IAB230: Bushfire Management System for National Parks

Conceptual Design for Satellite and Drone IoT Solution

GROUP 2

DECLARATION

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Contents

TASK 1: SUMMARY OF IoT SOLUTION

Summary of Problem:

The problem that the *Satellite and Drone IoT solution* solves is that of detecting when a bushfire has started in remote parts of Queensland national parks, and providing helpful, up to date information on bushfires to Queensland Firefighting and Emergency Services (QFES) and the Queensland Parks and Wildlife Service (QPWS) so that the fires can be managed. This problem stems from the remoteness of the national parks, the vast expanse of land that the parks cover and the limited resources of managing services, with traditional methods such as 000 calls and watch towers insufficient due to their slow response times and chance of not spotting the fires at all (Matthews et al., 2021).

Proposed Solution

The *Satellite and Drone IoT solution* would work via having an array of satellites in orbit as well as a fleet of drones on the ground. All but one of the 33 satellites would be stationed in Low Earth Orbit (LEO) and equipped with infrared imaging cameras, constantly taking inferred video of Queensland and its national parks. This image data would be sent to and then processed by the fog at the nearest ground station to detect the location and size of fires, from initiation to end, and immediately alerting via SATCOM the QPWS and QFES (ABC, 2021). The location and size information would also be sent via radio waves to a Geostationary Orbit (GEO) satellite with a powerful LIDAR sensor, able to scan the location of the fires and return a 3D scan of the environment to the ground station. The location and size information would also be sent to a drone in a drone hub, which would then fly to the site of the fire, drop a load of water on it, and if it persists, provide a video feed of the blaze as well as weather information about it, which would all be sent to the ground station. The ground stations and fog would connect via hubs to 4G and send the 3D environment, weather, and video information to the cloud. This information would be directly provided to services via Satcom enabled devices, as well as intermittently updating predictions of fire propagation, to let them fight the fire safely and more efficiently. The cloud will also provide long term generalized predictions of when fires are most likely to occur to help with long term strategies and resource allocation.

