Drone Mesh Communication Network

Problem Statement

Every year, numerous forest fires wreak havoc, consuming millions of acres of land globally. These fires pose a significant threat to natural habitats, surpassing other forms of land destruction, and causing widespread devastation to homes and businesses. The United States Forest Service underscores that effective prevention of forest fire destruction lies in proactive land management and early detection strategies.

A considerable challenge arises from the fact that many forest fires initiate in remote, hard-to-monitor areas. Often, these fires can propagate for weeks before being identified, making containment and extinguishment efforts considerably more challenging. The highest likelihood of forest fires occurs during hot and dry weather conditions. To enhance the capabilities of wildfire firefighters, there is a critical need for technology facilitating the management of wilderness areas and the early detection of forest fires when they are more manageable in their nascent stages.

Given the exponential nature of fire spread, the swiftness with which firefighters can identify these fires profoundly impacts their ability to control and extinguish them. A promising solution to this challenge involves the implementation of a system comprising autonomously flying drones. These drones would traverse wilderness areas, utilizing advanced sensors and imagery to promptly detect the presence of forest fires. This proactive approach holds the potential to significantly improve the effectiveness of firefighting efforts in curbing the destructive impact of these fires.

Introduction

To develop an effective system of drones, numerous design requirements must be meticulously considered to optimize the technology's performance. A paramount concern and top priority in this design are the communication protocols facilitating data exchange between the drones and a central HUB responsible for data collection and system control. Given that many forest fires occur in remote areas devoid of conventional communication infrastructure, ensuring reliable data communication becomes a critical challenge.

To address this challenge, the most viable solution involves establishing a mesh communication network, leveraging the collaborative efforts of multiple drones to relay data across expansive areas back to a central HUB for seamless data acquisition and system control. The rationale behind this approach is grounded in the fact that flying drones at altitudes just above the tree line is essential for capturing optimal data from the targeted areas. However, this proximity to the ground makes direct data communication over long distances nearly unattainable.

Therefore, the creation of a mesh communication network among a fleet of drones emerges as a crucial aspect of this technology's success. This network extension is imperative to ensure the design's viability and incorporates self-healing mechanisms to address potential issues or delays in data transmission or the flight programming of individual drones. By establishing a resilient mesh communication network, the technology can overcome the challenges posed by remote locations and guarantee the seamless functionality of the wildfire detection system.

Component Description

XBee:

Xbee is a brand of radio communication modules developed by Digi International. These compact and versatile modules are designed for wireless communication in various applications, including the Internet of Things (IoT) and embedded systems. Xbee modules use Zigbee or other wireless protocols, providing reliable and low-power communication between devices over short to moderate distances. They are commonly employed in scenarios requiring wireless connectivity, such as sensor networks, home automation, and industrial automation. The Xbee modules are known for their ease of use, scalability, and compatibility with diverse hardware platforms, making them a popular choice for wireless communication solutions.

Temperature and Humidity Sensor:

