RESEARCH NOTES

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Peer-to-Peer (P2P) Traffic Information Propagation
(ATMS TESTBED PHASE III FINAL REPORT)

Why was this Research Undertaken?

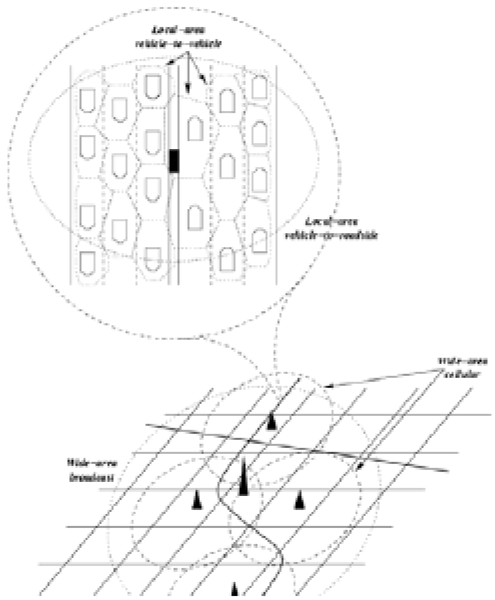
Since the introduction of intelligent transportation systems (ITS) in the early 1990s, there has been growing interest in potential applications of the use of wireless communication between vehicles, usually referred to as inter-vehicle communication (IVC). In IVC-based system, vehicles are envisioned to exchange precise position information from satellite navigation data (GPS) via IVC at low cost to optimize traffic flows and provide valuable, real-time traffic information to the drivers. Our focus is on the potential for the concept of IVC-based systems to serve aspects of transportation systems management. We attempt to give answers to two questions: (1) What IVC equipment penetration rate is needed for information propagation to extend to a substantial part of the whole network under various traffic conditions? and (2) What IVC system requirement is needed to disseminate incident information faster than the attendant traffic/vehicle wave propagates through the network?

For more in depth discussion and technical analysis, refer to TTR3-09 (Testbed Technical Report).

What was done?

This project investigated the feasibility of a distributed traffic information system based on IVC technology, focusing on such systems arising principally from the transportation application. Specifically, via simulation modeling techniques, we determined the thresholds for some of the parameters necessary to support the systematic collection and provision of useful and in time (real-time or close to real-time) traffic information in a self-organized, distributed traffic information system, dubbed Autonet, that is based upon the peer-to-peer information exchange among vehicles.

Potential applications of this Autonet concept for traffic management and traveler information are intrinsically based on achieving information propagation throughout the traffic network; however, because penetration of the necessary technology to the fleet of vehicles can be expected to be gradual, a "mixed" network of IVC-capable vehicles and non- IVC capable vehicles will exist for some period of time. In our research, we attempt to give answers to two questions: (1) What IVC equipment penetration rate is needed for information propagation to extend to a substantial part of the whole network under various traffic conditions, and (2) What IVC system requirement is needed to disseminate incident information faster than the attendant traffic/vehicle wave propagates through the network?



Peer-to-Peer Schematic

We analyzed the two issues mentioned above for various possible IVC technologies and for different roadway network formats and different road traffic conditions. In addressing these open questions that may be barriers for implementation of self-organizing, IVC-based traffic information systems, our focus is on the potential for the concept of IVC-based systems to serve aspects of transportation systems management; the traffic-oriented abstraction evaluation framework is developed without detailed electronic engineering and computer science modeling. Nonetheless, the results serve to identify, at least roughly, the system implementation requirements for both software and hardware sides as well.

We used PARAMICS (PARAllel MICroscopic Simulator) to build our simulation modeling framework. Three IVC scenarios were investigated in the research: uni-directional and bi-directional information propagation in one-dimensional highway network, and information propagation in two-dimensional arterial streets networks.

There are three major outputs from the simulation that were used in our analysis: 1) IVC success probability, representing the average chance that an individual IVC-equipped vehicle can find other IVC vehicles in the communication radius range and communicate successfully in the traffic network at any particular time; 2) communication bandwidth, indicating the average maximum amount of data that needs to be transmitted by each IVC vehicle in the traffic network, defining the basic requirement for the software and hardware implementation in the proposed system; 3) maximum information propagation distance, at any time an indicator of how fast the information flow is traveling in the traffic network, a key factor in determining whether or not this information flow may potentially benefit the traffic system.

What can be concluded from the Research?

Our results indicate that it may be extremely difficult to evolve the proposed self-organizing vehicle-to-vehicle based system to support information propagation for location sensitive, real-time traffic information in freeway networks in which communication is only among vehicles moving in the same direction, especially if the IVC equipment market penetration rate is low and communication radius range is short – two conditions that are likely to characterize the proposed system in its start-up period. Under incident conditions, for such market conditions and available IVC technologies, the incident information wave generally travels slower than does the traffic shock wave due to the incident.

Compared to information propagation employing information exchange only among vehicles in the same stream of traffic, efficiencies and effectiveness of bi-directional propagation systems built upon inter-vehicle communication technology are significantly easier to achieve because mechanisms for information propagation in this case not only include "hopping" along vehicles moving in the same direction of flow as well as "cross transference" of information to vehicles moving in the opposite direction. For market conditions and available IVC technologies that are likely to prevail during the system's start-up period, the incident information wave generally travels faster than the traffic shock wave due to the incident freeway networks in which vehicles that are moving in opposite directions in close proximity to each other can exchange information.

Traffic information dissemination in two-dimensional urban arterial networks via information exchange among IVC-equipped vehicles is also easier to achieve than in one-direction freeway network cases; however, propagation speed is generally slower than in two-direction freeway network cases. Bandwidth/data rate requirements for IVC in urban arterial streets are relatively high because of the representation of the complex network configurations and high density of vehicles in the traffic network due to the distribution of vehicles in two-dimensional space.

What do the Researchers recommend?

This study showed that a traffic information and management system based on P2P communication is technologically feasible. Significant additional study should be undertaken to identify traffic management efficacy, limitations and hardware requirements.

Implementation Strategies

There are many potential directions in which the research in this paper can be extended and improved. In this initial stage of the analysis of the proposed system, vehicle-to-roadside station communication is not included in the simulation evaluation framework developed for this research. In order to study the full version of the system proposed, the communication between vehicle and roadside infrastructure should be integrated into our simulation evaluation framework. The characteristics of roadside vehicle communication (RVC) need to be identified and modeled in the simulation framework. A system integrating IVC and RVC could potentially have an explicit transportation systems management focus.

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