UNIVERSITY OF ŽILINA
Faculty of Management Science and Informatics

FriStack
Reliability of ESP-NOW in IoT networks

ANDREJ ŠIMKOVIČ
SAMUEL GANCARČÍK
MICHAL KUBAŠČÍK
JÁN ŠUMSKÝ

Contents

FriStack:

Concept of FriStack

FriStack – Core

Future challenges

Reliability of ESP-NOW in IoT networks:

Concept of measurements

Results

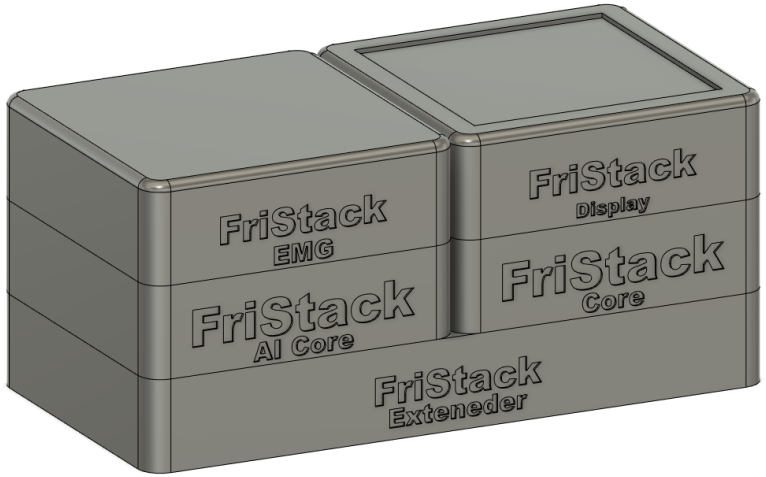
Conclusions

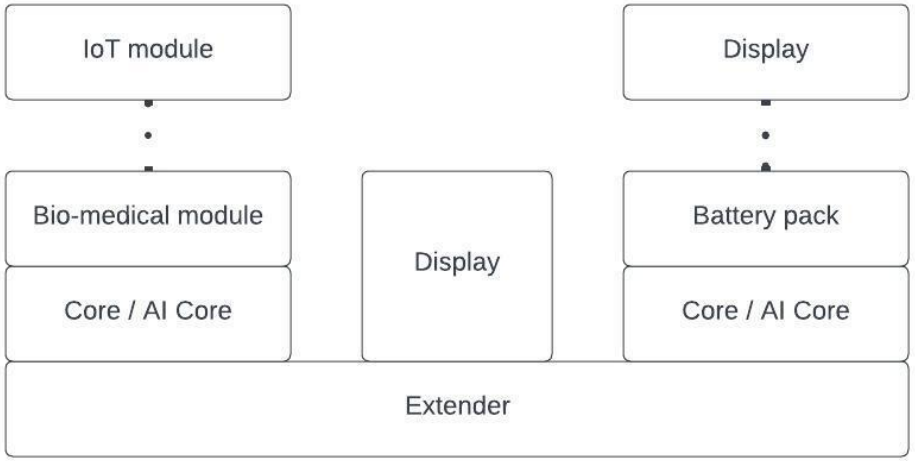
Concept of FriStack

- Modular stackable system based on ESP32

- Communication through standardized header

- Open-hardware, open-software





