### \*\*1. Physical Layer\*\*

#### \*\*Description\*\*

This layer involves modeling drone parameters and behavior considering physical factors. OMNeT++ supports such tasks through frameworks like \*\*INET\*\* or \*\*Veins\*\*.

#### \*\*Implementation\*\*

- \*\*Drone Model\*\*:

- Create a module (NED file) for the drone, including parameters such as the number of rotors, weight, and battery capacity.

- Use these parameters in calculations, e.g., energy consumption.

- \*\*Energy Consumption\*\*:

- Add a C++ class for calculating battery discharge

, depending on speed, weight, and maneuvers.

- Implement an event (`cMessage`) to decrement the battery charge during movements.

#### \*\*Approaches\*\*

- Use a custom `SimpleModule` to store and compute physical parameters.

- If advanced movement modeling is needed, consider integrating OMNeT++ with external engines like MATLAB or Python.

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### \*\*2. Basic Protocol Layer\*\*

#### \*\*Description\*\*

The goal of this layer is to enable message exchange between drones and the operator, as well as handling basic commands (movement, stopping, interactions).

#### \*\*Implementation\*\*

- \*\*Message Protocol\*\*:

- Use OMNeT++ messages (`cMessage`) for data transmission.

- Define standard message types (e.g., `MOVE\_TO`, `STATUS`, `CHARGE`).

- \*\*Network Topologies\*\*:

- Use the INET Framework to create wireless network models.

- Leverage WiFi modules for communication simulation.

- Implement swarm topologies: centralized (through a leader) or decentralized.

- \*\*Command Handling\*\*:

- Write C++ handlers for basic commands.

- Use message queues to manage drone actions.

#### \*\*Approaches\*\*

- Categorize commands into groups (e.g., control, status requests).

- Simulate network delays and message losses for real-world scenarios.

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### \*\*3. User Layer\*\*

#### \*\*Description\*\*

This layer allows users to write scripts that define the swarm's behavior based on the basic protocol.

#### \*\*Implementation\*\*

- \*\*User API\*\*:

- Create an interface for users to write behavior scripts.

- Scripts can be defined through `.ini` configuration files or an external interface.

- \*\*Script Execution\*\*:

- User-defined code should invoke commands from the basic protocol (`SEND\_COMMAND`, `GET\_STATUS`).

- Implement a standard interface to process user protocols.

- \*\*Visualization\*\*:

- Use OMNeT++ GUI to display the current state of drones and their trajectories.

- Add logging for analyzing the performance of user protocols.

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### \*\*Additional Steps\*\*

1. \*\*OMNeT++ Frameworks\*\*:

- \*\*INET Framework\*\*: For implementing network communications.

- \*\*Veins\*\*: For modeling swarm interactions.

2. \*\*Customization\*\*:

- Write custom extensions for energy consumption models and user commands.

3. \*\*Optimization\*\*:

- Implement routing and coordination algorithms for improved energy efficiency.

- Use OMNeT++ statistical modules to evaluate results.

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### 1. \*\*Navigation and Movement Commands\*\*

These commands control the position and movement of the drone:

- \*\*TAKEOFF\*\*: Initiates the drone's takeoff.

- \*\*LAND\*\*: Lands the drone.

- \*\*MOVE TO (x, y, z)\*\*: Moves the drone to a specified point by coordinates.

- \*\*HOVER\*\*: Keeps the drone hovering in place.

- \*\*ROTATE (yaw/pitch/roll)\*\*: Rotates the drone along its axes.

- \*\*SET VELOCITY (vx, vy, vz)\*\*: Sets the drone's speed in a specific direction.

- \*\*FOLLOW (target\_id)\*\*: Follows another object (e.g., another drone).

- \*\*RETURN TO BASE\*\*: Returns the drone to the starting point (or a designated base point).

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### 2. \*\*State Management Commands\*\*

These commands are used to control and monitor the drone's state:

- \*\*STATUS\*\*: Requests the drone's current state (battery charge, coordinates, speed, altitude).

