Problem Chosen	2021	Team Control Number
B	MCM/ICM	2116608

Summary Sheet

In this paper we take a look at how drones can be used to efficiently help out with the communication between firefighters on the front line of wildfires with the operation center. We also take a look at how drones can also be used to survey the land at how the wildfire is changing to further instruct the operations center on how to most effectively disperse firefighters to control the fire. We look at the optimal positions for the drone placement in order to stay in signal range while also covering the most area possible. Using actual data from bushfire in Victoria in 2020, we are able to calculate how many drones will be needed by anticipating much bigger than the fire in 2020 would not happen in the next decade. Taking into factors including topography, distance, and signal type we are able to place both SSA drones and repeaters on drones to maximize the effect the drones have on the situation. The cost and the benefits of the drone are taken into consideration when we calculate how many drones, we recommend to the Country Fire Authority.

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Introduction

Technology is changing the world around us, from electric cars to virtual doctor's appointments. In recent years technology has allowed drones to be used in order to assist in the fighting of wildfires. These drones can be equipped with two types of equipment, one for surveillance and situational awareness (SSA) or repeaters. The SSA technology uses data from its own cameras as well as data being sent from people that are on the front line of the fire. These drones help the Emergency Operations Center (EOC) work as efficiently as possible. The repeaters that the drones can be equipped with take any VHF/UHF bands from the radios of the front line and rebroadcast the signals at higher powers allowing the signals to travel a farther distance. This allows for the "boots-on-the-ground" to communicate back and forth with the EOC at father distances. The range of these repeaters is affected by the topography that the signals have to travel over as well as if there are any buildings or dense forests. One drone that works well for these functions is the Akme Corporation's prototype WileE-15.2X hybrid drone. It costs roughly $10,000 (AUD). One country that is no stranger to wildfires is Australia. Being very dry and hot, Australia has had some very big fire seasons producing very dramatic wildfires in its history including 13 major fires its Southeastern state of Victoria since 2000. These 13 major fires burned over 6 million acres, 1062 homes, 85000 livestock, and 175 lives. From November 2019 to February 2020 Victoria, and Australia as a whole, experienced an extremely terrible fire season. This was due to 2019 being the driest year on record combining with also being the hottest year.

Considerations

This section contains all the information that was taken into consideration during the thought process of the solution. The information is split into three categories of information; variables that are fixed and is given, variables that are changing in the application of the problem, as well as assumptions that were made to simplify the solution process.

Fixed Variables to consider

Range of radios on ground: 5 kilometers over flat ground, 2 kilometers over dense area
Range of repeaters: 20 kilometers
Range of drones: 30 kilometers

Maximum speed of drones: 20 meters per second

Maximum flight time for drone: 2.5 hours

Recharge time for built in battery: 1.75 hours

Auxiliary batteries can be swapped while the built-in battery recharges.

Each drone costs $10,000 AUD.

Changing Variables to consider

Fires vary in shape and size.

The number of fires at any one time across Victoria varies.

The elevation of Victoria ranges from the coast (0 m) to the top of Mt. Bogong (roughly 2000 m).

Assumptions made

Charging of the drones: It was assumed that the drones started and ended their flight at any EOC where they would also recharge. The time that it takes to change the battery and start the charging process was not taken into serious consideration

Placement of EOC: It was assumed that there were mobile EOC's that could get to within 50 km of any fire. If the EOC's were not able to get within 50 km of a fire, then even the drones at full range (30 km) would not be able to reach the front line with the 20 km repeaters.

Cost of drone: It was assumed that the $10,000 for a drone included the drone and one of the two technologies needed (SSA or repeater)

Solution

Initial thoughts

Looking at the range of the repeaters it was realized that the repeaters had to be within 20 km of one another to stay within range of one another as can be seen in Figure 1.

