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Evaluating the reliability of automated collision notification systems

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Abstract

The use of an automated collision notification (ACN) device in vehicles can greatly reduce the time between crash occurrence and notification of emergency medical services (EMSs). Most ACN devices rely on cellular technology to report important crash information to the proper authorities. The objective of this study was to examine the ability of the existing western New York cellular analog system to support ACN systems. The first task was to develop a model predicting the probability of successfully completing an emergency ACN call at attenuated levels of received signal strength indicator (RSSI), a measurement of the bond between cell phone and tower. Then, empirical estimates were made of the time necessary for call completion at given levels of the RSSI. The RSSI is sampled at locations throughout Erie County, New York, and this information is used to determine the probability of successful call completion for different locations within the county. This model was then applied to historic data for selected past crashes. Finally, the findings were compared with real-world crash data obtained from the ACN Field Operational Test program, where 750 ACN devices were installed in cars and their performance examined over time. An interpolated map of the sampled RSSI values suggests that cellular coverage in Erie County is adequate to support the automated collision network technology. The models and techniques described here are applicable to other areas and regions of the country.

Keywords: Automated collision notification; Received signal strength indicator; Geographical information systems; Global positioning systems; Emergency medical service

1. Introduction

The societal consequences of motor vehicle crashes in the United States include major public health concerns and a substantial economic burden (Bonnie et al., 1999; Walker, 1996). According to the National Highway Traffic Safety Administration (NHTSA, 2000), there were over 6.3 million motor vehicle crashes in 1999. These crashes led to over 40,000 deaths. Efforts to identify causes and to prevent motor vehicle crashes may be divided into four categories (Levine et al., 1995):

(a) *Environment analysis*: To identify effects of conditions such as urban versus rural, large versus small cities, state versus nation, etc.
(b) *Traffic analysis*: To identify effects of traffic volume, traffic speed, road types, intersections, etc.
(c) *Special factor analysis*: Particular corridors or neighborhoods that are socially and ecologically integrated are studied to identify causal factors.
(d) *Spatial analysis*: Divides large areas into smaller zones, and identifies the subsequent patterns.

Although work in these areas contributes significantly to the prevention of vehicle crashes, the number of vehicle crashes continues to climb due to increases in traffic volume and extended travel times. Correspondingly, the fatality rate remains at unacceptably high levels. This is particularly true in rural areas where fatality rates are disproportionately high compared to urban areas.

To reduce crash-related fatalities and minimize crash notification times, NHTSA sponsored Veridian Engineering in the automated collision notification (ACN) Field Operational Test Program from 1995 to 2000. ACN explored the ability of in-vehicle equipment to reliably sense and characterize crashes, and automatically transmit crash location and crash severity data to the proper public safety agencies. In general, the ACN system consists of a location and communication

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system linking an in-vehicle emergency notification device to emergency response service providers. The ACN system detects vehicle decelerations exceeding pre-determined crash thresholds, and is designed to only report crash events that have a likelihood of causing injury: “fender benders” and non-injury crashes are considered non-crashes or incidents. The ACN crash algorithm determines crash severity using both force of impact and direction of impact data. Every direction of impact has an accelerational threshold level the in-vehicle module (IVM) uses to recognize a crash. When a crash exceeds the threshold, an emergency message is assembled and transmitted to emergency personnel via cellular telephone. The message contains the latitude and longitude of the crash as well as an indication of the direction and severity of the impact. Once the data is received by emergency personnel, appropriate services such as fire, police and paramedics are dispatched to the scene.

Robust cellular communications are key to the ACN effectiveness, and concerns arise regarding signal strength issues. Received signal strength indicator (RSSI) is a measure of the bond between a cellular phone and the cell site. The strength of this bond can be used to estimate the likelihood of completing a phone call within a given “cell”. Many factors, such as cell site distance, foliage cover, topographical features, and loading of the cellular system contribute to RSSI. In urban or suburban areas, RSSI is commonly strong due to a large customer base. In rural, hilly or forested areas, the RSSI may be notably weaker. In some locations, RSSI may be too weak for establishing a cellular connection, or may cause a delay in establishing a call. In these weak signal strength areas, ACN performance can be severely affected. Emergency calls may be delayed or not go through at all.

1.1. Study objectives

This study addresses several topics regarding use of cellular communication in ACN and ACN-style devices. First, cellular signal attenuation (due to, e.g. foliage effects or loss of mobile antenna) is simulated, and its effect on RSSI examined. Second, RSSI is empirically measured on major and minor roads in Erie County, New York, providing a database for estimation of RSSI at unsampled points. Third, a simulation, estimating call completion rate and elapsed call time, is developed using information gathered during the first two phases of the study. Fourth, this information is applied towards inputting real crash data into the simulation and determining ACN effectiveness using known ACN crash locations.

1.2. Review of literature

There is a substantial body of literature regarding the impact of emergency medical service (EMS) response time and time to definitive care on trauma victim outcomes. Terms like ‘golden hour’ (Jacobs et al., 1984; Lerner and Moscati, 2001), ‘silver day’ (Blow et al., 1999) and ‘platinum 10 min’ have been coined to describe the importance of time in treating trauma injuries. While additional research is required to identify the numbers of trauma victims whose outcomes would be improved by the more rapid delivery of EMSs, it is apparent that approximately 50% of fatalities occur within minutes of the injuries, 30% occur within hours, and 20% occur within days to weeks. This is consistent with data showing that more than 50% of crash related fatalities occur before the victims arrive at a hospital.

Table 1
EMS response events and time intervals

Event	Time
Crash occurs	t_0
Notification received at emergency response	t_1
EMS dispatch notified	t_2
EMS services dispatched	t_3
EMS arrive at the scene	t_4
EMS gain access to patient(s)	t_5
EMS depart the scene	t_6
EMS arrive at the hospital	t_7
Intervals	
Notification time	t_1-t_0
EMS response time	t_4-t_1
EMS treatment time	t_6-t_5
Patient transport time	t_7-t_6

If we accept that reducing time to care is important for crash injury victims (Petri et al., 1995, Sampalis et al., 1993, Pepe et al., 1987), then it is useful to identify the timeline of events from the crash to definitive care. Many models for defining EMS response timelines have been used and reported. Table 1 illustrates the key EMS response events and time intervals. It is worth noting that to establish accurate event timelines, it is important to have an accurate time of the crash (t_0). In fact, crash times are the least dependable reported times, particularly for unwitnessed crashes where occupants sustain severe injuries. Of greatest interest is the elapsed time between the crash and emergency response notification ($t_1 - t_0$). Available data for 1998 rural fatal crashes indicate that statewide averaged times between a crash and EMS notification range from a low of 1.22 min in Connecticut to more than 18 min in South Carolina (NHTSA, 1992).

