

Node-Based Range Extending Recon Drone

Team 27

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1. Introduction

1.1 Objective

The utility of drones in reconnaissance roles is an expanding field. Drones are currently used to assess the spread of both urban and forest fires. However, their utility is still largely limited to exterior action, either operating above the canopy of the forest or in the air around a burning building, as examples. Their ability to operate is limited by where their command signals can reach, making control in locations like building interiors, forests floors, sewers or tunnels, or anywhere dense with obstructions unreliable.

Our project addresses this issue with a node-based range-extending solution. Our vehicle will use deployable nodes - which are capable of receiving and re-transmitting command instructions - that the lead segment can jettison while moving as it nears its operators maximum range. These nodes will serve as middlemen, routing instructions to the vehicle and allowing the operator to continue controlling the vehicle as it enters an otherwise unreachable region. Our project ultimately expands on drone control methodologies and allows for operation in previously inoperable environments.

1.2 Background

Our project is not the first foray into drones as a means of reconnaissance and rescue. In the days following the September 11, 2001 attacks in New York City, researchers from the University of South Florida, funded by the National Science Foundation (NSF), were on-site at ground zero using prototype robotic vehicles to search the rubble for survivors and remains. They were limited in their ability, however, as their vehicles were tethered to their operators with a maximum range of 100 feet. We hope to improve on this maximum range with vehicles that can deploy nodes at critical junctions and nexuses in their search space [1]. We aim to forgo the

need for a tether to navigate commands from an operator to a vehicle, given that a convoluted or constrained path lies between the two.

1.3 High-Level Requirements

- Controller should be able to control the vehicle.
 - Instructions from the controller should be able to send instructions via ZigBee communication protocol to the vehicle, which should then move, without error, as instructed by the controller.
- Nodes should deploy from the vehicle
 - The vehicle should begin with two nodes attached to its main segment which, at the operator's instruction, should be fully released from the main segment.
- Nodes should route instructions from operator to vehicle
 - The nodes, once deployed, should be capable of retransmitting control instructions from the controller to the main segment of the vehicle. Control instructions should be capable of controlling the vehicle through the following paths: Controller -> Main segment, Controller -> Node 1 -> Main segment, and Controller -> Node 1 -> Node 2 -> Main segment. Signals, routed through one or both of the nodes, should be capable of controlling the main segment while it is in a region that the controller could not directly reach without the assistance of one or both of the nodes. An example situation might be where the vehicle operator is outside of a building while the vehicle is navigating a convoluted floor plan inside the building.

