Triggered, Directional Vehicular Communication

John Lindsay

Dallas, TX

v2v@inventiveiplaw.com

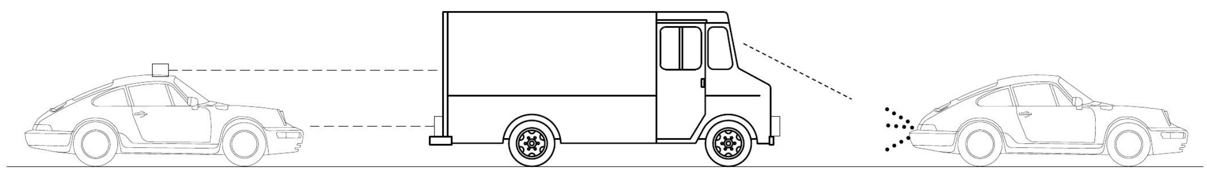
Background

Vehicle-to-vehicle (V2V), vehicle to infrastructure (V2I), and infrastructure to vehicle (I2V) are are technologies designed to allow vehicles and infrastructure to communicate with each other. Current V2V, V2I, and I2V communication focus on traditional omnidirectional radio frequency (RF) transmission. Some of the communication protocols and standards include Bluetooth, 802.11x and Dedicated Short Range Communications (DSRC). DSRC is intended to enable short to medium range wireless communications capability in the 5.9 GHz band for use in vehicle safety and mobility applications[1]. However, there are some driving scenarios, where omnidirectional RF communication is "noisy," with everyone within the transmission distance receiving the signal. This can lead to computationally expensive signal or data processing or introducing undue latency in order for the receiver to determine the utility of the signal. One such scenario is a leading vehicle applying its brakes, where traditional RF signaling would be noise to vehicles in adjacent lanes or require complex signal processing in order to determine the lack of utility of the signal data. This paper proposes a layer of vehicular communication which employs a triggered, directional vehicular communication system and protocol.

Triggered Directional V2V Communication

A common type of crash that occurs on the roadways is the rear-end crash, caused by one vehicle striking the rear of another vehicle when both vehicles are in the same traffic lane and are heading in the same direction, where approximately 29.7% of all crashes were rear-end crashes in 2000[2]. The National Transportation Safety Board (NTSB) called for wireless technology to enable vehicles to communicate with each other in response to one of its accident investigations[3] [4]. More recently, the Department of Transportation (DOT) announced legislation to make vehicular communication mandatory[5]. Vehicular communication systems enable each vehicle to provide each other with information, such as safety warnings and traffic information. In this cooperative approach, vehicular communication systems can be more effective in avoiding accidents and traffic congestion than if each driver tries to solve these problems individually. This remains true even as we make the transition to autonomous vehicle.

As mentioned above, one example of a driving scenario where omnidirectional RF communication is "noisy" or impractical for processing by the receiving vehicles is leading vehicle braking notifications, illustrated in Fig. 1.



In a braking situation, reaction time is one of the most significant factors in causes of rear-end vehicular collisions. In the above represented problem scenario, there is a leading vehicle 1, a first trailing vehicle 2, and a second trailing vehicle 3. When the leading vehicle 1 directly ahead of the first trailing vehicle 2 stops, the driver of the first trailing 2 vehicle has a line of sight to the visual red brake signal, and makes a decision to apply the brakes. The second trailing vehicle 3 makes the same decision with respect to first trailing vehicle 2 but may not have line of sight to leading vehicle 1. Second trailing vehicle 3 is dependent upon intervening first trailing vehicle 2's driving style and ability, which leads to lost reaction time and more collisions, due to lost reaction time to apply the brakes at the earliest possible opportunity.

Driver braking reaction time can have a major effect on crash avoidance probability[6]. In one major study, Olson et al found that driver "surprise reaction times" had a mean equal to 1.1 seconds, with a range (2 to 98 percentile) of 0.81 to 1.76 seconds[7]. Brake reaction times vary widely, in part because they include the component times of driver perception, decision, and response initiation[8]. Furthermore, detection times can vary depending on whether the signal is visual or auditory[9].