1.3. Background Information

Erie County is located in western New York State, bounded by Lake Erie to the west. Most of Erie County is flat, except for rolling hills in the southeastern corner. The population density is 359 people per square kilometer. According to the New York State Department of Transportation (2000), there are 7273 km of highways across the county, including 1086 km for the city of Buffalo and 690 km for the Town of Amherst.

In 1998 there were 654,333 registered drivers in the county. In the same year, 13,450 car crashes were observed, with 42.1% of those reported as crashes with damage.

Injury crashes comprise 4.2% of the total crashes, and 5.4% of these injury crashes resulted in fatalities.

2. Call completion/signal attenuation tests

2.1. Equipment and methods

To study the effect of signal attenuation on call completion, two modified ACN systems were built. The main component of the ACN system is the IVM, a small "black box" containing a global positioning system (GPS) board, modem, accelerometers, digital signal processing circuitry, non-volatile memory, and handset control circuitry. The accelerometers and digital signal processing components, needed for crash event detection and data analysis, were not used in this test. To transmit the IVM emergency message, a 3 watt radiotelephone cellular transceiver, made by JRC and identical to the ACN field units, was mated with a JRC hands-free, alphanumeric/icon display handset. For these tests, the transceiver used the "A"-side band of cellular frequencies. Both cellular and GPS antennas were mounted on the roof of the Veridian Engineering building. To simulate signal attenuation by environmental factors, barrel-type attenuators in 5 dB multiples were placed inline with the cellular antenna prior to emergency call initiation. To receive the call from the ACN system, a modem was connected to a dedicated landline connection with a laptop computer operating a serial port modem. There were 865 test calls conducted during periods of both peak and non-peak times of cellular system demand, during January and February 2000. (Peak times are usually during normal business hours and for a little while in the evening).

Data is transmitted by the IVM through the transceiver in three data packets. The first packet contains the most important information: crash location and cell phone number. The second and third data packets contain less important data history. The IVM is given five opportunities to send all three packets, with a 1 min waiting period between failed attempts. For test purposes, each re-attempt was considered a separate emergency call. If the call failed on the fifth attempt, the IVM switched the call from data to voice. RSSI is reported by the transceiver in 5 dB increments and displayed continuously on the handset. RSSI is noted at the beginning of each call attempt. An example of the test data is shown in Table 2.

Probabilities of completing a phone call were calculated based on the number of attempts performed at each level of attenuation during the call completion/signal attenuation tests. Also, the expected time for call completion was calculated. Both are shown in Fig. 1. The expected time for call completion was determined by

$$E(r) = \sum_{n=1}^{5} P(n, r)\, t_n \qquad (1)$$

where $E(r)$ is the expected time in min for call completion at a given RSSI value r; $P(n,r)$ the probability of a call going through on trial n, at RSSI r the time taken for call completion with n trials (in min).

2.2. Data analysis

During the test, some calls had to be discarded, due to insufficient information. For example, there were some cases where the ACN device reported only the GPS location, and not the signal strength, or vice versa. Such calls were omitted during the modeling of the call completion probability flow chart. In Fig. 2, the number of discarded calls for each value of RSSI is denoted by $D(k)$:j, where k is the number of the trial and j is the number of omitted calls in that trial. For example, for RSSI $= -99$ dB, there were 150 total trials; of these, 140 went through on the first trial. Out of the remaining ten, two had to be discarded because of insufficient information on the second trial. This is shown as $D(2)$:2. There were four calls that went through on the second trial and four were unsuccessful. One of the calls had to be discarded on the third trial ($D(3)$:1). All of the remaining three attempts were successful.

From Fig. 2, we observe that for RSSI values greater than −89 dB, calls connect in the first attempt. For RSSI values less than −119 dB, calls never go through. For intermediate values of RSSI, call completion has a certain probability, and it may take a few attempts to achieve call completion. For example, at RSSI values of −104 dB, 174 calls were attempted, with 168 successful completions. Two calls failed to connect, and four calls (corresponding to $D(2)$:3 and $D(3)$:1) that did connect had corrupted data. There were 16 trials that required more than one connection attempt.

It is clear from Fig. 1 that for RSSI values greater than −119 dB call completion has an associated nonzero probability. For any value greater than −99 dB, the probability of

Table 2
Pre-call attenuation tests

Date	Time	Attenuation	Displayed RSSI at time of call (dB)	Data packet 1 received	Data packet 2 received	Data packet 3 received
19 January	13:20	0	69	Y	Y	Y
19 January	14:12	0	69	Y	Y	Y
19 January	15:03	0	69	Y	Y	Y
1 February	15:28	30	99	Y	N	N
2 February	6:42	35	104	N	N	N

