Performance Analysis of Heterogeneous Networks for Robotic Navigation

By Hersch Nathan

Problem Statement:

In the absence of WiFi network, LoRaWAN is a potential candidate to transmit data. However, the data transmission can be impacted due to low bandwidth. We analyze the performance of LoRa to observe the delay. We compare the same with WiFi.

In short: Is LoRaWAN a viable option for data transmission in the absence of WiFi?

Road Map

- Premise of Research & Background Information
- Related Works
- Methodology
- Results and Problems
- Conclusions
- Skills and Research Experience
- Acknowledgements

Premise of Research & Background Information

Research Premise - Environment

Large Scale Disasters cause:

- Hazards
  - Collapsed Buildings
  - Hazardous Materials
  - Flooding
- Destruction of Infrastructure
  - Roads
  - Powerlines
  - Wireless networks

Research Premise - Need

- Danger to deploy humans
- Ought to use robots
  - Navigate hostile terrains
  - Autonomously make application-oriented decisions
  - Send data to human personnel for decision-making
- Need for **easily deployable**, **long range**, and **low-cost** wireless communication

Research Premise – Problem 1

- Humans are smart
  - Can synthesis environments
  - Effective communicate via vocal radios
- Robots are dumb
  - Long time/high power to process environments
  - High wireless bandwidth to send data
- Lack of Infrastructure
  - Damaged/Destroyed

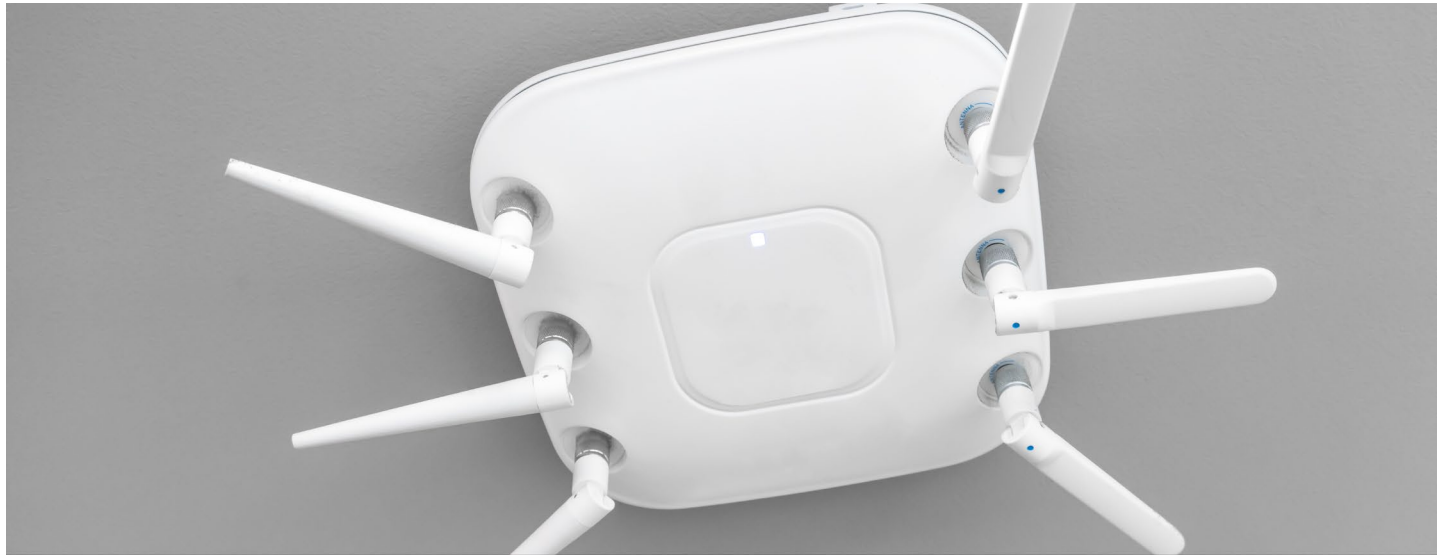
Research Premise – Wireless Options: WiFi

Wi-Fi

- Common place (i.e., pre-existing integrations with our robots)
- Short effective range (~50 meters)
- Need for much infrastructure

MQTT

- lightweight, publish-subscribe, machine to machine network protocol for message queue/message queuing service



Research Premise – Wireless Options: Satellite-Based

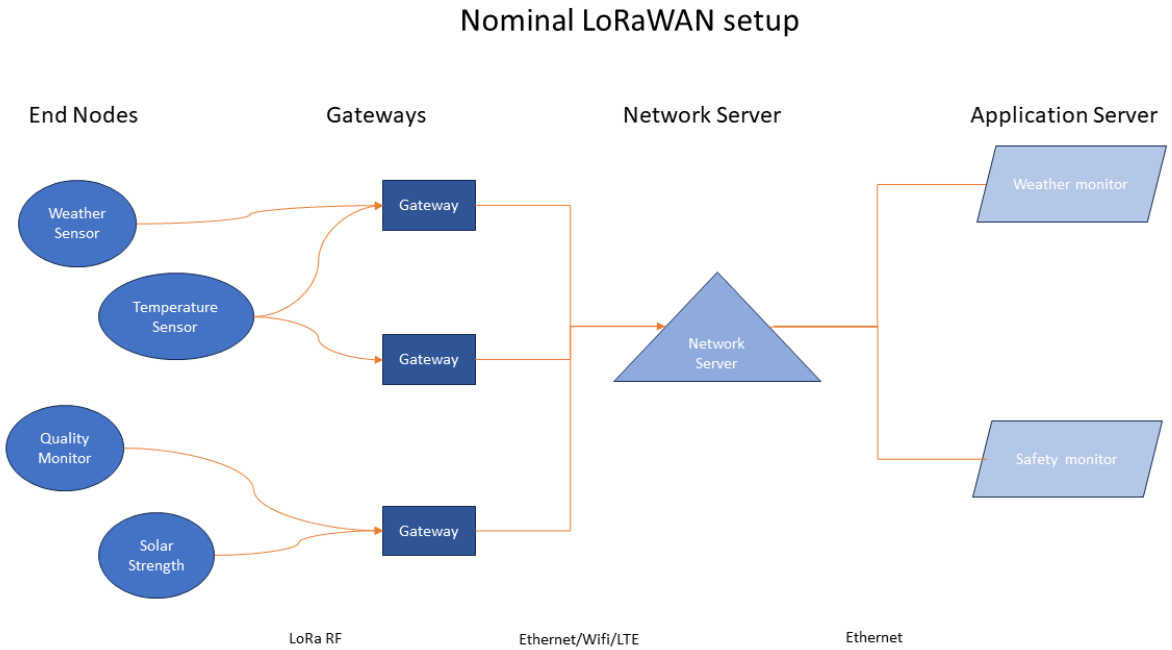
Satellite-Base Communication (i.e., LTE, 4G, 5G, Starlink, OneWeb, etc.)