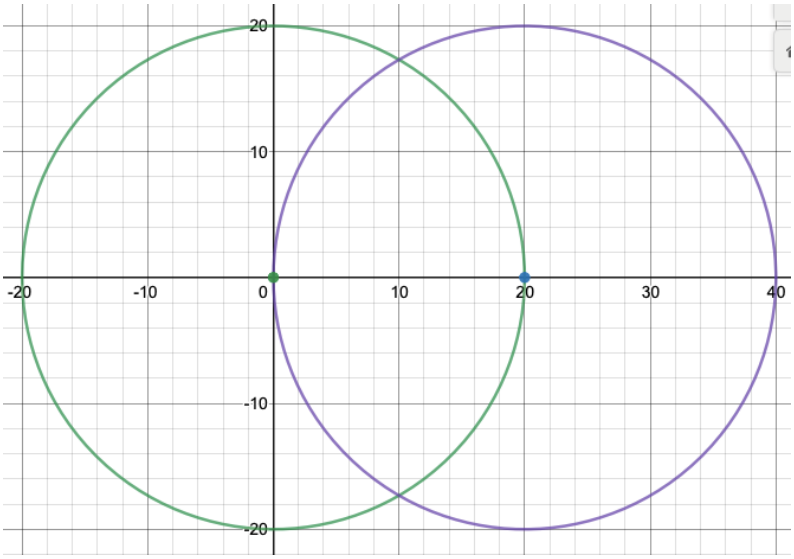

Figure 1: A drone is represented by a point and the circles represent the repeater range. The color of the circle correlates with the color of the drone it is associated with.

It was then realized that if a drone went the full 30 km range that it would be out of range and unable to relay information back to the EOC as can be seen in Figure 2.

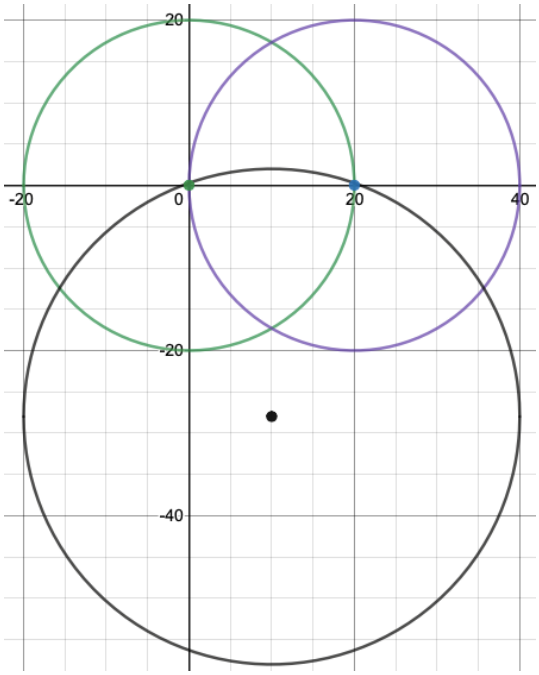

Figure 2: This is the same scenario of Figure 1 with the added black circle to represent the EOC as can be seen the repeater ranges

This means that it would need a third drone to relay the information further which is seen in Figure 3.

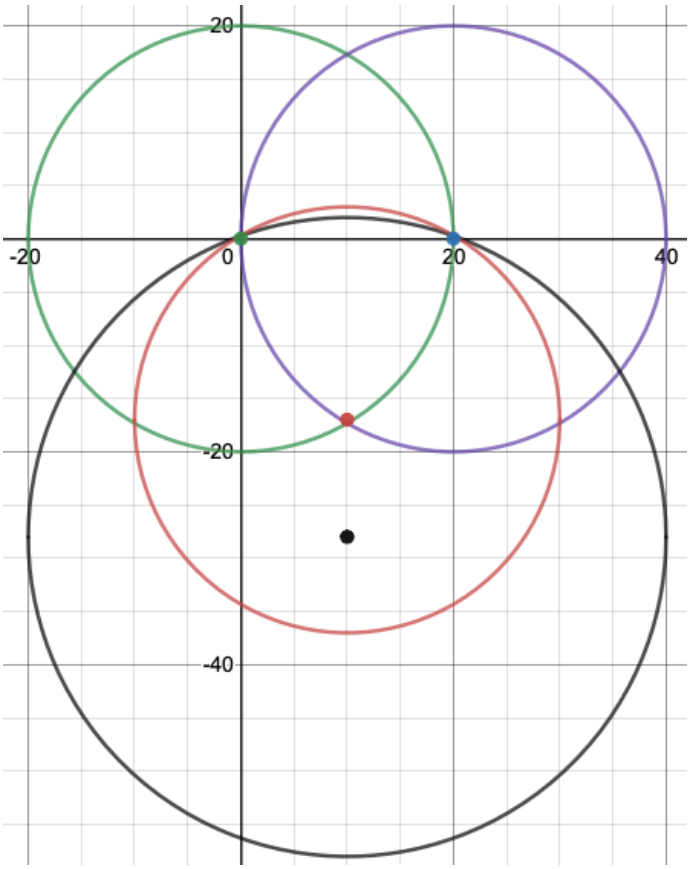

Figure 3: A red circle and dot representing a third drone and repeater have been added to the scenario from Figure 2 so that the EOC is able to communicate with the two furthest drones.

