Measured Cellular Signal Strength Along Alaska Roadways and Implications for Timely EMS Notification and Response

M. Flanigan, A. Blatt, K. Majka (CUBRC)
R. Perkins, B. Schuerman (AIPC)
J. Sullivan (AKDOT&PF)

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- James Sheppard, Adrian Sandstrom (ZK Cell Test, Inc)
Introduction

- Nationwide, rural roads are the site of:
  - 57% of fatal car crashes
  - 37% of all vehicle miles traveled\(^1\).

- In Alaska, 61% of fatal crashes are rural\(^1\).

- Increasingly, notification that a crash has occurred relies upon cellular phone systems.
  - Voice calls (occupants or witnesses).
  - Data calls (in-vehicle Automated Crash Notification (ACN) systems).

- Accurate crash location information is also critical for rapid emergency system response, especially in remote areas with few landmarks.

461 Fatal crashes in AK (2001-2006)\(^1\)
61% (280) crashes rural
39% (181) crashes urban

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AKEMSO Project

Alaska Emergency Medical System Optimization (AKEMSO) Project

– Research effort (funded by USDOT) supports Alaska's Highway Safety Office (AHSO) & Injury Prevention & EMS Section (IPEMS).

– Objectives:
  • Support IPEMS efforts to standardize EMS data collection in Alaska (i.e., become NEMSIS compliant) and link with databases from Alaska Trauma Registry and Alaska DOT&PF.

  • Assess needs / requirements for GPS equipment in EMS & law enforcement vehicles.

  • Examine Alaska’s current emergency response infrastructure & protocols to determine how responders can best exploit Automatic Crash Notification (ACN) technologies, especially in rural areas.

    – ACN Systems: OnStar (GM), Tele Aid (Mercedes Benz), ASSIST (BMW), SYNC (Ford)
Focus

First Project Steps

• Determine where along Alaska’s major roadways, the vehicle location & wireless communication technologies associated with ACN will perform as expected.

• Examine utility and benefits of ACN technology for crash victims as well as public safety and EMS responders.

Two Presentations in this Session

“Measured Cellular Signal Strength Along Alaska Roadways & Implications for Timely EMS Notification and Response”

“Issues Associated with Motor Vehicle Crash Locations as Provided by ACN Systems.”
Outline – Talk 1

Measured Cellular Signal Strength & Implications for Timely EMS Notification and Response

• Automatic Crash Notification (ACN) Overview
• Cellular Systems in Alaska
  – Cellular Signal Strength Measurements
  – Signal Strength at/near Motor Vehicle Crash Locations
    ➢ OnStar crashes
    ➢ Fatal crashes
• Implications for EMS Response
  – Key Related National Initiatives
• Summary
Automatic Crash Notification (ACN)
ACN Components & Functional Requirements

ACN System

In-Vehicle Components
- Front Sensors
- GPS Antenna
- Sensor Diagnostic Module
- Side Sensors
- OnStar Telematics Module

- Sense (& survive) crash
- Determine vehicle location / orientation
- Establish communications

External Components
- Infra-structure
  - Cellular Network (phone call)
  - Global Positioning Satellite (GPS) System (lat / long)
- Customer Call Center
- 9-1-1 PSAP

- Receive and display crash messages
- Confirm need for help
- Process crash data and provide actionable information

Today
ACN Fundamentals

Telematics Service Provider (TSP)

OnStar Customer Service Center

Voice

Emergency Services

9-1-1 PSAP

ACN (1st Generation Systems)
- Automated crash message (triggered by an air bag deployment)
- Crash location (lat, long)

AACN (2nd Generation Systems)
- Automated crash message (triggered by an air bag deployment or other above threshold event)
- Crash location (lat, long)
- Crash Delta Velocity
- Crash Direction
- Rollover (yes or no)
- Multiple impacts

Estimated # ACN-equipped vehicles in Alaska = ~13,500
Cell Phone Providers in Alaska &
Equipment to Measure Cellular Signal Strength
### Cell Phone Providers & Technologies in Alaska

<table>
<thead>
<tr>
<th>Major Wireless Provider in Alaska</th>
<th>Technology</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska Communication Systems (ACS)</td>
<td>CDMA</td>
<td>Motorola KRZR</td>
</tr>
<tr>
<td>GCI / Cellular One / AT&amp;T</td>
<td>GSM</td>
<td>Nokia 6125</td>
</tr>
</tbody>
</table>

- OnStar utilizes CDMA cell phone technology in their ACN system.  
  - Contracted with ACS to provide wireless service for subscribers in Alaska.