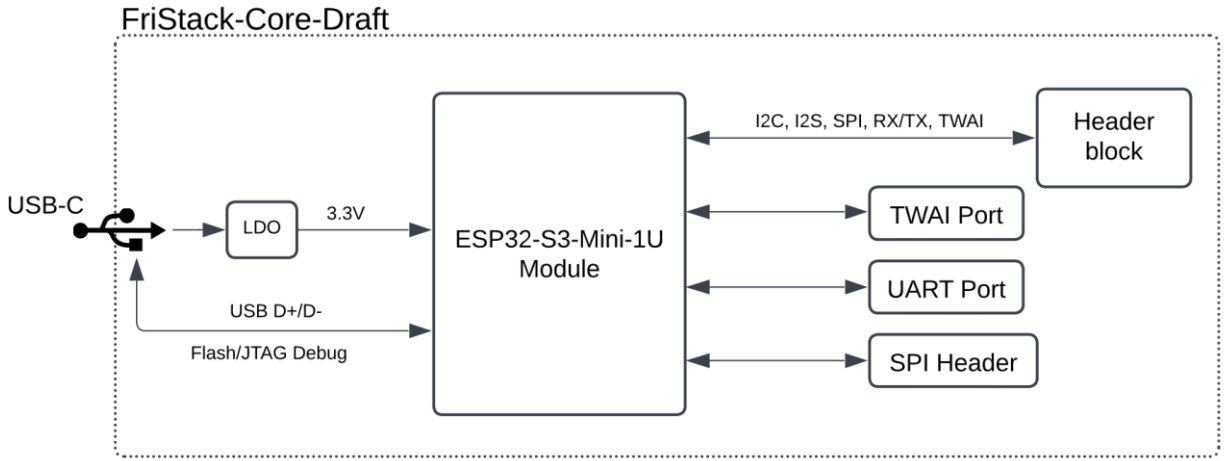
FriStack - Core

- Based on ESP32-S3-Mini1U

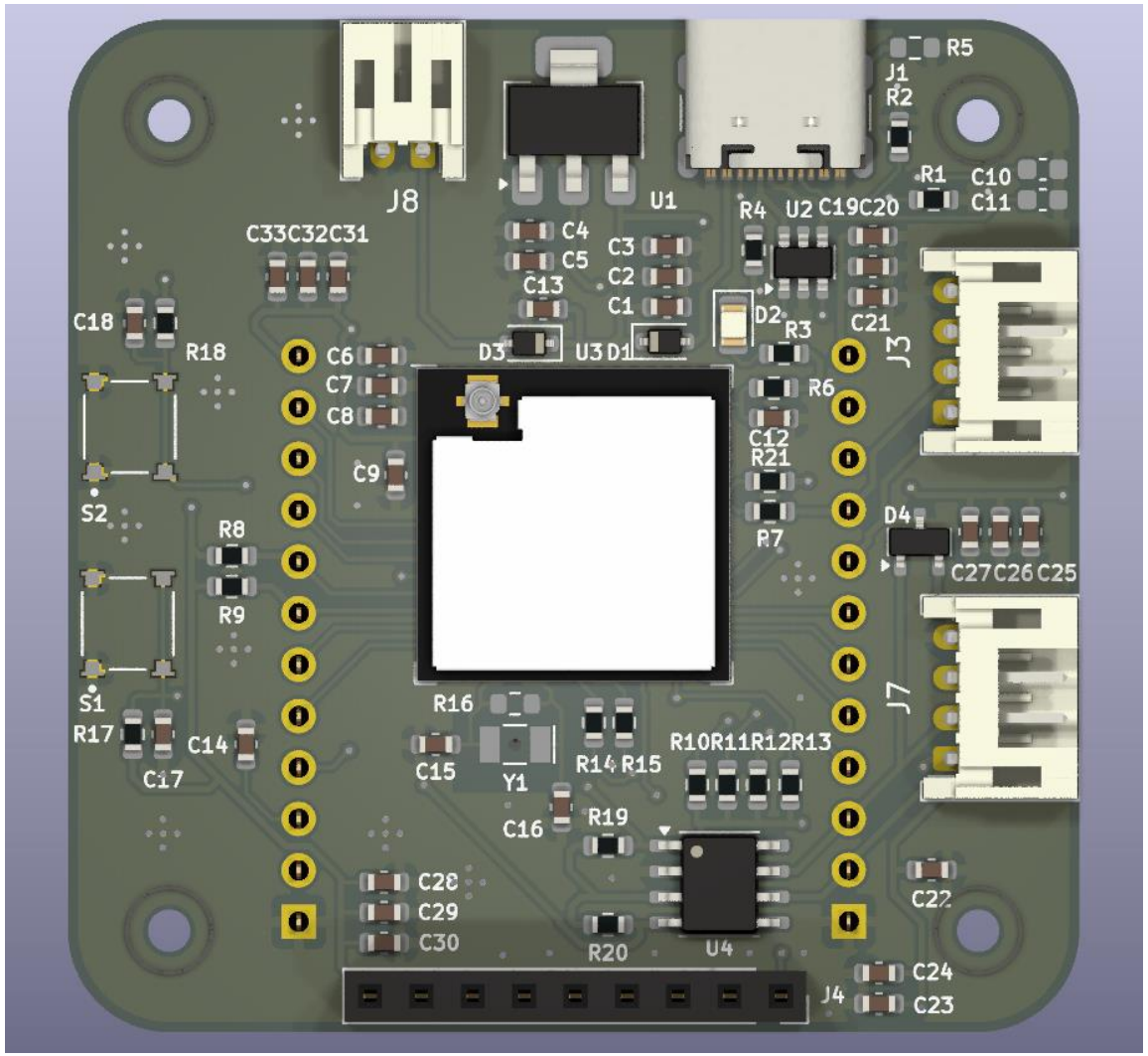
- Dimensions 5x5 cm

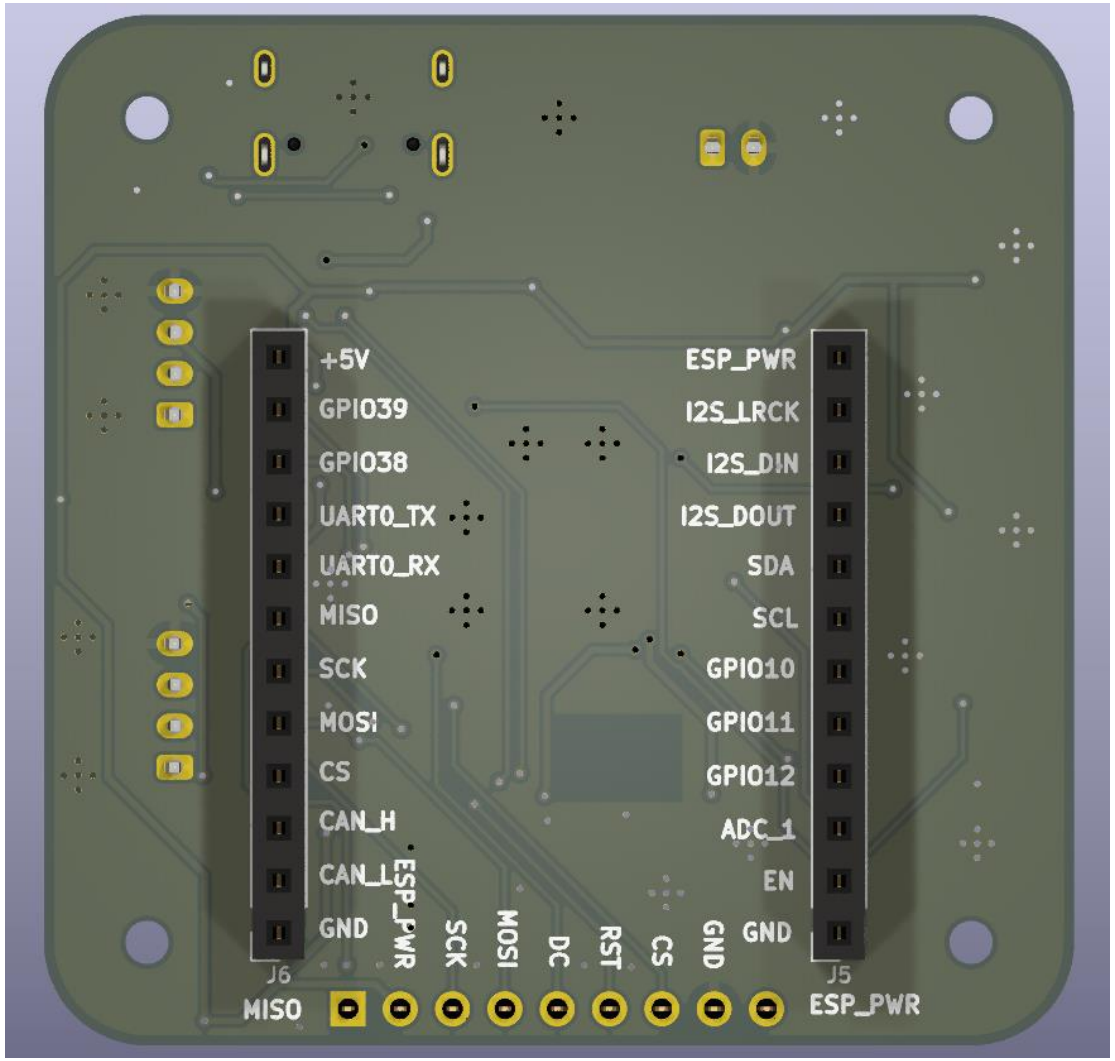
- USB-C power and programming

- Header for display



FriStack - Core





Future challenges

- Flashing modules through Core using DFU, OTA or SPI

- Development of AI, IoT, battery modules

- Compatibility with M5Stack CoreS3

Reliability of ESP-NOW in IoT networks

Concept of measurement

- Use of two ESP32-C6-DevKitM-1

- Two types of environment: **open field** and **forest**

