Network Communication System using Drones

Bianchi Arianna
s222890@dtu.dk
Danish Technical University
Lyngby, Copenhagen, Denmark

Jolly Aleena
s223045@dtu.dk
Danish Technical University
Lyngby, Copenhagen, Denmark

Jónsdóttir Halla Margrét
s222991@dtu.dk
Danish Technical University
Lyngby, Copenhagen, Denmark

Khurana Divya
s220041@dtu.dk
Danish Technical University
Lyngby, Copenhagen, Denmark

Nursultanova Aidana
s212994@dtu.dk
Danish Technical University
Lyngby, Copenhagen, Denmark

Pravdova Katerina
s222959@dtu.dk
Danish Technical University
Lyngby, Copenhagen, Denmark

ABSTRACT

After an emergency situation, such as a hurricane, a flood or a war, people are in danger, and they need help. There is a chance that the Internet connection is interrupted, hampering people to ask for external help. During this scenario, communication between people affected by the unexpected event and the people outside this scenario is vital, since they can provide help. For this reason, our project investigates and simulates the employment of drones providing Internet connection in the damaged area. We evaluate and compare several parameters such as the optimal number of drones to cover the entire area, the control algorithms of the drones, the capacity of the battery, the feasibility of the drone's cost and the number of base stations.

KEYWORDS

drones, parameters, emergency situation, simulation

1 CONTRIBUTIONS

Contrib.	s222890	s223045	s222991	s220041	s212994	s222959
Prj. Mgmt	16.6%	16.6%	16.6%	16.6%	16.6%	16.6%
Problem.	16.6%	16.6%	16.6%	16.6%	16.6%	16.6%
Model.	17%	17%	17%	10%	22%	17%
Implem.	10%	5%	50%	10%	20%	5%
Simul.	14%	5%	17%	14%	25%	25%
Report.	16.6%	16.6%	16.6%	16.6%	16.6%	16.6%

2 INTRODUCTION

The number of disasters has increased by a factor of five over the past 50 years, driven by climate change [1]. Providing early warnings and improving disaster management systems like emergency evacuation can help reduce the death toll. In a disaster-related to weather, climate, or water hazard, it is more likely that the standard mobile communication systems are interrupted, which could affect the smooth functioning of the disaster management systems. An emergency evacuation system could only work efficiently when the people in the evacuation region constantly communicate with the station responsible for the evacuation. In the absence of a standard communication system, setting up an alternative wireless communication system is vital if the affected area needs an emergency evacuation. No well-known system can temporarily set up a quick mobile communication system that could connect the people and the station. Our project intends to ideate and test a network communication system model which can help set up temporary mobile data communication.

While there are a number of ways to set up a temporary communication system, our focus is on using drones to create a mesh network that provides a Wi-Fi network in the affected area. In a situation like floods or after severe earthquakes where the ground is not accessible, drones are the only best solutions to establish communications that could help authorities to get the necessary information about the people in the affected area. Drones that are capable of working in extremely windy weather conditions are already available in the market [3] that can be utilized according to the severity of the emergency situation. A swarm of autonomous drones can set up the communication system quickly and efficiently. These drones can use their Wi-Fi routers that provide a network. Access to a Wi-Fi network not only enables communicating the details, but also sending actual visuals about the severity of the situations.

3 MOTIVATION

The primary motivation for this project is the idea of using drones for emergency delivery, further developed by the inspiration of the loon project. The loon project focuses on expanding internet connectivity by creating a network of balloons [7]. Since this is slow, costly, and hard to manage, it is unsuitable for emergencies. Drones are already in use to deliver medicines or other necessary items [5]. They have proved to be fast and much more effective. Hence, modelling a Wi-Fi communication system using drones is sensible.

The changing weather and other factors can dynamically affect the system; therefore, it is essential to simulate how the system model reacts to this change. In the upcoming sections, You can see a detailed description of the model and the simulations done to validate the model.