In seeking to address this common scenario via traditional omnidirectional RF, when leading vehicle 1 decelerates upon brake application, all vehicles within the transmission distance would receive the signal, including those in front of the braking vehicle and those in adjacent lanes. Other articles have discussed visible vehicle to vehicle communication in a general context[10].

The base proposed vehicular communication system of this paper includes a rear facing infrared transmitter and a forward facing infrared receiver mounted to vehicles, along with an embedded communication protocol. The rear facing infrared transmitter should employ modulated infrared, such as that of a high-power LED transmitted through a lens, in order to be invisible and minimize interference from sunlight and other ambient infrared sources.

The rear facing infrared transmitter is triggered under two conditions. In the first, the rear transmitter is activated simultaneously with deceleration of the subject vehicle with the beam spread being transmitted such that it is less than one lane wide. Although it is technically possible to detect deceleration as the trigger via an accelerometer or other sensors, brake light activation is the preferred trigger in order to minimize false alerts. The infrared receiver polls for signals from other vehicles. When the receiver receives a signal from another vehicle, the second condition in which the rear facing infrared transmitter is triggered, effectively making the vehicle a signal relay.

As stated, the transmitted beam width is transmitted such that it has less than a selected signal strength outside the lane's width and less than a configured signal strength at a pre-configured distance for a given set of environmental conditions. In selecting a transmission distance, the distance should vary according to the vehicle speeds. Anticipated speed ranges of concern should be from about 20 miles per hour to 80 miles per hour, which translates to a range of about 30 feet per second to about 120 feet per second. It is proposed to transmit the beam at a distance of about one second of travel for the vehicle under optimum environments, calculating and maintaining that distance throughout that brake application. That is to say the beam should be transmitted to about 30 feet for a vehicle traveling 20 miles per hour and about 120 feet for a vehicle traveling at about 80 miles per hour under clear conditions. The additional beam distance is expected to compensate for processing by intermediate vehicle(s) 2 and offset degraded transmission conditions, such as rain or snow.

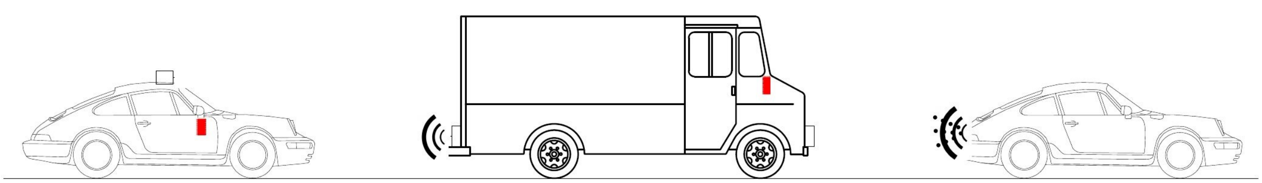
As all roads are not straight and level, the questions arises how the protocol should address vehicles changing direction, as the beam spread could signal those in adjacent lanes and fail to alert those trailing in the same lane. From a technical standpoint, the transmitter could receive steering wheel use, position data, accelerometer, global positioning system (GPS) data, or other similar sources to detect a vehicle turn state. However, it is a goal of the system to minimize “false alerts,” that is to say alerts where a leading vehicle is not braking. With the frequency of curves, turns, and altitude changes in roads, an undesirable percentages of false alerts would occur. Subject to simulation and testing, it is speculated that that the transmitter should be disabled where the vehicle change of direction of the vehicle is greater than 10º. It is speculated that the brake signal prior to the turn state should provide suitable notice to trailing vehicles.