- Performance metrics : **Latency, Speed, Packet loss**

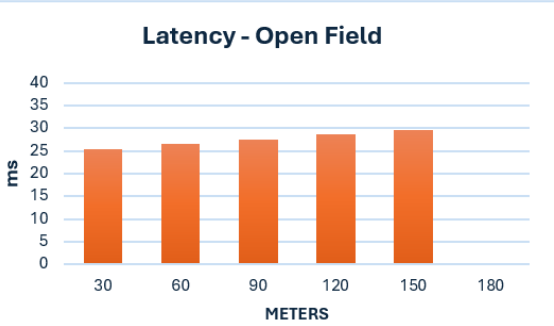
Theoretical characteristics – Wi-Fi

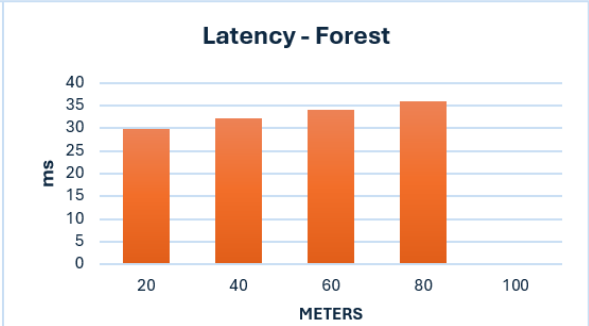
- **Range -** Up to 100 meters in open environments; reduced to 30-50 meters in dense forests

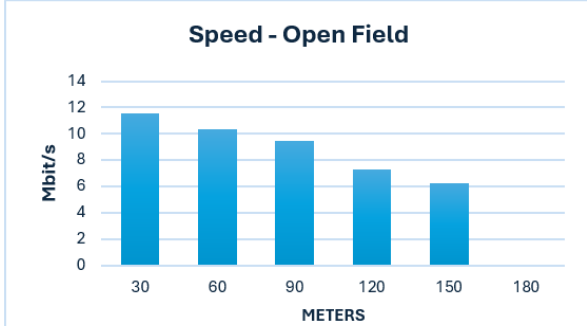
- **Speed -** High throughput in optimal conditions but heavily affected by obstructions

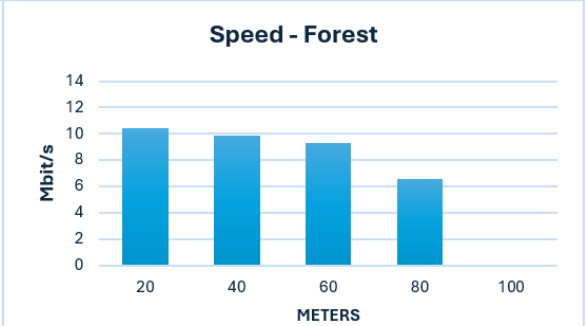
- **Latency -** Moderate, varying between 50-100 ms depending on network congestion and distance