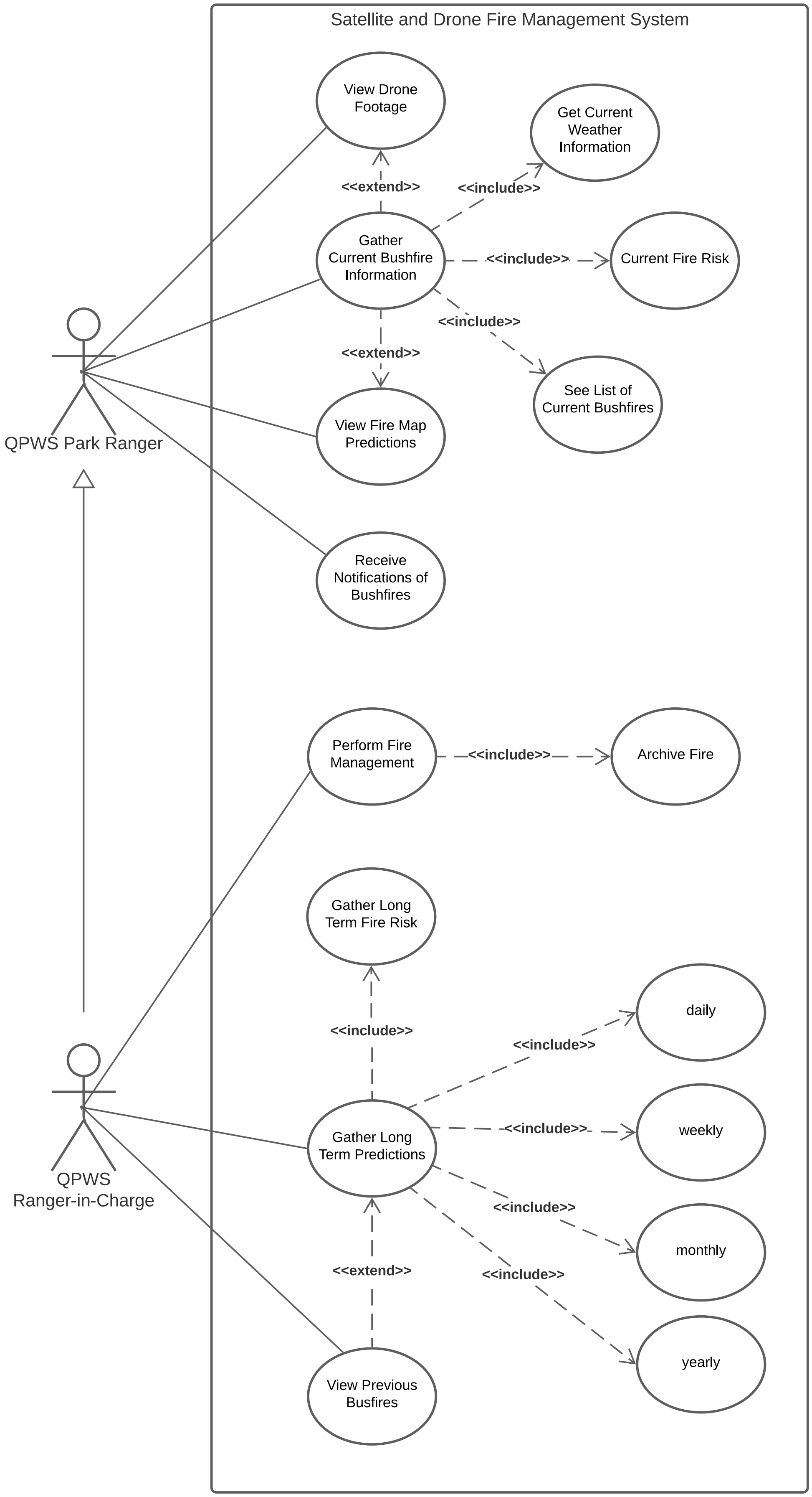
Key users and stakeholders

The key users of the *Satellite and Drone IoT solution* would be the park rangers and volunteers of the Queensland Parks and Wildlife Service, as well as the fire fighters, both professional and volunteer, of Queensland Fire and Emergency Services. QPWS would be using the solution for its long-term predictions as well as the video and propagation predictions for creating and maintaining fire lines (Queensland Government, 2021a). QPWS Ranger-In-Charges would be the administrators for the system. QFES would be using the fire alert with the location and size, as well as the video and propagation. Another user for the location and size information would be the public, both local and non-local, so they can avoid being caught in the fire (QFES, 2021a). Participants in the system would include the drone operating staff, as well as maintenance staff for the drones and ground stations.