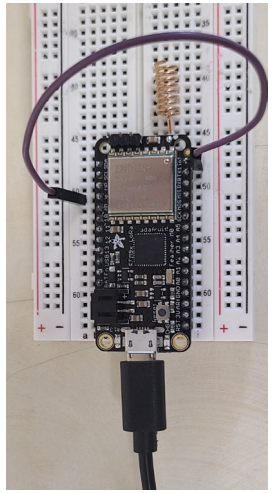
- Easy to integrate via a tunnel
- Long Range
  - Covers mass regions of the earth
- High Cost
  - Satellite and End Node

Research Premise – Wireless Options: LoRa and LoRaWAN

LoRa

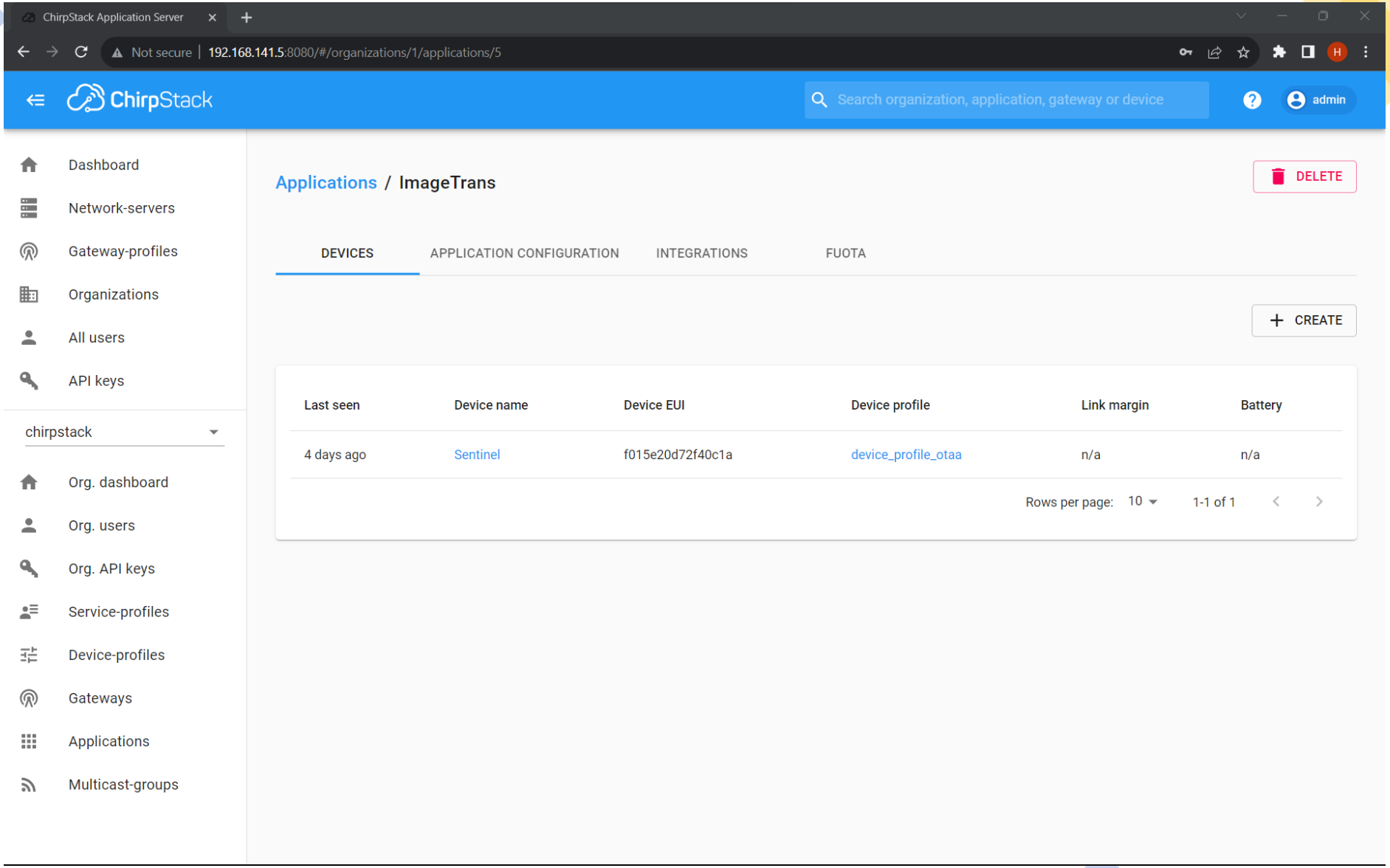
- Created for IoT applications
  - Long Range/Low Bandwidth
  - Leverage Chirp Spread Spectrum (CSS) technology
- Power efficient
  - Small chirps of data over Long Range
  - To sustain their battery life