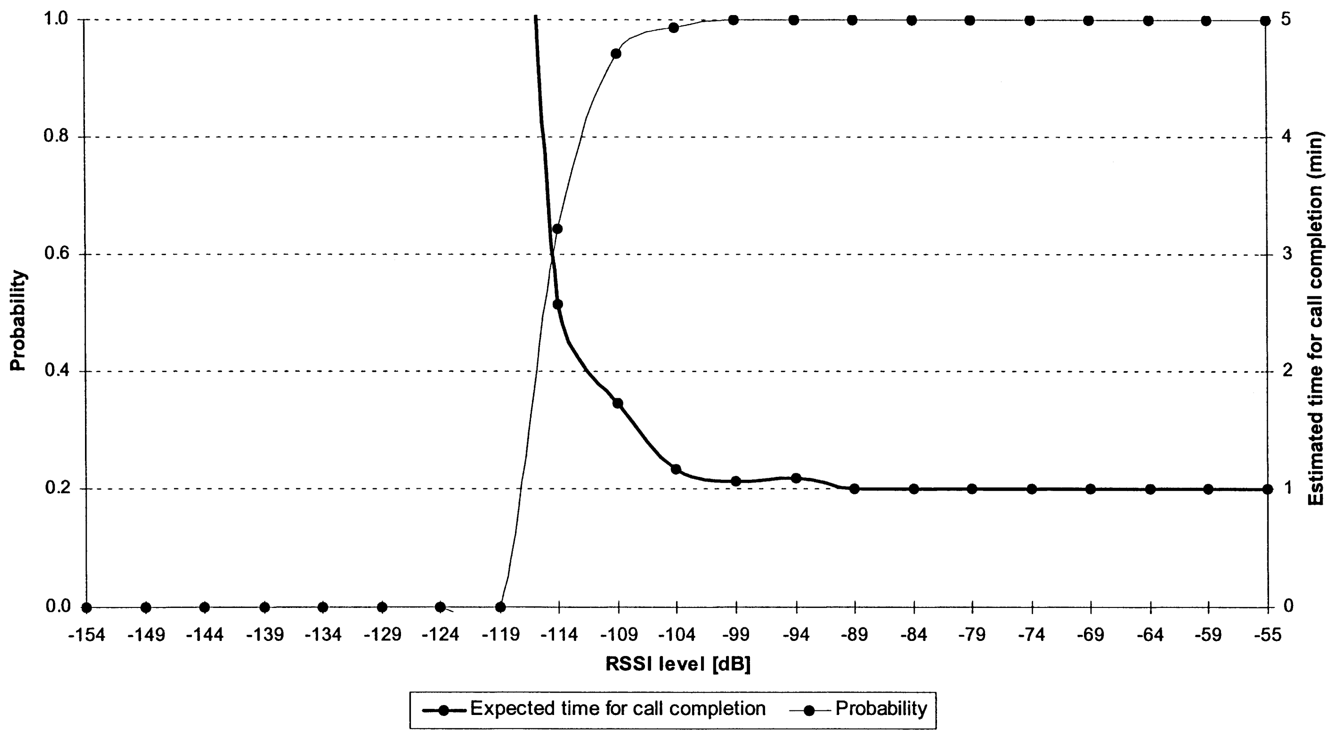

Fig. 1. Call completion probability.

call completion is close to 1. For intermediate values, the completion probability increases with increasing RSSI. The expected time for call completion decreases with increasing RSSI, asymptotically leveling at 1 min for RSSI greater than −89 dB. The slope of the time function decreases as RSSI approaches −104 dB, and then stabilizes at zero. We can conclude that regions showing RSSI values greater than −104 dB can be considered areas of strong cellular coverage. For regions with RSSI values of −104 dB and under, there is increased potential that the call will be delayed due to repeated attempts, and the call may not go through at all.

3. Erie County RSSI testing

3.1. Equipment and methods

RSSI data was collected for most major and minor roads in Erie County during the period of November 1999 through April 2000. RSSI data was collected for both “A” and “B” side bands of the 800 MHz cellular frequency. Care was taken to evenly record RSSI data in remote parts of the county, as well as in urban areas. The test apparatus used was identical to that used in the signal attenuation tests, with the exception that it was installed in a test vehicle, and utilized magnetic mount GPS and cell antennas.

The IVM records RSSI data by re-initializing the transceiver. Re-initialization discourages the transceiver from continuing to communicate with a weak or distant cell site when a stronger or closer cell site is available. The transceiver takes approximately 10 s to reinitialize, so it was important to give the transceiver enough time to re-initialize while traveling at highway speeds. To ensure closely spaced sample points and good RSSI readings, the IVM was programmed to re-initialize the transceiver every 0.8 km based on GPS readings.

3.2. Data analysis

ArcView Version 3.2 (ESRI, Redlands, CA), a geographic information system application, was used to analyze the Erie County RSSI data. Figs. 3 and 4 show the geographic distribution of the RSSI sample points in Erie County and the Town of Amherst, respectively. Table 3 shows a selected portion of the sample data set. Exactly 7150 data points were collected in Erie County and 926 points were sampled in the Town of Amherst.

Table 3
Erie County RSSI data sample

Date (mm/dd/yyyy)	Latitude (°)	Longitude (°)	RSSI (dB)	Speed (m/s)
4/24/2000	42.93	−78.72	−79	7.97
4/24/2000	42.93	−78.73	−69	17.26
4/24/2000	42.93	−78.74	−54	25.20
4/24/2000	42.93	−78.75	−59	32.06
4/24/2000	42.93	−78.76	−84	32.82

