Internet of Things: Vehicle Collision Detection and Avoidance in a VANET Environment

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Abstract— **In robotics, manufacturing and computer-simulation; accurate and fast collision detection between general geometric models is a fundamental problem. The elucidation of this problem will gravely improve driver safety and traffic efficiency. This paper develops a system for vehicle communication that addresses this problem. Vehicular Ad-Hoc Network (VANET) technology is utilized to create a distributed network allowing the exchange between automobiles on a large scale for the implementation of Vehicle-to-Vehicle (V2V), or Vehicle-to-Infrastructure (V2I) communication protocols. The goal of the research is to create a VANET environment and algorithm for collision detection. Collision avoidance emanates from the detection algorithm. A computer model involves running a simulation through a network simulation (NS3). To better understand the behavior of communicating vehicles and infrastructures, nodal representation of the road system will be generated to mimic real road topography. The physical experiment involves constructing a VANET implemented with microcontrollers, sensor systems and radio controlled cars. Integrating all these will generate a collision detecting system which helps improve traffic efficiency on a minute scale. This physical model was executed using an Arduino UNO, RGB LCD Shield, GPS Logger Shield, SR04 Ping Distance Sensor, RF 433 MHz Transmitter Module, RF 433 MHz Receiver Module and a DC motor (from the Car).**

Keywords **–Microcontroller; collision detection; wireless sensor network; Internet of Things (IoT); Vehicular Ad-Hoc Network (VANET); Dedicated short-range communications (DSRC); NS3; frequency.**

I. INTRODUCTION AND BACKGROUND

In the world we live in, traffic congestion is one of the most serious problems faced by big cities and therefore, it has made the population live in difficult situations. Developed countries, however, are increasingly characterized by a pervasive computing environment. Messages are transmitted at a speed faster than sound. A hyper society consisting of objects connected to mobile devices and to the Internet, while interacting with each other, has been brought forward by the rapid progress of information technology [1]. The Internet of things (IoT) is becoming a vastly growing concept in the digital world and is the idea of having millions of devices and objects connected together without requiring human interaction. As of 2020, there is to be an estimate of 20 billion devices to be in use growing three times what it is as at 2017 [2, 3]. This spike in devices is a direct correlation with its connection to the digital web. More devices will be developed; therefore, more standards of the internet technology will be created. The National Institute of Standards and Technology (NIST) has introduced next-generation precautions for Information Systems, IoT and for security and privacy safeguards to work successfully and protect users in the interconnected world. This means that devices will not be plagued with the complexity of compatibility, hereby improving communication. Telecommunication industry will play a unique role in the future of the vehicle industry. Traffic congestion and localization sufficient data are challenges that drivers on the road face now, more than ever. This paper, however, unfolds the implementation of VANET technology for drivers to make smart decisions on the road [3].

Vehicle-to-Vehicle (V2V) communication could enable a great number of use cases, mostly in relation to improve driving safety or traffic efficiency but also to provide decision igniting information to the driver. Cars can also receive connectivity from computing devices placed on the roadside or from a base station. These stationary transmitting infrastructures also communicate with each other, hence, infrastructure to infrastructure (I2I). The roadside unit does not have to be built on the side of the road as it can be implemented to a traffic light on the road or an exit in the case of a highway. This unit along with the base station acquires traffic data for speed, instance time and location of the vehicle; to further process it for filtering false information and understanding the character of the road [2, 4].

In VANET, magnetometers are used in some locations to detect the signature of different vehicles that travel on a given highway, such as the type of vehicle, the weight, the number of axes, etc. It is a new technology that uses sensor placed underneath the road and before the vehicle

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approaches, the sensor will experience a uniform field [8]. When a car travels over the sensor, the latter will measure the slight change in the magnitude and direction of the earth's magnetic field to determine the make and model of vehicle. For every vehicle, there is a designated signature to differentiate it with other automobiles on the road. When the signature of each car is identified, the sensor will send the information to a roadside unit.

A major concern in the V2V models is that a sensor node may be hacked and used to transmit false data. To prevent attacks of this kind, an Iterative Filtering Algorithm (IFA) is often employed. IFA compares sensor readings and decreases the aggregate weight of sensors that are outputting values which are largely different from expected values [5]. In this way, the IFA carry out the data aggregation as well as the data trustworthiness. IFAs have been used for years in digital signal processing for filter processes such as removing impulse noise from corrupted images [6, 7]. This research effort was able to simulate two scenarios so far. The first scenario simulates a basic model of two cars in the presence of a single roadside unit. The two nodes (cars) in the network collide on an intersection. The Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol is used in the simulation which is a protocol in computing networking in which carrier sensing is used. Nodes attempt to avoid collisions by transmitting only when the channel is found to be clear. The other scenario was an intersection having four nodes going in different directions with the nodes being able to transmit information to each other as well as to the roadside unit.

