On the Uplink Performance of 802.11a and 802.11b in Vehicular Environments

Syed Faraz Hasan, Nazmul H. Siddique and Shyam Chakraborty

***Abstract* – Opportunistic short interval connection to an AP for getting internet services while moving at vehicular speed has attracted attention of many researchers. In this paper, we evaluate performance of all data rates of IEEE 802.11a at three different vehicular speeds in terms of packet loss, end-end delay and amount of information sent on the uplink. We also evaluate 802.11b in terms of same performance matrices under similar set up. Main purpose of these calculations is to judge what benefits, if any, we can have from using 802.11b in vehicular set up when 802.11p WAVE is being developed on 802.11a standard. WAVE allows communication between vehicles and between vehicles and roadside infrastructure.**

***Keywords* – 3GPP Applications, IEEE 802.11, Infrastructure WLAN, NS-2, Vehicular Context, WAVE.**

I. INTRODUCTION

Wireless LANs have become popular in providing broad band connectivity with restricted mobility to users for some time. WLANs operate in two different modes: Infrastructure and Ad hoc. In infrastructure mode, mobile nodes form a Basic Service Set (BSS) by associating with a central element called Access Point (AP). All communications between nodes within a BSS are via AP over its coverage area, commonly known as footprint. Infrastructure mode WLAN APs can be connected to an external network, such as internet, to provide broadband connectivity. While WLANs offer restricted mobility, they are recently being studied for providing broadband services over larger geographical areas. Recent project on Intelligent Transportation Systems (ITS) focuses on providing communication between vehicles and between vehicles and infrastructure primarily for public safety. Short spanned interaction of vehicle with an AP might facilitate downloading traffic updates and more interestingly for providing internet services.

Evaluating 802.11a in vehicular environments is important because 802.11p WAVE (Wireless Access for Vehicular Environments) is being proposed as a modified version of 802.11a [1].

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An interesting question in this regard would be, "If 802.11p is being standardized based on 802.11a, what is the advantage of studying 802.11b for vehicular environments?" We, therefore, simulate 802.11a and 802.11b under similar vehicular set up to see what performance gains are available in using the former instead of the later.

Rest of the paper is organized as follows. Section II describes Related Work; Simulation Set up is explained in section III. Section IV is on Observation, section V on Conclusion and References are given at the end.

II. RELATED WORK

Some works have evaluated the performances of IEEE 802.11a and 802.11b in different vehicular environments; however, hardly any work on evaluating these two under similar vehicular set up is known to authors. This paper gives a performance evaluation of 802.11a and 802.11b under similar set up in terms of end-end delays, amount of data sent on uplink and packet loss at three different vehicular speeds. Consideration of real time traffic patterns is vital for evaluating 802.11 performances in vehicular context. Speed selection for experiments and simulations must consider, for instance, dense, normal and highway traffics. Measurements conducted for 802.11 APs in [3], suggest that speed variations of vehicles do not affect throughput while exact opposite is supported by [2] and [4]. Performance of 802.11a in vehicular context is evaluated in [2] for UDP traffic. Since most of the traffic in a typical internet session is dominated by TCP, our evaluation is based on TCP traffic. The results show that considerable amount of data can be sent on the uplink using an 802.11 AP; however, even better results may be obtained by using AP diversity [5]. Another important factor affecting the performance of 802.11 in vehicular environments is the connection time. Performance evaluations for 802.11g under vehicular set up show productive connectivity for around 1000m at 120km/hr which corresponds to a connection time of around 30 seconds [6]. Eriksson et al in [7] have conducted real-time experiments; their results show that average connection time is not more than 10 seconds. This apparent contradiction might be because of the fact that car used in experiments in [6] essentially encounters one AP only.