3.1 Potential use cases

We are addressing the first one, however there are other potential use cases which we have mentioned:

- **Provide Wi-Fi Connection During Natural Disasters.** Drones can be used to provide the communication like Wi-Fi in the situation of natural disasters.They can create a Wi-Fi mesh model and provide the Wi-Fi connection in the area which is affected by the disasters like earthquakes, floods or other natural disasters.

- **The Need for Mapping.**
  Areas that are prone to large-scale disasters such as earthquakes and flooding benefit greatly from visual imaging and 3D mapping. Manned aircraft are often too expensive to use, satellite mapping does not meet high-resolution needs, and both take too much time during emergency situations. The use of drones to map disaster areas provides greater advantages in costs and in rapid response times when compared to traditional methods. Drones can be deployed quickly, generate high-resolution and 3D mapping, identify hotspot areas that have sustained the most damage and upload the data in real time to coordinate relief efforts.
- **Assessing Structural Damage.**
  Relief workers often find it difficult and dangerous to assess structural damage from natural disasters. They often encounter buildings that are on the verge of collapsing, potential explosions due to chemical leaks and places that are hard to access such as tunnels and bridges. Drones can be used to assess the structural damage.
- **Delivering Emergency Infrastructures and Supplies.**
  Often after natural disasters or terrorist attacks, infrastructure supply lines are cut and disabled. When roads, bridges, communication cables and gas and water lines are compromised, the safety of residents in the area is also compromised. To mitigate suffering and further damage, rescue teams can utilize drones to support infrastructures, deliver supplies and establish communication.
  In areas that are nearly impossible to reach, drones can deliver supplies such as water and food to those in need, eliminating the risks of placing human-operated aircraft in harm's way.

4 METHODOLOGY

4.1 Conceptual Model

We made a conceptual model in order to get an initial understanding of the system and domain. The model provides the basis of how the system works. Figure 1 describes the structure of our conceptual model. The *drones* fly above all the buildings in the city and are used to create the Wi-Fi connection network after the natural disaster. Each drone can create node in the network and cover certain part of the area with WI-Fi signal. People will use the provided internet to ask for help, send their location or notify where people are and whether they are safe. The drones are connected to the *base station* which is managing all the drones, communicating back with the drones and charging the drones. Drones can also use *charging stations* to charge.

4.2 Assumptions

We built our model on the following assumptions:

- Emergency situation is either a hurricane, a flood or a war.
- There is a power supply in the base station.
- Every base station has at least 20 chargers.
- Base stations have internet connection.

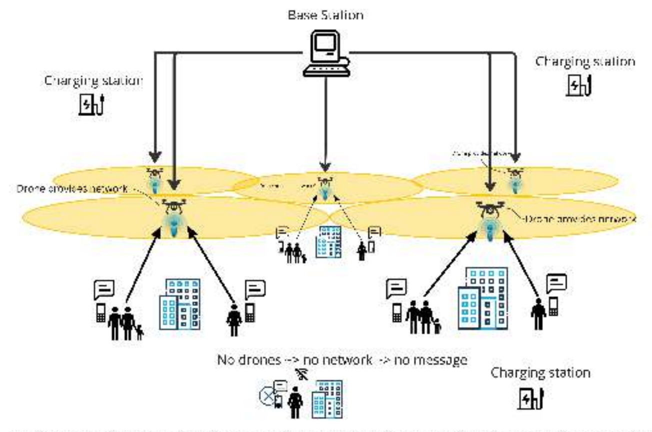


Figure 1: Conceptual model of Network Communication System using Drones

Name	TR016W	HouDeOS	HS720G	Gleto
Flight time [min]	15	56	26	60
Wi-Fi distance [m]	200	1000	500	100
Cost [USD]	330	200	150	248
Battery [Ah]	1.2	2	1.8	1.8

Table 1: Parameters of compared drones, part 1.

- There is at least one charged Wi-Fi device in every occupied building.
- Weather does not affect the flight time of the drones.
- Drones are autonomous and know their designated destinations.
- Drones can communicate with each other so that the nearby drone can fill in the connection of the drone whose battery is discharging.
- Drones know the status of power stations and can decide which nearest and free power station to fly to recharge.