Wireless mobile networks, therefore, have traditionally been based on the cellular concept and relied on good infrastructure support, in which nodes (cars in our case) communicate with access points connected to the fixed network infrastructure. The institute of electrical and electronics engineers (IEEE) develop wireless networks for device communications. The IEEE 802.11 standard body is currently working on a new amendment, the IEEE 802.11p, to satisfy internetworking communication with a frequency band of 5.9GHz [5-7]. It is important to know that the IEEE protocol was not used in the physical model as we achieved adequate results with a lesser frequency band of 450MHz using transceivers. For this research, the researchers have been able to run simulation on the Network Simulation 3 (NS3) on how to initiate cars on the road to receive and send information about the state of their current velocity (miles per hour), position and orientation could be geographic angles (longitude and latitude). The units are subject to change as simulations focus on the coded ratio rather than units themselves. The simulations are explained in details in coming sections. The organization of the paper is as follows. Section I introduced the background on the behavior of collision detection and avoidance as well as VANET network. Section II will briefly highlight the security complications in this technology. Modeling will be discussed in Section III. Section IV will focus on the future work and the conclusion will be in section V.

II. SECURITY

An overview of security challenges that correspond to approaches proposed for Vehicular Ad-Hoc Network is highlighted in this section. Considering what the base station does, false information happens to be an element. When 20 billion devices get integrated into the nearest future, the falsified information growth will increase [9, 11, 12]. The nodes that dissipate false information are sometimes called adversary nodes. To prevent this hack, the deployment of an IFA is needed. For this project, the focus will not be directed to the algorithm involved in Iterative Filtering. However, it is necessary to understand the problems faced in this project. When many sensors transmit data to a base unit at once in real time, there's often a data cluster in the unit. To prevent this, data aggregators are added to such systems. They are used to avoid multiple inputs to the receiver from low power sensors.

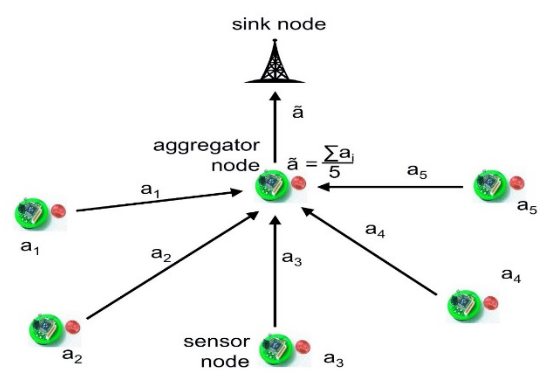

Figure 1: Sensor Network data aggregation [9]

Figure 1 shows how the aggregator receives numerous information from surrounding sensor nodes and averages the data received before transmitting it to the sink node which could be any transmitting infrastructure. The IFA is hereby used to identify false information through the aggregator to filter out adversary data.

III. MODELING AND RESULTS

1. PHYSICAL MODEL

For the physical experiment, two RC cars are used. Each car is equipped with a microcontroller, an RGB LCD screen for data display, an Mpu6050 accelerometer, a transmitter on one car and a receiver on the other one to pick up the message sent. The authors commenced with an algorithm for a microcontroller terminal to identify the users upon critical deceleration. The Mpu6050 accelerometer is designed especially for impact detection and was used to identify the cars motion. Based on the algorithm created, the vehicles could send corresponding information upon direct impacts (collision) to the receiving vehicles, hence, avoiding continuous data reading from the microcontroller. The microcontroller is connected directly to the LCD screen as well as the proximity sensor as shown in Figure 2.