2. Design

2.1 Block Diagram

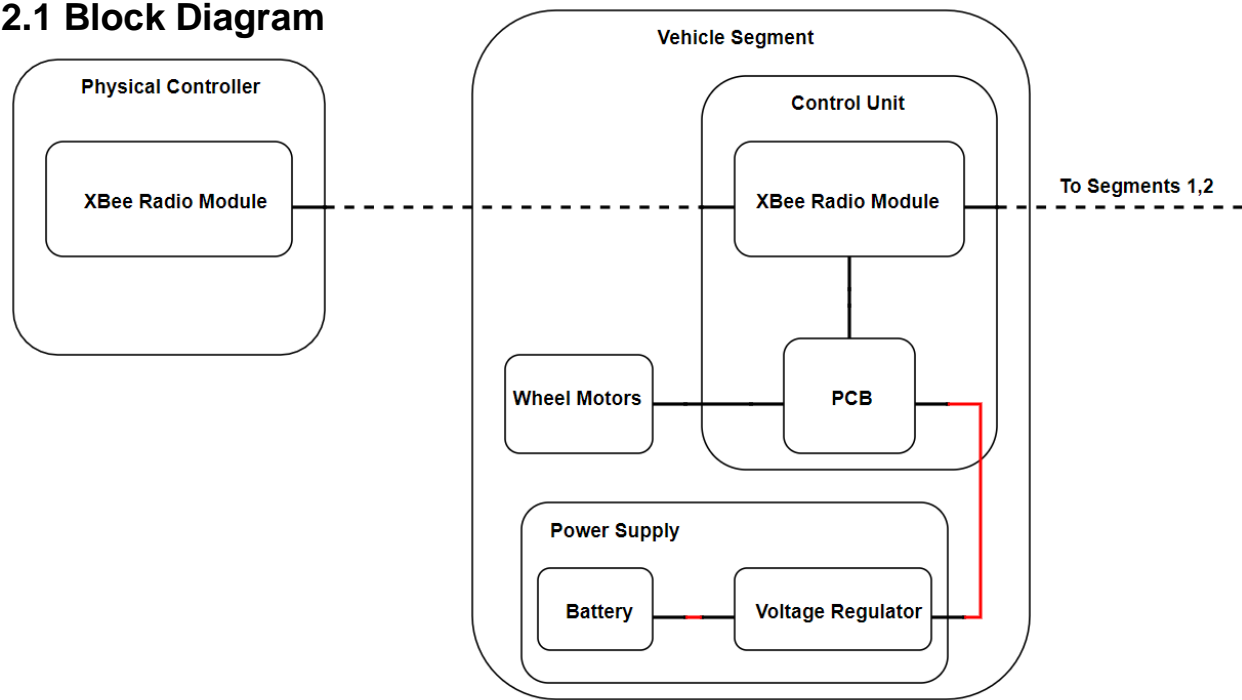


Image 1. High-level block diagram of a single segment vehicle

Image 1 illustrates the generic high-level modular block diagram for one of the vehicles that make up our project. Each segment will be designed off of this block diagram. Our design consists of three functional units: the physical controller used by a human operator, the control unit on each vehicle, and the power supply on each of vehicle. The power supply will consist of a lithium-ion battery and a voltage regulator, since the other components of our design do not require such high ratings. The control unit is comprised of a printed circuit board (PCB) and the XBee radio module, which will be necessary to control the wheels of our vehicles, as well as enable transmission of information between the controller and each vehicle segment. The physical controller will be used to send data to each XBee radio module through ZigBee protocol (UART).

2.2 Physical Design

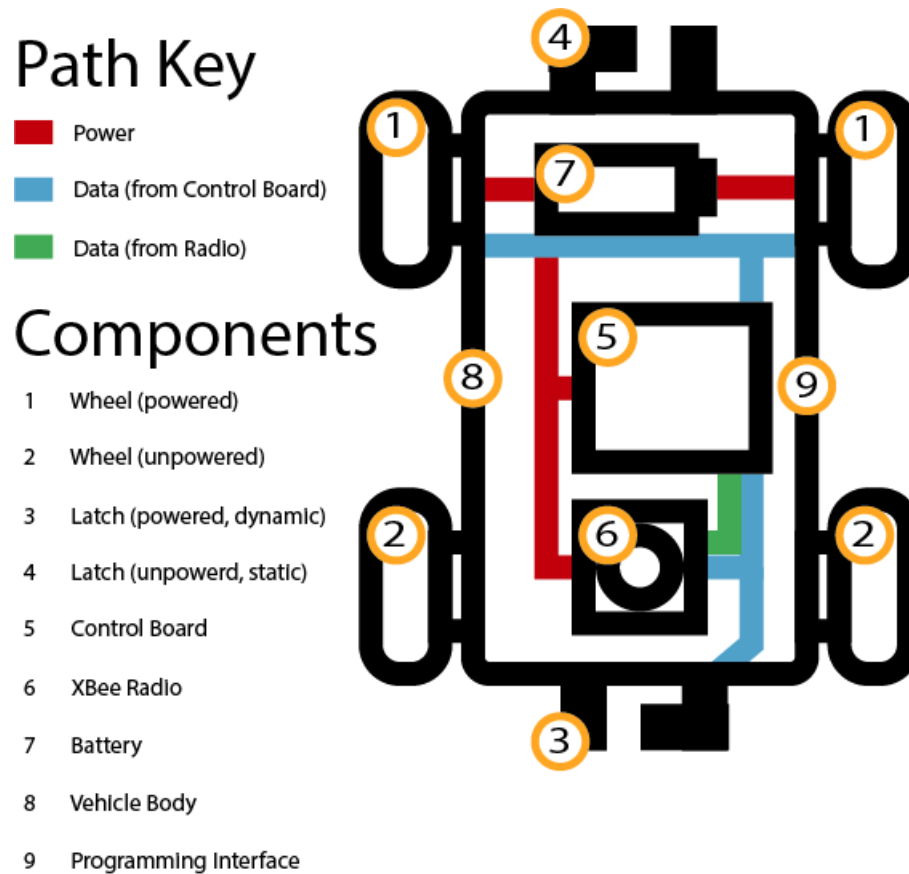


Image 2. Physical layout of a vehicle segment

The vehicle is to be made of 3 segments, with each segment linked together with a latching system. Image 2 displays the physical layout of one of the segments. It illustrates how power will be distributed from a segment's battery to the control board, the radio, the two driving/powered wheels, and the mechanical latch at a segment's rear. It also illustrates how data will be pushed to the control board when programmed, how data will be received from the radio module, and how instructions will be distributed throughout the segment to the powered/driving wheels, the radio module, and the mechanical latch.

