# Reducing energy consumption on internal communications of unmanned vehicles with HAMSTER's Navigation Phases

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# Introduction

- Unmanned Vehicle (UV) is a vehicle without a person on board;
- They can be remotely or autonomously controlled;
- Applications:
  - A wide range of environmental sensing activities;
  - High risk areas monitoring;
  - Driving assistance;
  - Monitoring activities;
  - And much more.
- Energy consumption is currently one of the biggest concerns.

# Fly by Wireless

- The substitution of cables for wireless communications **inside** the vehicle;
- Advantages:
  - More flexibility for topology changes;
  - Easier substitution of malfunctioning devices;
  - Reduction on vehicle's weight (up to 28%).
- Challenges:
  - Wireless communications are more challenging than wired ones;
  - Inherent wireless vulnerabilities regardng security and safety;
  - Energy consumption reduction.

# HAMSTER Architecture

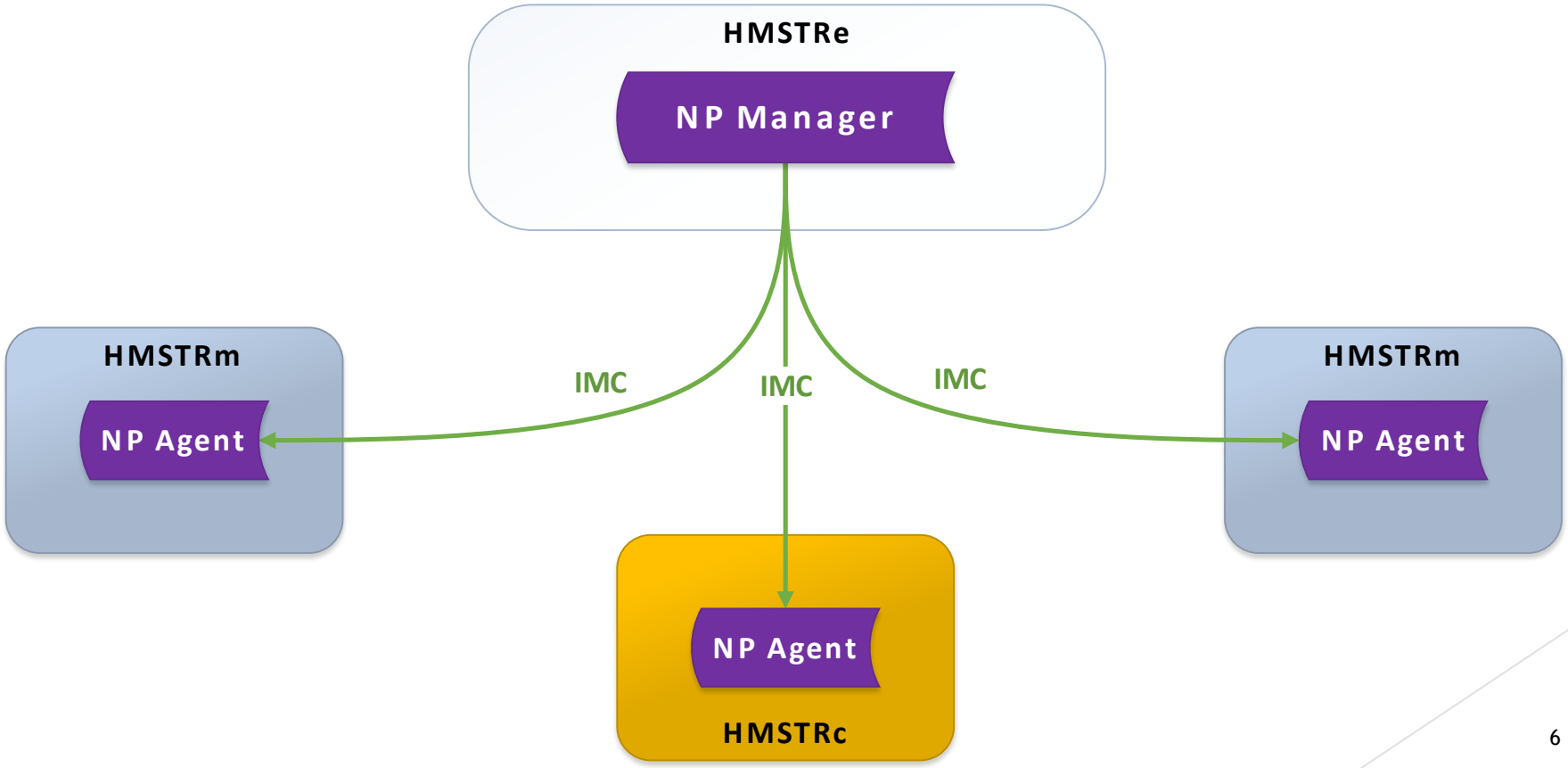
- **HeA**lthy, **M**obility and **S**ecurity-based data communication archi**TE**ctu**R**e
  - Provides well-defined ways of implementing communications in unmanned vehicles and systems;
- HAMSTER is designed for three main types of vehicles:
  - Aerial (Flying HAMSTER);
  - Ground (Running HAMSTER); and
  - Aquatic (Swimming HAMSTER).
- HAMSTER provides a platform for energy reduction:
  - Navigation Phases platform.

