RESEARCH NOTES

September 2007

Mobile Throughput of 802.11b
(ATMS TESTBED PHASE III FINAL REPORT)

Why Was This Research Undertaken?

Simulation research has shown that a traffic information/management system based on P2P communication is feasible. However, significant additional study is needed to identify traffic management efficacy, limitations and hardware requirements. In particular, the ability of current wireless communication technology, e.g., 802.11b, to successfully transmit traffic information between vehicles moving at high relative speeds to each other is questionable.
For more in depth discussion and technical analysis, refer to the testbed technical reports TTR3-03 & TTR3-16.

What was done?

The project investigated the capabilities of wireless local area networking (WLAN) technology for vehicle-to-vehicle and vehicle-to-roadside communication. An 802.11b (WiFi) card is inexpensive, and provides plenty of bandwidth. WiFi technology is being incorporated into PDAs, cellphones, and in Intel's Centrino laptop chipset. It requires very little imagination to suppose that drivers will soon have easy access to a computing device of some sort, which supports WiFi or a related technology. This project focused exclusively on vehicle-to-roadside communications. The work is part of a larger effort to benchmark the practical throughput of off-the-shelf wireless technologies. The work is on going, with further vehicle-to-roadside and vehicle-to-vehicle tests planned.

The first step in testing wireless throughput was to install hardware both on the roadside and in a vehicle.
Two Cisco AP 350 series wireless access points were mounted on buildings on the UC Irvine campus fronting Peltason Road. The access points were connected to building-mounted 13.9dBd antennas. The antenna specifications are as follows: 3dB Beamwidth, Degrees E-Plane 30, 3dB Beamwidth, Degrees Hplane 34, Front to Back Ratio, dB 18, Gain dBd 13.9, and Impedance (ohms) 50.

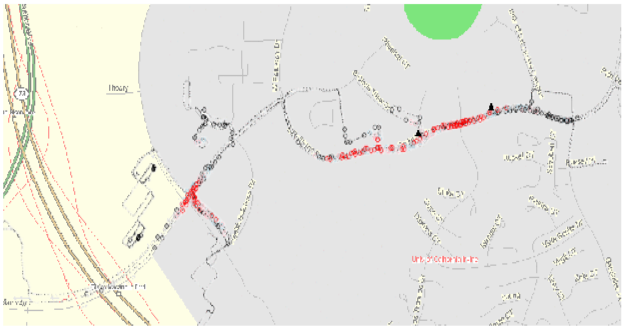
Inside of the vehicle, wireless connectivity was achieved using a Lucent Orinoco Silver PCMCIA card plugged into a laptop computer. A 5db gain omni directional external antenna was mounted on the vehicle roof using a magnetic base. The laptop was also connected to the Testbed's extensible data collection unit (EDCU), in order to obtain exact positioning for the wireless signal readings.

The primary study area is shown in the accompanying figure. One antenna was mounted on the Multipurpose Science and Technology (MST) building, shown in the center of the figure, and the other was mounted on the Engineering Gateway (EG) building, just to the right of the MST building. Both of the directional antennas are pointed in a westerly direction along Peltason Road, more or less towards the crossing roadways on the left side of the figure.

Study Area

In order to test the wireless link capacity, the utility program Netperf was used. Netperf is designed to test various aspects of a network connection. In this case, it was configured to repeatedly conduct throughput tests with one second duration. This resulted in one geocoded throughput measurement every two seconds.

Data were collected over several days. The maximum throughput observed was 4.62 Mbps, which compares favorably with WiFi used in an indoor environment. This maximum throughput value was measured while the vehicle was traveling at 30.7 mph, approximately 159 meters from the MST building access point. As can be seen from the figure, the connectivity is highly directional. This is for two reasons. First, the antennas are directional, and are pointing in a westerly direction along Peltason. Second, 802.11b requires a clear line of sight. Peltason road is quite hilly, and the roadside antennas are completely obscured at the intersection of Peltason and Bison. However, at the intersection of California and Bison (near the crossing roads), there is a clear line of sight to the MST building once again.



Map of 802.11b throughput test area.

Some simple regression tests were done to examine the relationship between line of sight, speed, and distance with the observed throughput. The regression results indicate that distance plays the most significant role in determining the throughput value. If all non-zero observations are included rather than just those clustered in the direction that the antenna is pointing (192 degrees), then the most important factor is the "degrees away from 192." Interestingly, speed is less important than we expected. This is perhaps due to the fact that our tests were performed on streets with a speed limit of between 35 and 45 mph.

What can be concluded from the Research?

This project demonstrated that it is possible to establish a useful, high-bandwidth link between a moving vehicle and a roadside, directional antenna. The connection strengths were surprisingly high, with a signal of about 4 Mbps established at an intersection approximately 1 kilometer from the nearest antenna. While this connection was not maintained for very long due to the road geometry, at this communication rate it is possible to download a PDF file containing the UC Irvine campus map within 1 second. The biggest factor limiting throughput was maintaining a clear line-of-sight to the roadside antenna. As the road curved away or dipped down behind a hill, the throughput rapidly went to zero.

The implications of these tests for possible applications are clear. If we continue to use the same directional antennas, it is possible to conduct short transactions with moving vehicle that are in range. These transactions might include downloading a map, or a short session requesting the nearest available parking to an intended destination. However, transactions that require long sessions, such as attending a lecture wirelessly or checking email, are not possible with this kind of connection.

What do the Researchers recommend?

There are several aspects of the vehicle to roadside connection, which still need testing. For example, the test protocol did not repeatedly attempt to establish a connection with the base station. That is, a single period of testing would include a single connection event. After that, the wireless antenna would be assigned an IP address and could concentrate on testing throughput. It would also be interesting to test the time required to negotiate the initial connection throughout the test area. The tests were also performed with very little ambient interference. While there are 50 or more open WiFi access points in the study area, they are all use low power omni-directional antennas, and did not offer any significant interference.

Implementation Strategies

There are several tests, which still need to be performed. First, the various parameters relating to the network performance test, such as the test message block size and the send and receive socket sizes need to be varied to ascertain their impact upon the throughput.

Secondly, it is desirable to measure instances where the throughput decreases to zero based on distance alone, and speed alone, in order to properly characterize the effects of these parameters. To date the vehicle to access point communications has been limited only by line of sight considerations (buildings and hills). Another important class of tests is vehicle-to-vehicle communications. These tests will follow more complete characterization of vehicle to roadside communications.

List of Contacts

Principle Investigator:
Dr. Will Recker
Institute of Transportation Studies
University of California; Irvine, CA 92697-3600
Tel.: (949) 824-5642: Fax: (949) 824-8385
Email Address: wwrecker@uci.edu

Other Investigators:
Dr. James Marca)
Institute of Transportation Studies
University of California, Irvine, CA 92697-3600
Tel.: (949) 824-6544; Fax: (949) 824-8385
Email Address: jmarca@translab.its.uci.edu

Contract Manager:
Fred Yazdan
Caltrans, Division of Research and Innovations
Office of Technology Applications
Advanced Testbed Program Branch
6681 Marine Way, Irvine, CA. 92618
Tel.: (949) 936-3462; Fax: (949) 936-3461
Email Address: fred.yazdan@dot.ca.gov