LoRaWAN

- WAN
  - Wide area network
- Built ontop of LoRa
  - Easier to Manage for IoT


ChirpStack Application Server
Not secure | 192.168.141.5:8080/#/organizations/1/applications/5
ChirpStack
Search organization, application, gateway or device
admin
Dashboard
Network-servers
Gateway-profiles
Organizations
All users
API keys
chirpstack
Org. dashboard
Org. users
Org. API keys
Service-profiles
Device-profiles
Gateways
Applications
Multicast-groups
Applications / ImageTrans
DELETE
DEVICES
APPLICATION CONFIGURATION
INTEGRATIONS
FUOTA
CREATE
Last seen
Device name
Device EUI
Device profile
Link margin
Battery
4 days ago
Sentinel
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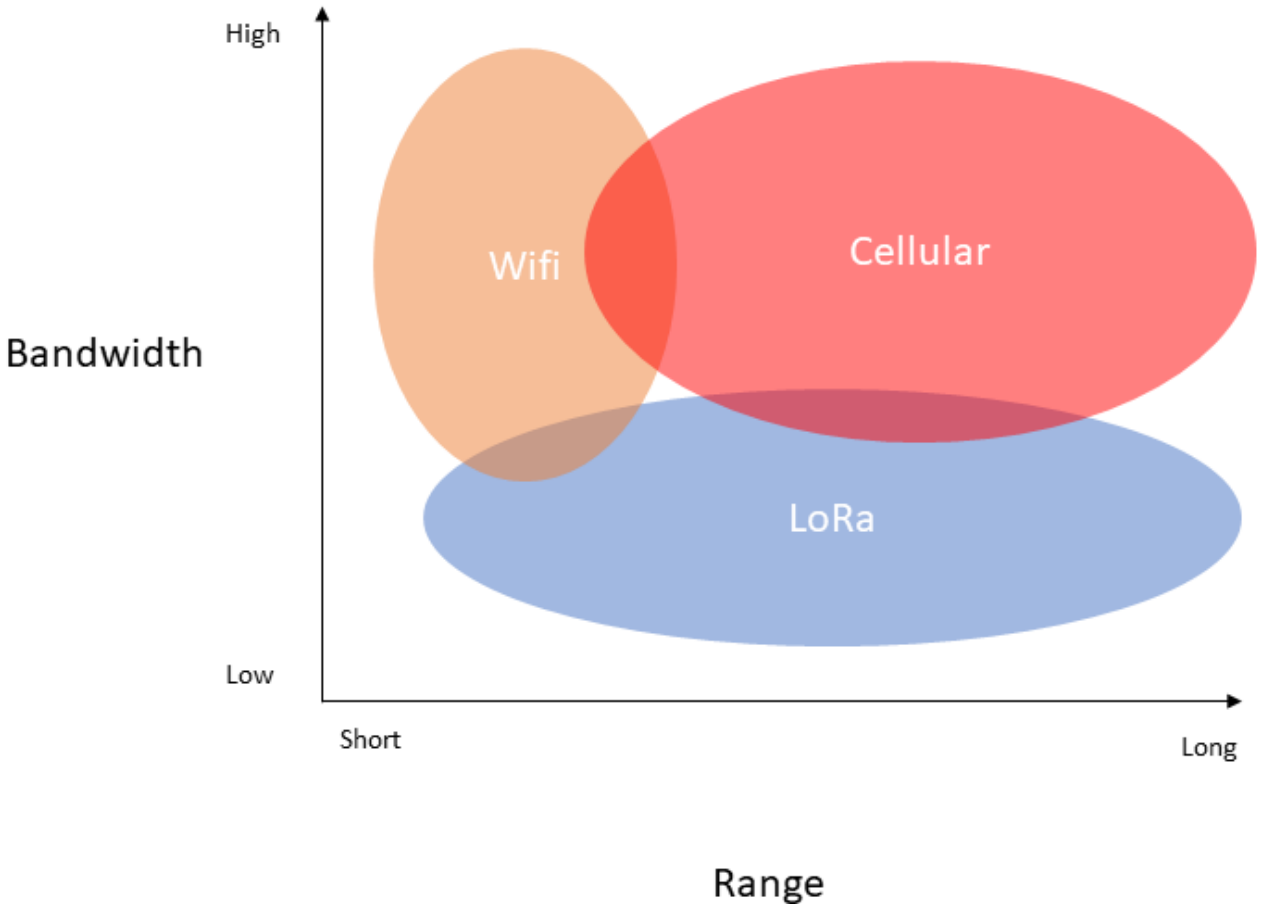
device_profile_otaa
n/a
n/a
Rows per page: 10
1-1 of 1



Research Premise – Wireless Options: Summary

Our Robots

TurtleBot3
Burger

Related Works

Related Works – Edge Computing

HetroEdge	Previous Work of Saied Optimizing computing resources (time/power/bandwidth/latency) across a diversified network
Heindall	mobile GPU coordination for Deep Neural Networks
MASA	framework for memory and computing resources for multi-Deep Neural Networks applications
MAUI	automated system for allowing fine control of offloading of computing
BALB	(batch-aware latency-balanced) scheduling algorithm to drive object detection via images
Others	Resource optimizing algorithms

