MIDDLE EAST TECHNICAL UNIVERSITY

NORTHERN CYPRUS CAMPUS

CNG 436 Wireless Communication and Networks

Spring 2024-2025

Assignment 2

UAV Network with Priority Queuing and Task Offloading

Release Date: Tuesday 29th April 2025

Submission Date: Sunday 1st June 2025 11:59 P.M.

Introduction

In many real-world scenarios (e.g., disaster response, surveillance, or search-and-rescue), Unmanned Aerial Vehicles (UAVs) form an ad hoc network to collect data from the environment or relay data between ground sensors and a base station. Some of these UAVs have additional **edge computing** capabilities, meaning they can process or analyse data on the fly (e.g., image recognition tasks). However, these edge resources are not uniform: some UAVs have powerful on-board devices with CPUs or GPUs ; others have minimal computing resources. Figure 1 displays a simple illustration.

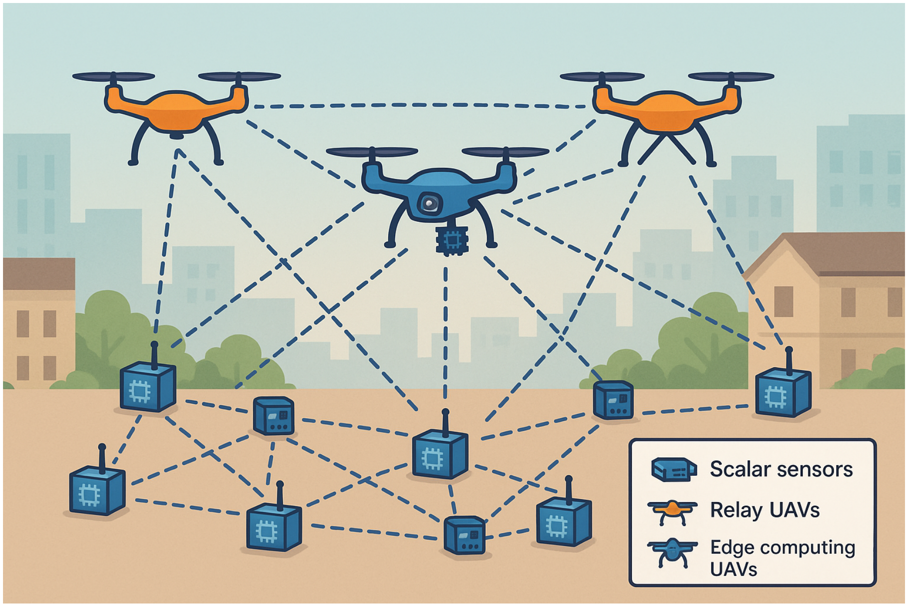

Figure 1: UAV-Sensor Network

Goals and Objectives

The primary goals and objectives of this assignment are:

- To implement simple probability distribution models for simulating packet arrivals, packet attributes (such as type, size, and priority), and UAV-specific attributes (including battery capacity and processing capability).
- To develop a priority queueing mechanism for managing network packets based on their assigned priorities.
- To implement a compute queue for local task processing, incorporating logic to offload tasks to other UAVs when local resources are insufficient.
- To analyse the impact of these mechanisms on overall network performance, focusing on metrics such as throughput, delay, and packet drop rate, under various traffic loads and network configurations.

In this assignment, you will be utilising FlyNet, a simulation platform for UAV networks in Python using SimPy -a process-based discrete-event simulation framework-. A set of guidelines regarding the simulation package will be uploaded on ODTUclass. The platform includes pre-defined:

- **Physical layer:** Channel formation, Path-loss modelling, etc..
- **MAC layer protocols:** Basic wireless medium access protocols such as CSMA/CA and ALOHA.
- **Routing protocols:** Basic protocols such as Distance Vector Routing, and more specialised for UAV ad-hoc networks.
- **Mobility Models:** Random Waypoint, Gauss-Markov and Mission-based mobility.