# Navigation Phases

- A navigation phase is a very well defined UV operation stage;
- Each phase defines:
  - If a module is ON/OFF;
  - The allowed transmission rate.

NP | HAMSTER Architecture

# Navigation Phases



# Methodology: phases definition

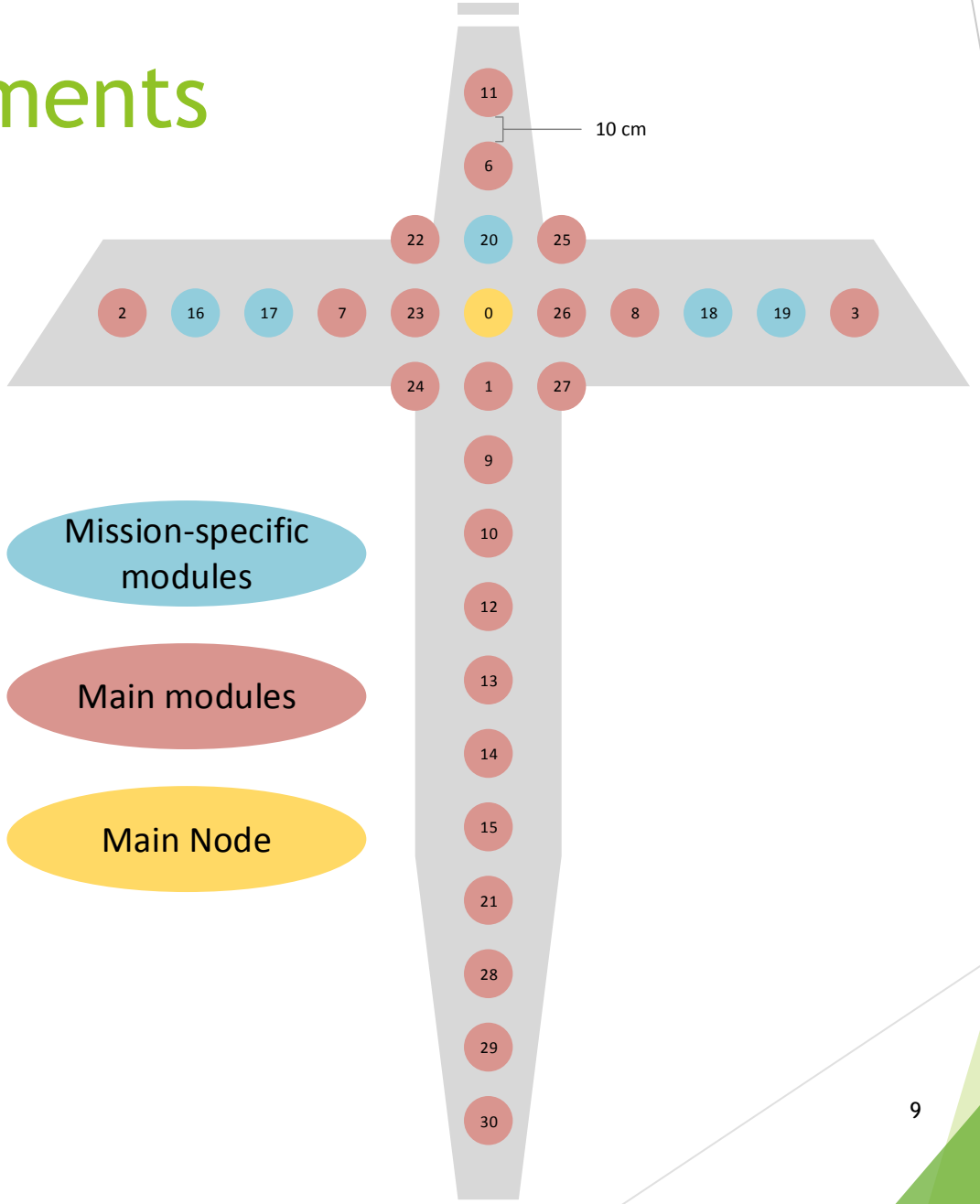
| Navigation phases | Navigation Sub-phases | ID | Description | Active modules | Identifier |
|---|---|---|---|---|---|
| 1 | Pre-flight | 1.1 | Modules health, energy and authentication checking | All nodes | ALL |
| 2 | Departure and climb | 2.1 | Taxiing | Main nodes only | MAIN |
| | | 2.2 | Taking-off | Main nodes only | MAIN |
| | | 2.3 | Climbing | Main nodes only | MAIN |
| 3 | Cruise | 3.1 | Stabilising from climbing | Main nodes only | MAIN |
| | | 3.2 | Heading to the destination | All nodes | ALL |
| | | 3.3 | Performing mission | All nodes | ALL |
| | | 3.4 | Preparing to descent | Main nodes only | ALL |
| 4 | Descent and approach | 4.1 | Descending | Main nodes only | MAIN |
| | | 4.2 | Landing | Main nodes only | MAIN |
| | | 4.3 | Taxiing | Main nodes only | MAIN |
| 5 | Post-flight | 5.1 | Modules health, energy and authentication checking | All nodes | ALL |
| | | 5.2 | Mission data manipulation | Mission nodes only | MISSION |
| E | Emergencies | E.1 | Returning to the Ground Control Station | Main nodes only | MAIN |
| | | E.2 | Landing ASAP | Main nodes only | MAIN |
| | | E.3 | Starting self-destruction (wipe data) | Mission nodes only | MISSION |
| | | E.4 | Stabilising (after non predicted movements) | Main nodes only | MAIN |