Related Works – LoRa and LoRaWAN

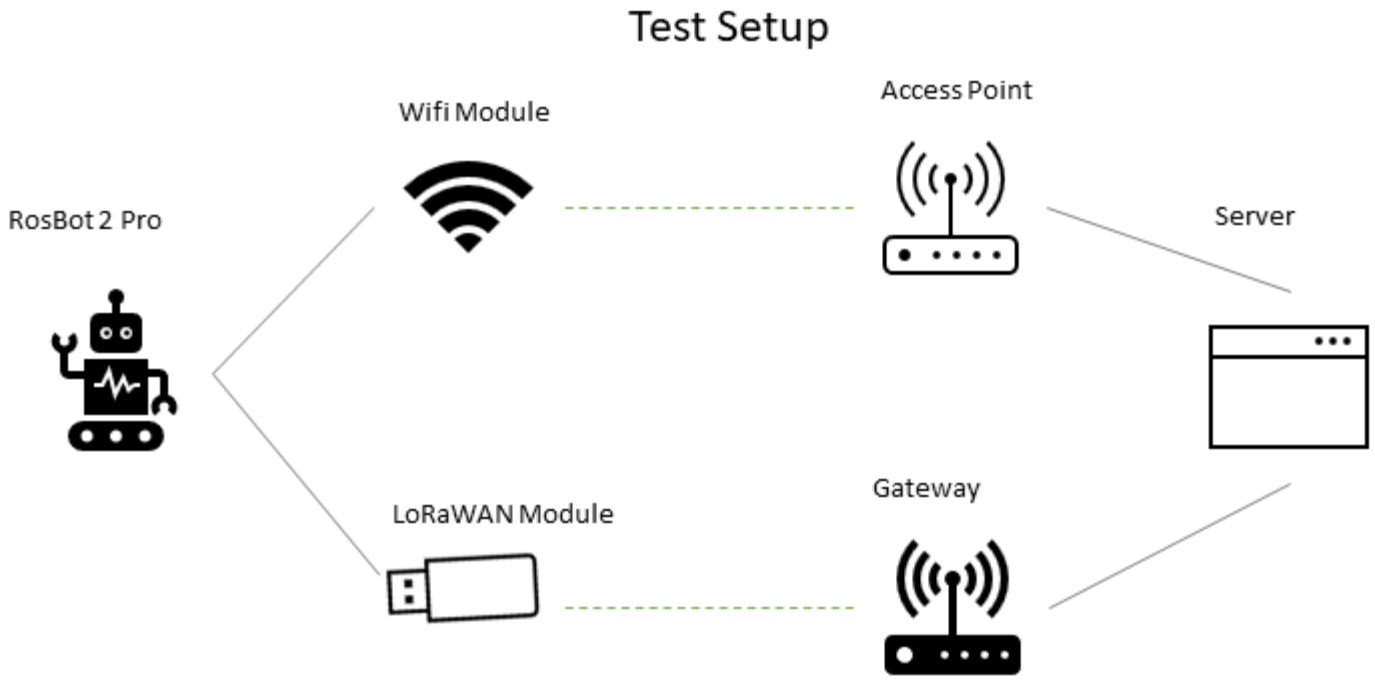
- Search and Rescue Case Study proposes X-IoCA (Internet of Cooperative Agents Architecture)
  - Framework for integrating heterogeneous sensor networks, heterogeneous robotic networks, multiedge computing, and 5G communications in cooperative field applications

Methodology

Testing Premise

What is the latency (time) to send unprocessed images across WiFi (MQTT) and LoRaWAN?

