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Final Report

Project Title:

Vehicle Infrastructure Integration (VII): Exploring the Application of Disruptive Technology to Assist Older Drivers

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The New England University Transportation Center is a consortium of 8 universities funded by the U.S. Department of Transportation, University Transportation Centers Program. Members of the consortium are MIT, the University of Connecticut, University of Maine, University of Massachusetts, University of New Hampshire, University of Rhode Island, University of Vermont and Harvard University. MIT is the lead university.

This report discusses the approach and findings of a research project aimed at the evaluation of an inter-vehicle communications scheme for Vehicular Ad hoc Networks (VANETs).

Because of the size, frequency, and expected number of receivers of periodic safety messages, traditional wireless protocols such as IEEE 802.11 need to be drastically revised in order to work with the U.S. Department of Transportation's Connected Vehicle system. The 'Universal Geocast Scheme for VANETs' presented by Mohammad Nekoui and Hossein Pishro-Nik from the ECE department of the University of Massachusetts, hopes to accomplish this by making changes to the various parts of the proposed IEEE 802.11p protocol. Although their scheme had been tested in theory, using probability models for average reception probability, it needed to be proven with a better, more defined simulation architecture that could encompass more of the behaviors of a mobile wireless communications network. The simulations done in this research provide improved comparisons to other leading proposals for the new inter-vehicle communication protocol and has allowed improvements to be made by evaluating situations in which UGS formerly performed poorly.

UGS implements periodic safety messages without the need for handshaking normally associated with routing protocols by combining multi-hop with single-hop transmissions. The approach shows the effectiveness of multi-hop transmissions for periodic messages in dense urban intersections, which often are effected by line-of-sight obstructions while still providing the efficiency of single-hop transmission in highway and other open road scenarios. Individual node transmissions are scheduled using probabilistic factors based on distance to target and remaining packet lifespan. Both vehicles and roadside equipment located in the center of an intersection can be used to retransmit packets. Transmission power is varied to reach targets within a defined geocast radius. The amount of time used to retransmit packets is probabilistically lengthened as packet retransmission count increases.

Following an initial transmission, a packet may be retransmitted at a random time between 0 and the backoff window. A distinctive feature of the UGS approach is a probabilistically determined increase in the backoff time for each subsequent retransmission of the same packet. The backoff window, from which the backoff time is chosen is increased exponentially based upon the number of times the packet has already been transmitted and the vehicular density of the neighborhood. In congested conditions, a packet which has already been transmitted will have to wait, on average, a longer time before retransmission. Each node retransmission uses a single or multiple hops based on the geometry of the surroundings and the remaining useful lifetime of the packet. In this research vehicles within broadcast range of the intersection are able to transmit via multiple hops while all other vehicles are not. Vehicles that have LOS communication with areas that other vehicles do not can forward multi-hop packets accordingly. For instance, a vehicle in an intersection with buildings on all four corners can communicate via LOS down all four roads, and is in an optimal position to forward the packets of vehicles on either road that are not in the intersection. Forwarding vehicles must maintain a packet queue of messages to forward, sorting packets first by the number of times they have been retransmitted and then by the useful lifetime remaining. They also must probabilistically decide whether they will next attempt to transmit their own packet or forward another vehicle's.

The improved UGS has been verified using several contemporary simulators. The core of our simulation environment is a significantly modified version of the NS-2 network simulator. Both the UGS and the protocol it was compared to were successfully simulated in NS-2. The motion of vehicles simulated in this research is modeled using Simulation of Urban MObility (SUMO), a vehicle mobility simulator. The accuracy of our simulations is enhanced with the use of a recently published radio propagation model, the University of Kangaku model, which is integrated into NS-2 and accounts for LOS and NLOS attenuation of signals.

For this research, we consider UGS and a comparison protocol deployed under two different scenarios: an open road four lane highway, and an urban four-way intersection. In both scenarios the vehicular density is varied along with variables specific to the UGS in an attempt to improve its performance. The two main measurements of performance used are reception ratio and delay.

In addition to vehicles, the intersection contains a roadside equipment (RSE) unit located near the center of the intersection. Vehicles may be within line-of-sight (LOS) or not (NLOS) depending upon their placement in the intersection. Two identical lengths of road with two lanes each cross in the middle where a traffic light is located. Buildings are assumed to be located on all four corners of the intersection. Vehicles wait at the intersection stoplight until they are given a green light, and continue straight across until they reach the other end of the road. Vehicles that are not in the intersection can transmit their own packets. Vehicles within the intersection can both transmit their own packets and retransmit packets received from other vehicles, per the multi-hop configuration of the UGS.

In the four lane highway scenario there are no RSE units, no turns, no exit or on ramps, and all vehicles are considered to be within LOS of one another. The four lanes are parallel to one another and vehicles all travel in the same direction at varying speeds, designated by the Krauss car-following model used in SUMO, with a maximum speed of 30 m/s (67 mph).

The UGS is contrasted against an accepted, previously published inter-vehicle communication scheme from the U.C. Berkley Partners for Advanced Transit and Highways (PATH) group that uses an Asynchronous Fixed Repetition with Carrier Sensing (AFR-CS) protocol. The simulations showed that UGS achieves a 6% improvement in reception ratio in intersection simulations and a 2.6% improvement in highway simulations. The Universal Geocast Scheme also provides an 82% decrease in delay in intersection simulations and a 90% decrease in delay in highway simulations over the PATH approach.

This research concludes that the Universal Geocast Scheme is a successful candidate for inter-vehicle communication of periodic safety messages. The next step would be to use the scheme in real life experiments. Currently work is being conducted in the UMass Transportation Department to allow for systems to be installed on cars to collect pertinent information and then use transceivers to broadcast this data to other vehicles. Another group of students is working to implement the Universal Geocast Scheme through the use of FPGA hardware. The work with FPGAs could be used in conjunction with the Transportation Departments work to allow the vehicular information to be sent using the Universal Geocast Scheme, so actually results may be collected.