The Impact of Dedicated Short Range Communication on Cooperative Adaptive Cruise Control

Anjan Rayamajhi*, Zoleikha Abdollahi Biron†, Roberto Merco†, Pierluigi Pisu†, James M. Westall ‡ and Jim Martin ‡

*Department of Electrical and Computer Engineering
†Department of Automotive Engineering
‡School of Computing
Clemson University
Clemson, SC

Abstract—This paper reports on aspects of the performance of three operational deployments of Dedicated Short Range Communication (DSRC) equipment. Performance metrics considered include throughput, latency, and the characteristics of the packet loss process. A laboratory deployment is used to establish a performance baseline for operation under ideal network conditions. Vehicle to infrastructure and vehicle to vehicle deployments are then used to evaluate the effects of real world deployments. The impact of degraded performance upon a Cooperative Adaptive Cruise Control (CACC) application is evaluated.

I. INTRODUCTION

Connected Vehicles (CV) and Intelligent Transportation System (ITS) have emerged as an important facet for future Smart Cities and the Internet of Things (IoT). Vehicular Networks bring the ability to communicate and share real time safety and urgent information in a reliable and timely manner. Coupled with Edge Computing and Cloud Computing, vehicular networks open possibilities for a broad range of applications which collectively bolster the idea of Smart Cities[1]. Recent increase in investments from US Government towards research and development in Smart Cities, Smart Grid and Smart Transportation have raised more interest in these areas of research. The regulation of USDOT requiring light weight vehicles to have DSRC radios pre-installed provides a solid framework for supporting many connected vehicle applications in real traffic scenarios [2]. Vehicles use wireless communication to communicate with each other primarily for sharing time constrained safety related informations. The wireless technology used for vehicular communication is DSRC which is a variant of Wi-Fi, operates over a 10 MHz channel in the 5.9 GHz frequency band and employs 802.11a OFDM modulation with 802.11e (EDCA) QoS queuing ability [3–5].

DSRC has been designated as the vehicular wireless communication technology for Vehicle to Vehicle and Vehicle to Infrastructure communication. Implementations have been proven to be capable of successful operation under high mobility and high congestion traffic conditions. Previous studies have investigated the performance and reliability of DSRC under various network conditions, congestion and noise [6–9]. In addition, US DOT has categorized and identified various connected vehicle applications in a blueprint architecture set known as Connected Vehicle Reference Implementation Architecture (CVRIA) [10]. CVRIA provides details on many CV applications precisely defining their design and implementation. Cooperative Adaptive Cruise Control (CACC) is one of the application defined in CVRIA. In this application the velocity and acceleration of the following vehicle of a vehicle pair are controlled to maintain proper headway distance between the two vehicles. CACC provides following benefits making it an interesting and practical application for real world deployments -

- Increased vehicle throughput in congested highways
- Increase safety and reduce collision risk
- Reduced fuel consumption because of reduced aerodynamic drag [11]

Various control theoretic approaches to controller design for the CACC application exist in the literature [12, 13]. Most of the analysis exists in the form of string stability theoretic approaches to understanding the effect of changes in velocity and acceleration of front vehicle and its rippling effect on following vehicles.

Though the baselines of CACC and Adaptive Cruise Control (ACC) are similar, the underlying technology is not similar. CACC uses the DSRC network to share position, speed, and acceleration data among participating vehicles along with on-board sensors like LIDAR and Radar which makes the inter-vehicle relative distance very small compared to ACC. In ACC systems, individual vehicles use on-board sensors such as LIDAR and Radar to identify the speed and headway of nearby vehicles. Some previous work exists where vehicles with autonomous or semi-autonomous capabilities have been configured to support CACC and tested for stability of platoon and network performance [14, 15]. Many papers provide modeling of the DSRC link between two CACC capable vehicles and try to evaluate the effect of network conditions...
on the efficiency and stability of CACC system [12, 16]. One of the assumptions made in the previous works is that the average packet loss rate of Basic Safety Message (BSM) transmitted between two vehicles is very low and further the loss process can be modeled as a Bernoulli Loss Process. Therefore the probability of a vehicle observing a gap in the BSM stream is negligible [16]. The related works also assume all vehicles synchronously update their velocity and acceleration to following vehicles. It is also assumed that all vehicles have a method for measuring the exact distance to the car ahead. Further, it is also assumed that all vehicles are in a single lane. We show through field test that burst of packet loss do occur especially in situation such as a large overload carrying vehicle moves into the lane cause No Line of Sight (NLOS) situations. The prior works make assumptions that under packet loss CACC falls back to ACC with increased headway distance causing decreased traffic throughput on the roadway. In order to understand these assumptions and their effect in the performance of a CACC controller, we have developed the emulation model for CACC controller and tested in real vehicles using DSRC communication. Using a set of network measurable performance metrics we explored the effect of network impairments on a CACC controller.