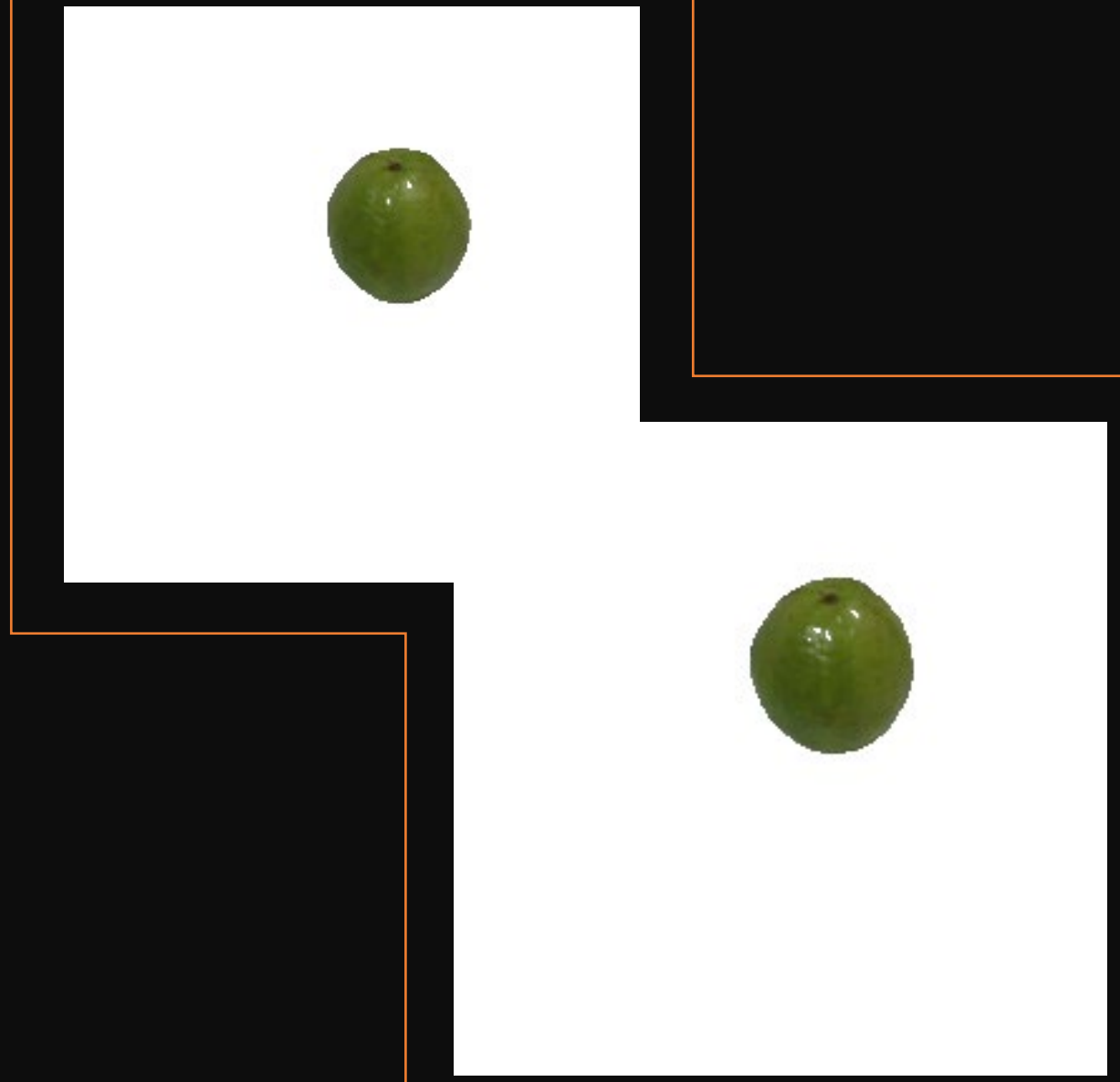
Test Setup – Overview



Datasets

Name	Type	Count	Average Size	Total Size	File Type	From
1A	Small Images	6	7.8kb	46.8kb	png	TestFileDownload
2A	Extra Small	6	2.31kb	13.9kb	jpg	bounding_box_test
2B	Extra Small	12	2.29kb	27.5kb	jpg	bounding_box_test
2C	Extra Small	24	2.18kb	52.5kb	jpg	bounding_box_test
3A	Medium	6	49kb	294kb	jpg	Saeid Feature Extraction
3B	Medium	12	55.7kb	668.8kb	jpg	Saeid Feature Extraction
4A	Large	6	0.25mb	1.5mb	jpg	Fire and Smoke Dataset
4B	Large	12	2.04mb	24.5mb	jpg	Fire and Smoke Dataset

