Detection of Anomalous Position Reports of Vehicles in a WAVE/SAB Network

Kevin Nelson, 100623432
knelson@connect.carleton.ca

1. Introduction

1.1 Context/Background

Everyday people rely on communications from within their vehicle, through cell phone use, radio, global positioning or remote assistance. There seems to be limitless forms of communications giving reason to create and explore the boundaries of each**.** One avenue of communications currently being explored is inter-vehicle communications. The primary benefit of this technology is that it could improve safety by issuing traffic and weather warnings, or even provide notification of an impending collision. Wireless Access in Vehicular Environments (WAVE) [1] is a developing set of standards that governs wireless communications between vehicles. As with any new standard, there are open issues that need to be solved. One such issue is the ability to track a vehicle over time and space [2]. This vulnerability arises from the WAVE standard's broadcast messages. A proposed solution to address this problem is an augmentation to the WAVE standard. Secure Anonymous Broadcasting (SAB) [3] creates certificate based security which allows for anonymous broadcasting. Naturally this augmentation comes with additional issues to tackle. One such issue is the topic of this paper.

1.2 Definition of the problem

The SAB protocol creates certificate based security within a vehicular network. Certificate based security has several requirements including: dissemination, authorization, and revocation to name a few. It is important to have a strong system for revocation of certificates to maintain trust within the network. To accomplish this, a means of detecting anomalies in the network and assess trustworthiness must exist. There are many scenarios that require the detection of anomalies to ensure security and safety of the network. There must also be a means of detecting those who would subvert the security of the network for their own use.

A security threat that has been identified to WAVE is known as location spoofing [2]. SAB does not provide a solution to this threat, thus requiring further security measures. This threat is minor, but detection of this type of manipulation is important. It provides a *first line of defense* against attacks. For example, if someone intended to attempt a more sinister attack, it would first be prudent to hide their own location.

The problem that this paper addresses is a method of determining if a vehicle within a WAVE/SAB network is spoofing its location.

1.2 Summary of the Results

The findings of this paper give a description of revocation rules designed to prevent location spoofing as well as a detailed account of three possible schemes for anomalous position report detection.

1.3 Overview of the Report

The background information about the network and an introduction to the revocation scheme using anomalous position report detection are in Section 2. The setup for the simulation environment is described in Section 3. The results of the project are presented in Section 4. A discussion of the results and an evaluation of each solution are presented in Section 5. Finally, future work and the conclusion are presented in Section 6.

2. Detailed Background & Setup

2.1 Revocation

Detection of falsified reports is required in order to facilitate certificate revocation. This is accomplished by a series of rules which can identify a falsified position report. These rules require storage of each vehicle's past position report. A position report consists of a location, a direction, and a speed. This information is used to detect if a vehicle can be where it claims.

First, there must be a check to make sure that a reported location, received by a Road Side Unit (RSU) [1] is within the range of that RSU. If the vehicle is reporting a location that is not within the RSU's range, then that RSU should not be receiving the message.

Next, the RSU has to check if the current location of a vehicle is plausible given its previous location, direction, and speed. The RSU has to store this set of values for each vehicle and check them periodically using a set of plausibility rules to detect the truth of each position report. There must be some mechanism for creating an area bounding the possible location of a vehicle in a given amount of time.

2.2 Anomalous Position Report Detection

The objective of the anomalous position report detection mechanism is to calculate a tight area bounding the vehicle's future location, given its present speed, direction, and acceleration.

There are many different approaches to this problem. One approach suggests using both acceleration and direction as a constant, by using infinitely small periods of time between evaluations of position reports.

Another alternate approach is to use a very large period of time, and produce a large and encompassing anomalous position report boundary for the vehicle's location.

Finally, the approach this paper takes is somewhere between these two extremes. We create a tight upper bound at a useful interval of time. This approach is both practical and useful for our purpose.

I used OGRE to create a simulation of a car moving in a planar world with the three models for anomalous position report detection. OGRE (Object-Oriented Graphics Rendering Engine) is a scene-oriented, flexible 3D engine written in C++.