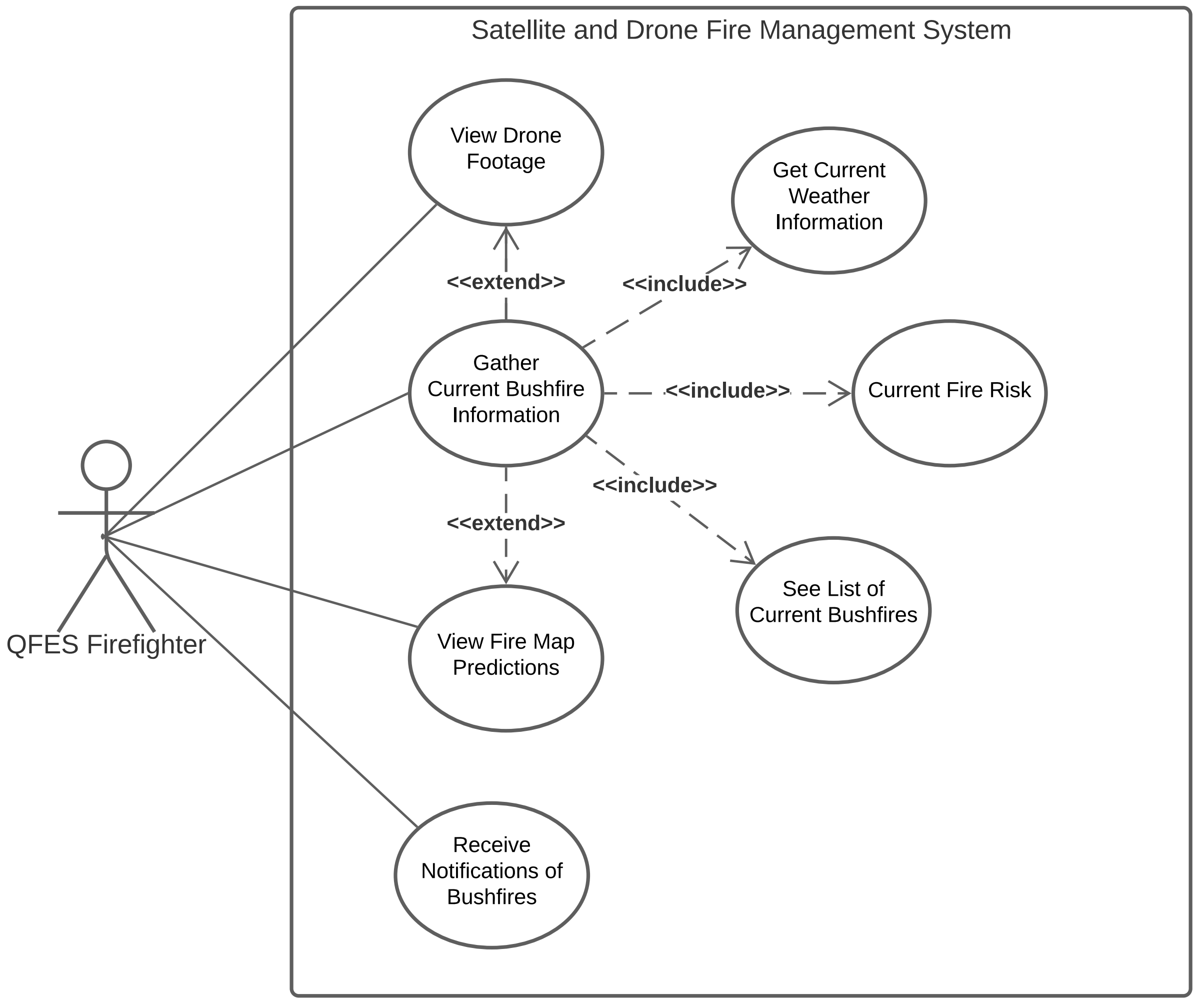
TASK 2: USE CASE DIAGRAM

Scenarios

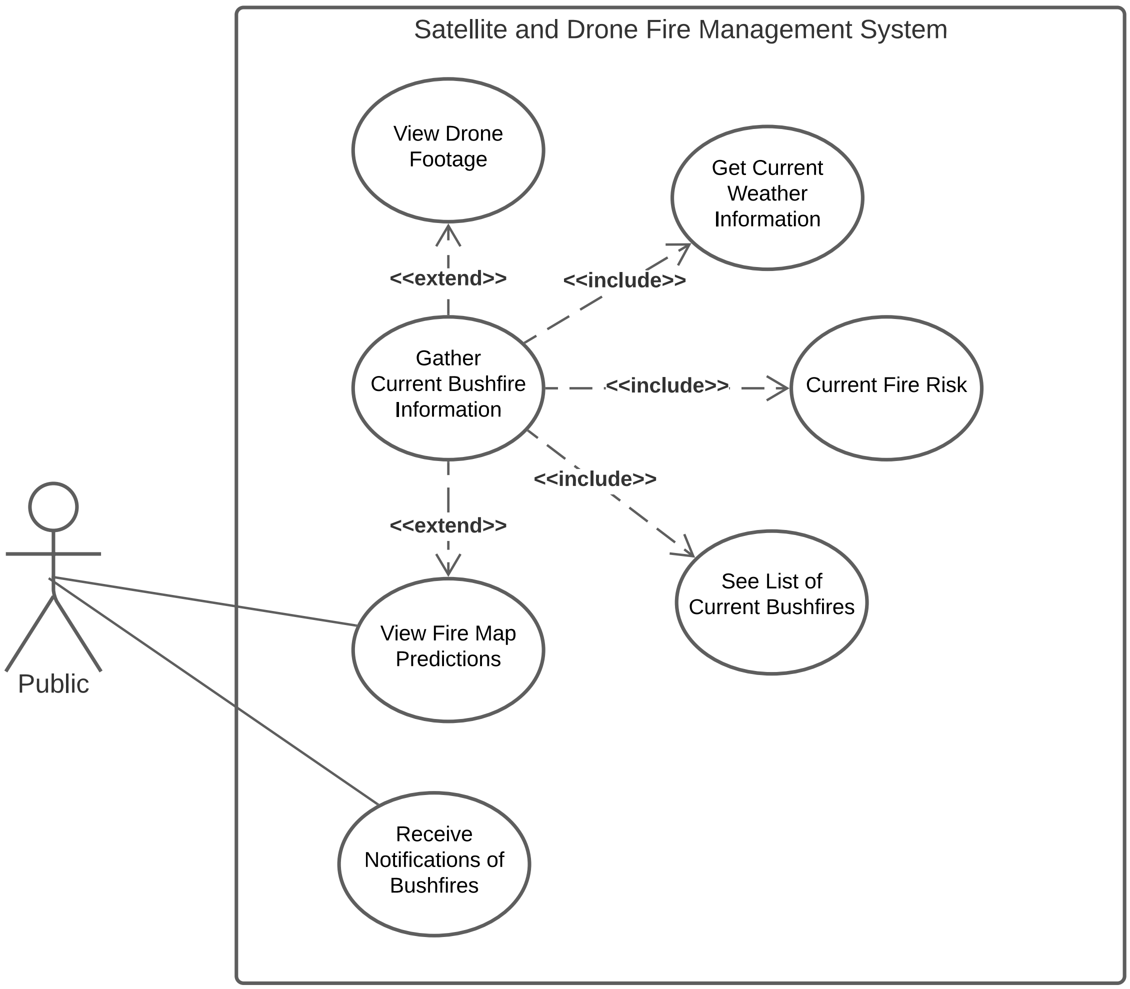
1. **As a** QPWS Ranger-In-Charge, **I want to be…**
    a. Notified of active bushfires, **so that** I can begin to orchestrate the firefighting effort.
    b. Able to see which bushfires are still active, **so that** I can continue to orchestrate the firefighting effort.
    c. Able to archive ongoing, and or previous, bushfires, **so that** I can use the data for future firefighting efforts.
    d. Able to see the current fire risk level of a chosen location, **so that** I can be aware if a possible fire starts.
    e. Able to view the drone footage **so that** I can see the intensity of the fire and command my park rangers to react to the live situation.
    f. Able to view the bushfire predictions **so that** I can tell if the planned burn is going according to plan and call it off if the prediction shows it escalating.
    g. Able to view generalized predictions of conditions **so that** I can plan when to have my park rangers do backburning, and where they need to do it.
    h. Able to archive fires **so that** the drones are not used to fight them since they are part of backburning, rather than an active threat.
2. **As a** QPWS Park Ranger, **I want to be…**
    a. Able to see active bushfires, **so that** I can prevent the fire from spreading.
    b. Able to see where the fire could spread to in the future, **so that** I can help prevent the spread.
    c. Able to see a bird's eye perspective of the bushfire, **so that** I can see the intensity of the fire.