The remainder of the paper is organized as follows - section II provides background on DSRC and CACC, section III details on testing methodologies, section IV shows results obtained with simulation and field tests and section V concludes the paper.

II. BACKGROUND

Vehicular Networks use different types of communication technology to communicate among themselves or with the infrastructure. DSRC is widely used wireless communication technology for vehicular networks. DSRC is a member of the IEEE 802.11 (Wi-Fi) family of protocols. Its PHY and MAC layers are specified in the IEEE 802.11p standard. It operates on a 10 MHz channel using Orthogonal Frequency Division Multiplexing (OFDM) over 64 sub-channels of which 48 carry data. The upper layers of of DSRC are specified in the IEEE 1609 Wireless Access for Vehicular Environments (WAVE) standard. WAVE is a light-weight non-routable protocol designed for high performance operation in a single broadcast domain [3, 5]. Frequency used in the U.S. is 5.9 GHz with a set of seven 10 MHz channels of which six are service channels and one in particular, channel number 178 (5.885 GHz–5.895 GHz), is used as control channel. The control channel is used as a rendezvous frequency for all DSRC radios to listen for access and timing information used by a particular application or services that they may be interested in. DSRC allows grouping of two consecutive channels to increase bandwidth to 20 MHz for reduced transmission time and collision but it becomes susceptible to background noise and inter symbol interferences [5]. We only consider 10 MHz channels and use one of the service channels. DSRC uses OFDM with combinations of coding rates and modulation schemes that support PHY layer throughput from 3 Mbps to 27 Mbps. The 802.11p MAC layer used in DSRC includes the 802.11e, Enhanced Distributed Channel Access (EDCA) protocol which provides different Access Class (AC) with different Collision Window and Arbitration Inter-Frame Space (AIFS) for supporting different Quality of Service [17].

A. Throughput Performance of DSRC

In order to support multitude of vehicular applications- from safety to information services, the maximum throughput available from a DSRC capable devices is important. Therefore, we consider the effective throughput achieved by 802.11p after the overhead and timing requirements for channel access and contention are included. The following discussion and field tests assumes the use of UDP/IP/IEEE 802.3 over 802.11p and not WAVE over 802.11p. Table I below shows different 802.11p Physical and Link layer parameters including the overhead bits, timing information and arbitration delays. Table II shows nominal and effective throughput (broadcast) attainable by different modulation and coding schemes in 802.11p for an Application Protocol Data Unit (APDU) of 1472 Bytes.

### TABLE I

<table>
<thead>
<tr>
<th>DSRC 802.11p PHYSICAL AND LINK LAYER PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11 Header + FCS (Bytes)</td>
</tr>
<tr>
<td>OFDM Service Bits (bits)</td>
</tr>
<tr>
<td>Tail Bits (bits)</td>
</tr>
<tr>
<td>SIFS</td>
</tr>
<tr>
<td>Timeslot</td>
</tr>
<tr>
<td>PLCP Header</td>
</tr>
<tr>
<td>Signal Field</td>
</tr>
<tr>
<td>OFDM Symbol Guard time</td>
</tr>
<tr>
<td>OFDM Symbol time</td>
</tr>
<tr>
<td>OFDM data subcarrier</td>
</tr>
<tr>
<td>OFDM pilot subcarrier</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Access Class</th>
<th>Voice</th>
<th>Video</th>
<th>Best Effort</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIFS</td>
<td>58 µs</td>
<td>71 µs</td>
<td>110 µs</td>
<td>149 µs</td>
</tr>
<tr>
<td>CW_{min}</td>
<td>3</td>
<td>7</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