# Methodology: phases definition

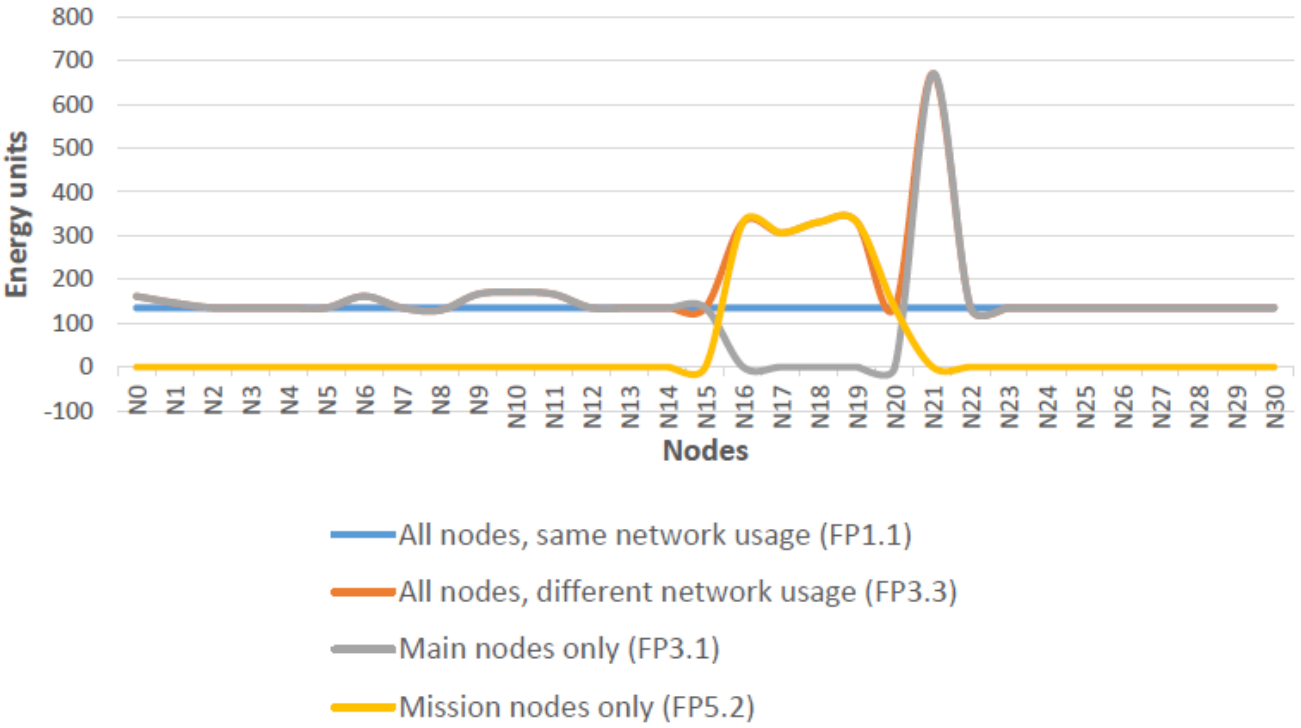
- **Pre-flight** phase is dedicated to several inspections;
- **Departure and climbing** phase occurs when the UAV is moving on the ground, taking off and stabilising in the air;
- **Cruise** phase is usually the longest flight. It represents the flight itself;
- **Descent and approach** phase is the period when the UAV starts to descend, land and then move on the ground;
- **Post-flight** phase is similar to pre-flight. Health checking and acquisition of mission data;
- **Emergencies** phase includes various abnormal situations, such as power outages, flight difficulties, adverse weather conditions, unexpected obstacles, security attacks etc.