Dataset – 1A



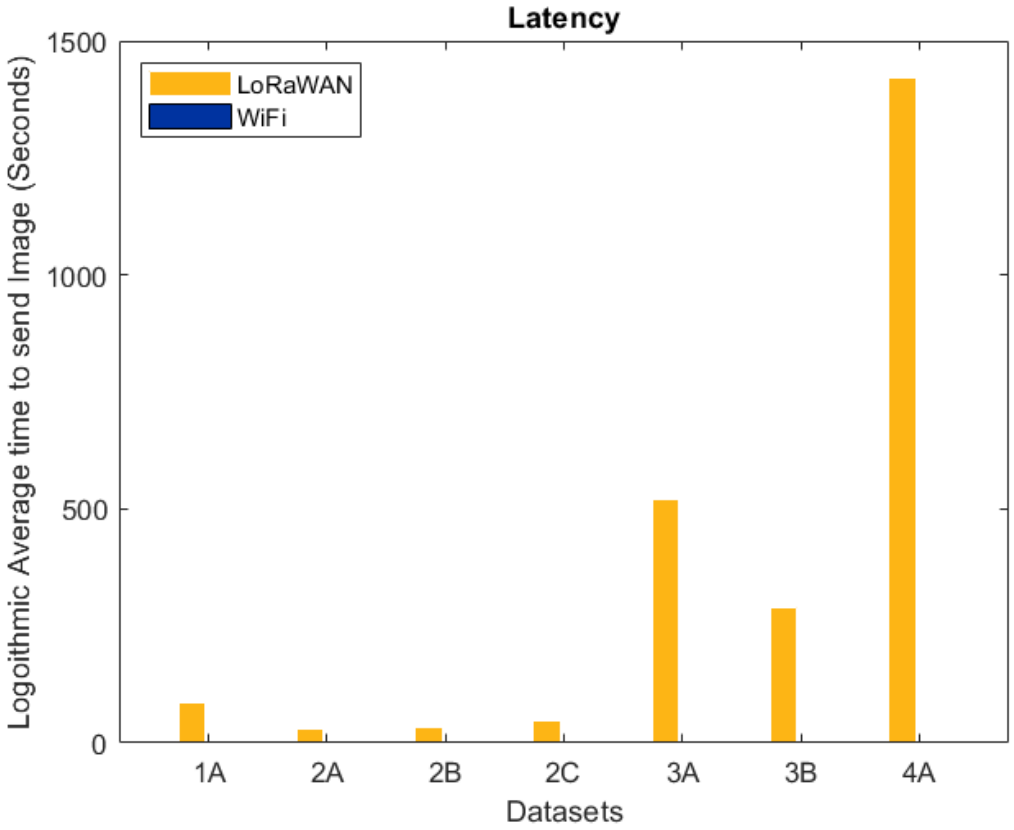
Dataset – 2A, 2B, 2C

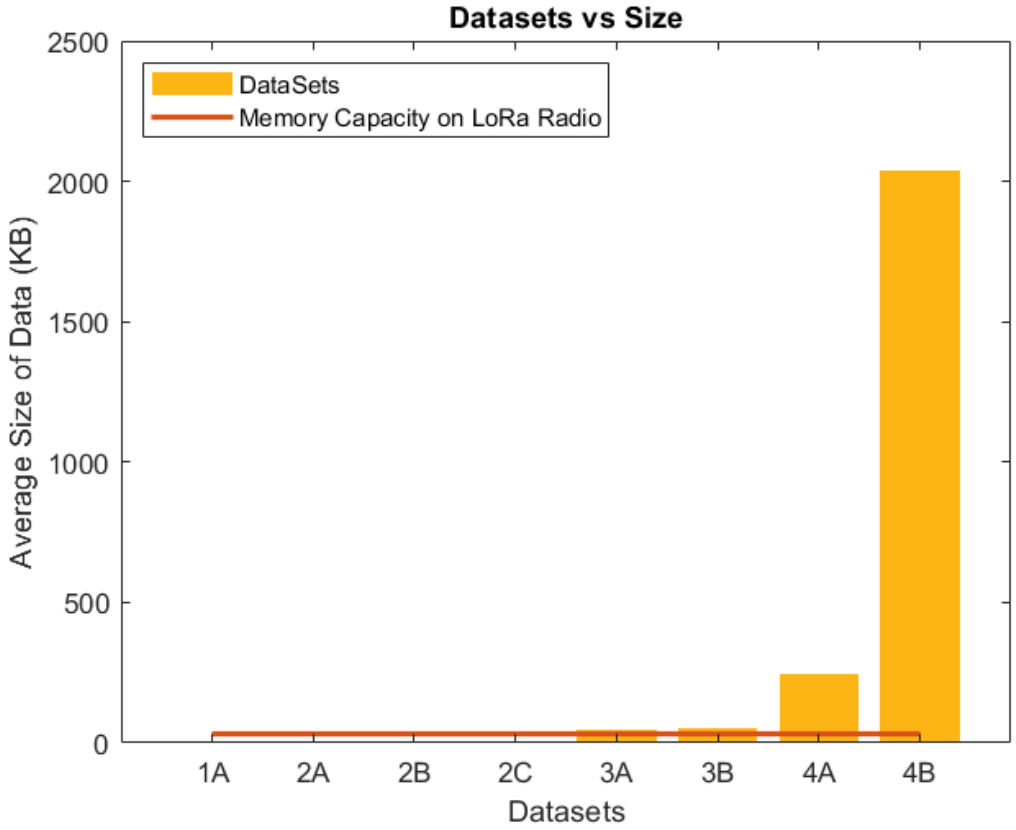
Dataset – 3A, 3B

Dataset – 4A, 4B

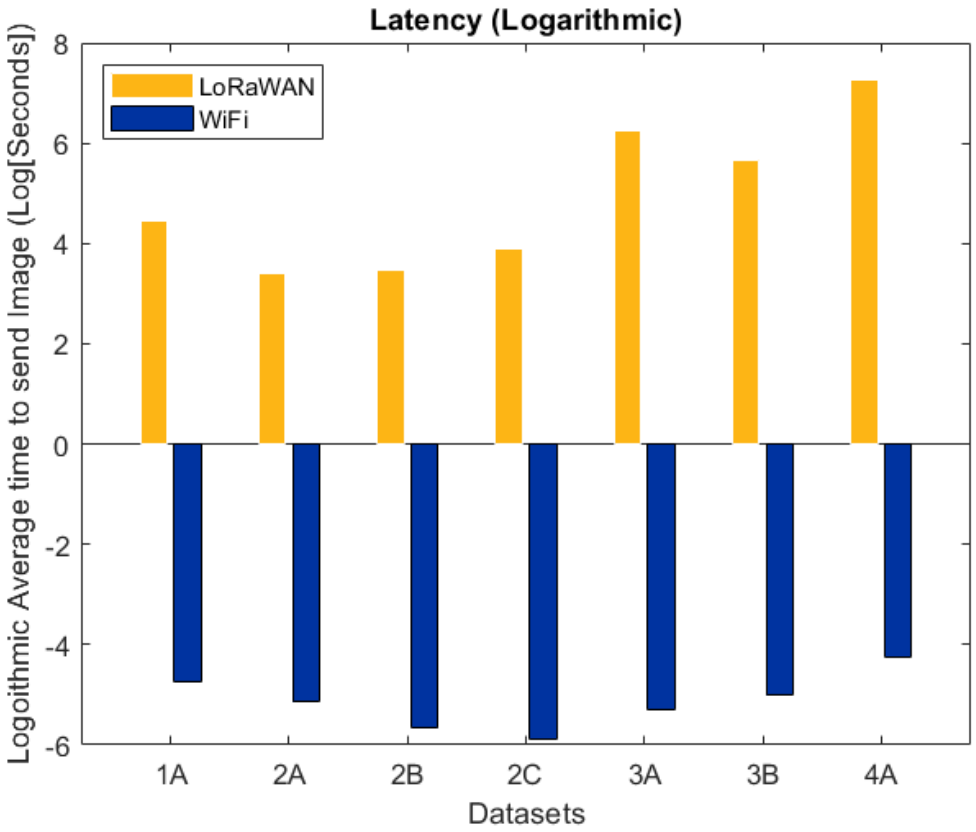
Results and Problems