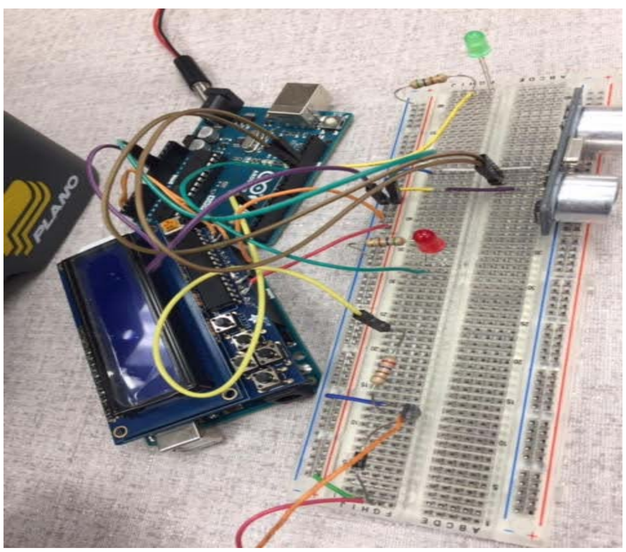

Figure 2. Circuitry for Collision Detection

Two different colors LEDs are used as indicators. If no obstacle is detected, the green LED remains on, turning off when the proximity sensor detects an object. At this point, the red LED lights up and the LCD screen displays a warning message and informs the user. The radio controlled car has been modified and enhanced with an IMU for acceleration readings, a proximity sensor, an arduino and an LCD screen. Figure 3 displays two pictures. The picture to the left shows the acceleration of the vehicle displayed on the LCD screen in Gravity force unit (Gs) in the occurrence of no object detection, while the picture to the right shows a warning message displayed on the LCD in a collision event.

Figure 3. Physical model of the collision detection

2. COMPUTER MODEL

The embryonic model aim of this project is to create a system whereby vehicles are able to communicate together without human interaction and transmit necessary information about the exact location, speed and direction to other vehicles (V2V) and base units (V2I) for better driving decisions. The ability to successfully do this would ultimately translate in solving collision avoidance and detection problems [13, 14].

A. Scenario 1: Two car collision in the presence of a roadside unit

NS3 (Network simulation) was the methodology used to evaluate our network topology without real world implementations, and as operating system, we worked with Ubuntu. Each vehicle and base unit is reduced to a node for simplification. Grids are used to represent the axis at which the system is perceived. To commence, the programming language C++ is used for the scripting of the algorithm. For the first simulation, a simple scenario of two vehicles is in collision mode in the presence of a roadside unit. Figure 4 highlights the simulation results of the first scenario showing a distance grid and the transmitting node as well as the collision by the two vehicles and the distance to the base unit. The communication radius is considered to be 175m.

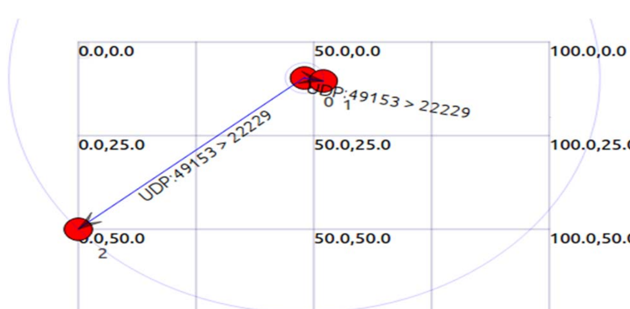

Figure 4: Simulation of two colliding cars and a base unit

The communication was created using the IEEE 802.11p protocol. The packet size of the transmitted data was about 45 bytes at a rate of about 3Mbps and 100Hz. From the simulation in Figure 4, it is seen that transmission is directed to all available nodes within the transmission range in the VANET. The figure also displays a distance grid to notify the observers of the nodal motion. It also displays a range of communication from the ensuing transmitter.

B. Scenario 2: Simulation of Four-way intersection with 4 cars and a roadside unit

The second simulation includes more vehicles to clearly demonstrate a real-life scenario. However, to avoid data clusters, the simulation is limited to only four vehicles and one roadside unit. The vehicles are traveling at different speeds and directions at an intersection to mimic a particular area in the University of Central Oklahoma (UCO). The area of interest is the intersection of Ayers road and University drive on UCO campus in Edmond, Oklahoma, Zip code 73034. Figure 5 shows the sketch of the road dimensions in real life including the vehicles and the RSU. This scenario assumes a red light for the horizontal vehicles and appropriate velocity for the vertical vehicles that corresponds to the street velocity at that intersection. The roadside unit in Figure 5 on the left is stationary while the rest are moving at about the intended speed limit.

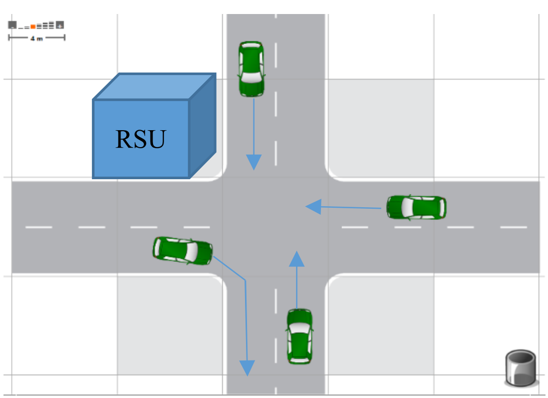

Figure 5: Ayers street and University drive intersection

C. SIMULATION RESULTS AND DISCUSSION

Figure 6 shows the simulation of this scenario in NS3 including the transmitting range and the location at one point in time. At first glance, it is observed that a node is transmitting information to other road entities for better decision making. The maximum range here was about 90m less than the maximum communication range.