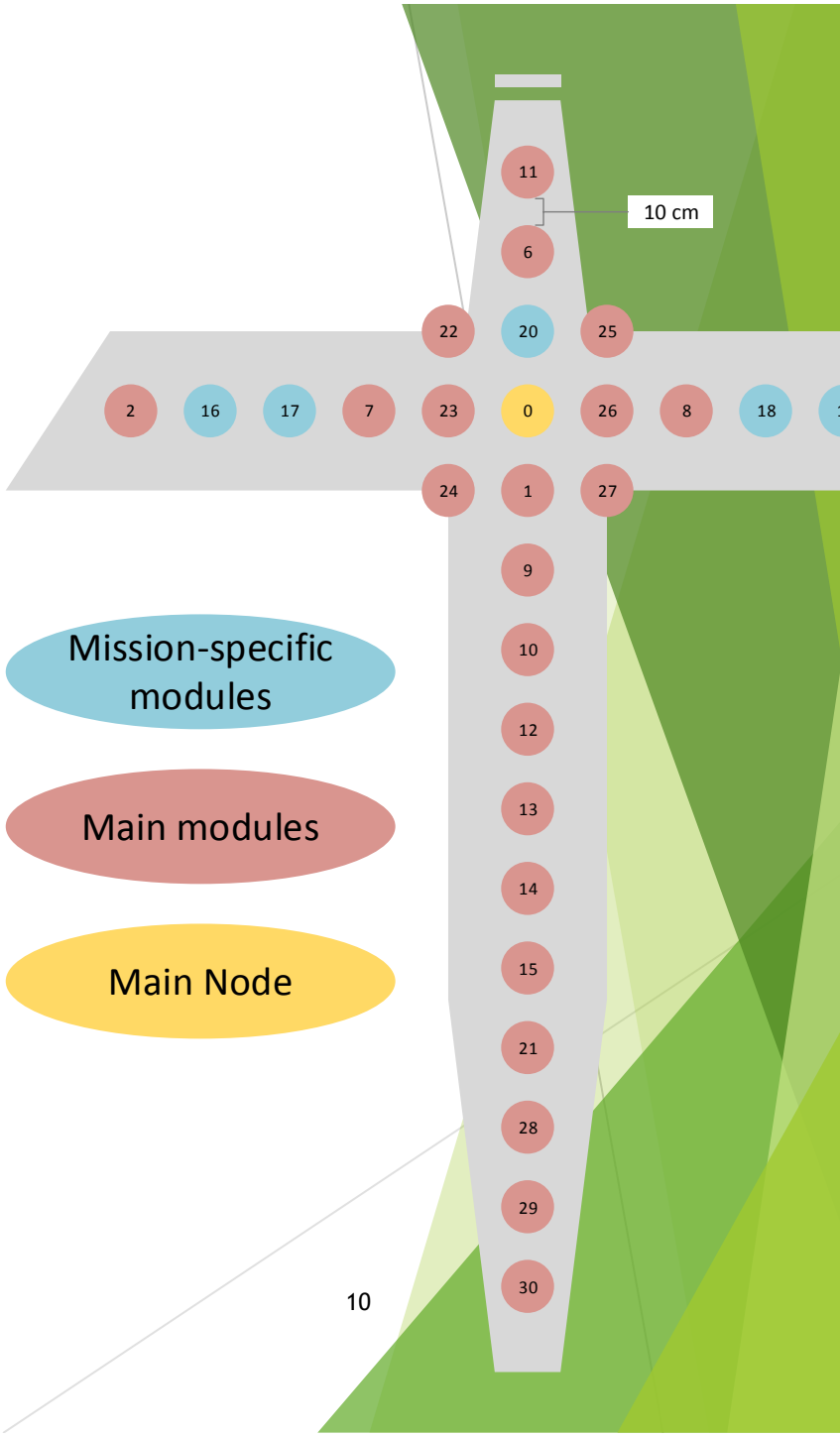
# Simulated experiments

- OMNeT++ simulator;
- Nodes were created with ZigBee adapters;
- All the simulation phases were modeled;
- Results show different consumption in each phase.



