RESEARCH NOTES

September 2007

Implementation Tests of a Peer-to-Peer (P2P) Network for Incident Exchange

(ATMS TESTBED PHASEIII FINAL REPORT)

Why Was This Research Undertaken?

The existing paradigms for vehicular traffic monitoring and control have a strong infrastructure bias data are collected centrally, processed, and then redistributed to travelers and other clients in response to requests. There are a number of research efforts to decentralize traffic state monitoring by leveraging advanced local area wireless technology. One version of such a traveler-centric system is called Autonet. Work to date consists of a preliminary *implementation* of some of the key Autonet concepts as well as some field measurements.

One of the key gaps limiting the broad adoption of Intelligent Transportation Systems (ITS) technologies by drivers is the lack of usable real-time data. According to a 2002 national survey of ITS technology adoption [ITS Joint Program Office, 2004], only about 30% of all signalized intersections on arterial streets had any form of electronic surveillance. Even if every *highway* were fully and accurately monitored, drivers attempting to plot an alternate route around an incident would be unable to evaluate conditions on the arterial street network.

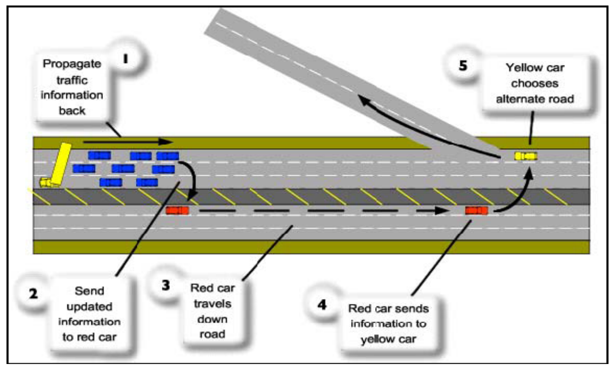
Automobile manufacturers have been installing more and more computer electronics and control systems into their cars, with high end models commonly sporting in-dash, GPS-based mapping systems. The contrast between the high cost and low penetration rate of *infrastructure* based traffic monitoring, and the declining cost and increasing capabilities of *in-vehicle* electronics devices implies that we should explore the abilities of the latter to augment or even replace the former. We suspect that a *decentralized, vehicle-based* traffic probe system may be cheaper, faster, and easier to implement than the centralized monitoring and traffic probe systems defined in the National ITS Architecture.

For more in depth discussion and technical analysis, refer to TTR3-11 (Testbed Technical Report).

What was done?

An in-vehicle client with an informative GUI has been developed. This client continuously listens for other clients, and exchanges knowledge about network incidents once contact is made. We demonstrated that knowledge about traffic conditions can be propagated successfully using this system. The client programs were also used to test the actual throughput possible for messages sent from one vehicle to another using 802.11b wireless hardware. These measurements establish the maximum throughput at about 4,000 incidents for two vehicles moving in opposite directions at highway speeds.

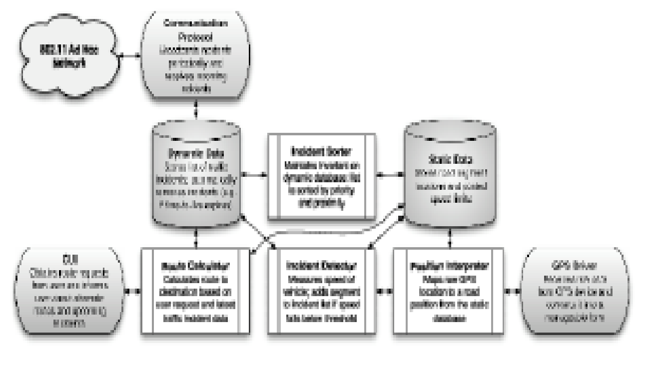
The main result of this project was to design the basic features of an Autonet system, and to then implement an Autonet peer that could perform the most important of those features.



AUTONET Scenario

The guiding scenario is shown in the figure. This picture shows a vehicle passing a traffic jam, collecting information about that jam from the affected cars, and then "carrying" that information upstream. At some point, travelers would use the information upstream of the incident to decide their optimal course of action, in this case, to exit the highway. This scenario led to a specification of the system requirements, which in turn led to a software architecture, shown in the accompanying figure, and an implementation.

The implementation was installed on a number of laptops. Each laptop was equipped with a GPS antenna to provide location and speed information, and a WiFi card to allow the peers to communicate with each other. Each peer was equipped with a common network model, based on the freely available TIGER/Line file data for Orange County.



Implementation Schematic

This provided a common framework for exchanging incident information. In repeated trials, we demonstrated the ability to transmit incident information between vehicles, and to have incident information be carried from one vehicle to another just as depicted in the basic scenario discussed above.

What can be concluded from the Research?

In addition to providing a proof of concept test, the initial Autonet peer implementation served a second purpose: the ability to benchmark the capabilities of off the shelf communications hardware and protocol stacks. In order to explore the feasibility of the Autonet idea, the proper approach is to implement a large-scale traffic simulation, and to slowly ratchet up the adoption rates. However, such simulations would be difficult to program without solid evidence about the capabilities of each wireless client. Using the initial Autonet peers, we were able to demonstrate the ability to transmit data in a highway setting between two oncoming cars, each traveling at 70 mi/h. The results are summarized in the accompanying table.

	40 mi/h	55 mi/h	70 mi/h
# of incidents exchanged	5,996	4,295	3,556
Time within range	23 s	18 s	10 s
Round trip time	71 ms	80 ms	81 ms

Test Results

This project demonstrated that a decentralized, vehicle based real-time traffic information system is technically feasible. We designed the necessary system architecture, implemented that architecture, and then tested our implementation on the road. We were able to transmit incidents in real time between moving vehicles using our software and off the shelf hardware.

What do the Researchers recommend?

A large question is how useful such a system will be if it is adopted by the general public. To answer this question, the next step is to expand simulation studies using the empirical capabilities of the prototype device as a starting point. Through simulation, we will be able to determine the relationships between adoption rates, information flow, and system awareness, which in turn will lead to traveler-centric applications such as route planning and incident avoidance.

Implementation Strategies

The primary goal of the work documented in this paper was to prove that the Autonet concept would work in the real world using COTS hardware. The results show that the basic incident handoff scenario can be achieved. Detailed tests of the communications software developed over 802.11b show that at least a thousand incidents can be exchanged between vehicles moving in opposite directions at 70 MPH (relative speed 140 MPH). This implementation provides working protocols and communications parameters for improving future large-scale simulation studies. Finally, the prototype allows us to conduct attitudinal studies of drivers to explore questions about adoption rates, privacy concerns, and overall market acceptance.

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