4. Result

We have created a simulation that illustrates the movement of a vehicle as well as the graphical representation of a bounded anomalous position report detection model. The anomalous position report boundary is updated when the vehicle reports its location, speed, and direction. This gives us a visual test to see if the vehicle stays within the boundary. In our model, the previous position report's boundary is green coloured, while the current position's boundary is white. To find the most effective boundary, three models for anomalous position report detection are assessed.

The first model uses the current speed as an indicator of the maximum distance a vehicle could travel.

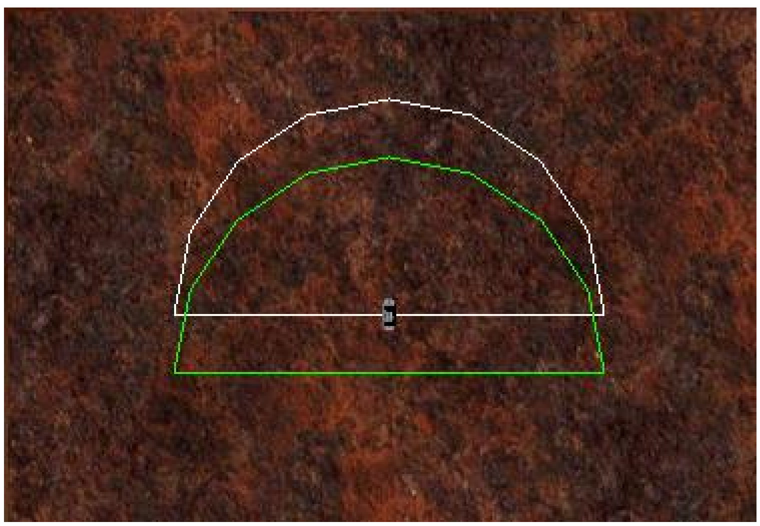

Fig.1. Semi-Circle Boundary for Current Position (White)

Using a semi-circle to represent this bound, the bound grows at a constant rate relative to the speed being traveled. As shown in Figure 1.

The second model, based on the first, uses present speed and acceleration to calculate the boundary. This also has a semi-circle representing the bound, growing and shrinking its radius with the current speed and acceleration of the vehicle.

The third model is much more complex than the first two. It is based on the polar equation of $r = 1 + \cos\theta$. This model produces a shape, which looks something like a heart, called a cardioid, as seen in Figure 2.

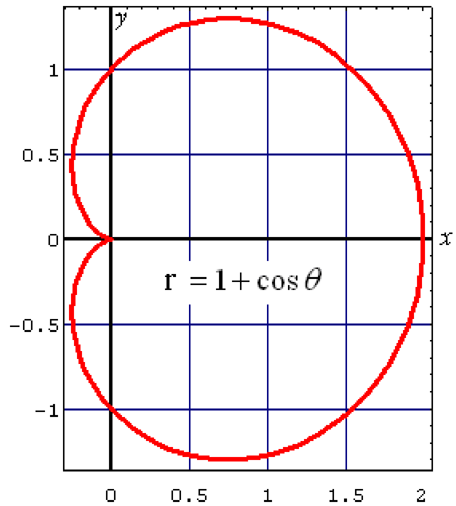

Fig. 2. Cardioid. [5]

The simulator's use of the equation is such:

$$r = (1 + percentOfMax * \cos(\Theta)) * abs(speed / (1 + abs(percentOfMax)))$$

Where percentOfMax equals the decimal percentage of the maximum obtainable speed of the vehicle and speed equals the current speed plus the acceleration of the vehicle. The part of the equation in the first set of brackets creates the boundary's shape which is dependant on the current speed. The second part of the equation scales the boundary accordingly.

This creates a circle around the vehicle when it is stopped as seen in Figure 3.

Fig. 3. Circle Around Car Using the Third Model

As it accelerates, the circle elongates in front and shrinks behind the vehicle in one smooth motion as seen in Figure 4.