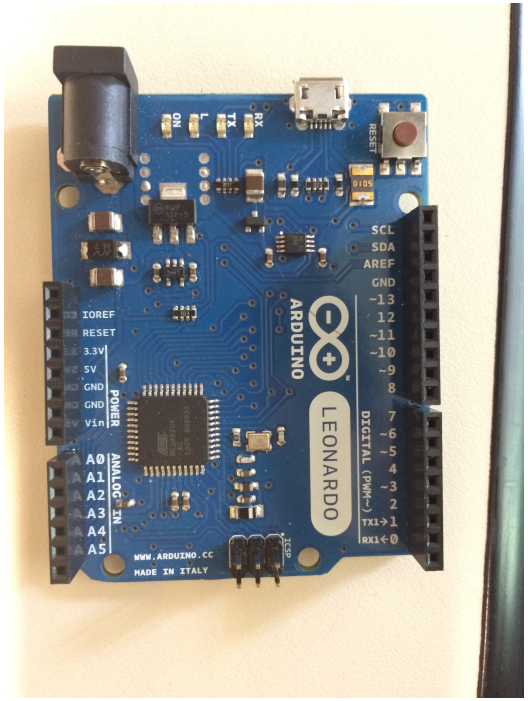
# Simulated experiments



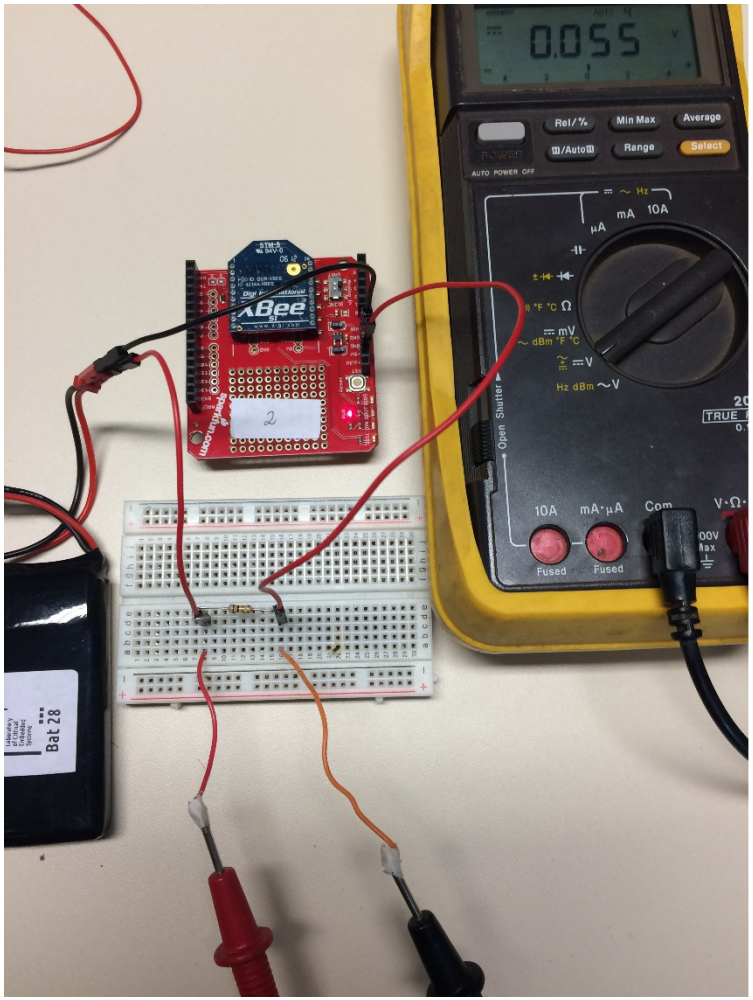



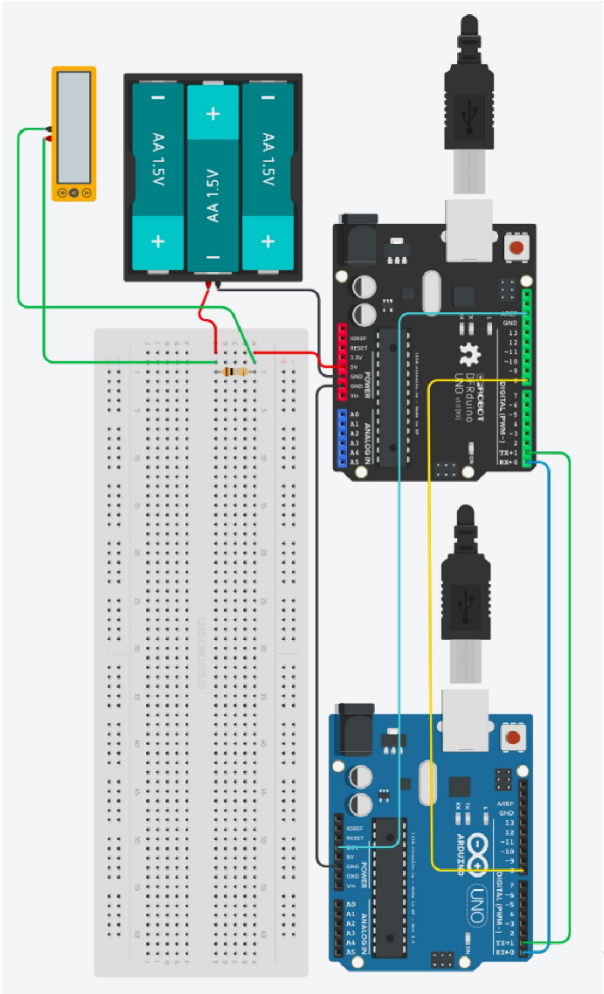
# Field experiments

- These experiments were performed using 6 modules:
  - Arduino + XBee.
- Different antennas for XBee were tested too;
- All modules send messages to a central one.