- GSM technology also important…  
  - Witnesses or passers-by may attempt to report a crash using a GSM phone.

- Measurements of digital cellular signal strength undertaken for each technology.
ZK-SAM Equipment Selected to Measure Digital Cellular Signal Strength

Equipment used by cell phone vendors

**Major Components**
- Display
- ZK-SAM Controller
- GPS Antenna
- Two Cell Phones

**In-Vehicle Power**
- Cigarette Lighter

Motorola phone charges over USB connection to ZK-SAM.

Nokia requires USB connection & separate charger cable.**
Equipment Packaged for Transport Along Alaskan Roadways

• Selection, packaging & initial checkout performed at CUBRC.
• First extensive measurements along the Alaska Highway System (by AIPC collaborators) began in May 2008
• Focus on measuring control channel signal strength.
Our AIPC Road Team
Cellular Signal Strength Measurements.
Route Taken & Results
Route where Measurements Collected Along Alaska Highway System

Alaska’s geographic area equals 21% of area of lower 48 states but major highways are relatively few.

- Data collected along ~2000 miles of roadway
  - AK Highway System & selected main arterials (Anchorage, Fairbanks)
  - May - Aug 2008
- Route highlighted in yellow.
- Heartbeat message every 30 seconds confirmed equipment working.
  - Critical in areas where no cell signal detected.
Received Signal Strength Indicator (RSSI) on CDMA Control Channel

OnStar uses CDMA

Nominal Signal Quality
Green = Service Possible

<table>
<thead>
<tr>
<th>RSSI (dbm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-89 to -38)</td>
<td>Very Good</td>
</tr>
<tr>
<td>(-99 to -90)</td>
<td>Adequate</td>
</tr>
<tr>
<td>(-105 to -100)</td>
<td>Marginal</td>
</tr>
<tr>
<td></td>
<td>NO SERVICE (Heartbeat detected but No Cell Service)</td>
</tr>
</tbody>
</table>

• Reasonable coverage along highways.

• Anchorage & Fairbanks have good signal.

• Segment ‘a’ = possible instrument anomaly. Revisit.

• At resolution shown, points are 3 miles in diameter. May obscure small ‘no signal’ areas. Expand…
SERVICE vs NO SERVICE in **CDMA** Control Channel

Expanded View of 10 mile stretch along N. Glenn Highway.

- Circled areas have several data points (●) with heartbeat but no cellular service.
Phone Calls Placed in ‘Low RSSI’ Areas
Highway between Palmer and Moose Creek

- Low RSSI levels measured along stretch of Glenn HWY (Rt. 1) between Palmer & Moose Creek.
- AIPC staff returned to these areas and attempted to place phone calls.
  - Green X = call successful.
  - Black ✗ = call failed.
- 3 of 11 calls failed. Failed calls had RSSI in ‘Marginal’ category.
  - RSSI measured -104 or -105 at these locations.
Estimated Percent of Route along Alaska Highway ‘Ring’ with Indicated Signal Quality

CDMA

- Route Length (outside of large cities) = 2,173 miles.

- **Estimated** percent of route with indicated signal level.

  - 42% **Very Good** (-89 to -38)
  - 41% **Adequate** (-99 to -90)
  - 6% **Marginal** (-105 to -100)
  - 11% **No Signal** (or possible equipment problem.)
Alaska OnStar Crash Reports in 2008
CARS (Condition Acquisition and Reporting System) is a web-based system with critical road, travel, weather and traffic information.

- At least 10 states have deployed CARS; Alaska is one of them.

CARS is of interest to the AKEMSO project, because it receives OnStar crash reports in near real time.

In Dec 2007, AKDOT provided CUBRC with a link to the Alaska CARS xml webpage. CUBRC programmers created software to monitor the CARS data postings for Alaska, and identify & store OnStar crash alerts.

