Vehicular WiFi Access and Rate Adaptation

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Abstract—Vehicular WiFi access is distinct in two respects, (i) continuous mobility of clients and (ii) possibility of predictable link quality. As part of this study, we aim to comprehensively evaluate existing rate adaptation algorithms in real environments. Further, if required, we aim to develop a simple, low-overhead rate adaptation algorithm suited for vehicular WiFi access.

Categories and Subject Descriptors: C.2.1 [Computer-Communication Networks]:Network Architecture and Design[Wireless communication]

General Terms: Experimentation, Measurement, Algorithms

Keywords: Experimentation, Measurement, Algorithms

1. INTRODUCTION

Use of 802.11 (WiFi)-based access for communication in outdoor environments is on the rise—vehicle-to-vehicle communication, sensor network applications, delay-tolerant networks, road-side wireless access [3] etc. In this paper, we concern ourselves with the Vehicular WiFi Access scenario—use of roadside 802.11 installations (access points) to provide communication facilities from/to vehicles [2, 3, 4], to enable networking applications. An obvious question is, how to maximize usage efficiency of the available network capacity between access points and mobile clients (vehicles)?

One of the widely used techniques for efficient use of network capacity is rate adaptation. 802.11 supports several transmission rates, each with different modulation techniques for PHY layer transmissions. Since, bit-error-rate (BER) is proportional to bits/symbol, different modulations techniques implicitly result in different BERs. Rate adaptation techniques aim to dynamically choose appropriate data rates in order to simultaneously minimize BER and maximize throughput. Several rate adaptation techniques [1], ARF, SampleRate, RBAR, CARA, ONOE, etc. exist. Adaptation heuristics are based on different parameters like packet delivery probability, signal-to-noise ratio, and receive signal strength (at receiver), etc. Almost all of these adaptation techniques have been designed and evaluated for indoor environments, where client devices are more or less static and suffer from multi-path effects due movement of people/objects and interference due to other transmitting nodes.

Vehicular WiFi access is distinct in two respects (i) continuous mobility of clients and (ii) possibility of predictable link quality. The first aspect refers to near continuous movement of vehicles resulting in a rapidly changing multi-path and interference effects. [2] reports association durations of 10 to 60 secs for speeds 10 to 100 kmph. The second aspect is more subtle. Consider a roadside access point and an approaching vehicle. As the vehicle enters and leaves the coverage area of the access point, the signal quality perceived by the vehicle will change from low to improved to probably best when close to the access point before the signal quality follows a similar trajectory of decreasing quality. Figure 1 shows the received signal strength of a vehicle moving past a roadside access point (mounted at 125m from the starting point) on a straight road. As can be seen from the figure, a distinct trend of signal strength is observed corresponding to the location of the vehicle, low (-90 to -95 dBm for first and last 25 m) and high (-60 to -65 dBm 25 m on the both side of the access point). A previous study [4] has identified the presence of such distinct regions—entry, production and exit. The duration of these phases is dependent on the speed of the vehicle. Since conventional rate adaptation algorithms are agnostic to the presence, duration and order of these regions, they might behave (choose rates) sub-optimally. A conservative heuristic may choose higher rates at the end of the production phase or an aggressive heuristic may choose higher rates in the entry/exit phase, leading to sub-optimal usage of the link (due to increased link layer retransmissions).

Our aim is to compare performance of popular rate adaptation algorithms using a measurement-based approach in 802.11-based vehicular access scenarios1. Specifically, we aim to (i) compare the performance of three rate adaptation algorithms—AMRR, SampleRate, ONOE. (ii) comment on whether any of these existing techniques intrinsically adapts to the nature of vehicular wireless access, and (iii) explore the possibility of exploiting the predictability of link quality

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1There are several issues to be solved to instantiate Vehicular WiFi Access - placement, channel assignment, coverage, security, disconnection-aware protocols, addressing etc.
for improved rate selection. This exploration also needs to be cognizant of the fact that factors other than RSSI (like interference) influence delivery characteristics.