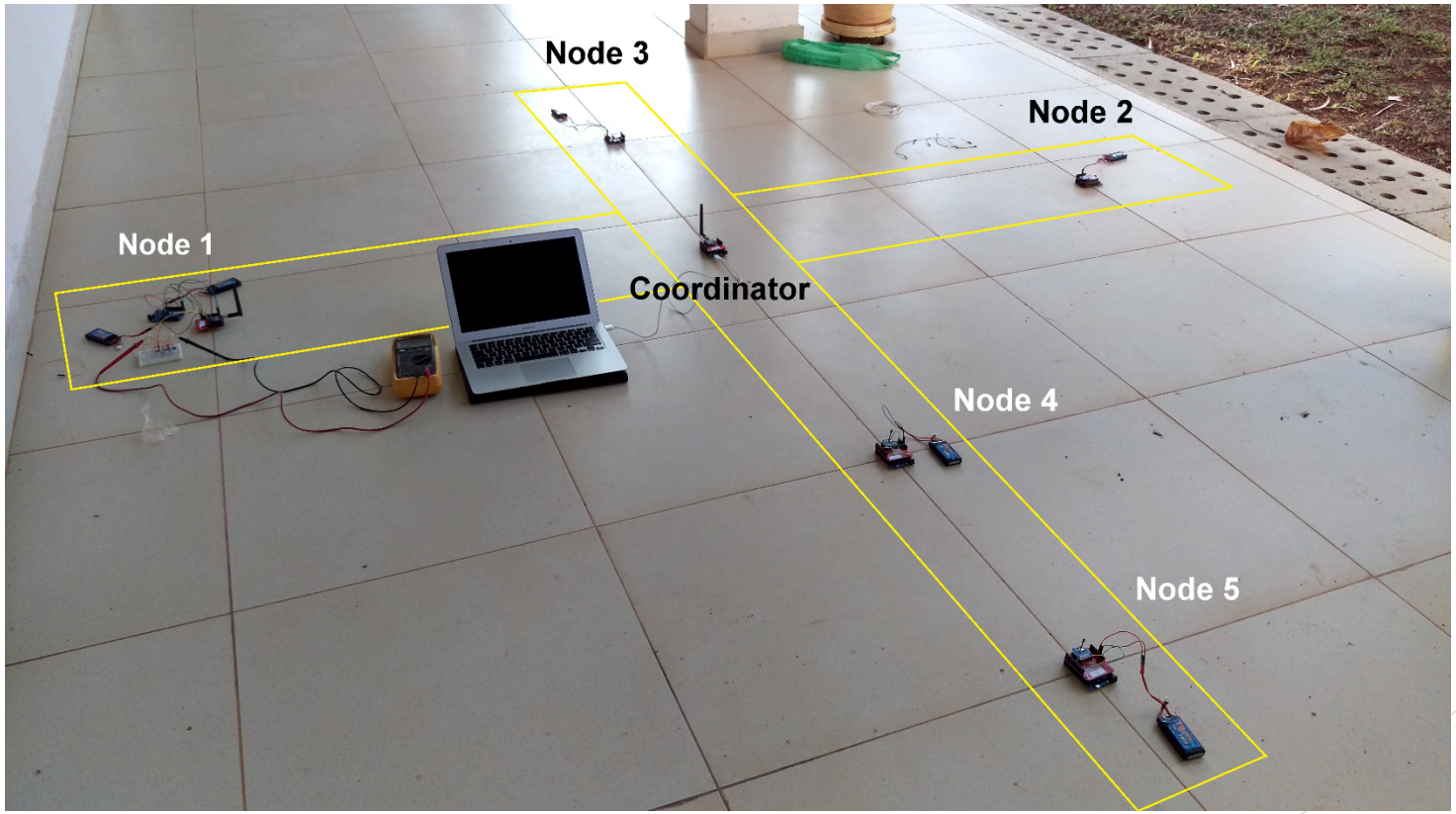

# Field experiments



# Field experiments

sages were sent with a frequency of **2 Hz** by defining a **delay of 500 ms**.
tal of **6 experiment replications** were carried out. In each replication, **nodes 1, 2 and 3**
t **648 messages** each, while **nodes 4 and 5 sent 400 messages**.