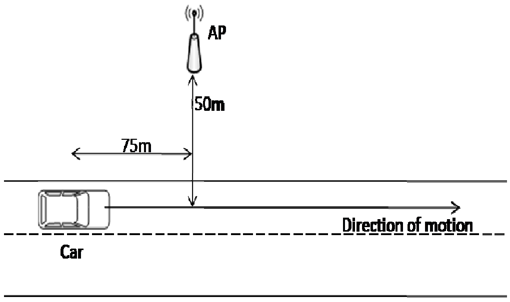

Figure 1: Simulation Set up

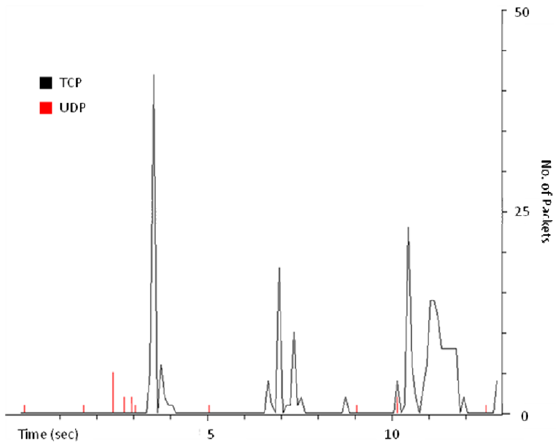

Figure 2: TCP and UDP traffics in a typical internet session

On the other hand in [7], car traverses along a populated city encountering several APs and hence initiating handovers periodically.

Mobile-AP separation is also a significant factor affecting the overall system throughput. Works on impact of mobile-AP separation on throughput are done in [3], [4] and [6] under 802.11b/g set up. We evaluate the same for 802.11a networks later in section IV.

III. SIMULATION SET UP

A typical simulation set up for performance evaluation of 802.11 networks at vehicular speeds involves a car moving by different APs located across an area, simulated in NS-2 [8]. As a car approaches an AP, it connects to it and uses its resources until it gets out of range within certain time duration. It then waits for encountering another AP to restart its session. Our set up comprises of a car moving towards an AP at three vehicular speeds 30, 60 and 90km/hr. As stated earlier, these speeds represent all possible traffic scenarios; dense traffic speeds are normally 30km/hr, normal urban speeds are 60km/hr and highway speeds are represented by 90km/hr. Antennas placed on car and AP correspond to Cisco 1240 series threshold values. Each simulation runs for 10 seconds, a practical connection time in urban environment, allowing the car to send TCP packets on the uplink. RTS/CTS handshakes are disabled to evaluate only the actual amount of data sent. Similar evaluations are carried out by configuring the set up with 802.11b parameters.

Our simulation set up, shown in Figure 1, can be visualized as an AP placed on the top of a building offering some coverage on the adjacent road 50m away. As mentioned in section II, we focus on time interval in which the car remains connected to the AP, or in other words, on the time period for which the car remains within the footprint of an AP, known as "production time" [4]. Since we want to evaluate connection benefits with in this time only, we ensure that the car is in the AP footprint at the beginning of simulation. To achieve this, horizontal mobile – AP separation is kept 75m, as shown in Figure 1.

The idea of evaluating TCP traffic is consistent with the fact that most of packet exchange during an internet session is dominated by TCP transfers. While browsing three different websites http://www.ulster.ac.uk, http://isrc.ulster.ac.uk and http://scis.ulster.ac.uk live traffic was sniffed using Wireshark. It is clear from Figure 2 that number of TCP packets exchanged in this internet session is much higher than UDP.