5 COMPONENTS

5.1 Drones

The most important part of our system are drones, since this is a drone system. They will be used to provide a Wi-Fi connection for an affected area. Many drones on the market are equipped with a Wi-Fi access point, but can also be used as a router after a few modifications. Then they can create a mesh network and connect people with the closest base station which has an actual internet access, as mentioned in subsection 4.2. Important parameters of our drones are flight time, short Wi-Fi radius with strong signal, long Wi-Fi radius with weaker signal, cost and the capacity of the battery. Possible drones that are available on the market are in figure 2 and their parameters can be seen in table 10 and 10.

Drones always know their designated destinations but since they are autonomous, they decide the exact path and movement by themselves. They can communicate between themselves, so they

Name	AE. E99	HS110G	Tech rc	AE. L900
Flight time [min]	20	13	26	32
Wi-Fi distance [m]	200	150	50	200
Cost [USD]	125	140	80	208
Battery [Ah]	4	1.5	1.2	1.5

Table 2: Parameters of compared drones, part 2.

Figure 2: Types of drones considered in the project.
First row from left: HouDeOS, HS720G, TR016W, Aerium L900; Second row from left: HS110, Aerium E99, Gleto.

can avoid collisions. Drone will never fly into the short radius of another drone.

5.2 Base station

Our base station has 2 major functions: charging the drones and providing an internet access point for the drones. Every base station can charge up to 20 drones at a time. If there is no space for an incoming drone, it can fly to the second-closest base station. If the battery of the drone is not high enough to fly there, it can wait in the base station until one of the chargers is free. The charging time of the drones might differ, but it is usually between 60 and 90 minutes. In our experiments, we assume the charging time is 60 minutes if not else noted.

One of our assumptions is that there is electricity in the base stations. In case of emergency, this might be very problematic, but it is possible to achieve it with backup generators. Also, we assume that there is an internet connection in the base station.

5.3 Environment

The drones are operating above the buildings - the approximate height is 17 m. The environmental factor that affects their function is mainly weather. Since drones are going to be used in emergency situations, it is very likely that the weather will be intense. The chosen drones therefore have to be resistant against heavy rain and wind. It is also very likely that the negative weather would affect the flight time of the drones. We do not consider this fact in our computations. This will not cause incaurracy in comparison of different types of drones, because they all are going to be affected in the same manner. However, it might affect the actual number of drones needed and the utilization of the drones, and that has to be taken into account in case of the actual implementation.

6 SIMULATIONS

During our project, two simulations were utilized, one we made ourselves using Unity and another simulation from Anylogic that we modified to meet our needs.

The scope of the simulation is to implement a virtual system in which the parameters are defined by the user, in order to investigate different scenarios and evaluate how they will affect the utilization of the components in the system. The results obtained are both graphical and numerical, and we use them to describe the effect of changing the input data.

6.1 Unity Simulation

Unity is the leading platform for real-time 2D and 3D creations [2].

Unity even have a software dedicated to simulations, which is called Unity Simulation Pro[6]. However, we used the normal version of Unity, similar to what game designers use, for our simulation since it was sufficient in our opinion, and we did not want to pay for the Unity Simulation Pro.

We wanted this simulation to tackle these questions:

- What type of drones would suit our system best, cost-wise?
- How many drones are needed of each drone type?

6.2 Implementation

The simulation was made using Unity version `2021.3.12f1`. The simulation is a 2D simulation illustrating how the drones go from their base stations to the affected area in some city that needs a network connection. The affected area can be moved in the simulation, and the drones will then move to that part of the city.

Several Project Assets were made that our simulation would often use, such as Drone, Base station, and an affected area. We decided to have them as assets since if we would change some parameter for one drone, all the other drones would then also be updated accordingly.

Additional logic needed for the simulation was programmed in C#, e.g. how the drones know not to crash into each other and how they find the nearest base station to charge.

The parameters we can change and test are the following for the drones; Speed, Battery life and Radius. The location and number of base stations can also be modified along with the size and location of the affected area.

In the simulation, the drones get notified about where the affected area is located that they should cover and provide network at. They go from their current location to that affected area, if they are not already at the designated area.

