Impact of RSS on the Performance of 3GPP Applications in a Net-on-Roads Connection

Syed Faraz Hasan, Nazmul H. Siddique and Shyam Chakraborty

***Abstract* – Several works have been done to explore the possibility of using randomly located WiFi APs for getting broadband services from vehicles on roads and highways. While different works address issues such as number of APs available, their authentication schemes, data rates and vehicle speed etc, we investigate the impact of Received Signal Strength (RSS) from an AP on performance of 3GPP internet applications. We draw out signal strength thresholds for each of these internet applications and establish that RSS is an important parameter to be considered not only while connecting to an AP but also for deciding which application may be supported by a certain AP. Conclusions drawn in this paper are based on measured RSS levels offered by WiFi APs during test drives.**

***Keywords* – 3GPP Applications, 802.11 networks, Measurement, Received Signal Strength (RSS), Vehicular Communication**

I. INTRODUCTION

WLANs have become enormously popular among domestic and commercial users seeking wire-free network connectivity mainly due to ease of mobility and cost benefits [1]. Several "hot-zones" enabling access to internet services via WLANs are being set up in major cities of the UK including London, Manchester and Birmingham [2]. Because of rapid deployment of WLANs across the cities, the idea of using these already available APs at typical vehicular speeds has gained significant popularity. Mobile node placed in vehicles is proposed to connect to a roadside AP opportunistically and use internet services until it moves out of its footprint. Because of random location of WiFi APs, mobile node experiences states of connectivity and dis-connectivity for certain period of time as it moves along its path at vehicular speeds. In line with this interesting research trend, authors are working on Net-on-Roads project which is concerned with bringing network connectivity down to roads, accessible from vehicles.

Our emphasis in this paper is to show that Received Signal Strength (RSS) from an AP plays an active role in deciding which applications can be used during a certain connection. RSS is a measure of power present in the received radio signal. Several models have been proposed to predict RSS in wireless communication systems, for example, log-distance path loss model as given in eq. (1).

Syed Faraz Hasan is a Ph.D. student at School of Computing and Intelligent Systems, University of Ulster, UK. (Email: faraz_hasan-s@email.ulster.ac.uk.)

Nazmul H. Siddique and Shyam Chakraborty are with School of Computing and Intelligent Systems, University of Ulster, UK. (Email: nh.siddique@ulster.ac.uk and ss.chakraborty@ulster.ac.uk.)

$$P_r(d) = P_{ro} - 10\alpha \log(d) + X_\sigma \qquad (1)$$

where, P_{ro} is signal strength 1 meter from transmitter, α is the Path Loss Exponent and X_σ represents gaussian random variable with zero mean and standard deviation of σ dB [3]. In this model (like many others), parameters (α, σ) vary with environment and are assigned values empirically. In this paper, we measure the RSS available on roads experimentally and evaluate its impact on 3GPP applications commonly used by internet users.

3rd Generation Partnership Project (3GPP) classifies the internet applications as Background, Interactive, streaming and conversational. Chakraborty et al. in [4] have defined 3GPP applications as follows. Conversational applications are delay sensitive applications meant for real-time traffic flow while streaming applications are mainly intended for semi-real-time applications such as streaming audio/ video clips. Interactive applications are internet messaging or SIP applications and background applications are meant for sending and receiving information over the network, for instance in the form of emails. In this work, we evaluate minimum required signal strength values for such applications to work properly in a drive through environment. We also conduct test runs to see what levels of signal strengths are available in a typical drive run across different areas of the city.

Rest of the paper is organized as follows. Section II covers related work; section III defines experimental set up. Section IV is on observations, section V contains conclusion and references are given at the end of the paper.

II. RELATED WORK

Vehicular communication has gained considerable research attention for quite some time. Several projects, for instance REACT [5], Fleetnet [6] and Network on Wheels [7] etc are addressing different issues related to bringing network connectivity on roads. Drive Thru project [8] studies 802.11g APs for providing network connectivity from vehicles. Their results have shown up to 70MB of data exchange in a single 60 second mobile node–AP connection. Some works have studied 802.11a [9] along with 802.11b in vehicular set up. Gass et al. in [10] have recorded observations in a desert to evaluate impact of speed of vehicles on performance of different applications. In contrast to the experiments in [10], we perform test runs in realistic urban settings to reach more accurate conclusions.