Over a 27 week period in 2008, there were 23 OnStar calls entered into CARS.
OnStar Crash Locations Overlaid on Measured Cellular Signal Strength

- CARS OnStar crash events provide a form of ‘truth data’ by demonstrating where ACN cellular calls were successfully completed.

- Thus far, OnStar crashes all in areas with measured RSSI values in ‘Adequate’ to ‘Very Good’ range.
Measured RSSI in Vicinity of Selected OnStar Crash Locations

Sorted by distance (m) between OnStar crash location and RSSI data location.

<table>
<thead>
<tr>
<th>Event_ID</th>
<th>Date</th>
<th>Incident</th>
<th>Lat</th>
<th>Long</th>
<th>City</th>
<th>Satellites</th>
<th>RSSI</th>
<th>Dist (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1081455576</td>
<td>1/19/2008</td>
<td>serious accident</td>
<td>64.849229</td>
<td>-147.812627</td>
<td>Fairbanks</td>
<td>8.00</td>
<td>-74.00</td>
<td>2.90</td>
</tr>
<tr>
<td>1161751815</td>
<td>8/11/2008</td>
<td>serious-accident</td>
<td>64.85323</td>
<td>-147.712671</td>
<td>Fairbanks</td>
<td>8.00</td>
<td>-65.00</td>
<td>3.43</td>
</tr>
<tr>
<td>1159413084</td>
<td>8/5/2008</td>
<td>accident</td>
<td>61.453149</td>
<td>-149.369922</td>
<td>Eklutna</td>
<td>8.00</td>
<td>-91.00</td>
<td>3.74</td>
</tr>
<tr>
<td>1147150689</td>
<td>7/3/2008</td>
<td>accident</td>
<td>64.849811</td>
<td>-147.699948</td>
<td>Fairbanks</td>
<td>8.00</td>
<td>-57.00</td>
<td>5.30</td>
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<tr>
<td>1133520717</td>
<td>6/6/2008</td>
<td>serious-accident</td>
<td>61.143099</td>
<td>-149.847778</td>
<td>Anchorage</td>
<td>7.00</td>
<td>-75.00</td>
<td>6.74</td>
</tr>
<tr>
<td>1117110813</td>
<td>4/25/2008</td>
<td>serious-accident</td>
<td>61.821937</td>
<td>-150.078505</td>
<td>Matanuska</td>
<td>8.00</td>
<td>-99.00</td>
<td>8.45</td>
</tr>
<tr>
<td>1148465256</td>
<td>7/11/2008</td>
<td>accident</td>
<td>61.574905</td>
<td>-149.40214</td>
<td>Wasilla</td>
<td>8.00</td>
<td>-82.00</td>
<td>12.48</td>
</tr>
<tr>
<td>1110868146</td>
<td>4/10/2008</td>
<td>Accident</td>
<td>61.584327</td>
<td>-149.545213</td>
<td>Matanuska</td>
<td>8.00</td>
<td>-92.00</td>
<td>13.69</td>
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<tr>
<td>1148193087</td>
<td>7/11/2008</td>
<td>accident</td>
<td>61.188111</td>
<td>-149.868313</td>
<td>Anchorage</td>
<td>6.00</td>
<td>-61.00</td>
<td>149.61</td>
</tr>
<tr>
<td>116392163</td>
<td>8/16/2008</td>
<td>serious-accident</td>
<td>61.599448</td>
<td>-149.128876</td>
<td>Palmer</td>
<td>7.00</td>
<td>-71.00</td>
<td>326.87</td>
</tr>
</tbody>
</table>

Locations plotted on preceding map.
Fatal Motor Vehicle Crash Locations Provide Larger Sample of Serious Injury Crashes in Alaska
Fatal Crash Locations from FARS 2001-2006
Overlaid on Cellular Strength Map

- The 405 geocoded fatal crash locations in FARS provides a representative spatial distribution of serious injury crashes.
  - For every fatal crash, typically about 5 serious injury crashes.
- 176 fatal crashes (43%) occurred on or near route driven with ZKSAM.
Why is ACN so important for Alaska?