6.3 Experiment

An experiment in the unity simulation was conducted to find out what type of drones from considered drones which are available on the market (can be seen in Figure 2) with parameters stated in section 10 and section 10 would be the most cost-effective. Unity simulation was used to compute the number of drones needed to cover the chosen area in total 6 hours, under the condition that every single building in the area is covered at least 1 hour.

Every measurement was being conducted recursively for each type of drone until the optimal number has been found. Afterwards,

Figure 3: The Unity Simulation in action

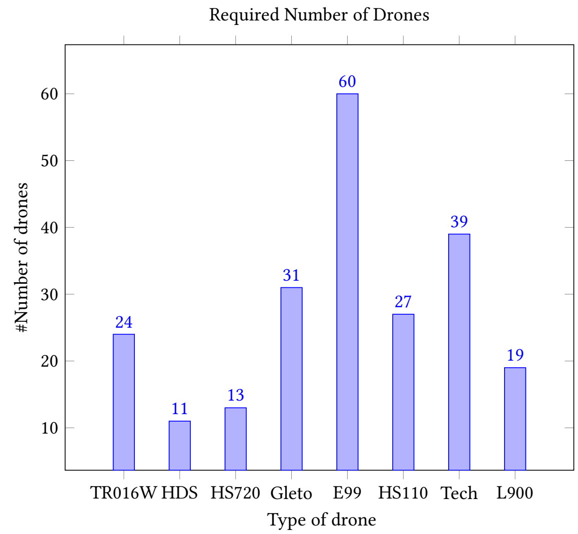
measurement with discovered optimal number was performed 3 times to confirm correctness of the value.

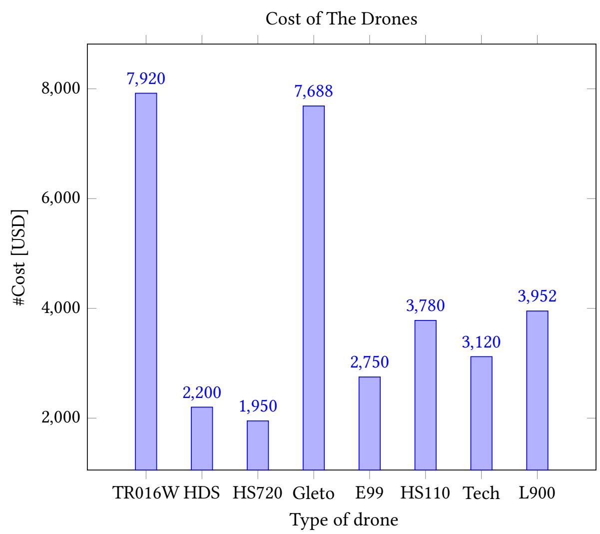
Process used for finding the optimal number of drones:

(1) Radius and flight time was set according to Table 10.
(2) An approximate number of drones was selected (lower than we would have expected).
(3) The simulation was performed, and we have evaluated whether the chosen number of drones is sufficient to fulfil the requirements stated before (cover whole area in 6 hours and in that time every building for at least 1 hour).
(4) If the number was not sufficient, the number of drones was increased and the whole process was repeated from point (1).
(5) If the number was sufficient, the simulation was performed three more times to confirm the correctness of the results.
(6) The cost of the drones was calculated from the discovered number of drones.

The results of the experiment are showed in graph item 6.3a and graph item 6.3b. We can see that the least amount of drones is necessary for the HouDeOs 6K, but the cheapest option would be HS720G.

Another insight from the experiment was that the bigger is the radius, the less it's increase cause the difference in the number of needed drones. For example, a radius's change from 150 m to 200 m could mean the difference of up to 5 drones. But changing the radius from 500 m to 1000 m would cause only 3 drones difference. The reason is that the drones with greater radius are harder to replace, and they have larger issues with consistent coverage of the area.





6.4 Anylogic Simulation

AnyLogic is a software used to model simulations, developed by AnyLogic North America, LLC's ("AnyLogic") proprietary software [4].