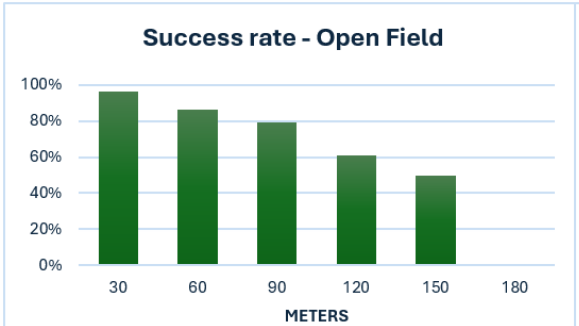
Wi-Fi

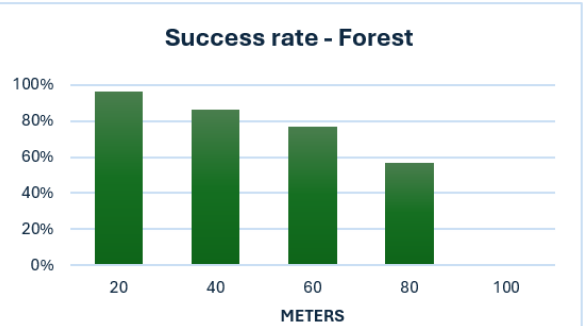

Latency - Open Field
ms
40
35
30
25
20
15
10
5
0
30
60
90
120
150
180
METERS


Latency - Forest
ms
40
35
30
25
20
15
10
5
0
20
40
60
80
100
METERS


Speed - Open Field
Mbit/s
14
12
10
8
6
4
2
0
30
60
90
120
150
180
METERS


Speed - Forest
Mbit/s
14
12
10
8
6
4
2
0
20
40
60
80
100
METERS


Success rate - Open Field
100%
80%
60%
40%
20%
0%
30
60
90
120
150
180
METERS


Success rate - Forest
100%
80%
60%
40%
20%
0%
20
40
60
80
100
METERS

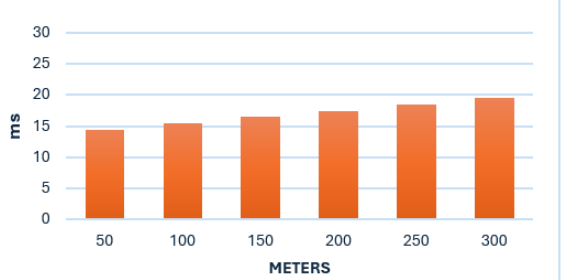
Theoretical characteristics – ESP-NOW

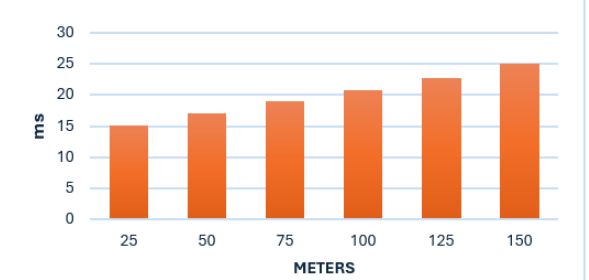
- **Range -** Up to 300 meters in open fields; 100-150 meters in dense forests

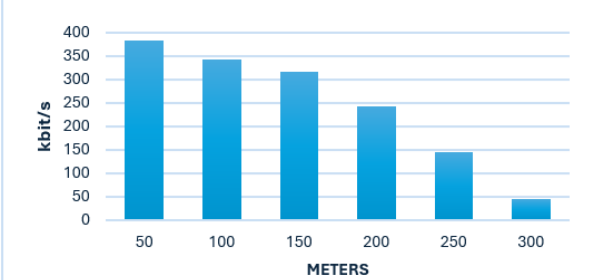
- **Speed -** Moderate (250 kbps to 500 kbps), sufficient for IoT data exchange

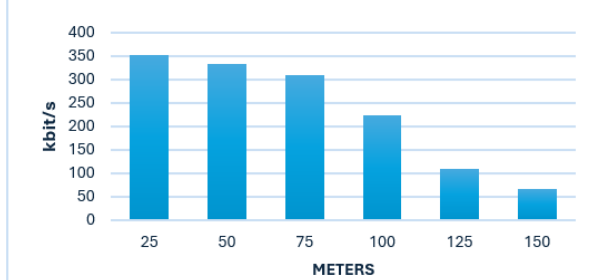
- **Latency -** Very low (10-20 ms), making it ideal for real-time applications

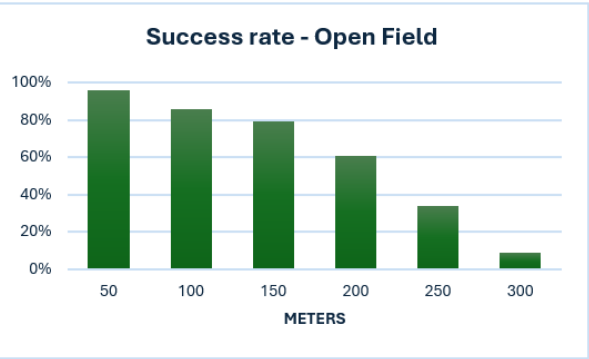
ESP-NOW

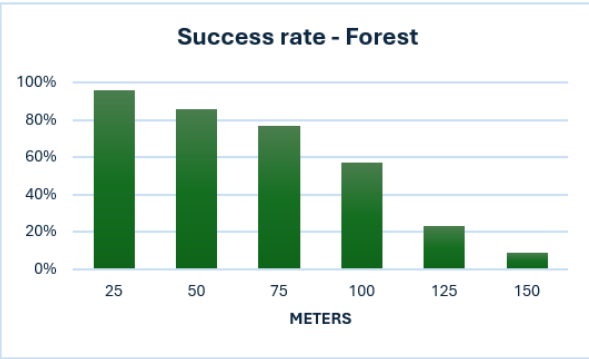

Latency - Open Field
ms
30
25
20
15
10
5
0
50
100
150
200
250
300
METERS


Latency - Forest
ms
30
25
20
15
10
5
0
25
50
75
100
125
150
METERS


Speed - Open Field
kbit/s
400
350
300
250
200
150
100
50
0
50
100
150
200
250
300
METERS


Speed - Forest
kbit/s
400
350
300
250
200
150
100
50
0
25
50
75
100
125
150
METERS


Success rate - Open Field
100%
80%
60%
40%
20%
0%
50
100
150
200
250
300
METERS


Success rate - Forest
100%
80%
60%
40%
20%
0%
25
50
75
100
125
150
METERS

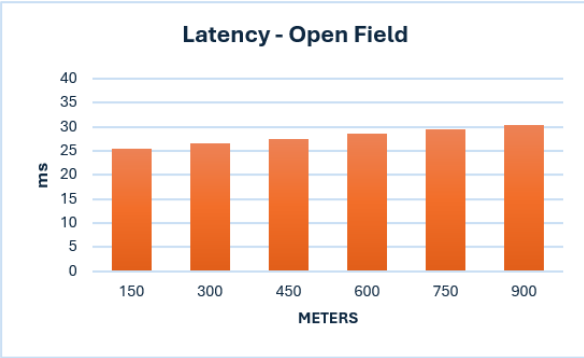
Theoretical characteristics – ESP-NOW-LR