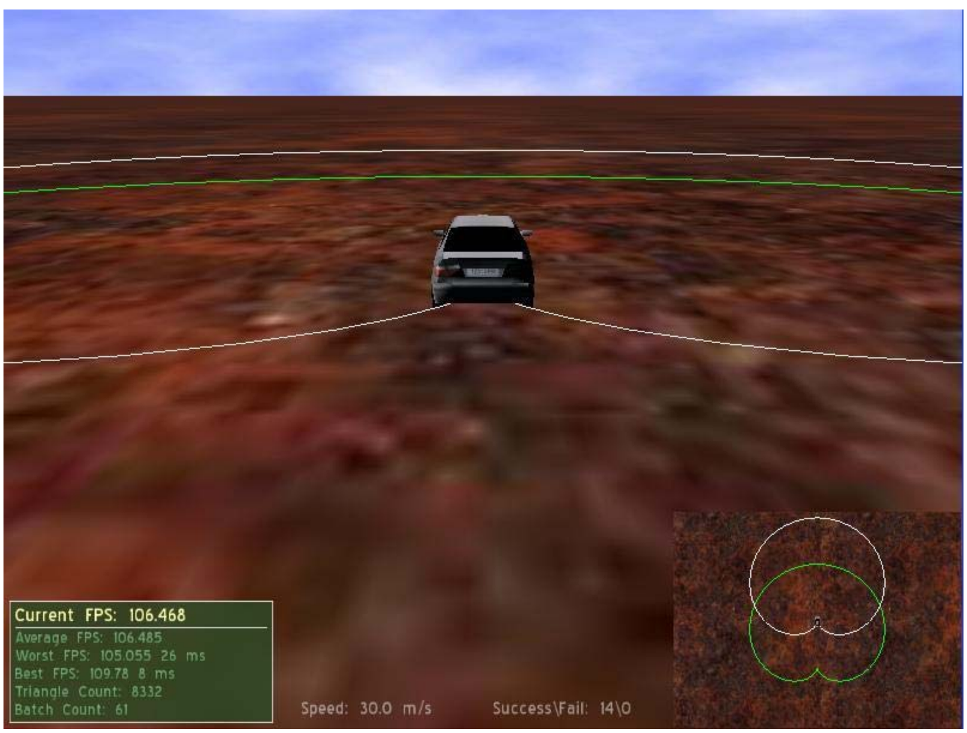

Fig. 4. Cardioid In Front of the Car Using the Third Model

This creates a situation where the car cannot slow down and then reverse fast enough to leave the boundary behind it.

One problem faced is, how to test each model without having human interaction skew any results. A macro program is employed to take the human factor out of the equation. Using a set of predetermined random turns at random intervals for each model should compare them on equal ground.

5. Evaluation of the Result

Using the macro (see Appendix) to drive the simulator for each of the three models, the following results were obtained.

	Model 1	Model 2	Model 3
Success	232	293	275
Failure	61	0	18

Table 1. Results from simulator driven by macro.

Each success of a model means that a location report was within the boundary that it created, and a failure indicates that the location report was outside of that boundary. Since the model is attempting to bound normal driving practices, we are trying to have a maximum amount of successes, and minimum amount of failures. That is to say that with *normal* driving, the number of times a model will wrongly detect an anomalous report is, the number of failures divided by the total number of reports. The model with the smallest number of false positives is preferred.

The first model has proven to be insufficient in detecting anomalous position reports. If, within the time between reports, a vehicle is (on average) accelerating, then the boundary fails to contain the vehicle's location.

Fig. 5. Simulator Demonstrating the First Model.

The reported location and corresponding boundary (green) has been exceeded by the accelerating car. This will continue as long as the car continues to accelerate. Any time the vehicle accelerates, we fail to predict a boundary for its location. This is an unacceptable result because vehicles are expected to accelerate and decelerate often in the real world and should not be reason for certificate revocation. Since this model's failure rate is be quite high as seen in Table 1, it is insufficient to use for this revocation scheme.