The beam should include encoded data, with pulse width modulation being the expected format. A minimal packet should include a car identifier(s), brake status, and hop count data. Other supported data for encoding should include accelerometer data, velocity data, directional data, GPS data, lane indication data, inter-vehicle distances, and other data from the subject or leading vehicles. The received data for encoding can include sources from the vehicle computer, sensors, portable computers of a vehicle occupant, or other vehicle to vehicle communication systems. For example, the beam can incorporate inter-vehicle distance data, such as that between the leading vehicle and the subject vehicle from a range sensor system. The vehicular communication may process the data prior to encoding. To illustrate, the system may accumulate the distance data of leading vehicles and add distance between the subject vehicle and leading vehicle for encoding and transmission.

receiver. Relayed data through the vehicular chain is configurable based on the count. For example, a total relay count is the number of vehicles that have relayed a signal (ie a "hop count"). In such a situation, the transmitter can increment the received active relay count data prior to encoding for transmission to trailing vehicles. An active relay count is the instantaneous number of signal use conditions, such as activated vehicle signals, within range of one or more vehicular communication systems in the chain.

The post-implementation scenario for the base system and protocol is illustrated.

3 2 1



The vehicular communication system and encoded data form the basis for mobile ad hoc vehicular networks. One such data element that the beam can incorporate is relay count data, which facilitates peer to peer, vehicle to vehicle network type communication, that is to say a "chain" of vehicles relaying data as nodes. Relay count data can facilitate how many vehicles back in the chain a signal is relayed. Relay count data facilitates configurable conditional signal transmission through the vehicular chain. A base relay count can be provided by the

The vehicular communication system with the front receiver and rear transmitter incorporating the protocol, both of which are attached to each vehicle. Simultaneous with brake and brake light application, the rear transmitter of the lead vehicle 1 emits the infrared overlay wave having a one lane width where it is received by the front sensor of the first trailing vehicle 2. The rear transmitter of first trailing vehicle 2 relays the brake application status of the lead vehicle 1 to the second trailing vehicle 3, where a dash indicator or heads up display indicator alerts the driver or the control system of an autonomous vehicle.

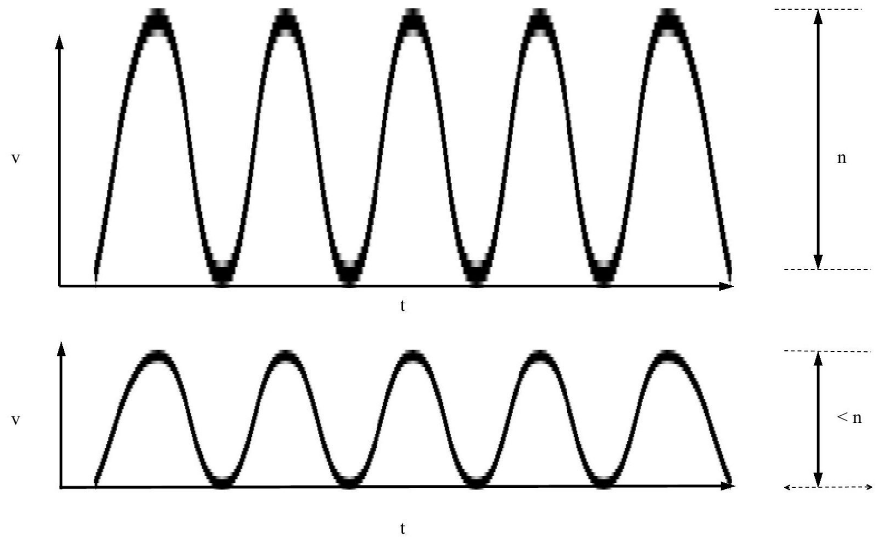
Directional vehicular communication facilitates other proposed traffic system improvements. In congestion zones or peak driving times, there is an increased frequency of brake application, frequent hard deceleration, frequent acceleration, a poor driving experience, and increased collision rate. An improved V2I and I2V traffic analysis module may be employed based on the directional vehicular communication.

