Wireless LAN Performance Under Varied Stress Conditions in Vehicular Traffic Scenarios

Jatinder Pal Singh, Nicholas Bambos
Department of Electrical Engineering
Stanford University, CA 94305
{jatinder, bambos}@stanford.edu

Bhaskar Srinivasan and Detlef Clawin
Robert Bosch Corporation
Research and Technology Center, Palo Alto, CA 94304
{bhaskar.srinivasan, detlef.clawin}@rtc.bosch.com

***Abstract*—Mobile ad-hoc networking with wireless LAN infrastructure can be employed to build inter-vehicle communication based applications. The associated high velocities and hostile driving environments pose a challenge to the performance of a wireless LAN. This paper assesses the performance of a wireless Local Area Network in different vehicular traffic and mobility scenarios. The network throughput and the quality of the wireless communication channel, measured on IEEE 802.11b compliant equipment, are observed to degrade with increasingly stressful communication scenarios. The test scenarios are varied by conducting the experiments under different vehicular mobility, peer-distance and driving environment conditions. We present results that can facilitate development of efficient applications for inter-vehicular communication. We also suggest optimization measures through aggression control via variations in packet size.**

Keywords—Local Area Network, IEEE 802.11b, aggression control.

I. Introduction

Inter-vehicle communication can be used to facilitate applications [8, 9] improving driving safety and convenience. Potential uses of such applications are dynamic traffic routing, driver assistance and navigation, entertainment, co-operative driving and platooning [4], etc. Multimedia devices supporting communication and entertainment are already being deployed in vehicles. The existing ad-hoc networking infrastructure can be leveraged and performance enhancement measures can be innovated for provisioning seamless inter-vehicle communication. As opposed to a centralized service, an ad-hoc network is much better suited for vehicle-related applications that exchange data having local relevance. Inter-vehicle communication support by 3G networks has been discussed in literature [3]. However, in a centralized network topology, the information has to propagate from a vehicle to a central base station and back from the base station to another vehicle. The centralized architecture is hence not very efficient for applications that distribute data only between groups of vehicles that are spatially close to each other. An ad-hoc network can instead be employed between vehicles to help dispense traffic-related information, emergency warning in case of accidents, etc.

The ongoing FleetNet [1] project aims at developing an ad-hoc network for inter-vehicle communications and for data exchange between running vehicles and fixed gateways at the roadside. However, the project is at the proposal and demonstration stage and requires development of exclusive infrastructure. The existing 802.11 compliant devices can be used for providing wireless connectivity between moving vehicles. With the advent of 802.11a hardware, bandwidths of upto 54 Mbps have become realizable. The unlicensed communication in the ISM bands provides a cost effective solution for supporting vehicular communication applications. However, vehicular traffic scenarios pose greater challenges than the indoor WLAN applications, due to associated driving speeds, varying vehicular traffic patterns and driving environments.

Performance measurements for 802.11 based wireless LANs have been done in indoor office and industrial environments [2]. These results do not provide performance indication for the more challenging vehicular scenarios. Through the tests we conduct, we investigate the performance achievable by an 802.11b-based WLAN in vehicular scenarios.

The paper is organized as follows. The test set up and experimentation details are discussed in Section II. The conducted tests are compiled in Section III. The test results are presented in the subsequent section. Result analysis and inferences drawn there from, and performance optimization policies are suggested in Section V. Future Work is presented in Section VI and the paper is concluded in Section VII.

II. Test Set up and Experimentation Details

The tests are conducted by driving through various environments at varying speeds and inter-vehicle distances. The two vehicles have laptops running Linux, and are equipped with ORiNOCO IEEE 802.11b WLAN cards. The range of connectivity is enhanced by deploying ORiNOCO omni-directional antennae on top of cars. The location and velocity are tracked using GPS devices.

One laptop is set up as a receiver and the other as a sender that streams UDP packets. The wireless cards are configured to operate in broadcast ad-hoc mode. The broadcast mode disables the MAC retransmissions. The UDP packets consist of randomly generated bits at the sender end. Netperf [5], a Hewlett-Packard software utility, is modified and used as a network performance assessment tool. The GPS devices give the latitude, longitude, speed and bearing of the vehicles every second. The wireless MAC software utilities [6] are used to log the signal quality information at the receiver. The

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throughput, which is the bit reception rate at the receiver, is calculated on the basis of number of packets received every second. Throughput is logged at the receiver end, along with the number of lost packets. The link quality is measured by noting the signal to noise ratio at the receiver. The GPS information is parsed to obtain the location, velocity and relative velocity information of the vehicles every one second. The corresponding signal quality and throughput values are noted.