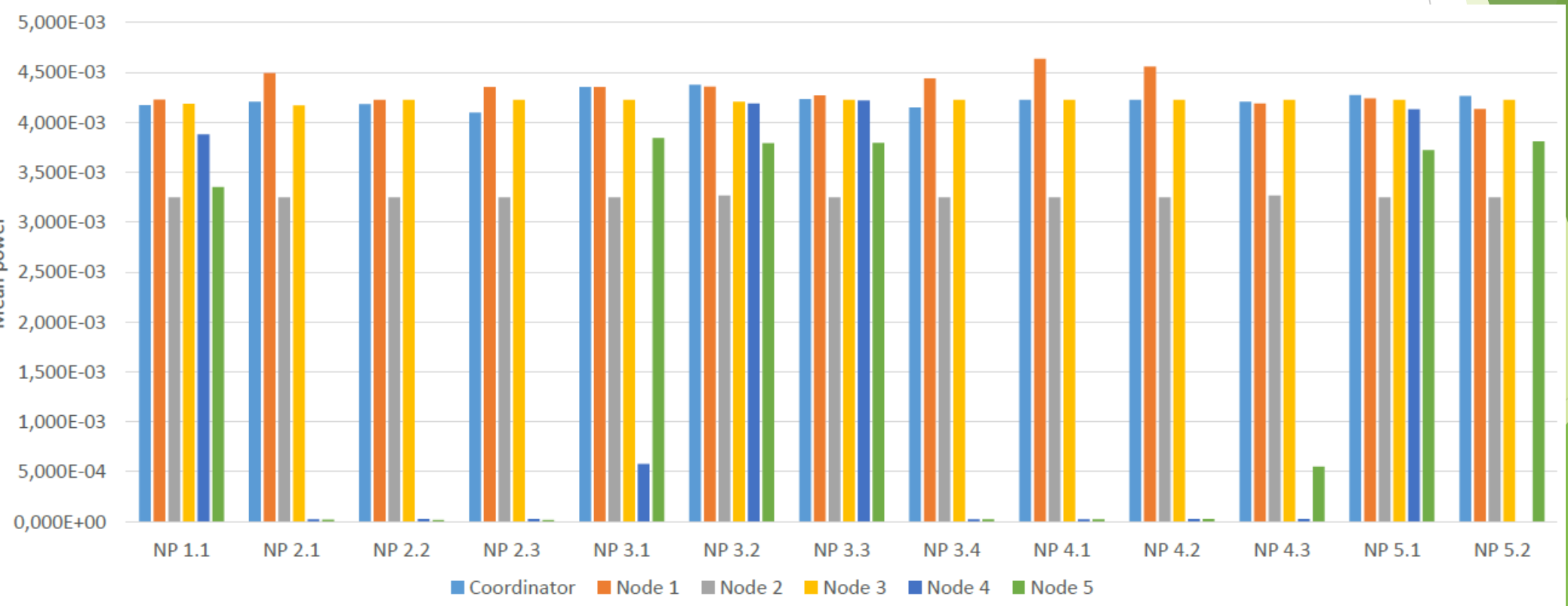
# Field experiments

| avigation Phases | Main nodes | | | Mission Nodes | | Duration (s) |
|---|---|---|---|---|---|---|
| | N1 | N2 | N3 | N4 | N5 | |
| 1.1 | 1 | 1 | 1 | 1 | 1 | 40 |
| 2.1 | 2 | 2 | 2 | 0 | 0 | 30 |
| 2.2 | 4 | 4 | 4 | 0 | 0 | 10 |
| 2.3 | 4 | 4 | 4 | 0 | 0 | 6 |
| 3.1 | 4 | 4 | 4 | 0 | 0 | 2 |
| 3.2 | 4 | 4 | 3 | 5 | 5 | 30 |
| 3.3 | 2 | 2 | 2 | 5 | 5 | 60 |
| 3.4 | 4 | 4 | 4 | 0 | 0 | 20 |
| 4.1 | 4 | 4 | 4 | 0 | 0 | 20 |
| 4.2 | 4 | 4 | 4 | 0 | 0 | 6 |
| 4.3 | 2 | 2 | 2 | 0 | 0 | 30 |
| 5.1 | 2 | 2 | 2 | 2 | 2 | 40 |
| 5.2 | 3 | 3 | 3 | 5 | 5 | 30 |

| Reference | Size in bytes |
|---|---|
| Off (0) | 0 |
| Low (1) | 4 |
| Medium-low (2) | 8 |
| Medium (3) | 16 |
| Medium-high (4) | 32 |
| High (5) | 64 |

finition of a mission that contemplates different Navigation Phases. An
ividual packet size was defined for each and different time durations for each phase.