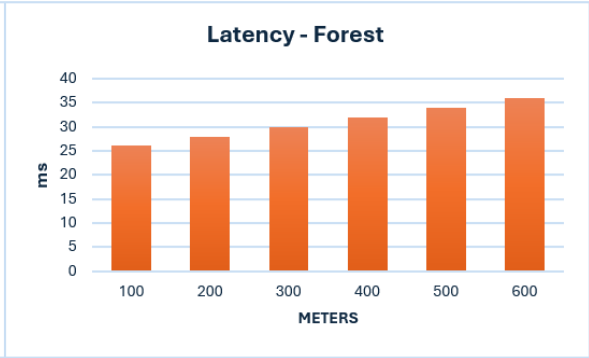
- **Range -** Up to 1 kilometre in open areas; 400 - 800 meters in forests

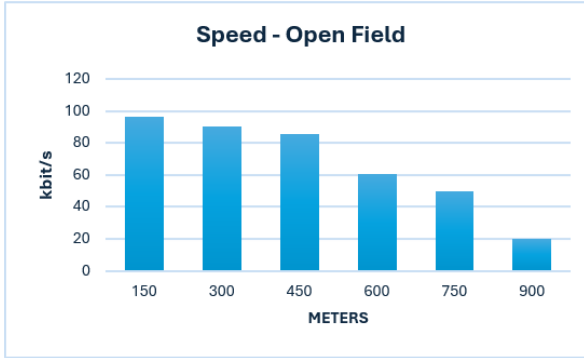
- **Speed -** Lower (50 - 100 kbps) compared to ESP-NOW, traded for long-range reliability

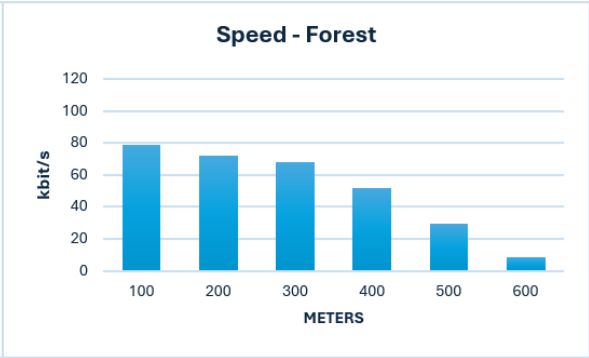
- **Latency -** Low (20 - 30 ms) but increases slightly with distance

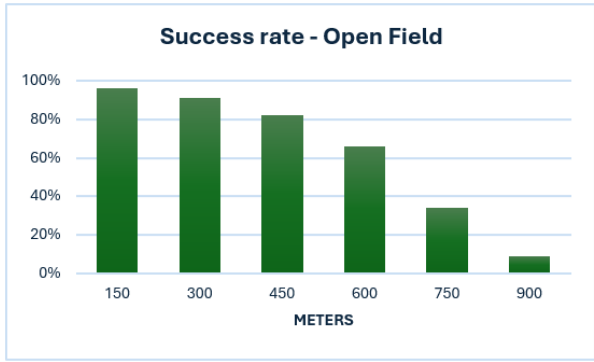
ESP-NOW-LR

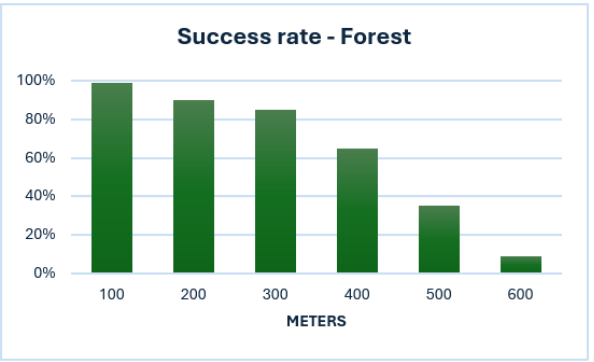

Latency - Open Field
ms
40
35
30
25
20
15
10
5
0
150
300
450
600
750
900
METERS


Latency - Forest
ms
40
35
30
25
20
15
10
5
0
100
200
300
400
500
600
METERS


Speed - Open Field
kbit/s
120
100
80
60
40
20
0
150
300
450
600
750
900
METERS


Speed - Forest
kbit/s
120
100
80
60
40
20
0
100
200
300
400
500
600
METERS


Success rate - Open Field
100%
80%
60%
40%
20%
0%
150
300
450
600
750
900
METERS


Success rate - Forest
100%
80%
60%
40%
20%
0%
100
200
300
400
500
600
METERS

Conclusion

- Wi-Fi is ideal for high-speed communication in controlled environments

- ESP-NOW balances power efficiency and responsiveness for local IoT networks

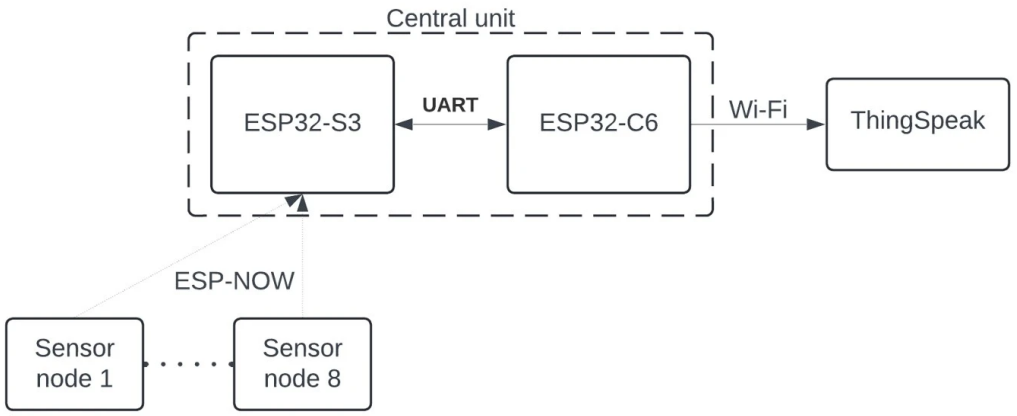
- ESP-NOW-LR excels in long-range, low-power communication, especially in dense forests