2.3 Functional Overview and Block Requirements

2.3.1 Physical Controller (XBee radio module)

The physical controller will be operated by a human. It will be outfitted with an XBee radio module that will send instructions to each of the three vehicle segments for motor control and range-extending capability

Requirement: Given directional input, controller must be able to interface with the three vehicle segments. XBee module will operate on a voltage source of 3.3V at 45mA – 50mA.

2.3.2 Vehicle Segment (Wheel Motors)

The physical vehicle itself consists of the power supply and control unit, which are described in further detail below. As for the wheel motors, we plan on using RC servos to control the wheels. Small servos are relatively cheap, and the ones we will use will most likely fall in the price range of \$20 - \$25.

Requirement: our servos must be provided 4.8V – 6V by our power supply to allow wheel maneuverability.

2.3.3 Power Supply

Battery

We will be using a 9V lithium-ion battery to power our PCB, XBee radio module, and servos to control the wheels.

Requirement: battery must supply 3.3V – 6V to power the various components of our design.

Voltage Regulator

We will use multiple voltage regulators to provide constant voltages to our PCB, XBee radio module and servos.

Requirement: voltage regulators must regulate battery source voltage to 3.3V – 5V for PCB, 3.3V at 45mA – 50mA for the XBee radio modules and 4.8V – 6V for the servos.

2.3.4 Control Unit

PCB

Our PCB will be the control center for each vehicle, interfacing with both the wheel motors and the XBee radio module.

Requirement: PCB must be able to receive instructions through the XBee radio module and control input voltage to servos.

XBee Radio Module

The radio module will provide the interface between the physical controller and each of the vehicle segments.

Requirement: XBee module must be able to send/receive instructions to/from the physical controller and other vehicle segments. It must operate at a voltage source of 3.3V at 45mA – 50mA.

2.4 Risk Analysis

The most critical component of our project is the ability to route commands from the controller, through the node segments of the vehicle, to the lead segment. This functionality is critical, as it allows us to complete our main goal of extending the range of our vehicle beyond the initial operational range of the controller. There are several potential areas of risk in completing this feature before the project demo.

First, we must ensure that we are able to send and receive signals through the XBee radio modules using the ZigBee communication protocol. This standard of communication will be the backbone of future networking features on our project. These radios will be integrated into our PCB, and proper integration will determine the success or failure of this project. While is a critical component of our project, both XBee radio modules and ZigBee communication protocols are well documented and are frequently used for hobby projects. Therefore, we, determine that this is only a medium level risk.

Much more critical will be designing functionality that allows our nodes to route radio signals from the controller to the main segment of the vehicle. We expect one node to receive and instruction and then retransmit it to be picked up by another segment. This process is not well documented and we expect this networking task to take significant technical skill. To reduce risk, we aim to tackle this functionality first and ensure our competence in it, as it is the keystone feature of our project. Regardless, we are considering this an area of high risk, in order to underscore the importance of successfully achieving functionality.

3. Safety and Ethics

Safe and ethical practices are also a concern in the completion of this project, and there are two components of the vehicle that require special consideration in this area.

The first is the radio module. All communications between the controller and the vehicle will be via radio. As much of the project's development will take place in the ECEB, and there are many signal processing student projects, both in senior design and in the rest of the ECE curriculum, being worked on in the building it is important that we do not interfere with their development. We will fully adhere to FCC standards for amateur radio communication while developing our project, so as to avoid harmful interference with other entities. As one of our group members is a certified amateur HAM radio operator, the FCC regulations are well documented, and our development does not call for transmitting without a specific goal in mind we judge this to be a low level, manageable risk.

The second area in need of consideration is the battery. We plan on using lithium-ion batteries to power our vehicle segments, which can be dangerous if handled incorrectly. To mitigate this risk, we are following common sense battery handling procedures. We will only transport our batteries, and our vehicle segments if the batteries are installed, in a protective, padded case to reduce the risk of puncturing them if dropped. We will also ensure that we are not storing our batteries, or testing our vehicle in any wet or damp environment. We will only test dry, controlled environments where fire-suppression tools are easily accessible. Through these practices and through constant awareness, we believe this risk will also be low.

4. References

[1] nsf.gov. (2001). *At WTC Search, Graduate Students Deploy Shoebox-Sized Robots*. [online] Available at: <https://www.nsf.gov/od/lpa/news/press/01/pr0178.htm> [Accessed 20 Sep. 2018].