IV. OBSERVATIONS

A. Performance evaluation of 802.11 data rates

Although 802.11 WLANs are originally meant for providing data services, studies have shown that they can support voice and video communications as well [9]. Evaluating the provision of such convergent services using 802.11 requires consideration of more parameters than just information sending capacity. For example, real-time communications are delay sensitive applications. Evaluation of end-end delay, therefore, becomes a parameter of interest in 802.11 WLANs. Applications belonging to 3GPP QoS Background class might tolerate end-end delays but can not tolerate large packet loss [10]. We, therefore, calculate the values of end-end delay and packet loss along with amount of data sent for 802.11 in vehicular context to account for all 3GPP QoS classes. From results shown in Tables 1 to 3 for 802.11a, we find that at all speeds, end-end delay decreased with increasing data rates. This trend suggests that higher data rates of 802.11a have a better tendency to support real-time and semi-real-time applications. On the other hand, amount of data sent on the uplink, increase with increasing data rates. However, performance difference between 48 and 54Mbps rates is quite small, rendering them to be considered as performing equally. Tables 1-3 suggest that speed variation does not significantly change amount of data sent on the uplink. This is an apparent contradiction to findings of [2] and [4]. We argue that speed variations play their part only in cases where more than one AP is located with null zones between them. Since our simulation set up is composed of one single AP, effect of null zones is absent. Our results are consistent with findings of [3] because it uses only one AP. We also note from Table 1-3 that speed variations do impact end-end delays. Smaller the vehicle speed, smaller is the end-end delay. This implies that 3GPP QoS conversational and streaming applications will have a tendency to perform better at slow speeds. Furthermore, 802.11a data rates 6, 24, 48 and 54 Mbps, result in comparatively smaller packet losses. It can, therefore, be concluded that 802.11a higher data rates 48 and 54Mbps perform better than others and almost identical to each other. Performance evaluation for 802.11b 11Mbps data rate under similar conditions suggests that trend of vehicle speeds not affecting amount of data sent and that of increasing end-end delays with increasing speeds is similar to 802.11a. Table 4 enlists performance of 802.11b rates at different speeds. Considering tables 1 – 3 for 802.11a 54Mbps and table 4 for 802.11b, we find that end-end delays are twice as high under 802.11b set up.

Table 1: Performance of 802.11a @ 30km/hr

Data Rate (Mbps)	End-End Delay (msec)	Amount Sent (MB)	Packet Loss (%)
6	1.59	2.24	0.002
9	1.11	2.64	0.033
12	0.88	2.89	0.0013
18	0.63	3.22	0.033
24	0.51	3.4	0.0013
36	0.38	3.61	0.0013
48	0.33	3.73	0.001
54	0.31	3.76	0.001

Table 2: Performance of 802.11a @ 60km/hr

Data Rate (Mbps)	End-End Delay (msec)	Amount Sent (MB)	Packet Loss (%)
6	1.77	2.25	0.002
9	1.24	2.64	0.033
12	1.07	2.88	0.0013
18	0.75	3.22	0.033
24	0.64	3.39	0.0013
36	0.52	3.59	0.0013
48	0.46	3.73	0.001
54	0.43	3.77	0.001

Table 3: Performance of 802.11a @ 90km/hr

Data Rate (Mbps)	End-End Delay (msec)	Amount Sent (MB)	Packet Loss (%)
6	1.79	2.24	0.002
9	1.33	2.63	0.002
12	1.03	2.88	0.033
18	0.78	3.22	0.0013
24	0.66	3.41	0.0013
36	0.54	3.61	0.03
48	0.47	3.73	0.0013
54	0.47	3.76	0.0013

Table 4: Performance of 802.11b

Speed (km/hr)	End-End Delay (msec)	Amount Sent (MB)	Packet Loss (%)
30	0.99	3.38	0.033
60	1.09	3.40	0.033
90	1.13	3.4	0.033

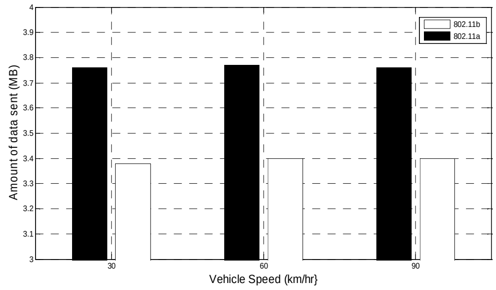

Figure 3: Comparison in terms of amount of data sent by 802.11a and 802.11b at different speeds

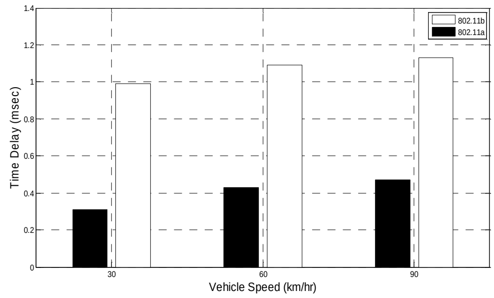

Figure 4: Comparison between 802.11a and 802.11b in terms of end-end delay at different speeds

With regards to amount of data sent, 802.11a 36Mbps and higher rates perform better than 802.11b. Packet losses tend to remain constant with speed in 802.11b; however, their values remain higher than 802.11a packet losses. Figure 5 and 6 give a graphical representation of these facts.