Concept of measurement

- Central unit which consists of ESP32-S3 and ESP32-C6

- 8 sensor nodes based on ESP32 simulating sensor data

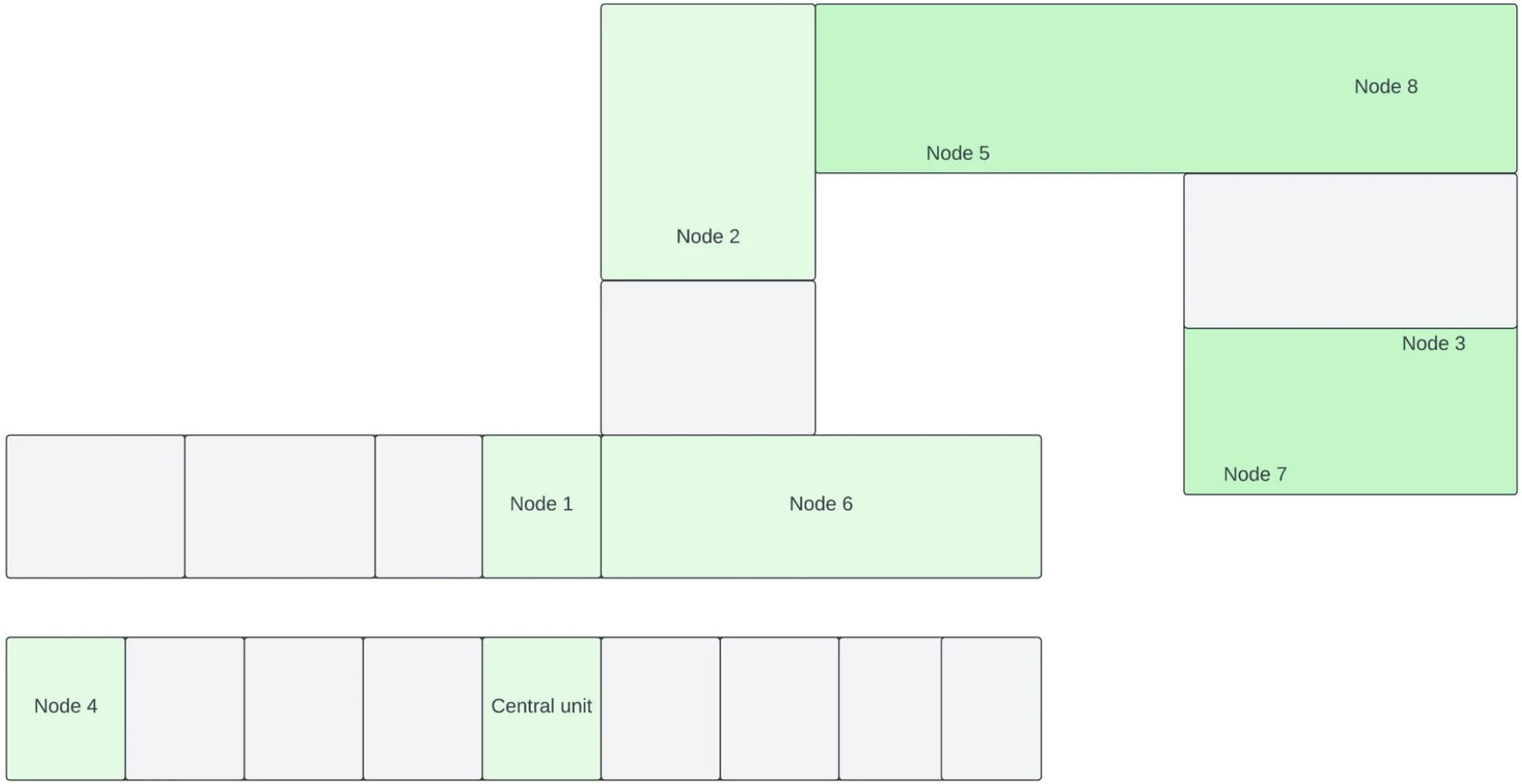
- System placement on our department