# Field experiments



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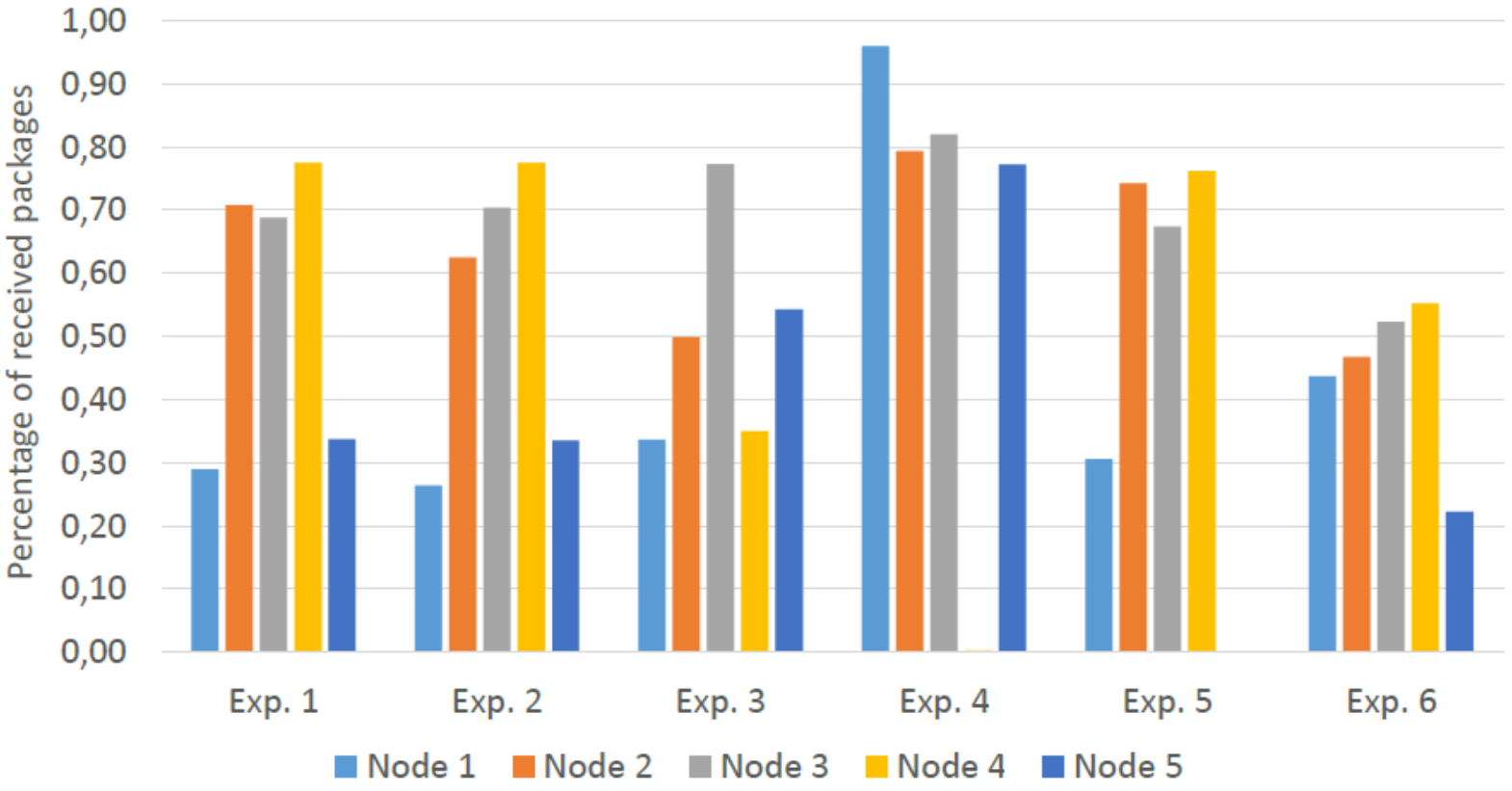

# Conclusions

- This paper presented results related on fly by wireless with Navigation Phases platform;
- Simulated experiments were performed to explore scenarios with a high number of nodes;
- Then, field experiments on a real prototype were also carried out to identify the impact on energy consumption by:
  - Different XBee boards;
  - Different antenna types; and
  - Inactive nodes.

# Thank you!

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www.lsec.icmc.usp.br/hamster


**HAMSTER**
**Architecture**