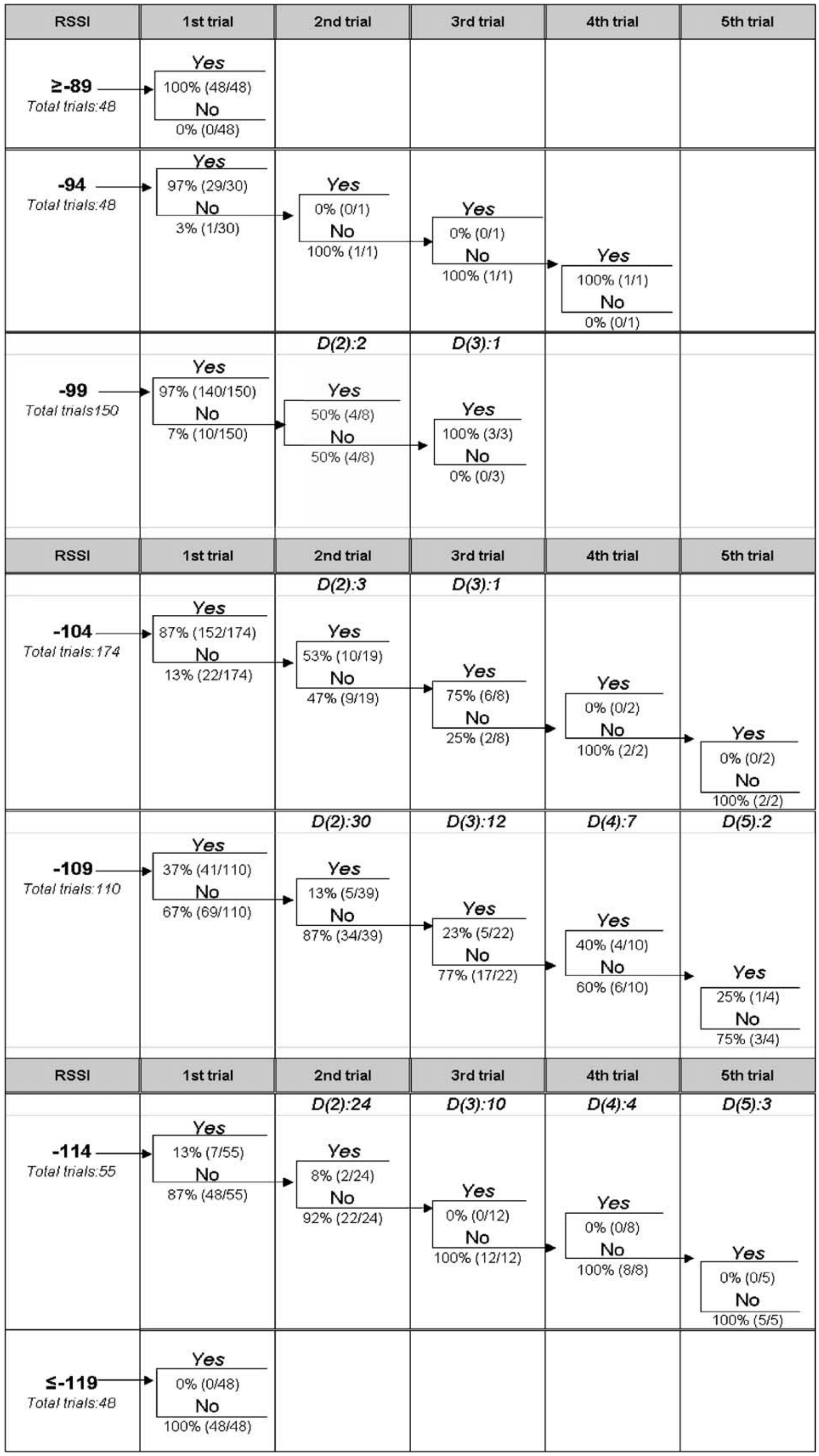

Fig. 2. Call completion probability flowchart.

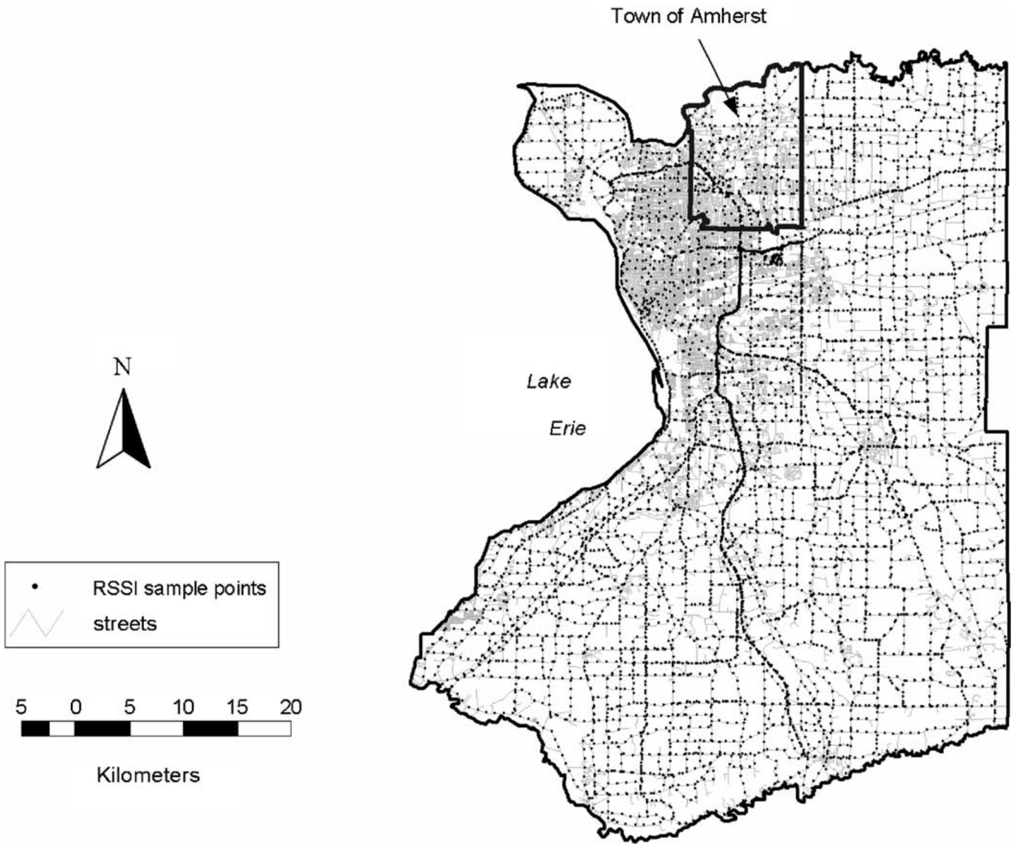

Fig. 3. RSSI sample points in Erie County.

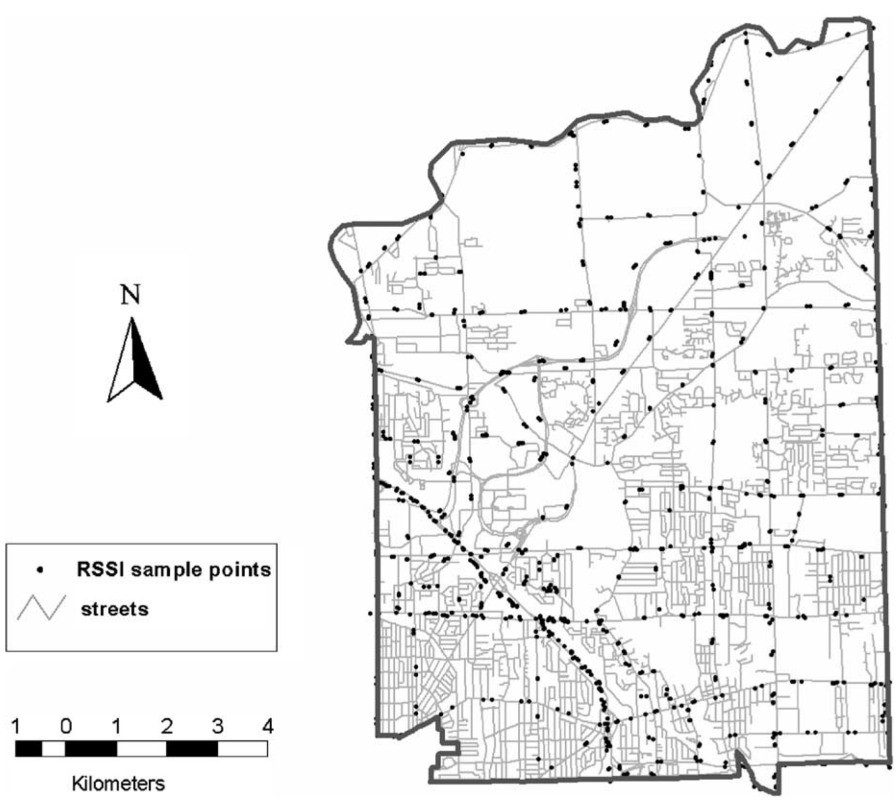

Fig. 4. RSSI sample points in the Town of Amherst.