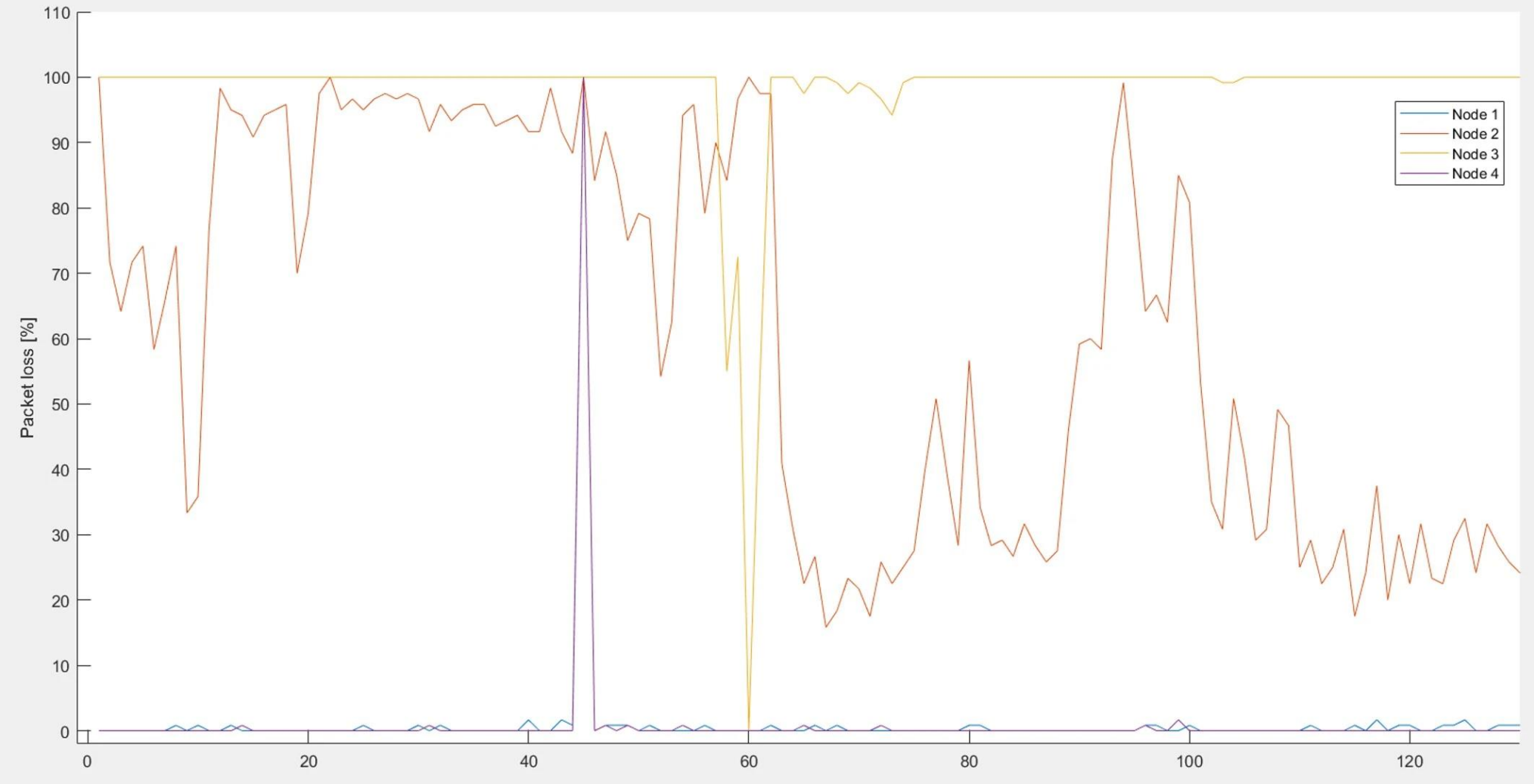
- Data has been sent to CU with period 250ms = 4 packets per second

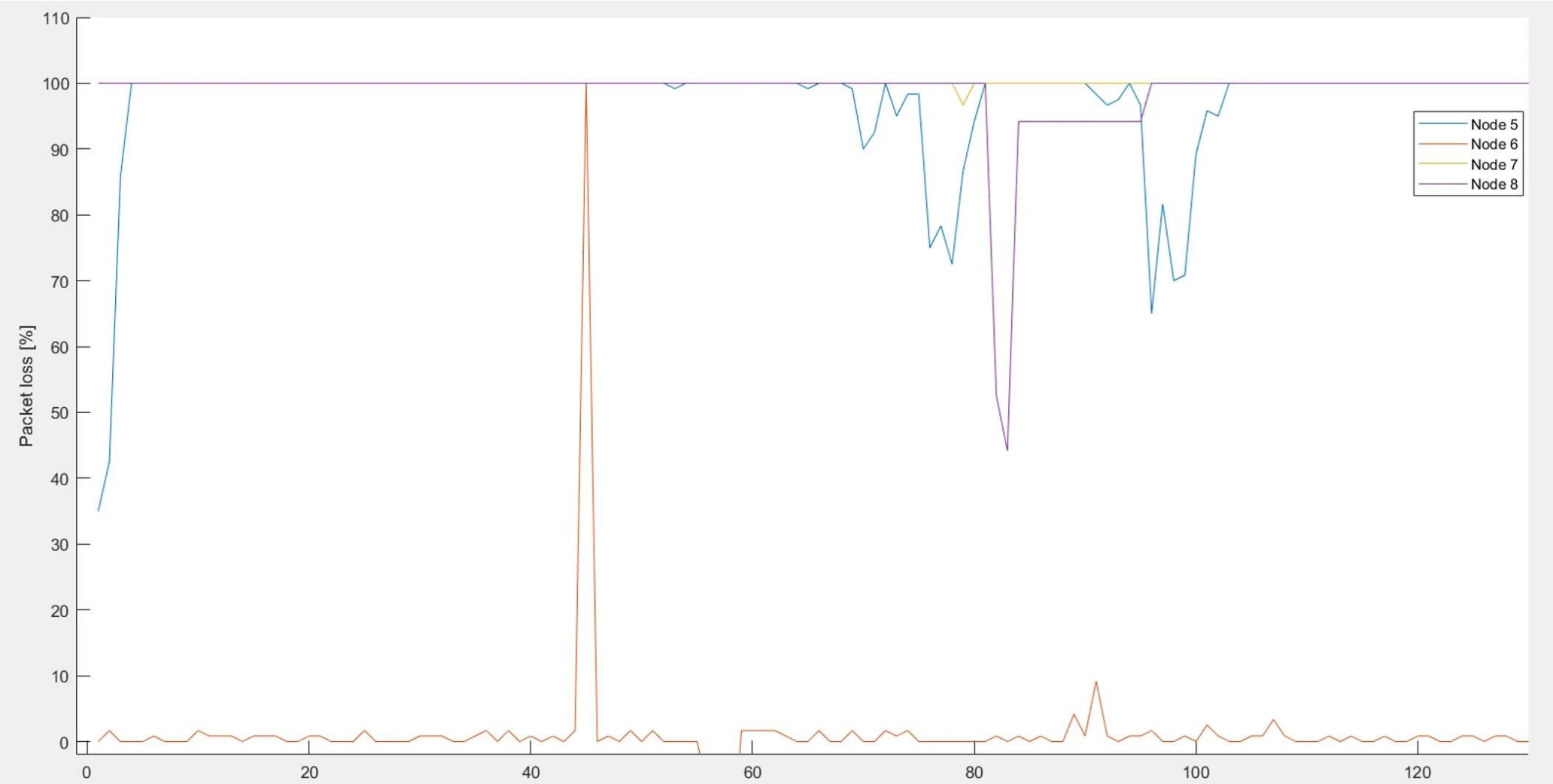
- Number of received packets is calculated for 30 seconds = 120 packets are expected with 0% packet loss