The effective throughput \( (\text{thr}_{ef}) \) achievable through 802.11p protocol considering the delays and overhead associated with packet transmission, assuming direct line of sight between transmitting and receiving nodes, and within the communication range of DSRC, with minimum packet loss and arbitrarily large transmit queue sizes can be calculated as shown:

\[
\text{thr}_{ef} = \frac{APDU}{(APDU + OVHD) x 8 + ST - 1} + 1 + \frac{P + S + A + CWM}{8}
\]

where,

- \( APDU \) is the size of Application Protocol Data Unit in Bytes.
- \( OVHD \) is the size of OFDM header in Bytes.
- \( ST \) is the size of the symbol time in microseconds.
- \( P \) is the size of payload in Bytes.
- \( S \) is the size of signal field in Bytes.
- \( A \) is the size of arbitration field in Bytes.
- \( CWM \) is the Collision Window in microseconds.
C. CACC Control Strategy and Networking

CACC is a control strategic application where a string of vehicles follows the vehicle immediately ahead by maintaining a fixed distance. There are number of controller strategies available for CACC. All attempt to optimize the inter-vehicle gap by regulating the speed or acceleration. We employ the decentralized methodology presented in [12] for our study. The objective of this control strategy is to minimize the deviation in the distance between two vehicles from a pre-defined reference distance. For proper operation, CACC requires a variety of sensors (Lidar, Radar) and actuators to work in tandem. CACC application requires distance data and GPS/CAN data such as location and speed/acceleration of the vehicle immediately in front. DSRC can be used for inter-vehicle wireless communications to acquire data for calculations. In worst case network conditions, the performance of CACC should be no worse than that of ACC.

The following set of equations describe the control strategy and is taken from [12]. An implementation of this controller would choose an appropriate value of $h$ as well as the timescale that determines when a control decision is to be performed. We used a value of $h$ of 0.1s based on the frequency of arrivals of BSM messages [12]. We assumed the controller makes a new decision every controller interval amount of time. We experimented with different settings, but by default used $h=0.1$ second.

\[
e_i(t) = d_i(t) - d_{r,i}(t)
\]
\[
\dot{a}_i = -\frac{1}{h}a_i + \frac{1}{h} (k_p e_i + k_d \dot{e}_i) + \frac{1}{h} a_{i-1}
\]

where $d_{r,i}(t)$ the reference distance between two vehicles, $d_i(t)$ required distance between preceding vehicle and vehicle $i$, $e_i(t)$ the error in current distance between two cars and $\dot{e}_i(t)$ the change in acceleration required to reduce the magnitude of $e_i(t)$ at desired rate

III. METHODOLOGY

The study presented in this paper is categorized into different tests that were done to understand the performance of 802.11p networks in broadcast modes at various scenarios such as:

1) Test I: lab scenario with good line of sight and perfect channel condition,
2) Test II: Vehicle to Infrastructure tests using Clemson University tested in [18] and
3) Test III: Vehicle to Vehicle tests imitating a model CACC application.

The motivation for these tests was to study the real world performance of 802.11p protocol and to characterize the performance in terms of different metrics using test data. The metrics we report include: • Channel Busy Ratio, • Latency, • Throughput • Packet Loss, • Mean Burst Length and
- **Reliability.** Channel Busy Ratio (CBR) is the fraction of time a receiving station finds the wireless channel busy. CBR provides an insight into channel usage variation of different modulation schemes.

We define Reliability \((R)\) similar to T-window reliability metric defined in [9]. We assumed a window \(T\) time of 10 ms.

\[
R = 1 - \frac{\text{failed}_N}{\text{Total}_T}
\]

where,

- \(\text{failed}_N\) sum of all events if \(N\) packets not-received in time \(T\)
- \(\text{Total}_T\) Total number of time slots of size \(T\)

**Packet Arrival rate, latency and packet loss** are particularly interesting in the case of vehicular networks because of the highly dynamic nature of the channel. Drastic changes in channel conditions can be triggered by sharp curves in the roadway, traffic congestion (especially when large trucks are involved), and even speed bumps. Also, due to the rapid changes in network conditions, the packet loss process is not intuitive. Losses are not always independent and uncorrelated as commonly assumed in the literature [12, 19].