6.5 Scope

The AnyLogic simulation represents a net of drones (UAV) which are located on a map, and follow a specific track. On the track, there are several base stations, in which the drones recharge the battery.

We address these questions:

- How will charging time affect utilization of drones?
- Can we predict the time needed for drones to complete the mission of providing multiple areas with internet?

6.6 Implementation

The simulation execution for each UAV follows a flow chart diagram, represented in Figure 4. We think it would be helpful to clarify a few terms that we refer to during the explanation of the steps.

- *Missions* are the points on the map where the UAV should move to provide internet.
- *UAV utilization time* is the time when the UAV moves and provides the area with internet.

The first step is the *preparing* step, in which the UAV is ready to be sent on its mission. The second step involves the *charging* process. It is assumed that the UAV must charge its battery before embarking on the mission. When the charging time is completed, there is a conditional block with two options: 1) if the UAV has not completed the mission yet, the algorithm decides to send the UAV to the mission point which is the *moving* step on the diagram; 2) if the UAV has completed the mission, it reaches the *end* state and the simulation for that UAV is finished. When the UAV is in *moving* block, we assume that it provides internet at mission points. When the UAV leaves the moving block to recharge or when finished the mission, the *completion()* action is executed by the trigger, which is shown as a 'flag' icon on the diagram. Basically, the completion() function calculates the UAV utilization time.

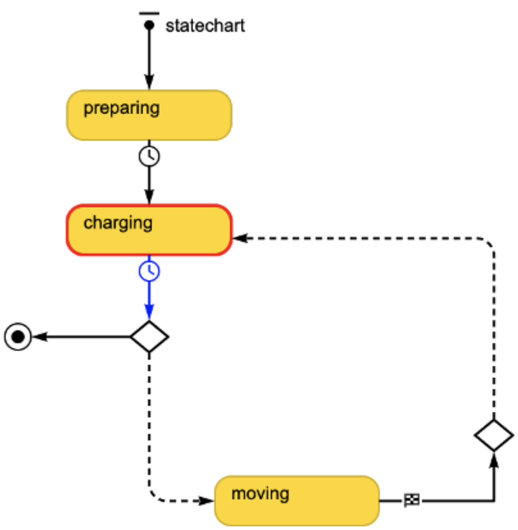


Figure 4: Flow chart of the simulation execution for the UAV

6.7 Experiment

In this section, we describe experiments with charging time and how it will affect the utilization of drones, e.g. when the drones are moving and providing the network. We experimented with changing the value of the chargingTime parameter with several inputs:

(1) Uniform(0,1) | units: hours, meaning that the value of the chargingTime parameter is chosen randomly from 1 min to 1 hour.
(2) Uniform(1,2) | units: hours, meaning that the value of the chargingTime parameter is chosen randomly from 1 to 2 hours.

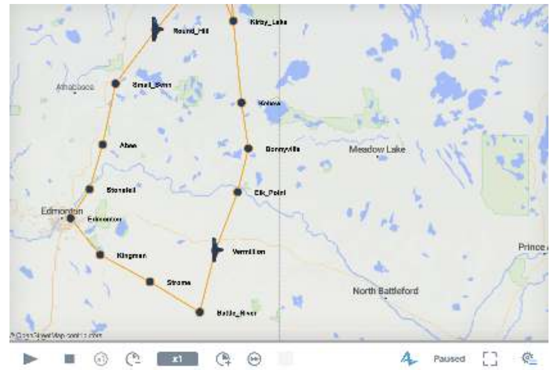


Figure 5: The route and mission points where UAVs should move to provide internet

	uav_1	uav_2	uav_3
1	Long_Lake	Vermillion	Round_Hill
2	Cheecham	Strome	Lesimer
3	Janvier	Kingman	Cheecham
4	Kirby_Lake	Edmonton	Lynton
5	Kehew	Stonefell	Athabasca
*			

Figure 6: Table with information about mission points for each UAV

(3) Uniform(2,3) | units: hours, meaning that the value of the chargingTime parameter is chosen randomly from 2 to 3 hours.

