Asset Tracking System Prototype

Changelog Table

Date	Prototype Version	Key Functionality Added	Summary of Work
06 - 08 April 2018	V1.1	• Initial Communications • Transmission and receiving data between two Arduino chips	• Component Testing • Breadboard testing • Error testing • 7-seg display • Accelerometer Test
09 April 2018	V1.1	• Basic location detection zone based on packet loss of the transmitted signal	• System clock differential tracking ruled out • Timed for a ping return tracking ruled out
15 April 2018	V1.2	• Received Signal Strength (RSS) based distance tracking	• Implementation of RSS module • Testing signal strength over distance • Mapping decay equation to measured data • Using equation to determine distance between transmitter and receiver
21 April 2018	V2.1 (Iteration 2 & 3)	• De-acceleration threshold warning system • Water immersion detection system	• Integration of accelerometer and water sensor into transmitter module • Coding system state logic to respond to different stimulus • Testing entire system
27 April 2018	V2.2	• Circuit streamlining • Signal lost state	• Code refinement • Soldering components

Key Lessons from Prototyping

Determining the distance between transmitter and receiver

There are multiple ways to use the properties of electromagnetic waves to determine the distance between a transmitter and a receiver. Through the prototyping process, it was discovered that using the strength of the received signal was the most useful.

We started by looking into using the system clock, if the system clocks between the transmitter and receiver were synchronised, then all the transmitter would have to do is transmit its on-board time, the difference between the received message and the time of the receiver's system clock would give the time delay and ultimately the distance. Unfortunately, the Arduino chips don't possess a built-in system clock, so synchronising the clocks was close to impossible.

Still attempting to utilize time delay for distance calculation, since the calculation is simple and less susceptible to noise, we investigated pulsed communication (this would necessitate each device being capable of transmitting and receiving). Doing some basic calculations revealed an important flaw:

- Radio waves travel at 300,000,000 m/s
- Oil rigs are approximately 150m x 100m (http://theweek.com/articles/494480/oil-rigs-cities-sea)
- If the base station was located at the centre of the rig, and the tag at the extremity, a pulse between the transmitter and receiver would have to travel 150m, which would take 0.5 microseconds
- Even if the rig was 1km in diameter and the signal had to travel 1km, it would only take 3.3 microseconds
- Arduino chips only have a maximum time keeping resolution of 4 microseconds (https://www.arduino.cc/reference/en/language/functions/time/micros/)

Ultimately, while it would be possible to use time delay if we had sophisticated equipment with extremely accurate time keeping functionality, it is beyond the budget and feasibility of this prototype and would drive the cost up of a commercial system.

We next explored using packet loss, since the percentage of data lost in a known transmission could be used to estimate the distance between transmitter and receiver. It was discovered in testing the prototype that the amount of information lost in a short period of time had a lot of random variation. Increasing the distance between the transmitter and receiver didn't reveal much information, there was little consistency in the randomized loss second to second over short distances. Over slightly longer distances ~20m away, the signal from the transmitter was almost completely lost and not picked up by the receiver. This property could be used to establish a safe zone which could set off an alarm when one of the tags drifts outside of the zone but would not provide that much value as a fully-fledged tracking system.

We ultimately decided that we would have to modify the design to make use of received signal strength (RSS). To incorporate this functionality into the prototype, so that the distance between receiver and transmitter could be determined, an RSS Arduino receiver antenna was purchased and installed. Using RSS information would be the most feasible option in a more advanced system, due to the relatively short distances between transmitter and receiver in the context of the speed of light. Multiple receiver nodes could be used to reduce the impact of signal loss and narrow down the location of the transmitter to a specific point in 3D space.

Trade-off between tracking accuracy and sensor data

Programming in the logic for the water sensor was a bit complicated and reveal an interesting behaviour quirk of a real system. Since the device is primarily a tracking system, rapid location updates are crucial, and this is best achieved by having the transmitter send consistent short pulses of information very rapidly. This, however, brings up a trade-off with the sensors included on the transmitting device. Transmitting the recorded sensor data inevitably makes the messages larger, slowing down the rate that they can be sent at, which in turn reduces how quickly the location of the transmitter can be updated. Finding a balance is an important consideration in designing the system.

To work around this limitation, we increased the amount of data pre-processing from the onboard sensors that is done by the transmitter itself, so that the only thing that needs to be transmitted is a simple status number to the receiver. This ensures that simple messages can be constantly delivered, which in turn works with the RSS receiver to determine the distance of the transmitter, but this means that the transmitter is running more calculations, increasing its power draw, and raising the minimal viable complexity of the device.

Current State of Prototype

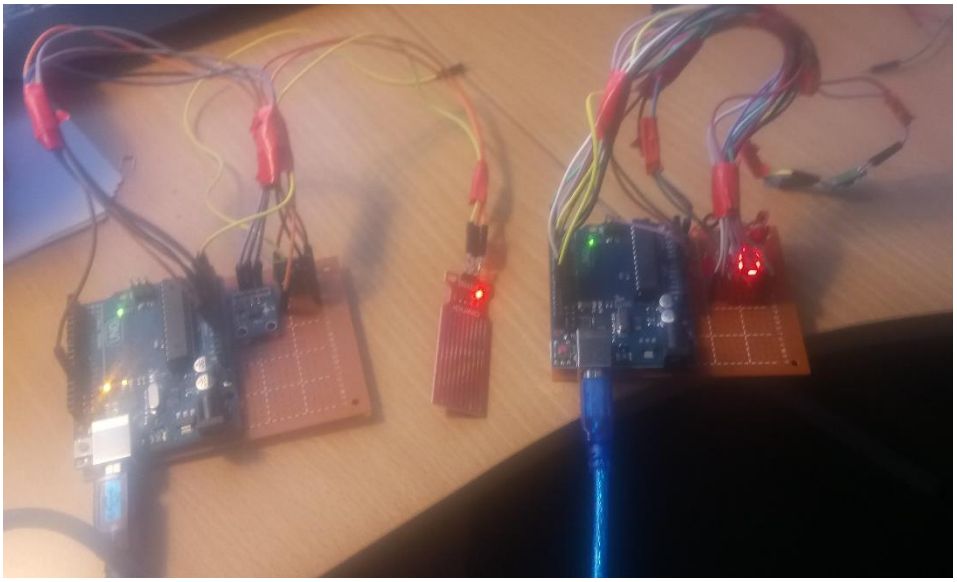

FIGURE 1: V2.2 (ITERATION 3) OF TRACKING SYSTEM PROTOTYPE

Key Features

- Self-contained transmitter and receiver, both capable of operating on 9V batteries
- Integrated sensor package in transmitter
- LED and 7-segment display alert system on receiver

Functionality

- Received signal strength (RSS) based tracking used to display the distance between receiver and transmitter on the 7-segment display of the receiver
- Immersion of the transmitter in water detection and subsequent alert on the receiver
- Harsh de-acceleration detection and notification
- Loss of transmitter signal identification