    d. Able to see the current fire risk level of a chosen location, **so that** I can be aware if a possible fire starts.
    e. Notified of fires, **so that** I can prepare for the fire (Queensland Government, 2021b).


Satellite and Drone Fire Management System
View Drone Footage
Get Current Weather Information
<<extend>>
<<include>>
Gather Current Bushfire Information
<<include>>
Current Fire Risk
<<include>>
<<extend>>
See List of Current Bushfires
View Fire Map Predictions
QPWS Park Ranger
Receive Notifications of Bushfires
Perform Fire Management
<<include>>
Archive Fire
Gather Long Term Fire Risk
daily
<<include>>
<<include>>
weekly
<<include>>
Gather Long Term Predictions
QPWS Ranger-in-Charge
<<include>>
monthly
<<extend>>
<<include>>
yearly
View Previous Busfires

3. **As a** QFES Firefighter, **I want to be…**
    a. Able to see the location of the fire, **so that** I can actively fight the fire.
    b. Able to see where the fire could spread, and how long it could take to spread, **so that** I can help prevent the spread.
    c. Able to see a bird's eye perspective of the bushfire, **so that** I can see the intensity of the fire.
    d. Able to see the current fire risk level of a chosen location**, so that** I can be aware if a possible fire starts.
    e. Be notified of fires, **so that** I can prepare and then move to the fire location (QFES, 2021b)



4. **As a** member of the public,
    a. **I want** to be able to see active bushfires, **so that:**
        i. I know where the danger lies.
        ii. Whether they pose a danger.
        iii. I know how long it will take me to evacuate the area that I am situated in.