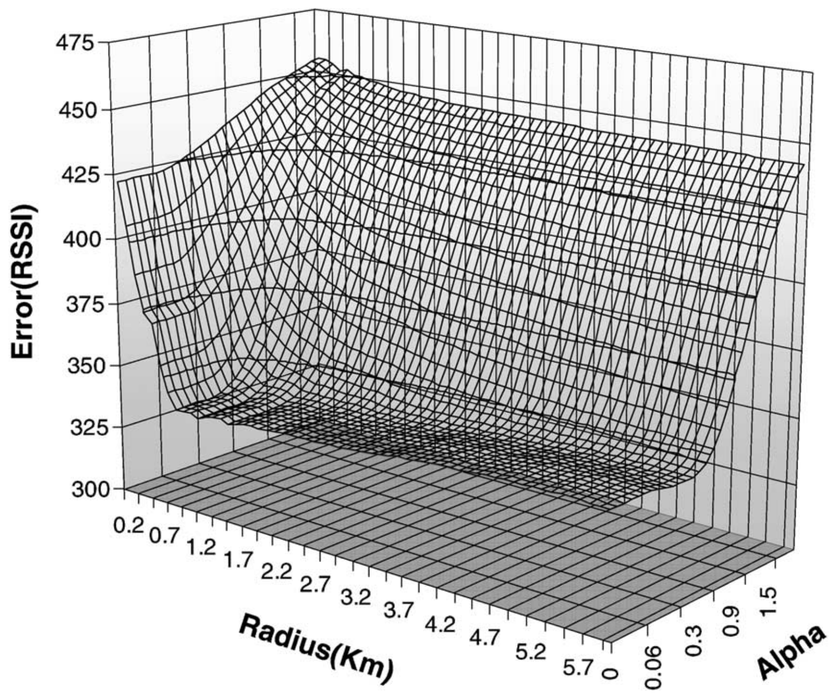

Fig. 5. Cross-validation model.

From Fig. 3, we observe that RSSI sample points are spread quite uniformly throughout the county, except where they cluster on the divided highways and major roads, where the test vehicle drove to and from testing areas. Fig. 4 shows the data points clipped to the Town of Amherst. The distribution pattern of sample points is similar to that of Erie County.

Inverse-distance weighted (IDW) interpolation was used to estimate the RSSI at locations between sample points. IDW interpolation assumes that each sample point has a local influence that diminishes with distance. Points closer to the processing cell are weighted greater than those farther away. All points within a specified radius (R) are used to determine the output value for each location. The power parameter (α) in the IDW interpolation controls the significance of the surrounding points upon the interpolated value. A higher power results in less influence from distant points (Burrough, 1986). The expression is

$$Z_i = \frac{\sum_{d_{ij}<R} X_j / d_{ij}^{\alpha}}{\sum_{d_{ij}<R} 1/d_{ij}^{\alpha}} \tag{2}$$

where X_j is the observed value of RSSI, d_{ij} the distance between the points i and j, Z_i the predicted value of RSSI, and R and α are parameters to be estimated.

A cross validation technique was used to determine the best values of R and α. Using the IDW method, the RSSI value is predicted at a known point. The difference between the observed and predicted values is squared and summed over all sample points. The square root of this sum gives the error E. A search was performed over a range of values for R (0–6 km) and α (0–2) to determine the best possible combination that minimizes the error.

$$E(R, \alpha) = \sqrt{\sum_i (Z_i - X_i)^2} \tag{3}$$

where E (R,α) is the value of error for a given value of R and α, Z_i the predicted value of RSSI as given in Eq. (2), and X_i is the observed value of RSSI at point i.

Fig. 5 shows a three-dimensional plot of RSSI error for different values of R and α for the Town of Amherst. From this plot we observe that the best values of R and α correspond to 1.2 km and 0, respectively. The value of R at which leveling starts is called the *range* and corresponds to the maximum distance for which one data value can be said to influence another. Because the RSSI readings were taken only every 0.8 km, and because the optimal radius is 1.2 km, the number of sample points within the range is usually quite limited (often less than four or five). Thus, it is difficult to estimate the true distance sensitivity. In our future work, we plan to collect data on a much finer spatial scale and hope to reveal any distance sensitivity that may exist on this finer scale.

Fig. 6 displays a surface interpolation of the RSSI data using the IDW method with calculated values for R and α. The lighter shade on the map represents RSSI values greater than −99 dB while the darker shade represents RSSI values at or below −99 dB. In those instances where no data point was within 1.2 km of a given point, we estimated the RSSI at that point by setting it equal to the average of all points within 1.7 km (*all* points had at least one sample point within