Tasks

1. Packet Generation & Basic Probability Distributions (15%)

Generate traffic arrivals (packets) in the simulation environment using Poisson processes and random distributions for various attributes. Implement a function that generates packet arrivals according to a Poisson process with rate λ, service (processing) times are also presented with μ. **Ensure that you have a stable system** by choosing appropriate λ and μ values (You can calculate the utilisation analytically). Assign packet type (e.g., text, image, video) via a categorical distribution (e.g., 60% text, 30% image, 10% video). Assign packet size (in MB) based on the type (e.g., smaller for text, larger for video), using an appropriate continuous distribution (uniform distribution could be used for example). Assign importance or priority (high/medium/low) via a discrete distribution (e.g., 20/30/50). Each UAV has a capacity (MB/s), drawn from a continuous distribution (uniform distribution could be used). UAVs also have a battery lifetime, which can be set in the simulation framework. Provide basic statistics: e.g., distribution of packet sizes, proportion of each priority, histogram of UAV capacities, etc.

2. Priority-Based Queueing & Basic Scheduling (25%)

Implement priority queueing for incoming packets at each UAV, with respect to priority classes. Modify the queue structure to store and handle packets of different priorities. Decide which packets should be handled first based on their priority, arrival, and processing times. Provide statistics on packets dropped, queue length over time, and packet delays by priority class. Decide on a drop policy if the UAV's processing capabilitiy is not enough for certain packets (e.g., a UAV with 5 MB/s processing rate receives a 25 MB video packet with a service processing time of 3 s. Since we need to process 8.3 MB/s to complete the task, we will drop this packet since we can only process 5 MB/s).

3. Simulation Experiments & Performance Analysis (15%)

Evaluate how the priority queueing system performs under different load and scenario conditions. Run simulations at low, medium, and high arrival rates λ, and different number of scalar nodes and UAVs. Observe how throughput, delay, drop rates, and queue lengths change with increasing load. Generate clear charts or tables for each performance metric (throughput, average delay, drop rate, etc.). More performance evaluation metrics can be found in the simulation framework.

4. Task Offloading & Compute Queue (35%)

Further extend your implementation by introducing an **offloading mechanism:** if a UAV cannot process a task due to limited CPU/GPU, instead of dropping the packet, it forwards (offloads) that task to a UAV with higher capacity. Implement a compute queue mechanism so that each packet (or certain packets) represents a compute task requiring processing time. If a UAV's compute queue is too long or its capacity is too low to handle an incoming task, forward the task to a known high-capacity UAV. Track how many tasks are offloaded, how many are processed locally, and how long tasks wait before completion. Compare scenarios with vs. without offloading to see the effect on overall network performance metrics.

5. Report (10%)

Write a report to present your findings. The coursework report should contain the following sections:

- Title page - giving the title, module, date and author details.
- Introduction - a short description of the work done.
- Design and development – The design and development of your simulation program. You can provide snippets of the important code parts you wrote.
- Results (use tabular formats), comparative study and discussions.
- Conclusion - A short summary of the work done, your conclusions, possible improvements, and enhancements.
- References used - a full list of all sources used; books, journals/magazines/research papers, electronic sources.

Guidelines

- A set of guidelines, walkthroughs, and default configurations will be mentioned in the simulation package uploaded on ODTUclass for your help. Please read the information mentioned there carefully.
- This assignment is a **group** assignment. You need to work in a team of **2**. You need to fill the spreadsheet available on ODTUclass with your team information latest by **Sunday 4th May 2025 11:59 P.M.**, otherwise, you might be randomly paired with a student.
- **All** teams will perform demo sessions. You should be ready to show your work. Questions will be asked regarding design choice, implementation, and general knowledge of the subject. Demo dates will be announced through e-mail.

- You can only get full marks if your submissions/codes are logically correct, fully work, and if you can provide a successful demo answering possible questions.
- You need to submit .pdf report and .zip folder containing your simulation work.
- Please refer to the course assistant (Hamzeh) for any queries regarding the simulation framework.
- Refer to the syllabus of CNG 436 for the measures taken in case of any academic dishonesty.

References

- Dattatreya, Galigekere R. *Performance analysis of queuing and computer networks.* Crc Press, 2008.
- Gross, Donald.*Fundamentals of queueing theory.* John Wiley & Sons, 2008.
- SimPy Documentation. `https://simpy.readthedocs.io/en/latest/index.html`
- Zhou, Zihao. FlyNet, Simulation Platform for UAV Network. `https://github.com/ZihaoZhouSCUT/Simulation-Platform-for-UAV-network`