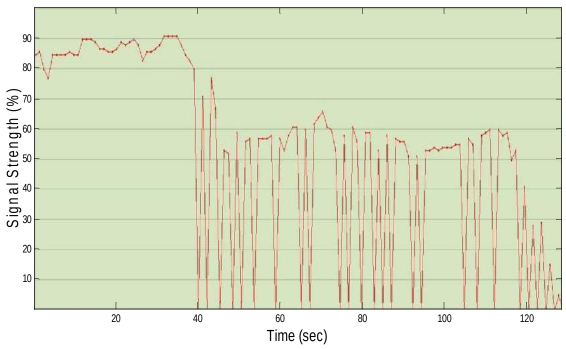

Figure 1: Signal strength variation as mobile node moves away from AP

Balasubramanian et al. in [11] have taken into consideration the signal strength issues but their major focus was on exploring the benefits of base station diversity. Their work studies the implications of signal strength information on getting a connection with an AP. Our work is different in the sense that we study the impact of signal strength information on performance of specific applications used in a typical internet session. In the light of our measurements and analysis, an AP with certain signal strength value might support one internet application but may fail in supporting others. Eriksson et al. in [12] have devoted one section on studying effect of antenna type and its placement on performance of a short lived internet session in the vehicular set up. Their results suggest that using an external antenna may increase the signal strength received by a mobile node but they have not considered the impact of this increase on performance of individual 3GPP applications. Mahajan et al. in [13] have studied RSS along with other parameters to predict "grey periods". Although their results suggest that RSS is not a good measure to predict faltering connection, we show that it can be a good measure of predicting which internet application may work under a given RSS level.

III. EXPERIMENTAL SET UP

As mentioned earlier in section I, this work, firstly, comprises of identifying the signal strengths at which different applications perform satisfactorily and secondly, involves measuring signal levels available from APs in a typical drive run from one place to another at vehicular speed. In this section, we highlight our experimental set up for recoding both these observations. Observed results are discussed in section IV.

A relation between receiver sensitivity and data rates of 802.11b has been established in [14]; however, the analytical approach adopted would remain incomplete until it is backed up by experimental evidence. It must be noted that our primary focus is on determining "signal strengths" required by 3GPP applications and those available from roadside APs; we are not concerned here with what data rates are achievable at different RSS levels. In order to establish minimum required signal strength values for background, interactive, streaming and conversational applications we run each of these applications one by one on a mobile node (laptop with Realtek 802.11g wireless card running Windows Vista) connected to an 802.11g AP. In our setup, we use web browsing to represent background traffic; interactive applications are represented by a MSN chat session, a 300kbps live streaming video represents streaming class applications and a Skype call is meant to represent the conversational class. While running each of these applications one by one, mobile node is gradually moved out of the AP footprint thus reducing it's RSS due to varying signal losses which may be mathematically modeled using eq. (1). The process of increasing distance between AP and mobile node continues until the application fails at a certain signal strength value which is recorded as the minimum value required for that specific application to run satisfactorily. Figure 1 shows the decrease in signal strength as the mobile node is moved away from the AP at walking speed.

In order to address the second issue of evaluating signal strengths available from randomly deployed APs around the city, we perform two test runs; one each for domestic and commercial areas. We identify domestic area as one in which the vehicle traverses through residential buildings with little or no commercial infrastructure. Commercial areas are those which are dense with commercial entities like businesses, shopping malls etc. Relevant information regarding available APs is recorded by Vistumbler (Windows Vista version of Netstumbler) [15]. The drive runs are done using public buses instead of cars. Intuitively, buses reflect traffic patterns better than cars and are widely used by the general public. Speed of cars in an urban environment may vary from person to person but speed of buses is more or less consistent with the traffic pattern. Observed results from both experiments are discussed in the following section.

IV. OBSERVATIONS & ANALYSIS

A. Signal Strengths for 3GPP Applications

Observations shown in Table 1 suggest that 3GPP Interactive Class requires least signal strength to operate as compared to other classes while conversational class requires highest signal strength level. Since Interactive applications perform well even at very small signal strengths, chatting sessions in a drive through environment might have a tendency to perform better than other forms of communications. Background applications such as web browsing work fine above 55% RSS level. It was observed that browsing speed becomes very slow in the RSS range 30-55% and below 30% web browsing does not work at all.