Implications for EMS Response
Utility and Benefits of ACN for Emergency Medical Response

• Nationwide FARS data shows that ~50% of fatal crash victims die at scene or en-route to hospital.
  – Immediate notification with accurate crash location information can help speed EMS response to crash scenes & likely reduce these statistics.
  – Sizeable fraction of past Alaska fatal crash sites in areas where ACN calls will likely succeed.

• Specific crash information with accurate location can also help reduce exposure of public safety and EMS responders to hazardous weather and road conditions.

• Future sharing of ACN alert with secondary recipients (e.g., nearest air medical base and surgical hospital) can help expedite crash victim access to definitive surgical care.
  – Parallel notification can allow air medical pre-flight and warm-up to begin.
  – Early alert can also enable trauma team preparations to begin, even as first responders traveling to scene.
## Level of Emergency Medical Care Available in Alaska by Community Type

<table>
<thead>
<tr>
<th>Community Type</th>
<th>EMS Level of Care</th>
<th>No. of Fatal Crashes 2001-2005</th>
<th>% of Total Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I – Isolated Village/ Highway Village</td>
<td>Community clinic with a CHA or EMT</td>
<td>98</td>
<td>25%</td>
</tr>
<tr>
<td>II – Isolated Sub-regional Community</td>
<td>Community clinic with PA, NP or physician; health care services provide by public or private sector</td>
<td>123</td>
<td>32%</td>
</tr>
<tr>
<td>III – Large Town or Regional Center</td>
<td>Community hospital &amp; physicians; health care service agencies include both public &amp; private sector</td>
<td>33</td>
<td>9%</td>
</tr>
<tr>
<td>IV – Small City</td>
<td>Hospital with 24 hr ED &amp; full continuum of care; multiple providers of health care &amp; other services including both public &amp; private</td>
<td>48</td>
<td>12%</td>
</tr>
<tr>
<td>V – Urban Center</td>
<td>Some specialized medical &amp; rehab services for low incidence problems.</td>
<td>83</td>
<td>22%</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>385</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

CHA= Community Health Aide; NP=Nurse Practitioner; ED=Emergency Dept.

**Over 55% of the Alaskan fatal crashes occur in communities without a community hospital.**  
**Rapid notification & optimized transport is therefore critical.**
Alaska Emergency Medical Response Infrastructure

Geographic Information System

- EMS Responder Locations
  - Ground Ambulance
  - Air Medical

- Hospitals
  - Trauma Center
  - Acute Care Hospitals

- Alaska Highway
- Principal Arterial
Related National Initiatives

Next Generation 9-1-1
• NHTSA initiative to establish national architecture and transition plan for the NG 9-1-1 system. Will enable transmission of text & data (e.g., ACN) as well as images and video along with voice into the 9-1-1 system.
• Statewide network projects are underway as well as smaller scale demos

New and Emerging Technologies 9-1-1 Improvement Act
• Signed into Law 7/23/2008
• Intended to promote and enhance public safety by facilitating the rapid deployment of IP-enabled 911 and Enhanced 9-1-1 services

CDC Field Triage Medical Protocol for Vehicle Telematics
• Revised ACS COT\(^1\) field trauma triage guidelines include consideration of vehicle telematics data.
• Developing recommendations on how to best use the telematics crash data to support dispatch and triage decisions.

1. ACS COT = American College of Surgeons Committee on Trauma
Summary

• Transmission of an ACN alert requires successful placement of an automatic cell phone call.

• To determine where ACN systems can communicate along the Alaska Highway System, CDMA cellular signal strength was measured.
  – 83% of highway system measured had adequate to very good cellular signal
  – Areas with marginal or ‘no service’ were identified.
  – In general, CDMA reception was geographically more extensive than GSM.

• OnStar crashes are now being extracted in near real time from the Alaska CARS system and compiled into an ACN crash database. These data provide a form of ‘truth’ data by demonstrating where ACN calls were successfully completed.

• FARS crashes have been mapped to illustrate where serious injury crashes are occurring in Alaska. Over 55% of the Alaskan fatal crashes occur in communities without a community hospital. Rapid EMS notification & optimized transport to distant medical care is therefore critical.
  – This argues for making ACN alert available in real time to nearest air med base & hospital.