A next thought that was considered was how high could these drones fly. This information was not directly specified but the highest drone flight was to an altitude of 11,000 feet which is equivalent to over 3000 meters. Taking into consideration the tallest altitude of Victoria being Mt. Bogong of 2000 meters the drones then will have no problem getting to a height where the signals can be transmitted effectively.

Final Solution

We decided for our model we would have a setup of repeater drones so that any SSA drone on the perimeter of the fire would be able to communicate with the EOC and with each other. This would be done by subdividing the perimeter of the fire into roughly equal segments, each with a length less than the 20 Km range of the repeaters. Then we set one SSA drone on the perimeter of the fire at the ends of each of these segments, and one repeater drone for each pair of adjacent SSA drones, which is equidistant to both SSA drones. These SSA drones will be able to patrol the edge of the fire freely without worry of going out of range of the repeaters. Once the drones were set, the mobile EOCs were positioned so that the EOC forms a circle of radius 20 Km with the locations of the two repeater drones on the edge of the circle, and the location of the EOC as the center. This setup allows communication with all of the EOCs and SSA drones, which are allowed to move freely around the perimeter of the fire. To calculate the required number of each type of drone, we first considered the average size of the fires from Oct 1, 2019 to Jan 7, 2020, then considered the size of the fire if it was all connected in a large circle. The area of this fire would be ~1,350 sq Km on an average day, and we calculated the number of SSA and repeater drones to each be ~6.6. However, this assumes the area of the fire is concentrated into one large fire, which would lower the ratio of the number of drones required per area of fire. We then squared the 6.6 number to account for this and ended up with an estimate of ~43 drones of each type. This number may greatly overestimate the actual number required, but it provides an approximate upper bound on the number required.

Next Decade Projection

Considering the current precipitation change and global temperature rising, Australia has been experiencing severe wildfires. The wildfire known as “bushfire” is typically happening in eastern Australia where their area is prone to wildfire, but its vegetation is resistant to fire. However, the wildfire from October 2019 to February 2020 damaged New South Wales and Victoria significantly and threatened peoples and wild animals’ living. According to BBC news, overall Australia has warmed by slightly more than one degree Celsius since 1910, and the annual mean temperature recorded the highest by the Australian Government Bureau of Meteorology. It is assumed that mean annual temperature will be increasing in the next decade, but the study conducted by Kelly (2020) shows there will be increase and decrease in fire events in southern

Australia. This is correlated with the area's vegetation will become resilient to fire more by increasing areas covered by trees. Also, a figure of changes in the carbon cycle over Australia through the 21st century in response to climate changes driven by the RCP8.5 scenario indicates the curve is almost flat, and there is not a significant change in fire flux in the next decade. Thus, it is concluded that we do not expect a significant increase of fire events in Victoria at least for a decade, which the number of drones newly needed would be very small. Therefore, it does not affect the calculation of the number of drones.

Strengths and Weaknesses of Model

This model focuses on covering the areas affected by fire rather than not failing to pass the signal to the EOC. From this strategy, EOC will be able to detect accurate front lines of fire and protect personnel who are physically fighting the fire on the front line. To achieve the initial purpose of this project which protects lives and minimizes damages by fires, this strategy was determined to be the best option. SSA drones radio coverage is extended by adding the third drone to the model, therefore it helps the budget for not having too many mobile EOC in the model. The difficult part of this model was figuring out the average size of fire which Victoria had in last year. We took an example from the total burnt area in a certain period and calculated it as one large circle to apply for the model. The shape is not quite similar to actual wildfires, which may increase or decrease the total drone they need for the front line. Some other weaknesses are that there is chance that our estimate is an overestimate of the number of drones needed and that the elevation was not directly taken into consideration since the drones can fly to a height of 3 km passing over any land in Victoria.

Annotated Budget Request

Dear Victoria State Government,

Over the years Victoria has seen an increasing number of bushfires, with 2019 being one of the worst years for fires yet. Global climate change will see these numbers do nothing but increase. To combat this, we propose a new "Rapid Bushfire Response" division of the *Country Fire Authority*, which will provide rapid response to any bushfires within Victoria's 37 counties. This new division will consist of a collection of frontline SSA drones, as well as several radio repeaters drones which will be necessary to boost the signals from the frontline Radios to

communicate with a nearby deployable EOC. We propose a team of 43 SSA drones ($430,000), and 43 radio repeater drones ($430,000), which will be able to provide adequate coverage of any potential fires in the state of Victoria. Both drones will be necessary for full coverage, since the range of the two-way radios is not enough to reach the EOC. Both types of drones together require a total of $860,000.

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