III. DESCRIPTION OF THE TESTS

Measurements are conducted for varied traffic types under different vehicular mobility and traffic density scenarios. The tests are conducted under the following environments:

- Sub-urban: The suburban scenario corresponds to vehicular speeds limits of around 40 miles per hour and driving environments with a few building structures and roadside tree plantations. The vehicles stop at traffic lights but not frequently.
- Urban: The urban scenario has speed limits of 25 miles per hour amidst roadside building constructions. The traffic scenario is the rush hour urban traffic, with vehicles often stopping at traffic lights and in jams.
- Freeway: The freeway is a open environment with scarce roadside vegetation and driving speed limit of 65 miles per hour. There can be vehicles traveling between and along the communication test vehicles.

As described in the previous section, the performance parameters (throughput, number of lost packets, SNR, etc) are evaluated for one- second intervals. The performance plots are generated by averaging typically thousands of readings. The performance is noted with respect to inter-vehicle separation and relative velocity. Data at different locations corresponding to similar kind of environments is averaged. The tests are done at different velocities and separation between the moving vehicles. The vehicle connectivity measurements are done in each scenario with the vehicles following and crossing each other.

IV. RESULTS

The results obtained from the experimentation are presented herewith. Wireless LAN performance for the ad-hoc communication between the two vehicles is noted by observing the throughput and link quality with variation in inter-vehicle separation, driving speeds and directions.

Figure 1 shows the link quality variation with distance for various scenarios. Figures 2, 3, 4 and 5 show the throughput variation with distance in different environments. The plots correspond to varied ranges of velocities as according to the relevant scenario. Figures 2 and 3 compare the throughput in urban and freeway crossing scenarios for different packet sizes of 256 and 1400 bytes.

Figures 6, 7, 8 and 9 correspond to the suburban environment. Figures 6 and 7 depict the link quality and throughput variation with relative velocity between the vehicles. Figures 8 and 9 show the link quality and throughput variation with the average velocity of the two vehicles. The link quality and throughput plots include readings corresponding to different inter-vehicle distances.

Figures 10 and 11 pertain to a test with vehicles following each other and maintaining line of sight in suburban environment.

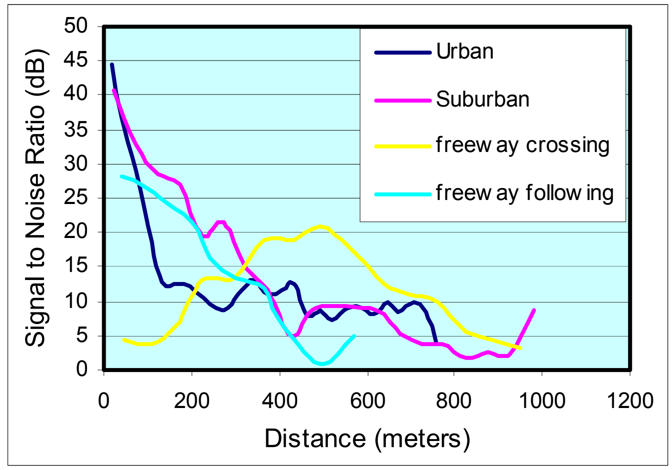

Figure 1. SNR vs Distance For Various Scenarios.

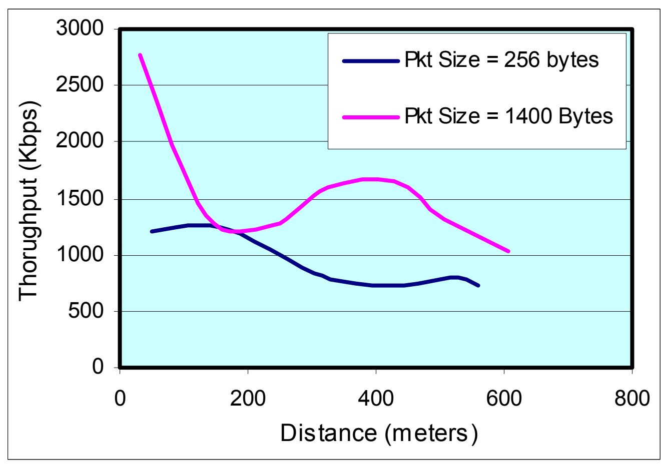

Figure 2.Throughput vs Distance for Urban Scenarios

V. RESULTS ANALYSIS

The 802.11b WLAN performance is observed to deteriorate with increasingly hostile communication scenarios. In this section, we analyze the results presented before.

