake2022-12-13-16:14:53.jpg |
| /var/tmp/fieldfile/shbt_boxshare-attached-3230322d572d3134| wildfire2022-12-13-16:14:55.jpg   |
+-----------------------------------------------------------+-----------------------------------+-
+----------------+------------+----------------+---------------+---------------+---------------------
| id_node_update | id_record  | time_calibrate | time_discard  | time_update   | timestamp_sync
+----------------+------------+----------------+---------------+---------------+---------------------
| BS202          | 202-W-1    |           NULL | 1671005184290 | 1670918784290 | 2022-12-13 08:07:14
| BS202          | 202-W-2    |           NULL | 1671005251650 | 1670918851650 | 2022-12-13 08:23:44
| BS202          | 202-W-3    |           NULL | 1671005311529 | 1670918911529 | 2022-12-13 08:24:14
| BS202          | 202-W-4    |           NULL | 1671005313139 | 1670918913139 | 2022-12-13 08:13:44
| BS202          | 202-W-5    |           NULL | 1671005322159 | 1670918922159 | 2022-12-13 08:14:44
| BS202          | 202-W-6    |           NULL | 1671005398618 | 1670918998618 | 2022-12-13 08:27:44
| BS202          | 202-W-7    |           NULL | 1671005405488 | 1670919005488 | 2022-12-13 08:15:44
| BS202          | 202-W-8    |           NULL | 1671005415898 | 1670919015898 | 2022-12-13 08:16:14
| BS202          | 202-W-9    |           NULL | 1671005444838 | 1670919044838 | 2022-12-13 08:16:14
| BS202          | 202-W-10   |           NULL | 1671005601267 | 1670919201267 | 2022-12-13 08:35:44
| BS202          | 202-W-11   |           NULL | 1671005608977 | 1670919208977 | 2022-12-13 08:34:44
| BS202          | 202-W-12   |           NULL | 1671005691956 | 1670919291956 | 2022-12-13 08:35:14
| BS202          | 202-W-13   |           NULL | 1671005693536 | 1670919293536 | 2022-12-13 08:35:14
| BS202          | 202-W-14   |           NULL | 1671005695556 | 1670919295556 | 2022-12-13 08:23:44
```

IV. PERFORMANCE EVALUATION

NerveNet Synchronization Latency

The size of total synchronized images is 647168 bytes.



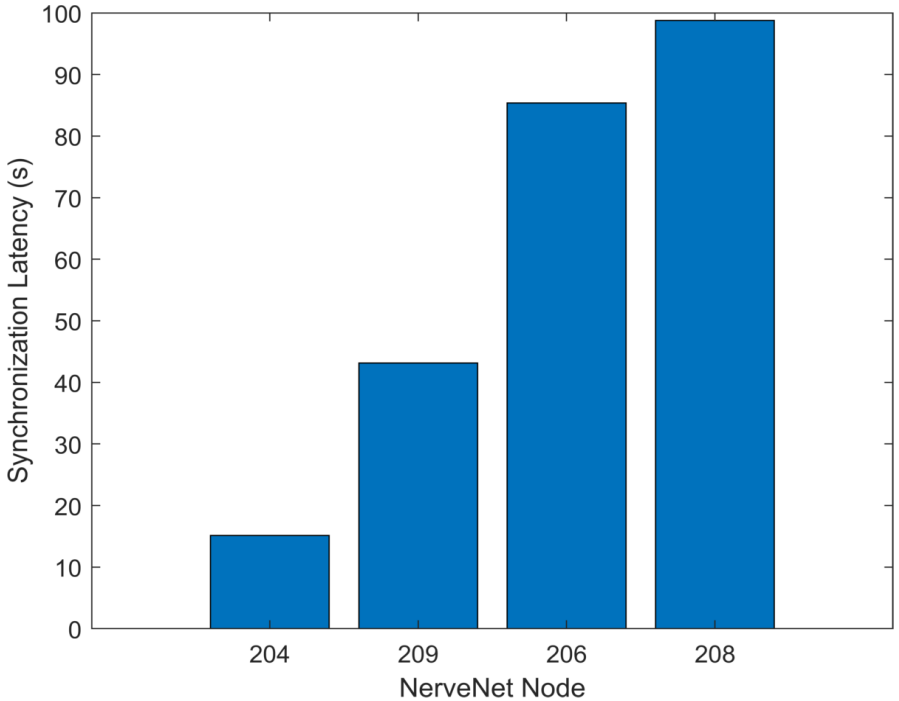


Figure 7: Synchronization Latency with respect to node 210. (a) Text. (b) Image.

V. Conclusions

- In this paper, we have proposed a AIoT-based disaster monitoring using NerveNet wireless mesh network.
- To reduce the heavy workload of AI inference, we utilized OpenVINO to accelerate the process so that it can be executed on low-powered Raspberry Pi device.
- As for the data robustness, we invoked the feature of data synchronization to disseminate the data among NerveNet nodes.
- The effectiveness of the solution has been demonstrated via a testbed implementation.
- In future, we plan to test the framework in a LoRa based mesh network.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