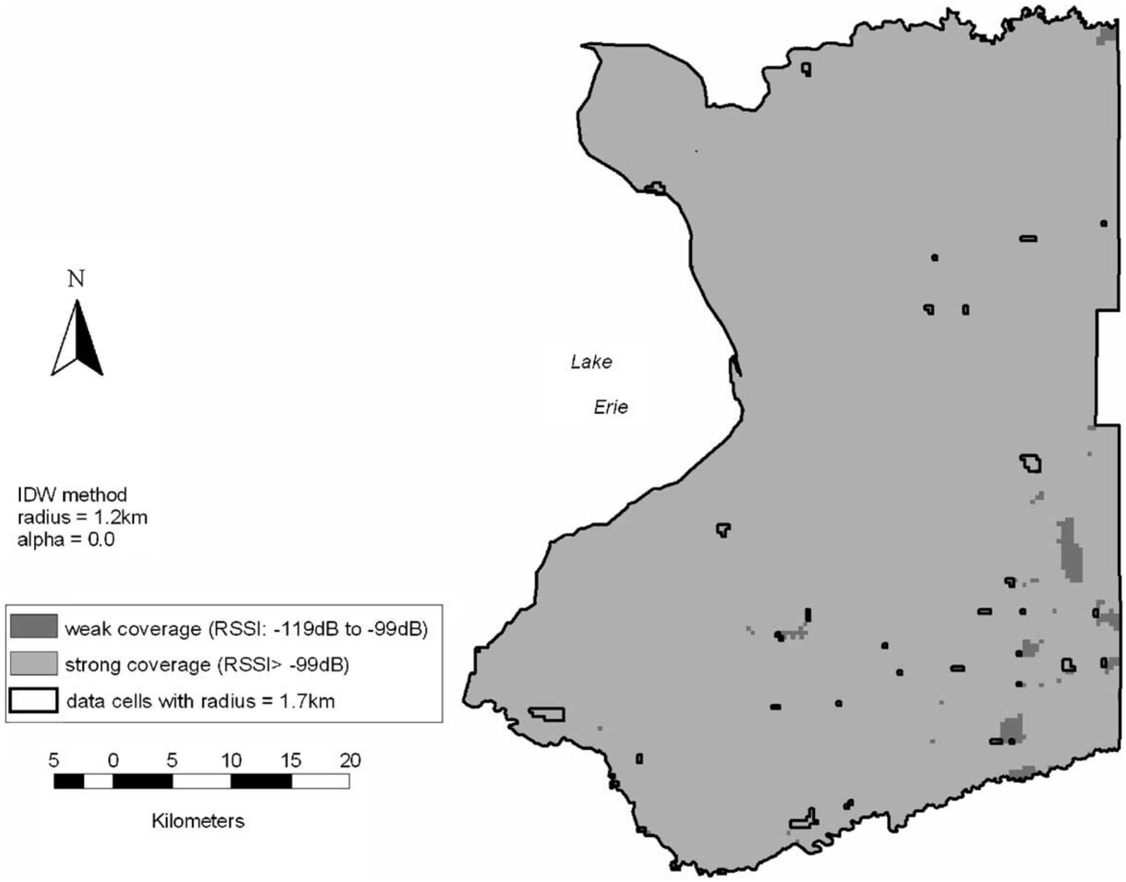

Fig. 6. Coverage strength estimated from interpolation of RSSI sample points, Erie County.

1.7 km). Taking the average in this way is consistent with our earlier observation that there is little distance sensitivity. As is evident from the map, most of Erie County has fairly strong coverage. The signal attenuation tests suggest that only one attempt would be required to complete an emergency call in most Erie County locations. However, there are a few isolated spots where coverage is weak. In these areas, the call might require a few attempts (and would consequently involve a time delay) or many not go through at all.

The effect of seasonal changes and the effect of terrain and buildings on the values of signal strength has not been considered in this study. Weather conditions and time of day do not seem to have a significant effect on signal strength (Meyer and Walton, 2000).

4. Crash data

This section examines estimated RSSI values at known crash locations. Two specific data sets are studied:

(a) All injury crashes for the Town of Amherst for the period January through March 1995 (Fig. 7).
(b) All injury crashes that required transport to a hospital in the rural sections of Erie County for 1995 (Fig. 8).

Both data sets contain the date, time of the crash, number of vehicle occupants, vehicle heading, and the closest geocoded address.

4.1. 1995 crash data—Town of Amherst

This case study determines the RSSI value for known crash locations within the Town of Amherst using the IDW interpolation method, described in Section 3.3. Based on the estimated RSSI value at the crash location, we can draw conclusions about the probability of completing an emergency call from that location, assuming the crash vehicle was equipped with an ACN system.

4.1.1. Analysis

A majority of crashes are concentrated in the southwestern part of the town with the remaining crashes distributed evenly throughout the town. A close look at Fig. 7 shows that most of the crashes occur at intersections of major roads. The mean estimated RSSI value for the crashes in the Town of Amherst was −66.26 dB, with a maximum of −59.85 dB and a minimum of −73.72 dB.

All calculated RSSI values for the crash locations were greater than −89 dB, the RSSI threshold where calls have a 100% probability of being completed. Accordingly,

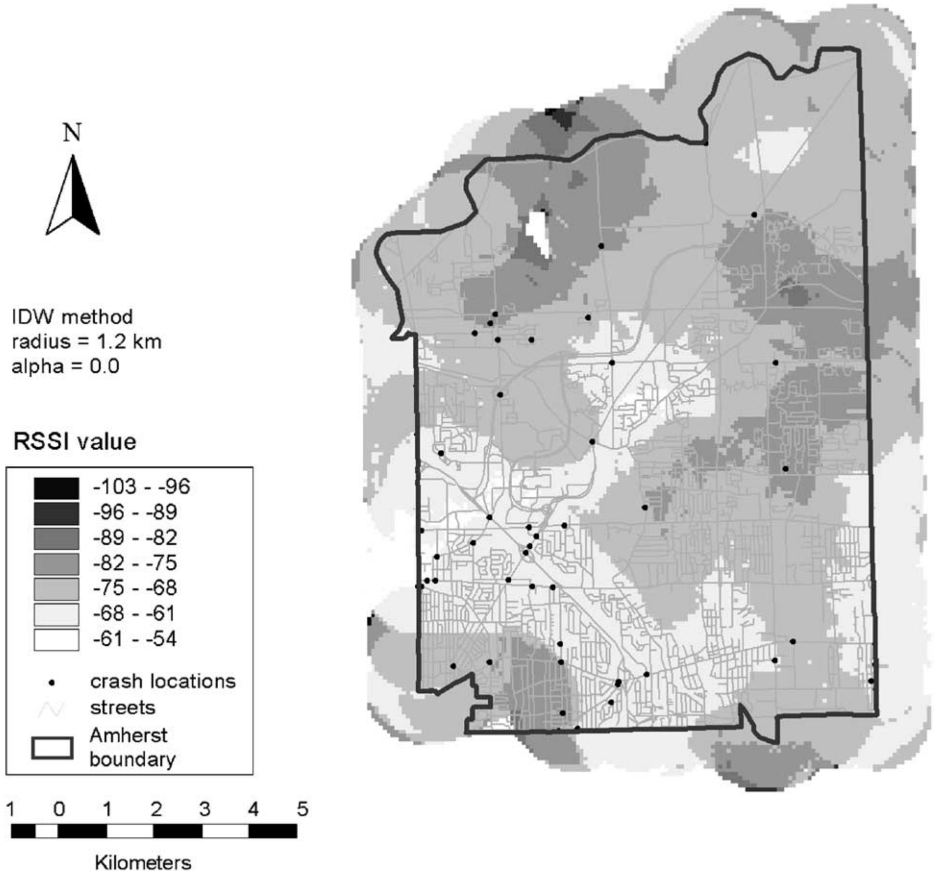

Fig. 7. Crash locations overlaid on interpolated surface of RSSI values, Town of Amherst.

the call completion probability flow chart shows that calls with RSSI above −89 dB should go through in the first attempt and complete their data transfer in less than 1 min.