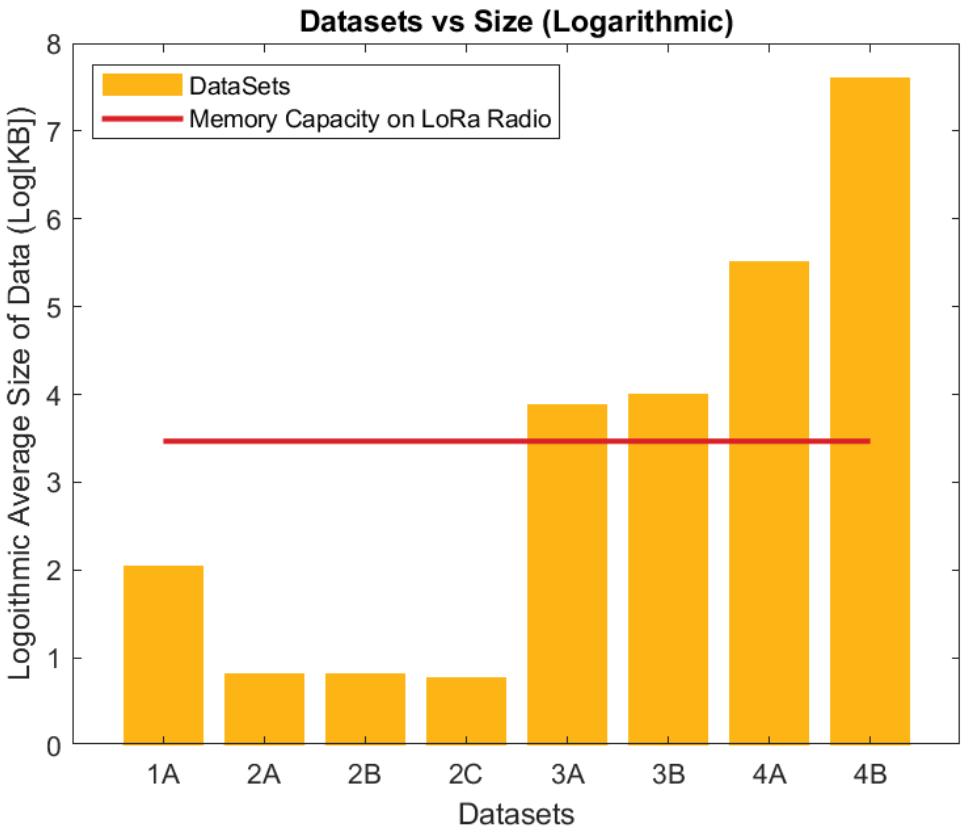
Results

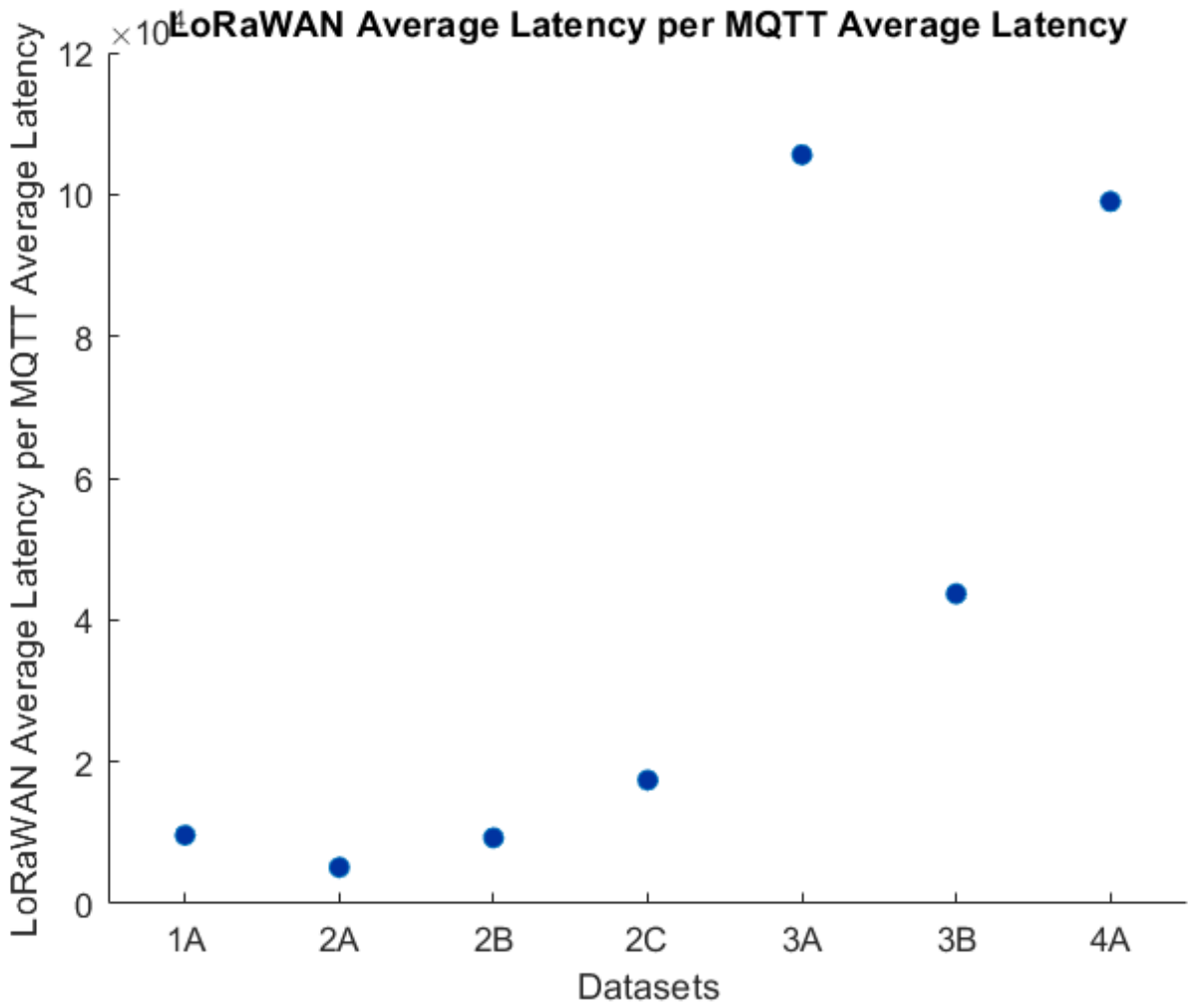

Latency
LoRaWAN
WiFi
Logoithmic Average time to send Image (Seconds)
1500
1000
500
0
1A
2A
2B
2C
3A
3B
4A
Datasets