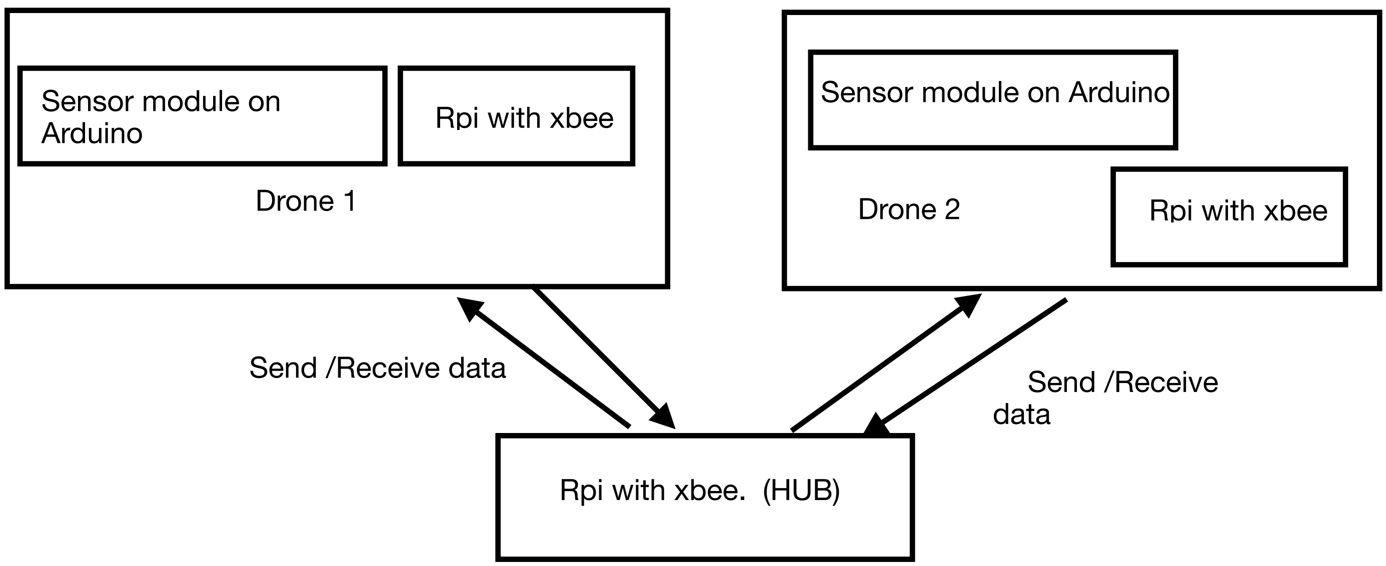
A temperature and humidity sensor is a device that measures and provides data on the ambient temperature and relative humidity of its surroundings. These sensors are commonly used in various applications, ranging from weather monitoring and climate control to industrial processes, agriculture, and home automation.

Wind speed sensor:

A wind speed sensor, is a device designed to measure the velocity of wind in its surrounding environment. It is a crucial component in various applications, including weather stations, industrial processes, aviation, and environmental monitoring.Wind speed sensors may undergo calibration to ensure accuracy in their measurements.

Raspberry Pi:

Raspberry Pi (RPI) is a series of small, affordable, and versatile single-board computers developed by the Raspberry Pi Foundation. These credit card-sized computers are designed to promote computer science education and facilitate affordable access to computing for hobbyists and enthusiasts. The Raspberry Pi boards typically feature a Broadcom system-on-chip (SoC), various input/output ports, HDMI output for display, and GPIO (General Purpose Input/Output) pins for hardware interfacing. With a range of models catering to different needs, Raspberry Pi has become widely popular for diverse projects, including home automation, robotics, educational initiatives, and as a platform for learning programming and electronics. The community support and a wealth of available software make Raspberry Pi an accessible and powerful tool for various creative and educational endeavors.



Project Design

Hub:

The HUB serves as a central command and control center, endowed with the necessary capabilities to monitor and manage the entire system effectively.

For monitoring purposes, the HUB is equipped with a Zigbee radio and functions as an integral part of the wireless mesh communication system, serving as the coordinator for the routed data transmitted from the sensors on the drones. Upon receiving this data, the HUB possesses the capability to store it for scientific analysis and machine learning applications. Machine learning algorithms can be integrated into the data acquisition system to discern patterns within the data measurements, enabling the system to make predictions and provide indications of potential fire existence based on identified patterns.

In terms of system control, the HUB has the capacity to communicate with the flight controllers of all drones. It can relay GPS coordinates and flight directions to each drone, facilitating centralized control over the entire fleet. To achieve this, a Raspberry Pi is employed as a computing unit to govern the flight programming of the drones. This control system ensures the most efficient and optimal positioning of the drones to establish and maintain a mesh communication network over a designated area of interest.