Table 1: Minimum Thresholds of RSS required for different 3GPP Applications

Traffic Class	Required RSSI (%)	Required RSSI (dB)
Interactive	30	-78
Background	55	-69
Streaming	80	-60
Conversational	85	-57

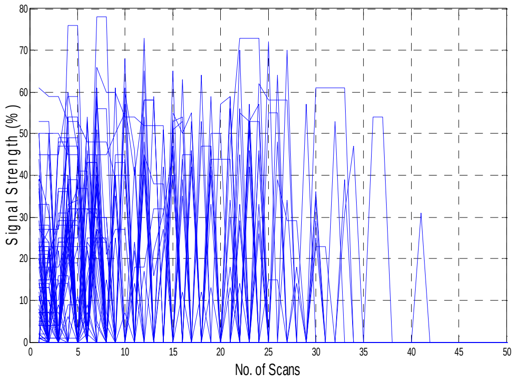

Figure 2(a): Signal strength observed from encountered APs in domestic area

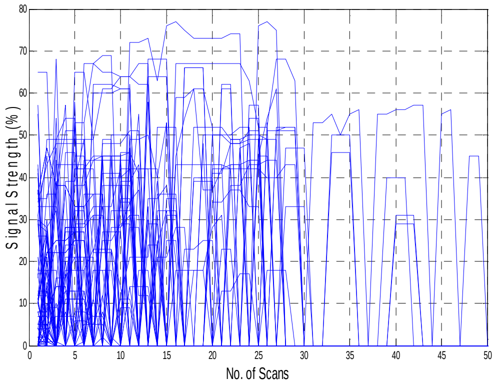

Figure 2(b): Signal strength observed from encountered APs in commercial area

Table 2: RSS statistics for domestic and commercial areas

	Domestic Area (%)	Commercial Area (%)
Mean RSS	30.59	32.25
Median RSS	30	32.5
Std Deviation	18.75	20.06

We observed that streaming applications can perform well for all RSS values above 50%. Further investigation with streaming applications suggest that these can not be started afresh at low signal values, but already running applications have a tendency to keep performing well if signal strength degrades up to 50%. Finally, conversational class requires largest signal strength, above 85% according to our experiments. We believe facilitating such applications in a Net-on-Roads connection would be the most challenging task because RSS values exhibit a very fluctuating nature in a rapidly changing vehicular setup.

B. Signal Strength Values on Roads

After quantifying the minimum requirements of signal strengths for various applications, we turn our attention to find out what RSS values are achievable from already available WLAN APs. Drive runs conducted in domestic and commercial areas resulted in encountering 185 and 274 APs respectively. Both runs lasted for around 25 minutes and observed RSS values are shown in Figure 2(a)