2. EXPERIMENTAL EVALUATION

Our preliminary setup (shown in Figure 2) consists of a stationary sender and a receiver (vehicle/client) moving continuously along a straight road.

The sender, a single-board Soekris (net4826) with a Ubiquiti XR2 wireless card, is placed in a near-road building at a height of 35 feet. The sender is equipped with a 14 dBi horizontally polarized sector antenna (90 degrees horizontal beam width and 10 degrees vertical beam width). This setup, with a transmit power of 10 dBm, results in a wireless coverage of 250 meters on the adjoining road. Both, the sender and receiver run MadWifi 0.9.4 driver instrumented for generating custom logs. The sender continuously sends UDP packets and the receiver traverses the ‘covered’ road at different speeds.

Using this setup, we first compare a set of rate adaptation algorithms (SampleRate, AMRR, ONOE). We are using original implementation of these algorithms with multi rate retry enabled. Table 1 shows usage percentage of each rate for the duration of each one-way traversal (with a speed of 11 kmph) and the average number of packets transmitted for each unique packet. As seen from the table, AMRR is most aggressive—75% of all transmissions use rates 24 Mbps or higher (48 Mbps and 54 Mbps account for 30%). SampleRate is not as aggressive as AMRR, 60% transmissions use rates 24 Mbps or higher. On the other hand ONOE is the most conservative algorithm with no transmissions with rates greater than 12 Mbps. Receiver throughput for SampleRate, AMRR and ONOE are 7.83 Mbps, 7.82 Mbps and 2.75 Mbps respectively. Though AMRR is more aggressive than SampleRate in terms of rate selection, aggregate throughput obtained with both techniques is approximately same. This is because aggressive rate selection of AMRR leads to higher number of re-transmissions and increased per packet transmission overhead. Expected overhead per transmission for SampleRate and AMRR is 1.08 and 1.24 respectively.

Next, we study the impact effect of speed (the duration under wireless coverage) on these algorithms. With increase in speed, heuristics have less time to adapt to changing conditions, decreasing the fraction of usage of higher rates and hence throughput. As shown in Figure 3, the achieved throughput with a speed of 15 Kmph is 6.2 Mbps with SampleRate and AMRR, and is 2.2 Mbps with ONOE. Reduction in speed to 7.5 kmph results in throughputs of 8.5 Mbps, 8.4 Mbps and 4.3 Mbps for SampleRate, AMRR and ONOE respectively. Throughput with ONOE is impacted the most, reducing by half with twice the speed.

The next question of interest is, whether there can be better rate selection strategies? To answer this question, we did extensive experiments with all the rates available in 802.11. Transmission rate was fixed for a run, no rate adaptation was used. Using these logs we determined the best transmission rate in terms of throughput for different sections of the road which we used as a rate setting corresponding to a particular location on the road. Throughput achieved using this strategy at the speed of 11 kmph was 8.4 Mbps, much higher than corresponding number for SampleRate and AMRR. This experiment indicates that current rate adaptation techniques can be extended and improved.

3. CONTRIBUTIONS AND FUTURE WORK

Previous work has identified and studied issues of WiFi-based Vehicular access—association overhead, TCP throughput, TCP timeout durations and bit rate selection [4]. In [5], the authors have studied performance of rate adaptation algorithms in real environments and (ii) developing a simple, low-overhead rate adaptation algorithm suited for vehicular networks (possibly operating under no knowledge of location of access points and vehicles etc.). In this extended abstract, we have provided a brief introduction to our initial work and aim to address the above mentioned goals towards completion.

Table 1: Comparison of rate adaptation algorithms.

<table>
<thead>
<tr>
<th>Rate (Mbps)</th>
<th>SampleRate</th>
<th>AMRR</th>
<th>ONOE</th>
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<tbody>
<tr>
<td></td>
<td>usage (%)</td>
<td>usage (%)</td>
<td>usage (%)</td>
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<tr>
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4. REFERENCES