The platform used in the study is Cohda Model MK5. A block diagram of the device is shown in Figure 2(a). It consists of an embedded Linux environment with two sets of DSRC radios connected to the Linux system via a high speed USB bus. Only one of the radios is employed in our test. Cohda provides a Software Development Kit (SDK) that can be installed on a host computer and used to develop applications for the DSRC systems. The applications are transferred to the DSRC systems using the Gigabit Ethernet interface as shown in Figure 2(b).

For our tests, the radios were configured to use a single fixed channel for all transmissions. Transmit power was set to 20 dBm (0.1 watt) for all tests.

**Test I (Lab Test):** Understanding the performance of DSRC radios without incorporating channel noise was the motivation for the lab tests in Test I. As shown in Figure 2(b) Two DSRC radios in line of sight and close range were used with a Constant Bit Rate (CBR) application to capture the performance metrics. During preliminary testing it was discovered that sending UDP data at rates approaching the maximum effective throughput could cause queue overflow and packet loss within the sending DSRC unit. One motivation for the lab tests was to identify safe sending rates below which these internal drops would not pollute packet loss data captured in field Tests II and III.

**Test II (V2I Test):** Test II consisted of vehicle-to-infrastructure (V2I) testings done using a DSRC On-Board Unit (OBU) installed on a vehicle and driving in and out of a DSRC coverage zone of an existing Road Side Unit (RSU) installation [18]. Our tests employed two of the eight supported signalling rates: 3/4 QPSK which provides a PHY layer bit rate of 9 Mbps; and 3/4 QAM 64 which provides a rate of 27 Mbps. One of the motivation for the set of measurements in Test II was to understand the packet loss process in good and bad network conditions. As illustrated in Figure 3(a) the mobile OBU would pass through a no line of sight zone as it entered the wireless coverage of RSU followed by good line of sight zone and leave the coverage zone as it drove away. The tests were done on a clear day with moderate vehicular traffic conditions.

**Test III (V2V Test):** Test III was also conducted with 3/4 QPSK and 3/4 QAM 64 signalling. OBUs were installed in two vehicles, and they were driven with one vehicle in the middle with no OBU as shown in Figure 3(b) . The test roadway is located on the campus of Clemson University. It provides varying signal conditions from good signal with line of sight (LOS) to no line of sight (NLOS). These tests provided observations into the loss process in vehicle-to-vehicle (V2V) communication. The results were than used in a CACC emulation model to explore the impact of network impairments on a hypothetical vehicle operating with the platoon.

**IV. RESULTS AND ANALYSIS**

In this section we provide results and analysis based on the observation from the tests performed during this study.

**Test I:** Figure 4(a) below shows the broadcast throughput observed during lab-tests with four different modulations. Transmit rates used were equal to the nominal throughput

<table>
<thead>
<tr>
<th>MCS</th>
<th>1/2 BPSK</th>
<th>3/4 BPSK</th>
<th>1/2 QPSK</th>
<th>3/4 QPSK</th>
<th>1/2 QAM16</th>
<th>3/4 QAM16</th>
<th>2/3 QAM64</th>
<th>3/4 QAM64</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFDM bits/symbol</td>
<td>24</td>
<td>36</td>
<td>48</td>
<td>72</td>
<td>96</td>
<td>144</td>
<td>192</td>
<td>216</td>
</tr>
<tr>
<td>Nom Thr (Mbps)</td>
<td>3</td>
<td>4.5</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>18</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>Eff Thr (Mbps): Voice</td>
<td>2.82</td>
<td>4.17</td>
<td>5.48</td>
<td>8.01</td>
<td>10.39</td>
<td>14.77</td>
<td>18.71</td>
<td>20.53</td>
</tr>
<tr>
<td>Eff Thr (Mbps): Video</td>
<td>2.80</td>
<td>4.12</td>
<td>5.38</td>
<td>7.81</td>
<td>10.04</td>
<td>14.08</td>
<td>17.62</td>
<td>19.23</td>
</tr>
<tr>
<td>Eff Thr (Mbps): Best Effort</td>
<td>2.74</td>
<td>3.99</td>
<td>5.17</td>
<td>7.36</td>
<td>9.32</td>
<td>12.70</td>
<td>15.50</td>
<td>16.74</td>
</tr>
<tr>
<td>Eff Thr (Mbps): Background</td>
<td>2.71</td>
<td>3.94</td>
<td>5.08</td>
<td>7.19</td>
<td>9.04</td>
<td>12.18</td>
<td>14.75</td>
<td>15.86</td>
</tr>
</tbody>
</table>