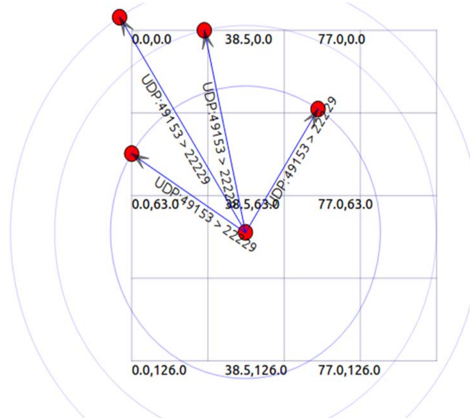

Figure 6: Simulation of a road intersection with four vehicles and one roadside unit

From Figure 6, the starting location of each node is being displayed. The grids represent the distance in two dimensions, x and y. Each node sends low energy data to each other rapidly before receiving information from another node. The data is seen to be transmitted within range therefore any node within the communication radius receives the information.

Table 1 below displays a sample of the collected data for three vehicle nodes. The data includes the transmitting vehicle number, the receiving vehicle, the time of transmission and the location. The data displayed in Table 1 can be explained as follow. The first column demonstrates the node number of the transmitting vehicle which sends data to other nodes. This explains why after each fourth row; a new transmitter emanates to broadcast data to the nodes in the second column (receiving nodes). Each node in the second column must receive data once from its fellow node (vehicle/infrastructure). The third column characterizes time in seconds. As mentioned earlier, the communication process occurs in a split second. This is perceptible in the time column where transmitting time is about 11 microseconds for the entirety of the simulation. This split-second communication makes all vehicles except one a receiver meaning they cannot report their location without waiting for the transmitting vehicle to complete its transmitting process. The next column is the location or User Datagram Protocol (UDP). UDP runs on Internet Protocol (IP) and is used to create low latency connection between objects and the internet, as well as to transmit information amongst the nodes.

Table 1: Ubuntu Simulation time and location for three vehicles

From vehicle	To vehicle	Time (s)	Location
0	2	0.01012	UDP 49153 > 22229
0	3	0.01012	UDP 49153 > 22229
0	4	0.01012	UDP 49153 > 22229
0	1	0.01012	UDP 49153 > 22229
1	4	0.0105223	UDP 49153 > 22229
1	3	0.0105223	UDP 49153 > 22229
1	2	0.0105223	UDP 49153 > 22229
1	0	0.0105223	UDP 49153 > 22229
4	2	0.0110285	UDP 49153 > 22229
4	1	0.0110285	UDP 49153 > 22229
4	0	0.0110285	UDP 49153 > 22229
4	3	0.0110285	UDP 49153 > 22229

While using UDP, it is important to be aware that it does not provide any trustworthiness. As a transport protocol, one of its main problem is that it does not transmit any lost packets. The ensuing set of numbers 49153 and 2229 are to extricate between user requests (data packets) and substantiate that the information arrived intact respectively. The data (message sent) was the same for all nodes, thus the same set of numbers. Depending on the type of data transmitted, the initial number post UDP will be altered. The maximum bit size is 16, hence, maximum transmittable data is 65507.

IV. FUTURE WORK

The car-to-car network has been an important technology for the safety of the driver on the road. More simulations should be done considering a higher number of cars and different road topologies. Further development of this prototype should focus on increasing the reliability of collision detection and reducing the latency between detection and receipt of the message. Some other areas of improvement are the improvement of RF controls for the vehicles. Multiple vehicles need to be introduced into the network. The receiving station should be programmed to send a message to the vehicle with instructions on how to go around the detected object. One consideration which might add to the convenience of the research is the development of a PCB for the IoT Lab which will provide easy wireless communication for vehicles and other devices. The Arduino Uno is a good starting point however as the complexity of the system increases, stability issues begin to occur and at that point other options can be considered such as using Raspberry Pi, Arduino Mega or Intel Edison.

V. CONCLUSION

The goal of this paper was to simulate a vehicular ad hoc network by sharing messages between sensor nodes. From the computer modeling, it is visible that the time involved in a small scale is about one-hundredth of a second. This is faster than the human processing brain. This rapid data received acts as a catalyst for a decision-making process. For the authors, all messages were sent successfully without any interference or adversary nodal complications. However, for this communication to be regarded as highly effective, messages transmitted between the cars should be of a small size and should be transmitted quickly and frequently. It is important to understand that the numerous data transmission could be inoperable except an adverse road condition or collision. To avoid this data cluster, we recall the aggregator for extensive filtering. The NS3 simulator provides a good environment for this communication process.

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