- \*\*STOP\*\*: Immediately halts all drone movements.

- \*\*CALIBRATE\*\*: Calibrates sensors (e.g., gyroscope, compass).

- \*\*SET MODE (e.g., manual, autopilot)\*\*: Switches between manual and autopilot modes.

- \*\*ARM\*\*: Activates the motors (preparing for takeoff).

- \*\*DISARM\*\*: Deactivates the motors.

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### 3. \*\*Sensor Data and Monitoring\*\*

Modern drones are equipped with various sensors. These commands enable data collection and processing:

- \*\*GET POSITION\*\*: Requests the current coordinates.

- \*\*GET ALTITUDE\*\*: Requests the current altitude.

- \*\*GET BATTERY STATUS\*\*: Checks the battery level.

- \*\*GET SENSOR DATA\*\*: Retrieves data from various sensors (e.g., camera, LiDAR, ultrasonic sensors, barometer).

- \*\*START STREAM (e.g., video, telemetry)\*\*: Starts real-time video or telemetry streaming.

- \*\*STOP STREAM\*\*: Stops the ongoing data stream.

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### 4. \*\*Inter-Drone Communication\*\*

These commands are useful for swarm coordination:

- \*\*BROADCAST (message)\*\*: Sends a message to all drones.

- \*\*SEND TO (target\_id, message)\*\*: Sends a command or message to a specific drone.

- \*\*SYNC POSITION\*\*: Synchronizes current coordinates with other drones.

- \*\*REQUEST NEIGHBOR LIST\*\*: Retrieves a list of nearby drones (based on network or physical topology).

- \*\*FORM FORMATION (shape)\*\*: Forms a specified shape (e.g., line, circle, triangle).

- \*\*LEAD (target\_id)\*\*: Transfers leadership to another drone.

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### 5. \*\*Energy Management Commands\*\*

These commands focus on energy efficiency and safety:

- \*\*CHECK CHARGE\*\*: Checks the remaining battery charge.

- \*\*GO TO CHARGING STATION\*\*: Directs the drone to a charging station.

- \*\*OPTIMIZE ROUTE\*\*: Calculates the most energy-efficient route.

- \*\*POWER SAVE MODE\*\*: Switches to a power-saving mode (e.g., reduces sensor update frequency).

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### 6. \*\*Emergency Commands\*\*

These commands ensure safe operation in critical situations:

- \*\*EMERGENCY LAND\*\*: Initiates immediate landing at the nearest safe location.

- \*\*RETURN TO HOME\*\*: Returns the drone to its starting point.

- \*\*SHUTDOWN\*\*: Immediately powers down all systems.

- \*\*ACTIVATE FAILSAFE\*\*: Activates fallback protocols (e.g., maintaining the current position).

Functions need to be implemented in physical layer:

1. Collision detection:

\* collision as result of received command

\*Optionally: collision with another object in environment

2. Energy consumptions calculation (depends on weight, movement, battery capacity, antena's needs and sensors)

3. Movement in 3D

4. TCP/UDP protocols

5. Telemetry functions

6. Must contains different frequences for antena

7. Need to be node "master" on map

8. Using different signal propagation models: Free-space path loss, two-ray ground-reflection model, Knife-edge diffraction model. And as result more accuracy in Packet Error Rate calculation.

9. User will be able to choose communication type: WiFi or Radio

**Collision detection:**  
 Option to check collision with near object using "sensors".

Option to check trajectory collision.

- For collision detection need to know drone size - maybe enough radius of sphere around middle point of drone.

**GUI:**

1. Must have an option for creating basis station before simulation start (1 - default value):

\* if more than one basis station created, need to assigne drones to relevant station (what number of drones starting at basis station number X).

2. Option to manual stop of simulation.

3. Maybe: option for pause.

4. Where drones starting simulation: on ground from basis station or in flight around basis station.

5. Option for move basis station to new location.