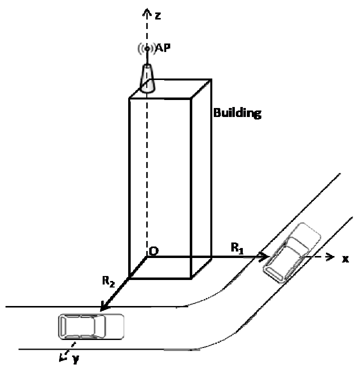

Figure 5: R1 and R2 representing Ground Distances on x and y axes respectively

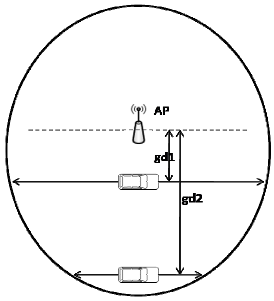

Figure 6: A larger Ground Distance results in a smaller connection time

B. Assessing AP- Mobile separation

In this section, we study the impact of mobile-AP separation on overall amount of data sent in terms of "Ground Distance". In Cartesian Coordinate System, we define this distance as the distance from foot of projection of an AP along z axis on xy–plane to the mobile node such that the position vector between them (foot of projection of AP along z axis and mobile node) lies on either of the other two axes. Figure 7 shows a diagrammatic description of ground distance. Point 'O' represents the point where AP projection along z–axis cuts xy–plane. Position vectors R_1 and R_2 represent the ground distances of two mobile nodes on x and y axes respectively.

To evaluate the impact of ground distance on throughput, we simulate a car passing by an AP along a straight road. In order to quantify the value of ground distance at which car gets out of AP range, we increase simulation period (to 20sec) and car speed (to 90km/hr), allowing it to travel a larger distance and hence get out of range. Increase in amount of data sent with decreasing ground distance, as shown in Table – 5, can be explained in terms of connection time. A larger ground distance results in less connection time and hence smaller data exchange takes place. As shown in figure 8, a car with a larger ground distance "gd2" remains connected to AP for a shorter time interval as compared to the car with smaller ground distance "gd1". Consequently, both will perform differently despite being under similar conditions. We note, from figure 9, that ground distance must remain less than 200m, beyond which amount sent on uplink is badly affected. We also find that for all ground distances greater than 500m, mobile node remains out of AP footprint.

Table 5: Impact of perpendicular distance on amount of data sent

Ground Distance (m)	**Amount Sent (MB) for 802.11a 54Mbps**
0	8.428
100	8.427
200	8.403
300	8.405
400	8.401
500	AP out of range

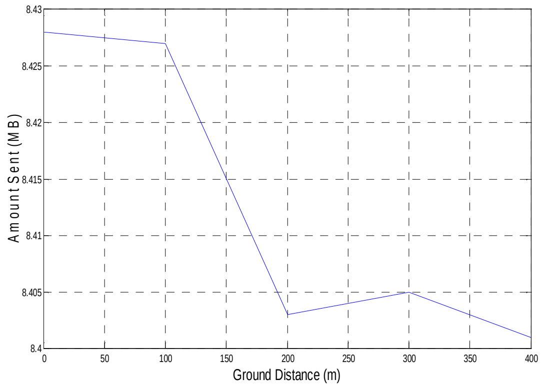

Figure 7: Amount of data sent on the uplink v/s ground distance for 802.11a 54Mbps

V. CONCLUSION

We evaluated uplink performance of TCP traffic with 802.11a and b data rates in a typical vehicular set up. We found that higher data rates of 802.11a perform much better than 802.11b for all 3GPP QoS traffic classes. Our simulation results also establish that speed variations affect data sending capacity in cases where multiple APs are present with null zones between them. Our study also suggests that for optimum throughput values, ground distance between mobile node and AP must be kept within 200m.

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