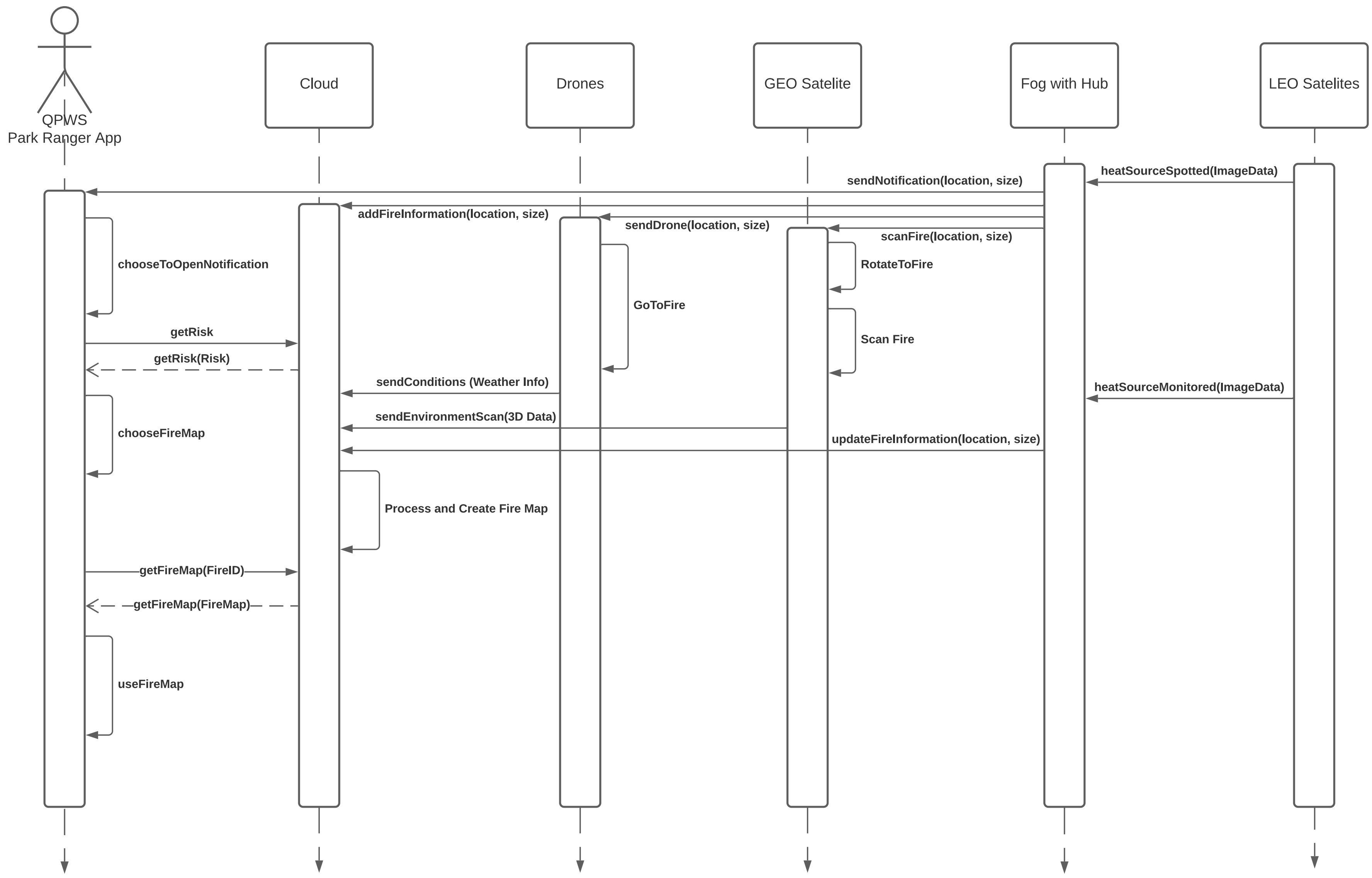


TASK 3: SEQUENCE DIAGRAM

Scenario 1: QPWS Park Ranger viewing Fire Map.