- Link quality variation: The Link Quality or SNR, as observable form Figure 1, is observed to degrade with increasing distance, as it intuitively should. The link quality measurements for distances upto 400 meters indicate that the sub-urban environment is most favorable and the urban driving conditions are the most hostile for

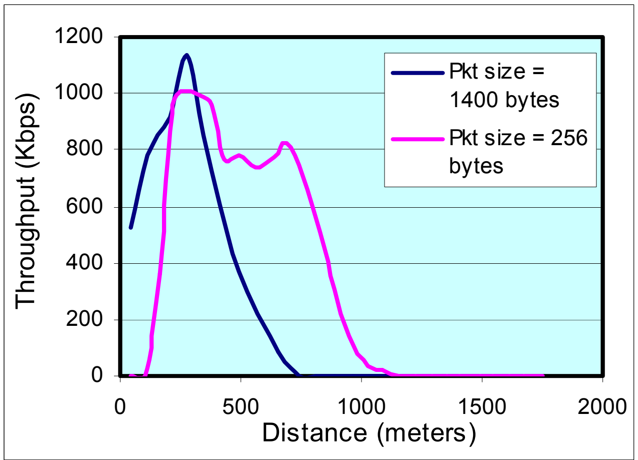

Figure 3. Throughput vs Distance for Freeway Crossing Scenarios

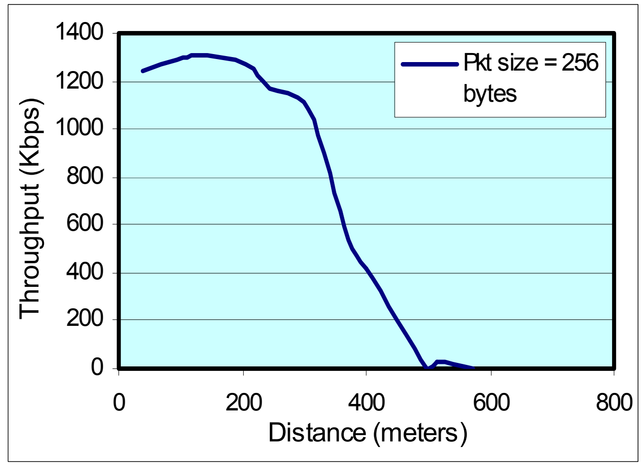

Figure 4. Throughput vs Distance for Freeway Following Scenario

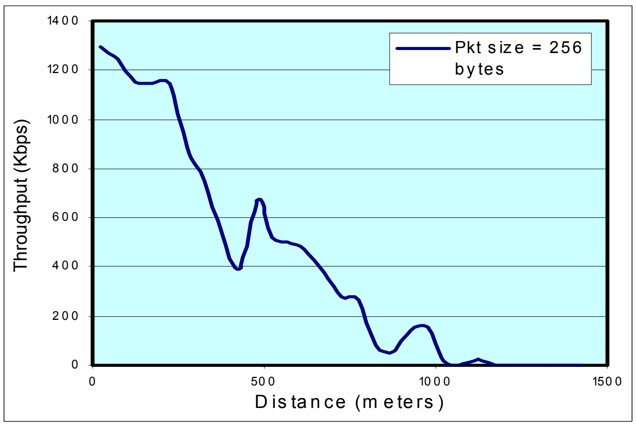

Figure 5. Throughput vs Distance for Suburban Scenario

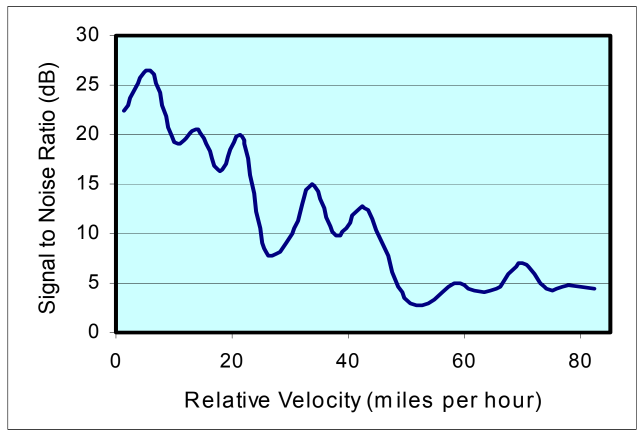

Figure 6. SNR vs Relative Velocity for Suburban Scenario

Inter-vehicle communication. The freeway environment link quality lies in between the two. The freeway- crossing test shows an increase in link quality until the vehicles have a separation of about 500 meters and then there is degradation with increasing distance. The link quality assessment is observed to be independent of the packet size employed in a given scenario. Figures 6 and 8 for the sub-urban scenarios demonstrate the deterioration in signal quality with increase in relative and average velocities of the vehicles.

- Throughput variation: Throughput shows a decreasing trend with increasing distance. There, however is a conspicuous feature in the freeway crossing case (Figure 3). The throughput increases with distance initially, before starting to fall with increasing distance. From figures 7 and 9 the throughput can be seen to fall with increasing relative and average velocities for the sub-urban scenarios.
- Aggression control via packet size variation: The increase is packet size form 256 to 1024 bytes is observed to increase the throughput for urban scenarios. For the freeway crossing case, the packet size increase is conducive to throughput enhancements at smaller separation. However, for larger distances, the throughput is better for smaller packet size. For adverse scenarios with vehicles separated by a large distance, a larger packet size would amount to a larger packet error rate and hence a lower throughput. It is therefore desirable to switch the packet size beyond a specific inter-vehicle separation. Similar work on adaptive frame length control for optimizing performance is discussed in [7].
- Connectivity range: Connectivity can be maintained for inter-vehicle separation of upto 1000 meters as demonstrated by the Figures 3 and 5 (freeway and sub-urban scenarios). Figure 3 shows that connectivity can be enhanced by decreasing the packet size.

Another test was conducted in suburban scenario, by maintaining line of sight between the two vehicles and having minimal obstructions between the two vehicles. Figures 10 and 11 depict the results. The throughput remains fairly constant with distance variation till about 200 meters. The