4.2. 1995 crash data—Erie County

RSSI values were estimated for 210 rural Erie County crash locations, excluding the City of Buffalo and its suburbs. The map of Erie County with the crash locations is shown in Fig. 8.

4.2.1. Analysis

Only 13 of the 208 crashes occurred at locations with estimated RSSI value less than −89 dB. For theses 13 crashes, the mean estimated RSSI value was −94.27 dB with a maximum of −89.00 dB and a minimum of −110.66 dB. A comparison with the call completion graph (Fig. 1) illustrates that all of these calls should go through, though there may be a delay involved due to repeated attempts. The expected time for call completion ranges from 1 to 1.7 min for these crashes. There were 195 crashes that occurred at locations where the estimated RSSI value is over −89 dB. The mean RSSI value for these 195 crashes was −73.89 dB, with a maximum of −55.50 dB and a minimum of −88.28 dB. Fig. 8 shows the Erie County RSSI interpolation map with the crash locations overlaid. As seen in the Town of Amherst, most of the crashes occur at intersections of major roads. A few crash clusters are observed to the south and to the east of Buffalo, possibly due to weather and terrain effects as well as road conditions.

5. ACN-equipped vehicle crash data

The final study objective was to evaluate the crash performance of 750 ACN Field Operational Test devices deployed in Erie County between Fall 1997 and Spring 2000. Since the in-field ACN device does not record RSSI at the time of the crash, the IDW interpolation method was used to determine the RSSI value at the known ACN crash locations.

5.1. Data collection method

As part of the ACN field operational test, detailed investigation records were kept on any crashes involving an ACN device. Data collected during any given crash investigation included the ACN device identification number, crash date, if and what type of medical transport was provided to the victims, crash type and severity, and crash latitude and longitude. Other important information, such

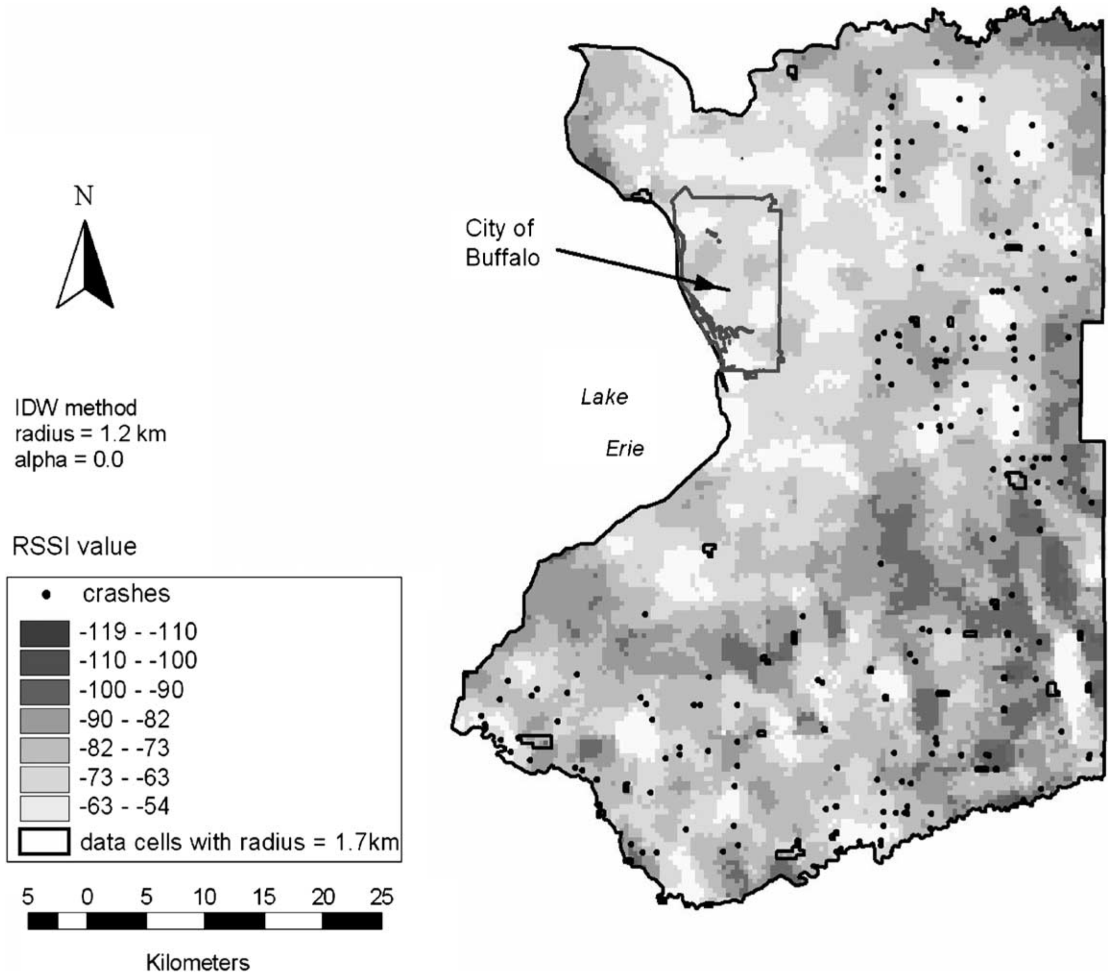

Fig. 8. Crash locations in rural Erie County.

as injuries sustained and crash kinematics, is also recorded. An example of the relevant data is shown in Table 4.

Much like the procedure described in Section 4 for analyzing crash data from Amherst and Erie County, the coordinates of known ACN crashes were used as input for the IDW interpolation model. The model then output the estimated RSSI for each crash location.

5.1.1. Analysis

Of the 70 ACN events that occurred during the test period, 48 were incidents where the severity was below the threshold, and 22 were crashes with severity above the threshold. Among the 22 crashes, 14 ACN systems operated flawlessly. Each system correctly detected the crash and its location, placed the emergency call, downloaded all crash information, and patched voice communication through to the dispatcher from the victim's car. Injury crashes comprised 15 of the 22 crashes. None were fatal.