In the improved traffic module, vehicles equipped with directional V2V systems pass through a monitored congestion zone. V2I receivers are spaced through the congestion zone sampling vehicle brake applications or velocity as the vehicles pass through the congestion zone. The aggregate vehicle data is processed and an optimum velocity is determined for a vehicle to pass through the congestion zone with a lower frequency of brake applications or lower slope on acceleration or deceleration. The optimum velocity is signaled to the vehicle as they enter the congestion zone.

The traffic module includes a series of I2V communication systems mounted in the congestion zone and networked, each infrastructure to vehicle communication systems being at a fixed location. The first I2V communication system should be mounted near the start of the congestion zone. The remaining I2V communication system should be mounted successively in the congestion zone. Each I2V communication system includes a “super-receiver” and “super-transmitter.” The super-receivers and super-transmitters are similarly configured as the described receivers and transmitter for the V2V communication systems except that they are mounted above the vehicle heights for improved beam reception by line of sight to multiple vehicles. For example, the I2V communication systems may be mounted on the overhead signs for each lane.

The traffic analysis module receives the vehicular communication data from the vehicles passing through the congestion zone at the points where each I2V system is mounted. The traffic analysis module may receive sample beam data of a single vehicle, a sample of vehicles, or larger data set(s) of vehicles within the congestion zone for analysis.

The traffic analysis module processes received vehicular signal system data for suboptimal traffic conditions, such as frequent sharp velocity changes or frequent braking. In one approach, the traffic analysis module processes the velocity of the vehicles in the congestion zone and calculates peak to trough velocities in the congestion zone, a simulated sinusoid of aggregate of which is shown in the first graph below. In an alternate approach, the traffic analysis module processes the number of concurrent brake signals as a basis for optimization.



After receiving sufficient data, the traffic analysis module optionally determines suggested instructions for optimizing traffic within the congestion zone, optimally signaling vehicles near the beginning of the congestion zone. The instructions correlate to the method employed to determine the suboptimal traffic condition. For example, in the discussed peak to trough velocity analysis, the traffic analysis module may send suggested deceleration signals in order to decrease the peak to trough velocity and "flatten the curve," as shown in the second simulated sinusoid above.

In the simultaneous active signal approach, the traffic analysis module can also transmit deceleration signals. The method of communicating the suggested instructions varies. Example methods include a visual signal near the I2V communication system, a signal from to sensor of the vehicles, a message to the on board computer or smartphone in the vehicle.

[1] United States Department of Transportation, "DSRC Fact Sheet", available at http://www.its.dot.gov/factsheets/dsrc_factsheet.htm
[2] National Highway Traffic Safety Administration, "Sampling Issues in Rear-End Pre-Crash Data Collection" DOT HS 809 54, April 2003, available at http://www-nrd.nhtsa.dot.gov/Pubs/809-541.PDF
[3] "NTSB calls for wireless technology to let all vehicles 'talk' to each other" available at http://www.nbcnews.com/news/other/ntsb-calls-wireless-technology-let-all-vehicles-talk-each-other-f6C10726342
[4] National Transportation Safety Board, "School Bus and Truck Collision at Intersection Near Chesterfield, New Jersey", February 2012, available at http://www.ntsb.gov/investigations/AccidentReports/Reports/HAR1301.pdf
[5] "The US wants cars to 'talk' to each other, sooner rather than later" available at http://www.engadget.com/2015/05/18/us-closer-to-v2v-legislation/
[6] National Highway Traffic Safety Administration, "Assessment of IVHS Countermeasures for Collision Avoidance: Rear-End Crashes" DOT HS 807 995, May 1993, page 41, available at http://ntl.bts.gov/lib/jpodocs/repts_te/769.pdf (page 41)
[7] Id. at page 41
[8] Id. at page 41
[9] Id. at page 41
[10] I. Takai et al., "Optical Vehicle-to-Vehicle Communication System Using LED Transmitter and Camera Receiver" IEEE Photon. J., Vol. 6, No. 5, 7902513, Oct. 2014, available at http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6887317