Datasets vs Size
DataSets
Memory Capacity on LoRa Radio
Average Size of Data (KB)
2500
2000
1500
1000
500
0
1A
2A
2B
2C
3A
3B
4A
4B
Datasets

Data (Log)

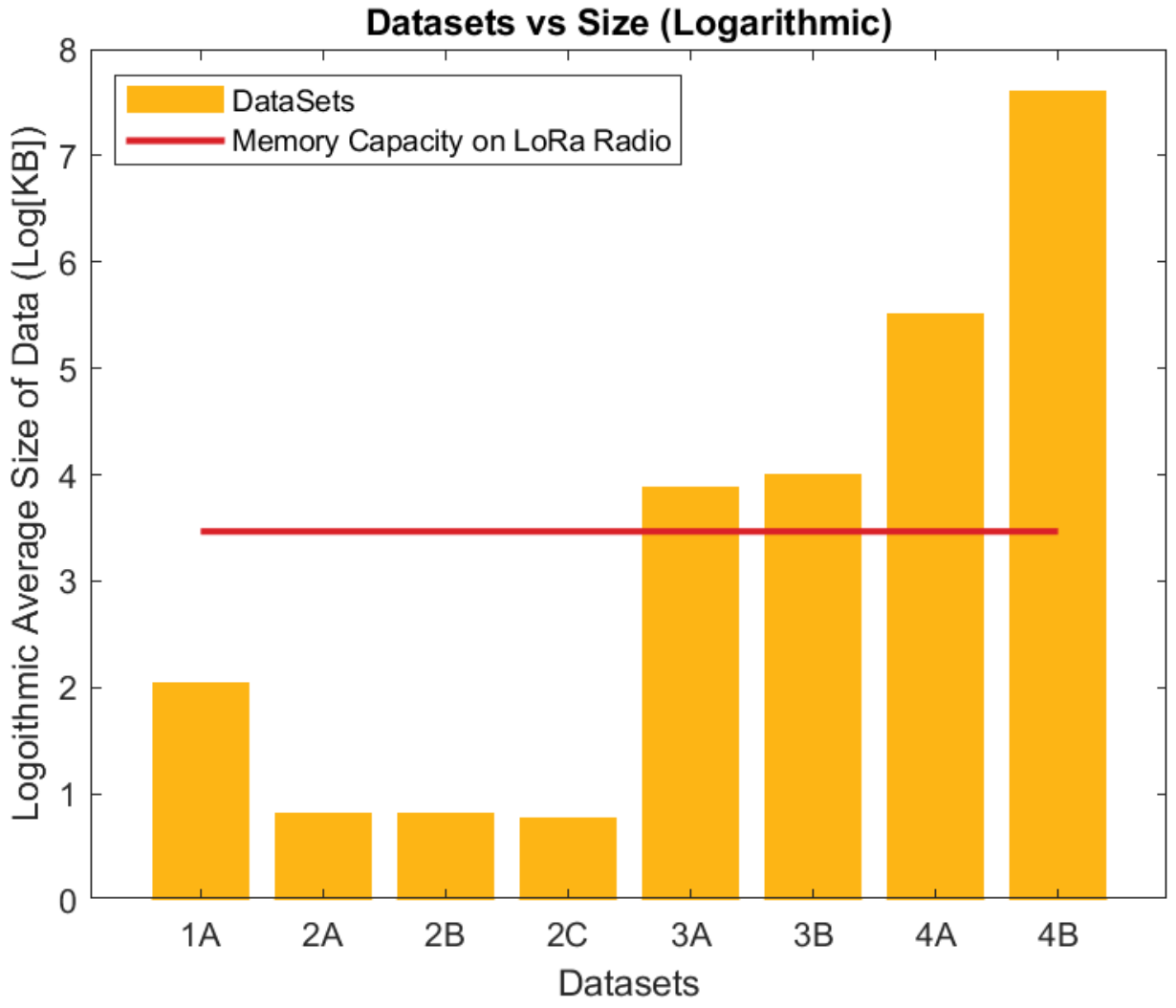

Latency (Logarithmic)
LoRaWAN
WiFi
Logoithmic Average time to send Image (Log[Seconds])
8
6
4
2
0
-2
-4
-6
1A
2A
2B
2C
3A
3B
4A
Datasets


Datasets vs Size (Logarithmic)
DataSets
Memory Capacity on LoRa Radio
Logoithmic Average Size of Data (Log[KB])
8
7
6
5
4
3
2
1
0
1A
2A
2B
2C
3A
3B
4A
4B
Datasets


LoRaWAN Average Latency per MQTT Average Latency
×10^4
LoRaWAN Average Latency per MQTT Average Latency
12
10
8
6
4
2
0
1A
2A
2B
2C
3A
3B
4A
Datasets

Problems – Memory of Radio

- Our radio based on Arudino M0
- 32Kb of flash
- Can’t fill a full glass with more water



Conclusions

Conclusions

Viable option

We can send large amounts of data using LoRaWAN

LoRaWAN preformed as expectedly

Orders of magnitude longer than WiFi

Need further research

Some sort of data compression is needed

Needs to balance latency with computational time

Skills and Research Experience

Skills

- Embedded Development
- MQTT networking
- Multi-layer Networking
- Python
- Dockers
- LaTeX
- Modal AI Drone Deployment
- Data Analysis

Research Experience

- Independently Explore Problems
- Read and Understand Academic Works
- Contribute to an ongoing project

Acknowledgements

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