The QPWS Park Ranger on duty for a park receives a notification about a nearby fire containing the location and size of the fire, transmitted from the nearest network hub connected to the location processing fog, after receiving the LEO satellite image data. The fire location and size is also sent to the cloud, drones and geo satellite. The park ranger opens the notification, and the app opens the home screen. The Park Ranger sees a current fire risk level of the location which was generated from the information stored in the cloud from previous fires. The park ranger selects the fire map screen and sees the current size and predicted movements of the fire from the cloud, which is using the information that the GEO satellite has scanned and sent to the cloud. The weather information surrounding the fire is also available and being shown the park ranger since it is now being communicated from the drone to the cloud since it has arrived at the fire (Fireball, 2021).

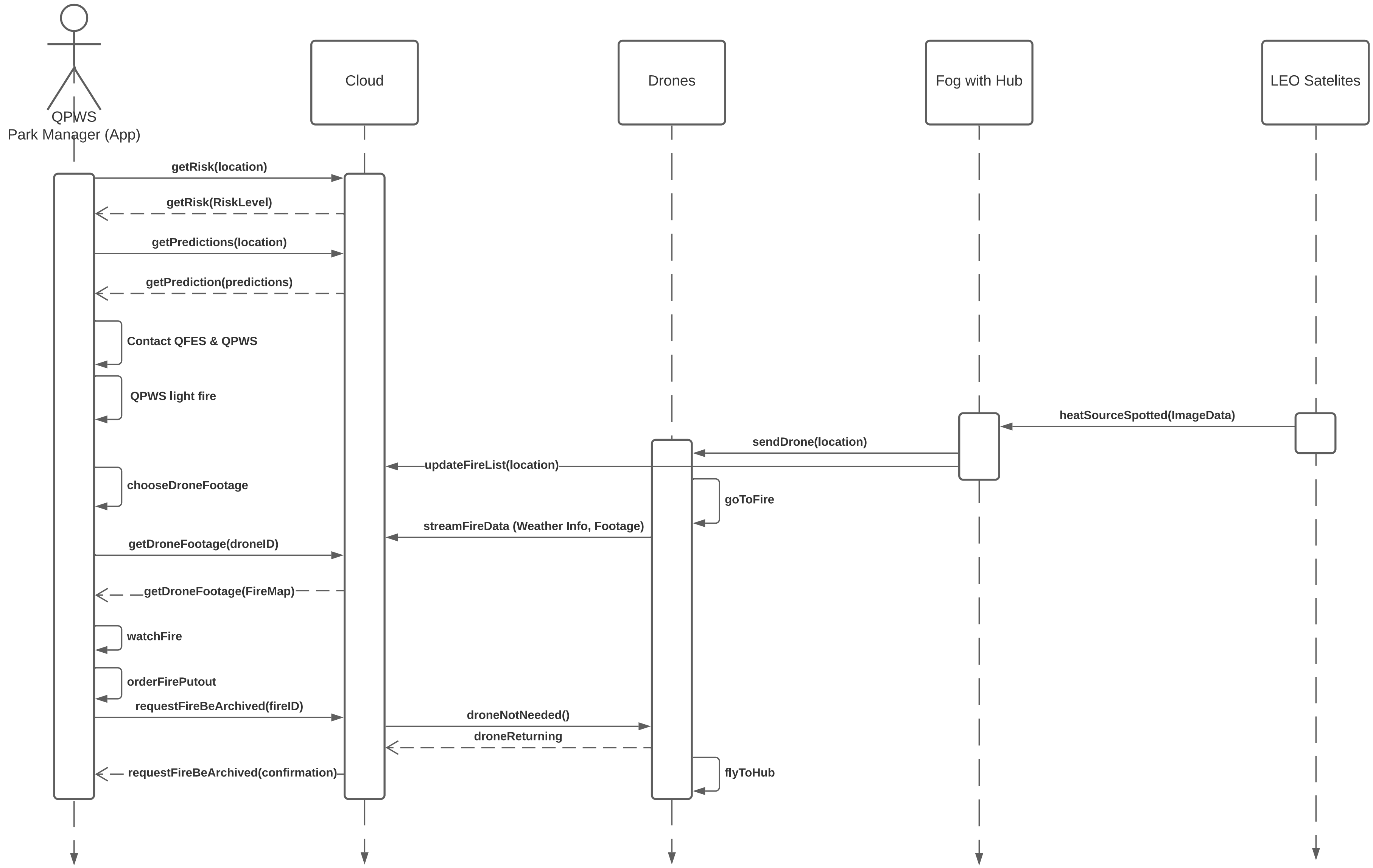
Sequence Diagram 1



Scenario 2: QPWS Park Ranger-In-Charge managing backburning.

The QPWS Park Ranger-In-Charge responsible for performing a back burn accesses the home page of the application and selects a location. The fire risk at the time is displayed to the user after being retrieved from the cloud. From here the park ranger-in-charge goes into the previous fire tab to view the previous fires and the long-term predictions surrounding whether it is a good time to do a backburn to reduce fire spreading in the future. The ranger-in-charge contacts the park rangers to start the burn and QFES to be on standby separately from the application. The burn starts and the park ranger-in-charge watches the burn via the drone footage of the drone that was sent to the fire when the fire started. The fire is watched continuously until it is ordered to be put out, where the drone returns to base, and the fire is archived by the park ranger-in-charge to be an 'old fire' (Drone World Australia, 2021).

Sequence Diagram 2



TASK 4: SECURITY AND PRIVACY CONSIDERATION

4.1 POTENTIAL SECURITY AND PRIVACY ISSUES