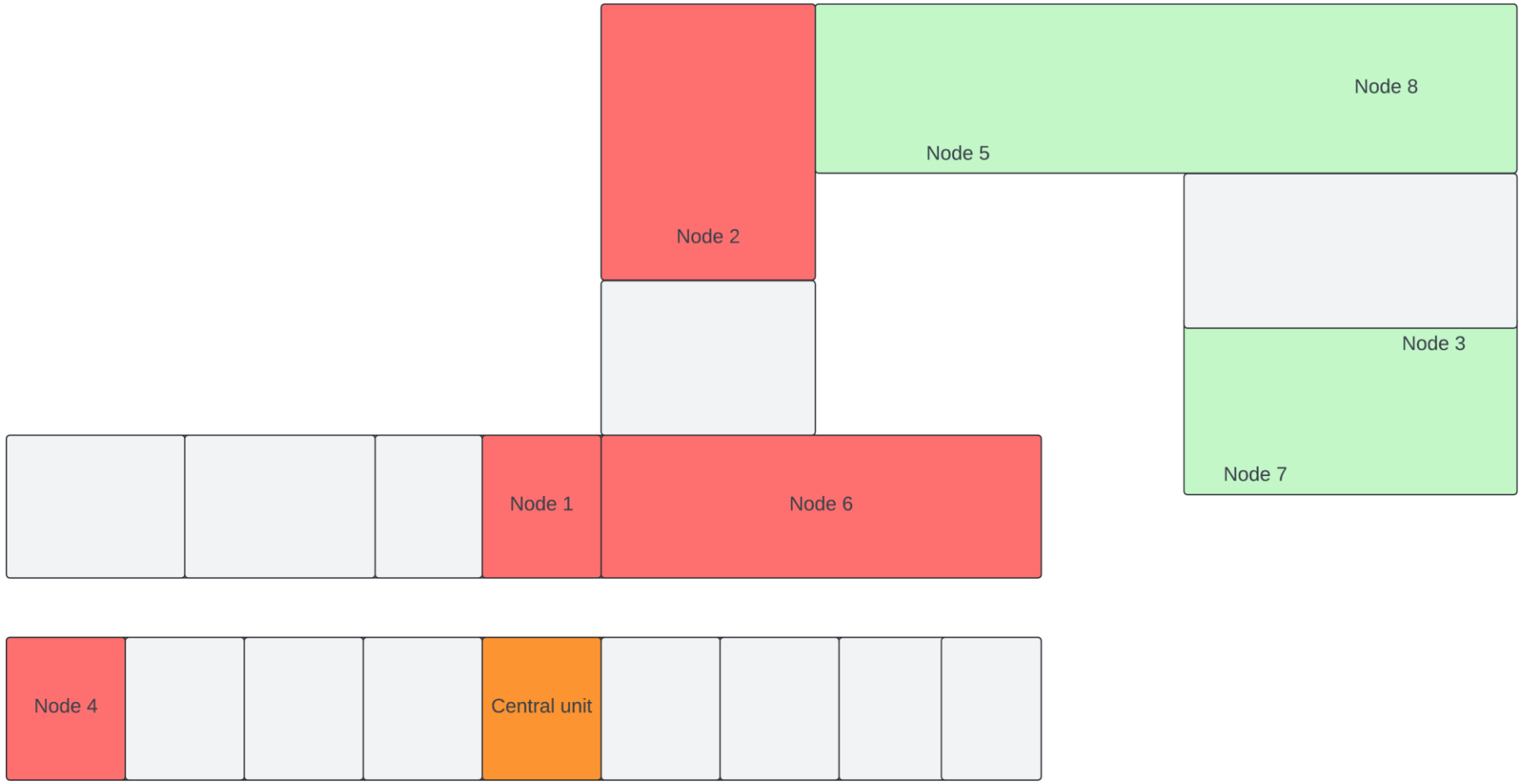
Placement


Node 8
Node 5
Node 2
Node 3
Node 7
Node 1
Node 6
Node 4
Central unit

Results


Packet loss [%]
110
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Node 1
Node 2
Node 3
Node 4


Packet loss [%]
110
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Node 5
Node 6
Node 7
Node 8


Node 8
Node 5
Node 2
Node 3
Node 7
Node 1
Node 6
Node 4
Central unit

Conclusion

- Packet loss highly depends on structure of the building – number and structure of the walls between devices, percentage of open space

- Research leads to add more nodes to increase precision of analysis

- Divide building to segments with highest percentage of open space, and usage of multiple central units

- Software control of packet delivery and solve the issue of non-delivery status

Thank you for your attention

simkovic4@stud.uniza.sk gancarcik2@stud.uniza.sk kubascik@stud.uniza.sk sumsky@stud.uniza.sk