Drones:

Each drone is integrated with a sensor module which consists of temperature, humidity and wind speed sensors to collect the values at a particular area.Every drone in the fleet should be equipped with the same sensor systems to expand the versatility of the system by creating more opportunities for the design to cover land and detect the presence of a fire. The design uses an Arduino to collect the sensor signals. These signals will then be processed and packetized into digital hexadecimal code and relayed though the mesh communication network back to the HUB.

Creating Mesh Network and Extending Range:

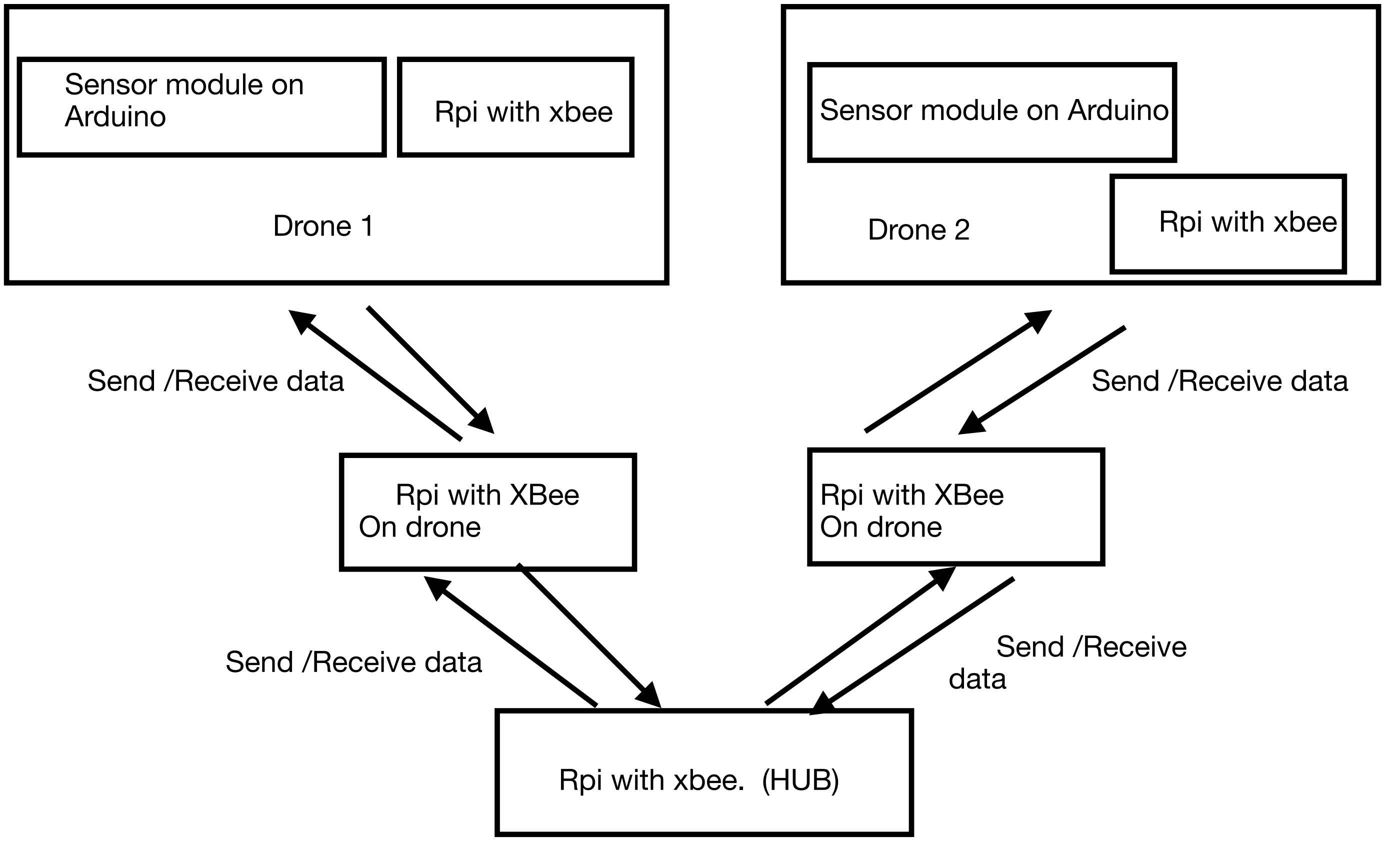
We are using zigbees to enable communication between drones and hub.These devices act as radios that can transmit and receive signals. All the drones and hub are equipped with a zigbee module.