Of the eight crashes where the ACN system was unsuccessful:

(a) one occurred well outside the test/coverage area;
(b) two had problems because of technical glitches at the Erie County Sheriff's Dispatch Center;
(c) one recorded the crash, but failed to call because of vehicle power failure;

Table 4
ACN-equipped vehicle crash data

ACN I.D. #	Crash date	Medical transport	Crash type & severity	ACN latitude (°)	ACN longitude (°)
440-1104	02/18/1998	Both drivers transported via ambulance	Car/car; intersection; moderate impact	42.54	78.52
440-1239	04/04/1998	None	Single car; roadside departure; moderate impact	42.79	78.55
440-1046	04/15/1998	None	Single car; roadside departure; moderate impact	41.47	78.37

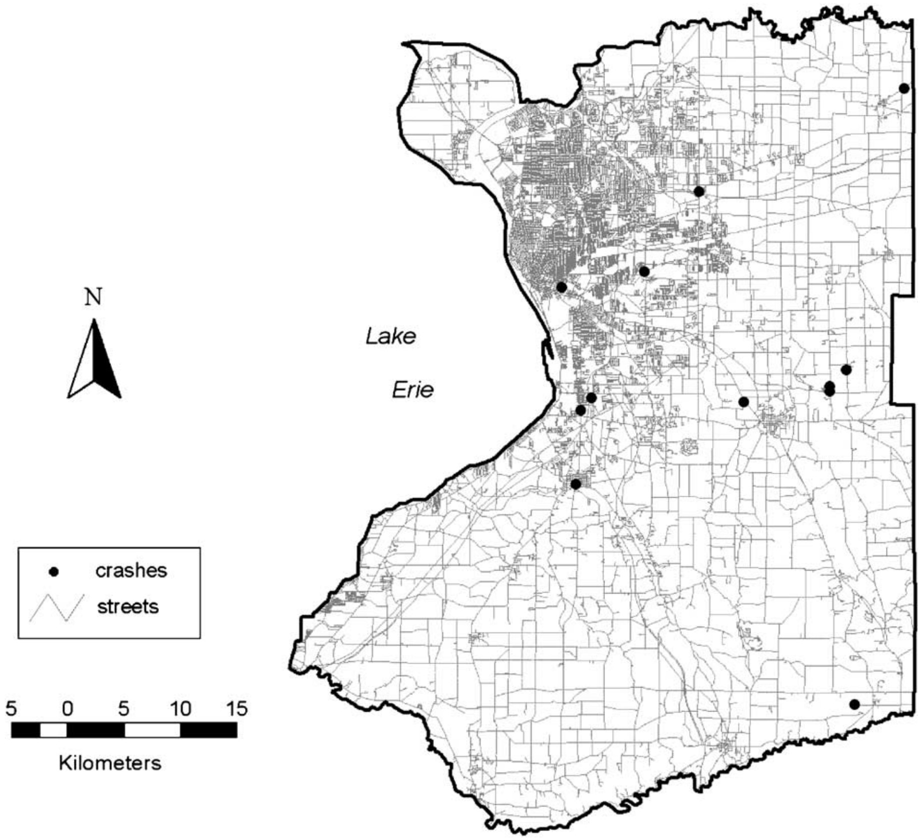

Fig. 9. ACN-equipped vehicle crashes in Erie County.

(d) one system was operationally damaged in the crash;
(e) one crash victim interrupted the voice call after the IVM sent its data;
(f) one system malfunctioned for unknown reasons, but the RSSI was strong at the crash location.

The eighth crash occurred in a rural location of weak cell coverage. Follow-up tests confirmed that RSSI was below −109 dB. Although this crash occurred within the cellular calling area, it was just outside Erie County and was not included in this study's RSSI simulation.

The mean RSSI value for the ACN equipped crashes in Erie County was −68.62. with a maximum of −57.72 and a minimum of −88.37. Fig. 9 shows a map of the ACN crashes where the severity level was above the threshold and the system detected the crash.

6. Summary

The effects of cellular signal attenuation on RSSI and the ability of an ACN device to complete a data call were studied. A call completion probability flowchart was created based on these data. For values of RSSI greater −89 dB, a cellular data call should be successfully completed in the first attempt. For values less than −119 dB, the call will not be completed. When RSSI values fall between −89 and −119 dB, there is a probability associated with call completion.

Tests were conducted to measure signal strength within Erie County. Since such data is discrete, an IDW interpolation method was employed to estimate RSSI values between sample points. Results from the interpolation suggest that cellular coverage in Erie County is adequate to support automatic collision notification technologies.

These results were applied to known crash locations in the Town of Amherst and to the rural areas of Erie County. All crashes that occurred in the Town of Amherst have an RSSI value greater than −89 dB, indicating that most calls would be successfully completed in the first attempt. A similar pattern was observed for crashes within the rural parts of Erie County.

Finally, 70 crashes within Erie County involving ACN-equipped vehicles were analyzed. Of the 22 crashes where the severity level was above the threshold, 14 ACN systems detected the crash and alerted the Erie County Sheriff. Of the eight systems that had problems, only one failed to alert the proper authorities because of poor RSSI.

7. Discussion

To date, testing of NHTSA's ACN system has involved less than 1000 vehicles. While this research has demonstrated that the technology works and can enhance emergency response, the number of units in the field does not approach the number necessary to generate sufficient crash data to verify medical predictions with actual patient outcomes. Regional and national testing is needed to gather crash data for a statistically significant number of vehicles. Moreover, further research should be done in a variety of communities to reflect geographic diversity, population characteristics, traffic density and environmental factors.

Other crash notification systems available on the market, such as GM's OnSTAR, have a much wider deployment than ACN. While crash data and call completion rates are proprietary information, efforts should be made to gather and analyze these data.

The existing method used to interpolate the RSSI values can be improved to obtain more accurate values. Interpolated values obtained by other methods can be tested by empirically measuring RSSI in the field and comparing it with predicted values. This forms an important tool to validate the interpolation method. In this study, terrain elevation of the test area was not taken into account while predicting RSSI values. Uneven terrain may influence the call completion process, especially when the crash occurs in a hilly region.

Currently, there is limited research regarding the relationship between automatic collision notification technology and cell tower locations. When considering placement of new cell sites, cellular service providers must weigh many factors such as customer benefit, construction costs, and net profit. Given the recent climate of negative public opinion on cell towers, showing that new cell towers may save lives in poor coverage/high crash-rate areas may help ease tensions and facilitate more creative tower construction solutions.

The ACN field operational test, while targeted at rural areas, did result in some urban crashes. None of these urban crashes had trouble transmitting emergency calls. However, in more urbanized cities such as New York City or Chicago, there may be an adverse effect of high-rise buildings and urban canyons on RSSI. Most urban crashes result in multiple emergency response phone calls from both landline and cellular phone users who witness the crash. While knowing the location is important, knowing the kinematics of the crash can be equally important. Kinematic information can help emergency personnel send appropriate rescue equipment and allow advanced warning of trauma hospitals regarding injuries.

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