**TABLE II**

| Test II (V2I Test):** Test II consisted of vehicle-to-infrastructure (V2I) testings done using a DSRC On-Board Unit (OBU) installed on a vehicle and driving in and out of a DSRC coverage zone of an existing Road Side Unit (RSU) installation [18]. Our tests employed two of the eight supported signalling rates: 3/4 QPSK which provides a PHY layer bit rate of 9 Mbps; and 3/4 QAM 64 which provides a rate of 27 Mbps. One of the motivation for the set of measurements in Test II was to understand the packet loss process in good and bad network conditions. As illustrated in Figure 3(a) the mobile OBU would pass through a no line of sight zone as it entered the wireless coverage of RSU followed by good line of sight zone and leave the coverage zone as it drove away. The tests were done on a clear day with moderate vehicular traffic conditions.

**Test III (V2V Test):** Test III was also conducted with 3/4 QPSK and 3/4 QAM 64 signalling. OBUs were installed in two vehicles, and they were driven with one vehicle in the middle with no OBU as shown in Figure 3(b) . The test roadway is located on the campus of Clemson University. It provides varying signal conditions from good signal with line of sight (LOS) to no line of sight (NLOS). These tests provided observations into the loss process in vehicle-to-vehicle (V2V) communication. The results were than used in a CACC emulation model to explore the impact of network impairments on a hypothetical vehicle operating with the platoon.

| Test I (Lab Test):** Understanding the performance of DSRC radios without incorporating channel noise was the motivation for the lab tests in Test I. As shown in Figure 2(b) Two DSRC radios in line of sight and close range were used with a Constant Bit Rate (CBR) application to capture the performance metrics. During preliminary testing it was discovered that sending UDP data at rates approaching the maximum effective throughput could cause queue overflow and packet loss within the sending DSRC unit. One motivation for the lab tests was to identify safe sending rates below which these internal drops would not pollute packet loss data captured in field Tests II and III.

---

**Fig. 2. Testing Platform and setup for Test I**

(a) Test Platform DSRC Radio  (b) Test I setup
calculated in Section II. The difference in nominal and observed throughput is caused by queue overflows within the transmitting system. From Figure 4(a) it can be concluded that to avoid queue losses at the transmitter, its necessary to avoid transmitting at rates higher than the rates given in Figure 4(a). Another important metric of study in lab settings was the Channel Busy Ratio (CBR), shown in Figure 4(b), expressed as average percentage of time the channel was found to be busy during a testing cycle. Figure 4(b) illustrates that higher modulation and coding can reduce congestion and collision probabilities due to reduced channel utilization.

Test II: Test II (V2I) was conducted on a four-lane roadway segment on the campus of Clemson University [18]. RSU’s were installed on lighting poles along the right-of-way as illustrated in figure 3(a). Multiple runs of similar driving patterns were conducted. The vehicle started at a distance of about 900 ft in a Non Line-Of-Sight (NLOS) condition and moved towards the RSU through Line-of-sight (LOS) condition and drove past the RSU. Test II was carried out by transmitting at rates to avoid transmit queue losses but much greater than 10 packets/second (Basic Safety Message transmit rate) in order to obtain large number of data points. A constant bit rate application was used and various physical, link and application layer parameters were recorded. Table III below describes the settings used in transmitter and receiver DSRC units for Test II.

We defined the reliability time slot (T) as 0.01 seconds and the minimum number of packets to be received (N) to be 5 packets. Another metric of interest is the Mean Burst Length (MBL) which is defined as the average length of burst loss.

Latency and its variation with packets per second transmitted is presented in Figure 5. Latency is calculated as an average observed latency of received packets at the application layer. With higher bit rates, latency decreases even with increased transmitted packet per second because of the reduction in packet transmission/reception time. In summary, the throughput and latency results are consistent with similar results published in the literature.
A correlated burst noise process will show larger MBL than independent uncorrelated noise process. This metric is a good measure of how much burst noise effects the communication channel and also if the loss process exhibits correlation.