The second model works much better than the first. It allows the vehicle to accelerate and remain within the bound. This model suits quite well for forwards and backwards motion, but it requires additional allowances to account for the transition between the two. This would be only a small source of error, occurring if someone was backing up, then moving forwards, or vise-versa. Since allowances have been made, it works with a one hundred percent success rate as shown in Table 1.

The third and final model works the best of the three visually, but in testing it shows some problems. It is able to bound the vehicle while accelerating also while transitioning between forwards and backwards motion. It fails a very small percentage of the time and only while doing what would be considered *extreme driving*. They could be eliminated by increasing the size of the bound by a very small margin.

6. Future Work & Conclusion

Anomalous position report detection forms a strong basis for detection and revocation of a vehicle attempting to falsify their location. A useful addition to this scheme would be a measure of trustworthiness for each vehicle. This would allow for a small margin of error in anomalous position report detection for variables in the real world that could not be simulated. Also the WAVE standard does not include messages containing speed, location and direction. A unique data structure would need to be developed for this purpose. An additional problem to explore is the requirements the RSUs will have to meet. Questions that need to be answered include: What is the optimal interval between reports? How many vehicles can an RSU keep track of at one time?

This revocation scheme is such that it greatly reduces the potential for a location to be successfully spoofed. To ensure security and trust within the WAVE/SAB network, revocation of certificates must be possible to prevent those who would subvert it. Anomalous position report detection is a possible solution to prevent successful location spoofing. Given the results shown in this paper, revocation using the anomalous position report detection scheme will increase the overall security and reliability of the network.

References

[1] IEEE Vehicular Technology Society, “5.9 GHz Dedicated Short Range Communications (DSRC) - Overview.” [Online]. Available: http://grouper.ieee.org/groups/scc32/dsrc/

[2] C. Laurendeau and M. Barbeau, “Threats to Security in DSRC/WAVE,” in Proceedings of the 5th International Conference on Ad Hoc Networks and Wireless (ADHOC-NOW). Lecture Notes in Computer Science, Springer Berlin / Heidelberg, Volume 4104, 2006.

[3] C. Laurendeau and M. Barbeau, “Secure Anonymous Broadcasting in Vehicular Networks”, First IEEE LCN Workshop on User Mobility and Vehicular Networks (ON-MOVE), Dublin, Ireland, 2007.

[4] ——, “IEEE Trial-Use Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages,” IEEE Std 1609.2-2006, July 2006.

[5] Wikipedia, “Cardioids”, [Online]. Available: http://en.wikipedia.org/wiki/Image:CardioidsLabeled.PNG

[6] ACTool, Macro Program for Asheron’s Call, [Online] http://www.actool.net/

Appendix

Macro used for simulator testing. Written and run in ACTool [6].

```
//Honours Project Macro
DELAY 1000
MousePos 190, 780    //Move mouse to open simulator
LEFTCLICK            //Click
LEFTCLICK            //Double click
MousePos 760, 700    //Move Mouse to start simulator
DELAY 4000           //Wait 4 seconds
LEFTCLICK            //Click
DELAY 3000           //Wait 3 seconds
Keys 3               //Select the Mode
                     //Start Driving
Keydown WD 4000
Keydown S 5000
Keydown D 8000
Keydown W 2000
Keydown S 6000
Keydown A 7000
Keydown AS 3000
Keydown D 2000
Keydown WD 5000
Keydown SD 9000
Keydown W 10000
Keydown A 8000
Keydown WA 6000
Keydown W 1000
Keydown WD 11000
Keydown AS 15000
Keydown D 10000
Keydown S 2000
Keydown W 14000
Keydown S 5000
Keydown D 6000
Keydown DS 4000
Keydown WD 5000
Keydown SD 9000
Keydown W 10000
Keydown A 8000
Keydown WA 6000
Keydown W 1000
Keydown WD 11000
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Keydown AS 15000
Keydown W 2000
Keydown S 6000
Keydown A 7000
Keydown AS 3000
Keydown D 2000
Keydown WD 5000
Keydown SD 9000
Keydown S 2000
Keydown W 14000
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