There are a range of security and privacy issues surrounding the Satellite and Drone IoT Solution. The diversity of the communication protocols used leads to a higher possibility of incorrect implementation occurring leading to system vulnerabilities. The LoS MN MMO protocol is handled by a third party for the drone, thus there is ample opportunity for spoofing to occur with a mix-up in communication or the external service being breached, since the protocol must handle a video stream and an extension enabling weather sensor information. The LEO-Star satellite has a huge range of other sensors with their own communication protocols, meaning a security flaw in one of those other sensors could then impact the ATLAS sensor (ESA, 2021).

There are a large range of interdependencies that the project has, with the main one being the reliance on the networks used to communicate information between the sensor devices, fog, cloud, and users, which includes the internet as well as a multitude of ground stations, hubs, and protocols. Man-in-the-middle (MITM) attacks on the network could steal confidential data such as 3D scans of areas and drone footage, breaching the privacy of those that are captured. It could also cause integrity problems, with drones having incorrect commands sent to them, satellites asked to scan victims houses or produce incorrect information to firefighters. This may also lead to availability issues for the drones since it could be hijacked. The entire solution relies on the CubeSat and the fog to provide location information, and then the other sensors and the cloud to provide accurate predictions and push the information to the end user. Any of these services being compromised by an attacker could result in QFES and QPWS not receiving information (Kaspersky, 2021). The ground stations and sensors transmitters, due to their constrained transfer rates, are at risk of DDoS attack, selective forward attacks, and sinkhole attacks, which would make the sensor information unavailable. During extreme fire events, the quantity of drones, speed and swath that the ATLAS can scan the landscape and processing power of the fog, is constrained and may not be enough to handle all the fires, leading to firefighters receiving no or outdated information about the fires. The satellites in space will be left unattended but are not at risk of physical tampering, though physical inspection in case of problems is impossible. The drones, ground stations and pairing fog computing are in remote locations and tampering could occur. Implementation of cloud services should be done by professionals. Those using the cloud may be inexperienced and fall victim to phishing, leading to vulnerabilities in the cloud system. Possible insecurities in ground station's locations could allow unknown attack vectors (Stremlau, 2021).