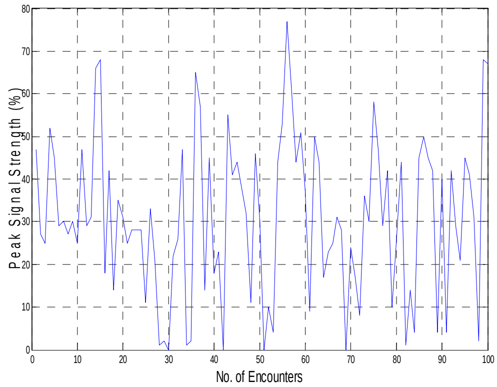

Figure 3(a): Peak Signal Strength observed during encounters in domestic area

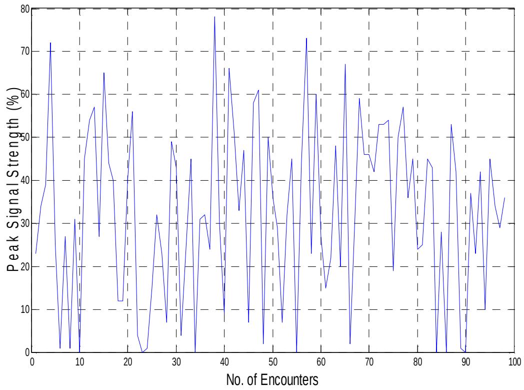

Figure 3(b): Peak Signal Strength observed during encounters in commercial area

and Figure 2(b). We note from Figure 2(a) and Figure 2(b) that highest signal strength offered by APs was observed to lie between 70 – 80%; however, such APs constitute a slight minority of the total APs encountered. To get an insight into the best case scenario, Figure 3(a) and Figure 3(b) plot peak RSS recorded for 100 encountered APs in the test run for domestic and commercial areas respectively. As can be seen from Table 2, mean RSS values for both areas is approximately 30%. Considering the previously discussed observations, 30% RSS is a considerably low value at which even the background class does not perform satisfactorily. It must be noted that Table 2 enlists the peak RSS values observed; it implies that RSS observed at different times with APs would have been even lower. An interesting question in this regard is, "do these RSS observations represent all traces in a city?" In other words, how we can ensure that values noted in these experiments will not deviate significantly if drive runs are performed in a different area. We argue that performance of a typical Net-on-Roads connection depends on several factors such as number of APs in an area, authentication schemes they follow, speed of vehicle, placement of AP and of course RSS values from each AP. Since all these factors alter with the area in which drive run is performed, we expect that our observations will vary with the location where test run is conducted.

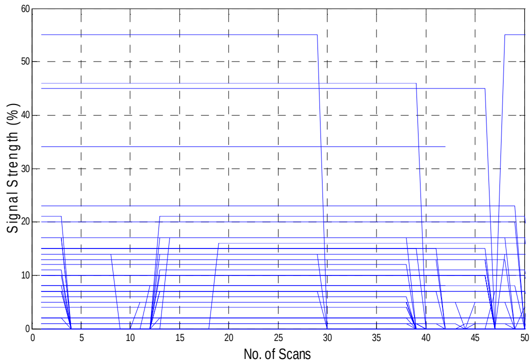

Figure 4(a): Signal strength observed from encountered APs for a different commercial area

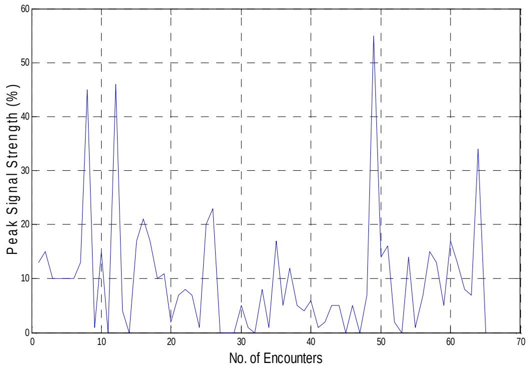

Figure 4(b): Peak Signal Strength observed during encounters for a different commercial area

To support this statement, we perform similar test run in another commercial area of the same city for around 25 minutes (like the former tests) and reach the following conclusions.

Firstly, we encountered far less APs in this test run as compared to the previous cases. This can be appreciated by noting that Figure 4(a) is far less dense than Figure 2(a) and Figure 2(b), indicating a smaller number of AP hits. From this observation alone, it follows that performance of a Net-on-Roads connection may vary from place to place. Secondly, statistics for peak signal strengths obtained in this trace, graphically shown in figure 4(b) and tabulated in table 3; highlight that mean RSS value is less than 10%. It follows that to exploit internet services from vehicles on roads and highways, an additional external antenna (such as one proposed in [12]) might improve performance of these short lived connections. Although it has been shown that an external antenna leads to performance improvement, its impact on performance of individual 3GPP applications can be an area of future research.

From afore mentioned observations, we note that “tolerating” disruptions in a Net-on-Roads connection might still not be enough to use WLANs from vehicles until sufficient signal strength is available from the roadside APs.

Table 3: Statistics observed during encounters for a different commercial area

	RSS (%)
Mean	9.93
Median	7
Std Deviation	11.10

V. CONCLUSION

Our project Net-on-Roads is concerned with accessing internet services from vehicles on roads. We note from our observations that RSS is an important parameter affecting the performance of a typical Net-on-Roads connection. We establish RSS thresholds below which different internet applications can not operate satisfactorily. We further showed that RSS levels offered by randomly placed APs differ from area to area and also that these are not enough to support all internet traffic classes. Studying the impact of an external antenna on the performance of Net-on-Roads connection for facilitating 3GPP applications is an area of future works.

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