"Adaptive Cooperative Awareness Messaging for Enhanced Overtaking Assistance on Rural Roads”

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Background and Motivation

Number of fatalities on Swedish roads per accident type

Source: Trafikverket 2008
Background and Motivation

- V2V-based traffic safety applications for rural roads have huge potential to save lives
  - E.g. overtaking warning
- Many emerging traffic safety applications based on periodic exchange of status messages
  - Densely trafficked scenarios (urban, highway)
    • Focus on accommodating large numbers of vehicles in the network
  - Sparsely trafficked roads (rural)
    • Make use of available bandwidth to reduce delay
Background and Motivation

• Low delay

→ Low probability of packet collisions
→ High update rate

• IEEE 802.11p MAC
  – CSMA/CA-based random access protocol
• For Europe: ETSI (European Telecommunications Standards Institute) defines 2 Hz report rate for periodic status messages
  – Set with high vehicle density in mind
  – For rural scenarios:
    • Unallocated bandwidth
    • Unnecessary delay
Background and Motivation

- Two message types
  - Cooperative Awareness Messages (CAM)
    - Periodically broadcasted beacons
    - Including e.g. position, speed, driving direction
  - Decentralized Environmental Notification Messages (DENM)
    - Event-driven, application specific warning messages

The overtaking warning scenario

- Leading vehicle "learns" about on-coming traffic through CAM exchange
- Overtaking warning issued to regular, non-leading vehicles (DENM)
How to make good use of the available bandwidth?

1. Prioritize packets from the ‘most important’ vehicle in a certain application and situation
   - IEEE 802.11p defines 4 priority levels
     - Different waiting times (Inter Frame Spacing – IFS) and backoff times ensure higher probability of channel access for higher priority class
   - Overtaking warning example:
     - Leading vehicle – highest priority level (802.11p QoS class 1)
     - Regular vehicles – lowest priority level (802.11p QoS class 4)

2. Adapt the send rate of a vehicle based on importance to a certain application and situation
   - Without overloading the channel!
     - ETSI recommendation: keep channel load < 25%
   - Overtaking warning example:
     - Leading vehicle – e.g. 10 Hz
     - Regular vehicles – e.g. 2 Hz
Simulation evaluation

- **System model**
  - Straight, single-lane, rural road
  - 90 km/h speed limit
  - 2 queues of vehicles approaching each other from opposite direction

- **Channel model**
  - Based on field measurements with 802.11p-equipped vehicles

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Simulation evaluation

- **Data traffic model**
  - Priority-based CAM report rate

<table>
<thead>
<tr>
<th></th>
<th>regular vehicle</th>
<th>leading vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 1</strong></td>
<td>2 Hz</td>
<td>2 Hz</td>
</tr>
<tr>
<td><strong>Case 2</strong></td>
<td>2 Hz</td>
<td>10 Hz</td>
</tr>
<tr>
<td><strong>Case 3</strong></td>
<td>2 Hz</td>
<td>20 Hz</td>
</tr>
<tr>
<td><strong>Case 4</strong></td>
<td>10 Hz</td>
<td>20 Hz</td>
</tr>
</tbody>
</table>

- **Interesting parameters**
  - **Delay** between the first CAM sent after entering the opposite leading vehicle’s transmission range and the first successful reception by that vehicle
  - **Distance** between the leading vehicle’s position at time of contact (with the on-coming traffic) and the position of the potential crash
  - **Time** left for the driver to react to a warning, i.e. time between the first successful CAM reception and the potential crash
Simulation evaluation

<table>
<thead>
<tr>
<th></th>
<th>Single-Side Contact</th>
<th>Full Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delay (s)</td>
<td>Dist. (m)</td>
</tr>
<tr>
<td><strong>Case 1</strong></td>
<td>2.60</td>
<td>468</td>
</tr>
<tr>
<td><strong>Case 2</strong></td>
<td>0.66</td>
<td>566</td>
</tr>
<tr>
<td><strong>Case 3</strong></td>
<td>0.47</td>
<td>575</td>
</tr>
<tr>
<td><strong>Case 4</strong></td>
<td>0.63</td>
<td>566</td>
</tr>
</tbody>
</table>

10 vehicles per driving direction.

Simulation evaluation

Reaction time from single side contact to potential crash. 10 vehicles per driving direction.
Simulation evaluation

Channel Busy Time for varying numbers of vehicles and CAM report rates

Conclusion

- Without changes to the standard, context-aware report rate adaptations
  - Lead to a significant reduction in response time
  - Lead to a more efficient utilization of the available bandwidth
  - Make it possible to fine-tune the utilization of the available resources to a specific scenario, application or combination of applications (e.g. sparsely-trafficked, rural roads vs densely-trafficked urban roads)