Each zigbee has a communication range of 100m in closed spaces and a range of 300m in open spaces. To extend the range and enhance the reliability of the communication network in the drone system, several strategic measures are implemented.

First, a Range Extension approach is adopted by positioning nodes strategically beyond the direct reach of each other. This ensures that the communication coverage extends over a larger area, especially in remote or challenging terrains.

Additionally, an Overlap Strategy is employed, ensuring that communication nodes have overlapping coverage areas. This guarantees continuous and seamless connectivity, minimizing potential communication gaps. To address long-distance data transfer challenges, the system utilizes Indirect Communication, employing intermediate nodes to relay messages over extended distances.

Furthermore, a Data Hopping technique is implemented, allowing messages to jump across multiple nodes to reach their destination efficiently. Collectively, these strategies contribute to the robustness and efficiency of the communication network, enabling effective data transfer and coordination in the monitoring and control of the drone fleet. To achieve this all the signees should be in the same network with same configurations.



Machine Learning:

In the proposed wildfire detection system, a Sequential TensorFlow model is employed as the core computational unit on the central HUB to predict the occurrence of forest fires. This model is structured as a sequence of layers, allowing for a systematic flow of information during both the training and prediction phases.Environmental data, including temperature, humidity, wind speed, photographs, and infrared sensor readings, is collected by the fleet of drones.The raw sensor data is preprocessed to handle any missing values, normalize numerical features, and encode categorical data if necessary. This ensures a consistent and standardized input for the machine learning model.A Sequential TensorFlow model is defined, comprising layers that process the input data sequentially.The model is compiled with appropriate loss function, optimizer, and metrics. Given that this is a binary classification problem (fire or no fire), binary cross entropy is used for the loss function, and the Adam optimizer is used. The model is trained on the prepared dataset, learning to map the input environmental features to the binary output indicating the presence or absence of a forest fire.The model's performance is evaluated on a separate test dataset to measure its accuracy and assess its ability to generalize to new, unseen data.Once the model is trained and deployed, it can make real-time predictions based on incoming sensor data from the drones. The Sequential model processes the data through its layers in sequence to produce a prediction.The model's output is often a probability value between 0 and 1. A decision threshold is applied to convert these probabilities into binary predictions.The binary predictions are then used to trigger an alert system, notifying relevant authorities or initiating preventive measures if a potential forest fire is detected.

In summary, the Sequential TensorFlow model processes the diverse sensor data from the drones through its layers, learning patterns and correlations during the training phase. Once deployed, the model provides accurate real-time predictions, contributing to the early detection and management of forest fires in the monitored areas.

Conclusion

In conclusion, the proposed wildfire detection system integrates autonomously flying drones equipped with advanced sensors and a mesh communication network. The use of XBee modules facilitates reliable data exchange between drones and a central HUB, overcoming communication challenges in remote areas. The incorporation of a Sequential TensorFlow model on the HUB enhances the system's predictive capabilities, leveraging machine learning to analyze environmental data for early fire detection. The strategic design considerations, including mesh network extension and machine learning integration, collectively contribute to an efficient and proactive wildfire monitoring and control system. This comprehensive approach holds promise for mitigating the devastating impact of forest fires on a global scale.