4.2 COUNTERMEASURES

Barely any information is collected on the stakeholders in the solution, other than usernames and passwords in the cloud for the application service. This information should be hashed, salted, and encrypted, with proper authentication for access to the cloud used, and a well-known, well maintained cloud service should be used such as AWS. Other countermeasures are to protect the infrastructure of the solution. To protect against MITM attacks end to end asymmetric encryption with subsequent symmetric encryption for data transfer should be used, as well as message authentication codes (MACs), covering all data transfer, including between the sensors and the fog and cloud, as well as from the cloud to user endpoint with transfer layer security (TLS). Frequent checks and physical barriers should protect the ground stations, fog computing and drone hubs. To prevent against the very strict dependencies on CubeSat and fog fire location data, multiple CubeSats in range of multiple ground stations should be implemented, meaning if a ground station node or CubeSat goes offline, the path redundancy will allow other ground stations and CubeSats to cover the load until the issues are resolved. Multiple drones will also be on standby in case issues arise with the drone sent to the fire (Eleks, 2021).

4.3 ETHICAL ISSUES

Ethically individuals should be able to opt-in/out (depending on if it is defaulted to opt-in/out ofc) of having their residences as part of this coverage. An alternate ethical choice to keep privacy and security for residences, only the useful visual data may be kept. While the rest of the unneeded data (e.g., scanned residences), may be censored out by utilizing the weakest possible image resolution. To reassure the public, the software could be open source. The information collected from these sensors could also be used in other unintended use cases such as criminal investigations. It would be ethically correct to share this information to the police if it were accidentally uncovered. However, it could be illegal if it were on private property and the pictures are being misused. When using the drones, an ethical choice would be ensuring the communication between the respective local communities about the purpose of the drone’s usage (Allhoff & Henschke, 2018).

TASK 5: UI DESIGN

Using Marvel App Link to view and interact with app:

https://marvelapp.com/prototype/5ag98ig/screen/79412242

Note:

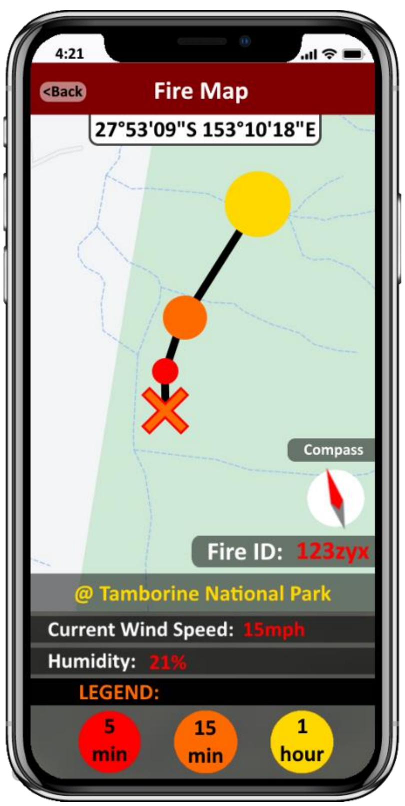
In Marvel App, only “Fire Map” and “Drone” Buttons function. Additionally, only the “Back” button functions for Drone and Fire Map Screen.

Home Screen

It contains the overall fire risk level with the QFES fire meter of a selected location, and has links to the current active fires, nearby drones, fires, archive current fires and the previous fires list. This app would be used by all stakeholders, but the public users would not have access to “Done”, “Put in Archive” and “View Previous Fires” menus.

Drone Screen

This screen would be seen after selecting from a list of drones that are currently assigned to a selected fire. It will show the drone number and a live feed of the drone footage with an overlay of detected fires. The weather information around the drone will also be displayed, including the current wind speed, humidity, and altitude. Hitting the back button will move back to the home page.



Fire Map Screen

This screen would show a Google Maps like top-down map which uses fire prediction information and displays it graphically, showing where the fire started and will spread in 5mins, 15mins and 1hour. The current wind speed and humidity is also shown, accompanied by coordinates at the top and compass so that the user can find their bearings in relation to the map and the fire.

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Disclaimer:

Word limit guidelines were adhered to in cases where the scale of the solution did not limit the ability to express the relevant information. For instance, the security and privacy concerns of the project were expansive due to the solution and thus the word limit provided was not enough to accurately express the information needed to meet the assessment criteria.