We showed graphically and numerically the results obtained during the experiments. There are two graphs for each experiment:

- The left-most graph shows the utilization of the UAVs over time, where the x-axis represents time in min, the y-axis represents UAV's utilization in percentage.
- The right-most graph shows how much of the total time was spent on each block in percentage by all UAVs.

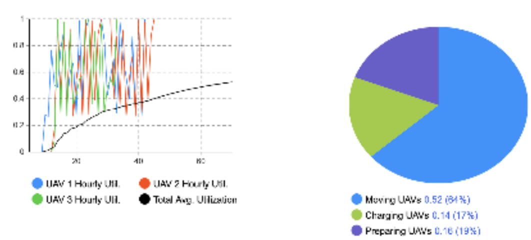


Figure 7: Results of experiment (1) with chargingTime = 0-1 hours

The black line representing the average UAV utilization time (Total Avg. Utilization) varies on each graph. Total Avg. Utilization

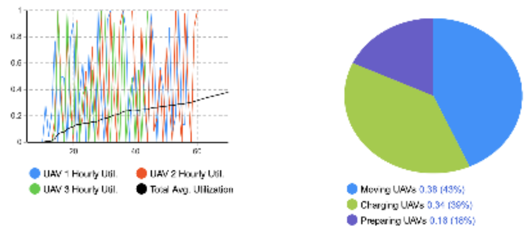


Figure 8: Results of experiment (2) with chargingTime = 1-2 hours

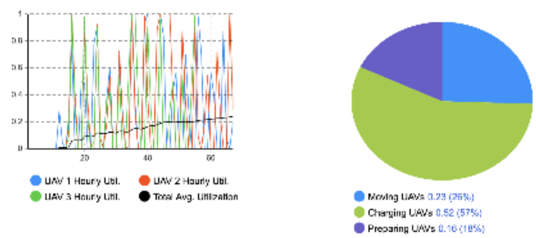


Figure 9: Results of experiment (3) with chargingTime = 2-3 hours

reached its highest value at around 55% in the graph for experiment 1 and reached its lowest value at around 20% in experiment 3, with the value of chargingTime between 1 min and 1 hour and between 2 and 3 hours respectively. According to the results obtained, we can conclude that the charging time is an important criterion when choosing a UAV model, especially when there is a requirement to immediately provide internet during emergency situations. Additionally, we discovered that it is possible to predict the average mission completion time by experimenting with different values of the chargingTime parameter and different numbers of mission points. For example, it can be seen from the left-most graph for experiment 1, that with chargingTime = 0-1 hours, the UAVs completed their mission in 40 min.

7 DISCUSSION

While exploring the ideas for simulation, initially we thought of using drones for supplies, but later we decided that it would be better to provide the Wi-Fi communication as it might not be working as expected.

We explored multiple simulation models and first tried to implement a Java based framework. But later, as time progressed, we picked up Unity software for simulating the drones in the affected region. We did the calculation of the area and the radius of each drone so that we can estimate how many drones would be required for the simulation. We considered all the different parameters for the drones like battery and how many charging stations would be required to charge the drones.

Later, we also explored simulation using AnyLogic software. We had multiple discussions with the Mosimtec team to understand the AnyLogic framework and later worked on modifying the framework as per our use.

We modified the parameters in the AnyLogic simulation model like the charging Time and some other methods to get different results for the simulation. By modifying the parameters, we were able to do different experiments and got different results for each simulation run.

8 REFLECTIONS

We initially explored existing simulations which were implemented to provide the Wi-Fi Connection using drones, for example we tried first implementing the java-based simulation mentioned before. But later found that we can do the simulation from scratch. So we explored the unity software. However, it had its own limitations.

Considering the time that we had, we could not learn a new tool. So we contacted Mosimtec which does simulation on a larger scale. With the help of Mosimtec framework for simulation, we were able to scale the existing simulation model as per our use. However, this came with its own set of challenges. We were able to modify some of the parameters and methods, but not everything that we wanted to do.

We could have prioritised exploring simulation models before and explore a new tool for simulation which would have given better results for the simulation.