**TABLE III**

<table>
<thead>
<tr>
<th>MCS</th>
<th>Rate 3/4 QPSK</th>
<th>Rate 3/4 QAM 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmit Rate</td>
<td>1.5 Mbps</td>
<td>2.5 Mbps</td>
</tr>
<tr>
<td>Message Size</td>
<td>184 Bytes</td>
<td>184 Bytes</td>
</tr>
<tr>
<td>Speed</td>
<td>30-35 mph</td>
<td>30-35 mph</td>
</tr>
</tbody>
</table>

Figures 6 below show the resulting plots of Mean burst lengths, Reliability metric and packet loss rate for multiple test runs of Rate 3/4 QAM64 modulation and coding. Similar observations were found for Rate 3/4 QPSK as well. Received packets and loss events were grouped based on distance from the receiver as the vehicle moved towards and away from the RSU. Subsequently each bin of data was used for calculating the metrics. The NLOS and LOS indications on the plots show the region obstructed and unobstructed by foliage and roadway curve respectively. We can observe the effect of NLOS and the loss behavior through the reliability metrics degradation and increased MBL as well as increase in packet loss. The average MBL over all the data set was found to be 4.925 and average packet loss rate over the entire test was 0.2925. The average MBL value shows that Bernoulli random process is not accurate for implementing packet loss in vehicular networks. The degradation in channel performance for the DSRC network in our study was due to distance and lack of line of sight, but factors such as as weather and high vehicular traffic congestion can also decrease the performance. The study of congestion involving larger numbers of vehicles is very difficult to evaluate in real testbeds. The vast majority of Vehicular studies are therefore based on simulation. While our results are based on a single data set, it represents an interesting loss process sample path that includes correlation. We have posted the raw data (and will post future results at the same location) as we expect the community can use the data to aid in parameter selection for simulation studies.

**Test III:** Test III was carried out using three vehicles $V_A, V_B, V_C$ in platoon in order to create less than ideal channel conditions. Only vehicles $V_A$ and $V_C$ were equipped with DSRC Radios. The presence of unconnected vehicle ($V_B$) in the middle provided a mechanism to test with different distance between $V_A$ and $V_B$. Vehicle $V_C$ obtained distance from vehicle $V_A$ through GPS position sent from $V_A$ but it could be improved with a Lidar or Radar. The test roadway selected contained a curved section with a large number of tress resulting in a NLOS zone and an clear road section with good LOS. The objective of these tests were to study the loss process associated with two moving DSRC radios and also to understand the effect of the loss process on a modular CACC application.

We created a modular CACC application based on [12] that can be used offline and in situations where autonomous or semi autonomous vehicles are not available. The emulation settings used were $K_s=0.2, K_d=0.7$ and $h=0.1$ as described in [20]. By recording the speed and distance between two vehicles using GPS coordinates and feeding that information in the CACC emulation we can model the output from the controller with and without the presence of noise. The input to CACC emulation included the observed loss process effects. Figure 7 above shows the results obtained from Test III. Part (a) shows the speed profile of $V_A$ and calculated speed profile when the velocity and acceleration from $V_A$ was used as input to CACC controller mentioned in Section C. The resulting speed profile shows a rapid fluctuation in speed which occurs relatively close to the high burst loss event indicated by large MBL and smaller Reliability. From these tests, the effect of network conditions on different metrics can be observed. Our next steps include conducting a robust measurement study of V2V scenarios allowing us to develop appropriate loss process models offering a parameter to set the level of correlation. Such models can then be used to build more robust and reliable CACC controllers that are able to tolerate worst case network environments.

**V. CONCLUSION**

We have considered the impact of dynamic wireless channel conditions in mobile Vehicular networks in safety and mobility application like CACC. The objectives of the research was to
define a set of readily measurable metrics that can be mapped to a utility measure for a safety oriented vehicular application such as CACC. Initial tests illustrated the throughput and latency performance of 802.11p radios. We collected metric results from a testbed on campus and showed evidence of correlated loss. This confirms that recent studies of CACC that make assumptions of a Bernoulli loss process are not realistic. In future work, we plan to develop robust loss models that parameterize the wide range of loss process dynamics that we expect to see.

REFERENCES