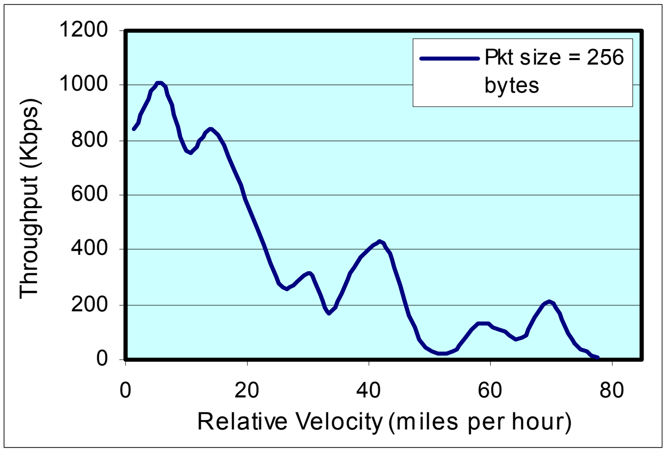

Figure 7. Throughput vs Relative Velocity for Suburban Scenario

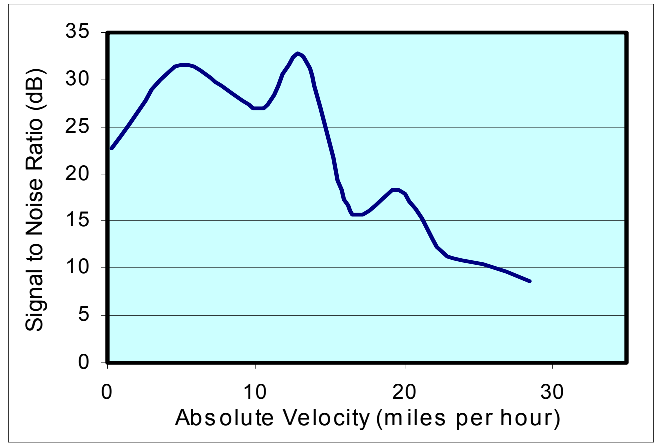

Figure 8. SNR vs Average of Absolute Velocities for Suburban Scenario

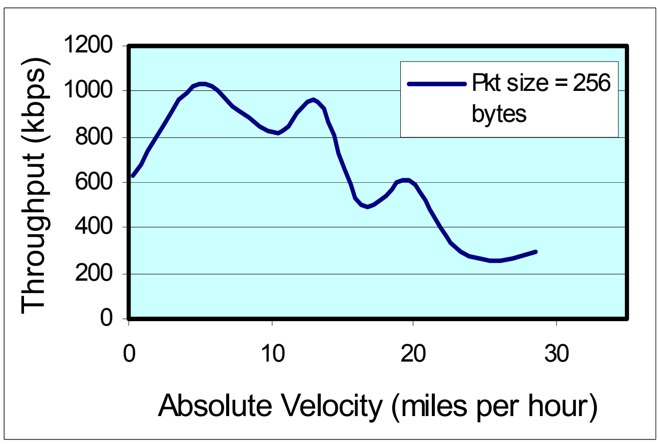

Figure 9. Throughput vs Average of Absolute Velocities for Suburban Scenario

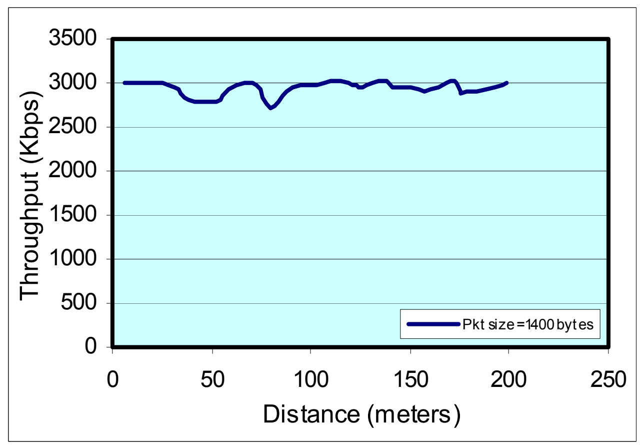

Figure 10. Throughput vs Distance for Suburban Scenario with Line of Sight

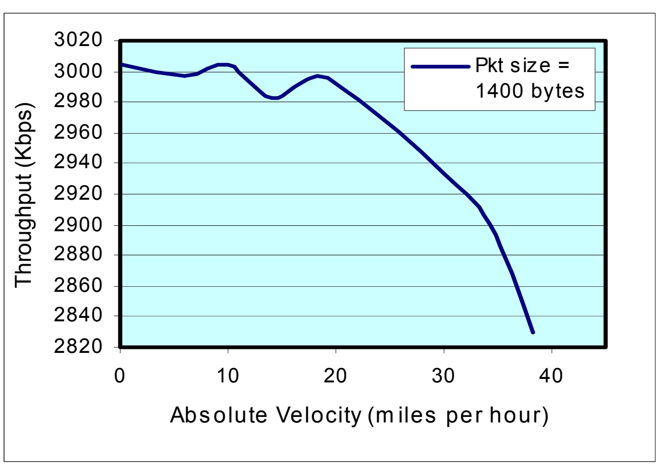

Figure 11. Throughput vs Average of Absolute Velocities for Suburban Scenario with Line of Sight

relevant plot accounts for readings corresponding to different vehicular velocities in the suburban scenario. The throughput decreases with increasing average velocity of the two vehicles.

VI. FUTURE WORK

The performance variation with distance, relative velocity and absolute velocity can be selectively highlighted by selecting a specific varying parameter and having the others fall in a small range. For instance, the performance dependence on distance could be selectively analyzed by taking readings falling in narrow ranges of relative and absolute velocities of the vehicles. This requires a significant diversity in readings which in not quite easy to achieve in real driving environments. We plan to do more exhaustive tests to make this analysis possible.

VII. CONCLUSIONS

We have assessed the performance of a wireless Local Area Network in different vehicular mobility, peer-distance and driving environment conditions. The 802.11b compliant equipment is seen to be suitable for inter-vehicle communications. The performance of the wireless network is observed to degrade with increasingly hostile communication scenarios. We observe that connectivity range of upto 1000 meters is achievable under suitable driving conditions. The link quality measurements for inter-vehicle separations upto 400 meters indicate that the sub-urban environment is most favorable and the urban driving conditions are the most hostile for inter-vehicle communication. The freeway environment link quality lies in between the two. We also suggest optimization measures via variations in packet size. Switching the packet size at suitable inter-vehicle separation in certain scenarios can help enhance the ad-hoc network performance.

The results presented in this paper can be used as performance references for development of inter-vehicular communication applications.

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