We also could have picked up comparing the results for both the simulation models which we worked on like Unity and Anylogic one and could have provided some data points from both the simulations.

9 FUTURE WORK

We can modify the existing simulation model to have more number of drones and see the results. As currently in the Anylogic simulation we have only three drones, so we can increase the number of drones and the region that the drones are covering to see different results.

- Minimal considerations regarding connection failure. A better security and emergency landing system in case of connection failure could highly improve the overall safety.
- An optimum and efficient message routing algorithm can optimize payload.
- Factors like the wind, atmospheric pressure are not compensated.

10 CONCLUSION

Our project focuses on the comparison of different drones and the evaluation of different scenarios with different conditions.

Firstly, we defined the environment on which our project would have taken shape, and we opted for the emergency situation, and the usage of drones to provide network communication in order to save people.

Secondly, we populated the environment by designing the components, which are the drones and the base stations.

As a next step, we investigated more on the different types of drones that exist on the market, in order to understand the feasibility of the project. We decided to focus on nine different types of drones, as shown in and , and on the following parameters: flight time, Wi-Fi distance, cost and battery of drones.

We conducted two simulations using two software programs, Unity real-time development platform and AnyLogic simulation modelling software tool. The first simulation evaluates the most cost-effective drone among the nine drones we decided to consider, under several conditions. The results showed that we can cover the entire area with the minimum number of drones with the HouDeOs drone model; and we can cover the entire area with the maximum number of drones with the E99 drone model. Moreover, the most cost-effective drone is HS720G, and the less cost-effective drone is TR016W. Furthermore, in the second simulation, the drones' execution followed a flow chart diagram, and we focused on three scenarios in order to evaluate the parameters of drones' battery.

And future works imply the extension of the project with more parameters involved, and more optimized conditions and assumptions.

ACKNOWLEDGMENTS

- For the AnyLogic simulation we collaborated with the company MOSIMTEC which provided us the basic implementation of the simulation. MOSIMTEC is founded with the core focus to leverage modern advancements in modelling simulation science and technology, in order to solve complex issues for clients across various industries.
- We are also thankful for all the help we got from our Professors, especially Edward, who mentored us during the process of this project.
- We also want to thank Kristinn Bragi for introducing us to Unity and guiding us through our first steps doing the Unity simulation.

REFERENCES

[1] World Meteorological Organization (WMO). *Weather-related disasters increase over past 50 years, causing more damage but fewer deaths.* URL: https://public.wmo.int/en/media/press-release/weather-related-disasters-increase-over-past-50-years-causing-more-damage-fewer. (accessed: 04.12.2022).

[2] *About Unity.* https://unity.com/.

[3] Sharon Advik. *7 Best drones for windy conditions: (2022 Guide Reviews).* URL: https://bestoflens.com/best-drones-for-windy-conditions/. (accessed: 04.12.2022).

[4] Anylogic. *AnyLogic: Simulation Modeling Software Tools Solutions.* URL: https://www.anylogic.com/.

[5] Matt Petronzio. *9 brilliant ways drones can help tackle the world's biggest problems.* URL: https://www.fabertranscription.com/9-brilliant-ways-drones-can-help-tackle-the-worlds-biggest-problems/. (accessed: 04.12.2022).

[6] *Unity Simulation Pro.* URL: https://unity.com/products/unity-simulation-pro. (accessed: 15.11.2022).

[7] X. *Loon: Expanding internet connectivity with stratospheric balloons.* URL: https://x.company/projects/loon/. (accessed: 04.12.2022).

11 APPENDIX

We have two readme files, one for each simulation, describing how to run the simulation. The readme files are in the appropriate zipped folders, the Anylogic zip file and the Unity zip file.

Throughout the project we used the SCRUM methodology where we have separate roles for each team member. We had the scrum meetings where the scrum master facilitated the meeting.

The SCRUM roles were as follows:
The Scrum master: Divya
The Product owner: Arianna
The Development team: Aidana, Halla, Katerina, Aleena

We also had the retrospective meeting in which we discussed what went well and what did not go well. We considered all these points and collaborated to work more efficiently.