Congestion Control in CSMA-based Vehicular Networks: Do Not Forget the Carrier Sensing

Razvan Stanica, Emmanuel Chaput, André-Luc Beylot
Institut National Polytechnique de Toulouse

IEEE 9th Annual Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON)

Seoul – 21 June 2012
Safety Communications in Vehicular Networks

Types of Losses for Vehicular Beacons

Safety Range CSMA

Protocol Evaluation

Conclusion & Future Work
VANET objective: Building an accurate image of the exterior world

- Cooperative Awareness Message (CAM)
- Decentralised Environmental Notification (DEN)
Safety Messages

- Cooperative Awareness Message (CAM)
  - Periodic
  - Position, speed, direction, steering angle ...
  - ETSI TS 102 868

- Decentralised Environmental Notification (DEN)
  - Special events
  - Hazard location, type, dissemination area ...
  - ETSI TS 102 869
Safety beaconing

- Broadcast mode – no exposed terminals
- A beacon expires if the next CAM is produced
- Practically no internal contention on the CCH
- MAC delay automatically considered in the expiration probability
- Metrics of interest: reception probability, number of undetected neighbours
IEEE 802.11p on the CCH

100% broadcast communication

No ACK message

Collisions can not be detected

Always use the minimum value for CW

BEB mechanism deactivated

Protocol Evaluation

Safety Range CSMA

Types of Losses

Safety V2V

Razvan Stanica

University of Toulouse

SECON 2012

5

VANET Congestion Control: Do Not Forget the Carrier Sensing

21.06.2012
Congestion Control

- Beaconing Frequency
- Data Rate
- Transmission Power
- Contention Window

Safety Range CSMA

Protocol Evaluation

Razvan Stanica
University of Toulouse
SECON 2012

6 VANET Congestion Control: Do Not Forget the Carrier Sensing
21.06.2012
Congestion Control

- Beaconing Frequency – problems in some scenarios (left turn assistant)
- Data Rate – questioned by field tests
- Transmission Power – included in SR-CSMA
- Contention Window – included in SR-CSMA
Why are safety messages lost?

- Propagation Problems
- Expired Beacons
- Collisions
  - Synchronized Transmissions
  - Hidden Nodes
Why are safety messages lost?

- Propagation Problems
- Expired Beacons
- Collisions
  - Synchronized Transmissions
  - Hidden Nodes
<table>
<thead>
<tr>
<th>Safety V2V</th>
<th>Types of Losses</th>
<th>Safety Range CSMA</th>
<th>Protocol Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Razvan Stanica</td>
<td>University of Toulouse</td>
<td>SECON 2012</td>
<td>21.06.2012</td>
</tr>
</tbody>
</table>

VANET Congestion Control: Do Not Forget the Carrier Sensing

*Capture Effect, Collision, Capture Effect*
Collision Capture Effect Capture Effect
Collision
Collision
Capture Effect

Safety V2V
Types of Losses
Safety Range CSMA
Protocol Evaluation
Razvan Stanica
University of Toulouse
SECON 2012

8 VANET Congestion Control: Do Not Forget the Carrier Sensing 21.06.2012
Safety Range CSMA

- More neighbours – longer back-off
- More neighbours – more expired beacons
- More neighbours – more collisions
Safety Range CSMA

- More neighbours – longer back-off
- More neighbours – more expired beacons
- More neighbours – more collisions

Collisions can not be avoided under high node density
The New Access Method

Protocol Evaluation

Safety Range CSMA

Types of Losses

Safety V2V

10 VANET Congestion Control: Do Not Forget the Carrier Sensing

Razvan Stanica

University of Toulouse

SECON 2012

21.06.2012
Idle channel – transmit (IEEE 802.11 approach)
The New Access Method

- Another transmission detected – estimate the position of the transmitter
- Cross layer approach (PLCP – MAC)

<table>
<thead>
<tr>
<th>Safety V2V</th>
<th>Types of Losses</th>
<th>Safety Range CSMA</th>
<th>Protocol Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Razvan Stanica</td>
<td>University of Toulouse</td>
<td></td>
<td>SECON 2012</td>
</tr>
</tbody>
</table>

11 VANET Congestion Control: Do Not Forget the Carrier Sensing 21.06.2012
Estimate if a collision could be solved by the capture effect inside the two safety ranges.

The New Access Method

Collision

Safety V2V

Types of Losses

Safety Range CSMA

Protocol Evaluation

Razvan Stanica

University of Toulouse

SECON 2012
One of the two safety zones is not safe, regardless of the used transmission power – back-off (IEEE 802.11 approach)

Safety Range

Collision

Safety Range
The safety zones are safe – transmit (using the highest transmission power that keeps them safe)
If you can’t beat them, use them

Safety Range

Possible Estimation Errors

Force Collisions

Carrier Sense Range

Safety V2V

Types of Losses

Safety Range CSMA

Protocol Evaluation

Razvan Stanica

University of Toulouse

SECON 2012

15

VANET Congestion Control: Do Not Forget the Carrier Sensing

21.06.2012
If you can’t beat them, use them

Safety Range

Possible Estimation Errors

Force Collisions

Carrier Sense Range

- Increased spatial reuse
- Higher (but manageable) interference
- More transmission opportunities
- More collisions at far distances
- Increased reception probability inside SR

Safety V2V

Types of Losses

Safety Range CSMA

Protocol Evaluation

Razvan Stanica

University of Toulouse

SECON 2012

15

VANET Congestion Control: Do Not Forget the Carrier Sensing

21.06.2012
Reverse Back-off Mechanism

- Can not detect collisions
- We can detect expired beacons
- Relatively high initial CW (e.g. 127)
- CW = CW/2 after every expired beacon
- CW goes back to the initial value after N beacons
Reception Probability inside the Safety Range

![Chart showing reception probability for different vehicular densities and protocols.

**X-axis:** Vehicular density [cars/lane/km]
**Y-axis:** Beacon reception probability

- **SR-CSMA + RB**
- **SR-CSMA**
- **CSMA**

**Legend:**
- Solid line: SR-CSMA + RB
- Dashed line: SR-CSMA
- Dotted line: CSMA

**Data Points:**
- For each density level (25, 34, 43), the chart shows the reception probability.

---

Safety V2V | Types of Losses | Safety Range CSMA | Protocol Evaluation
---|---|---|---
Razvan Stanica | University of Toulouse | Safety Range CSMA | SECON 2012

VANET Congestion Control: Do Not Forget the Carrier Sensing | 21.06.2012
Consecutive Lost Beacons

Protocol Evaluation
Safety Range CSMA
Types of Losses

SR-CSMA
SR-CSMA + RB

Compared with CSMA [%]

100
50
0
-50
-100

10- 10-20 20+
Consecutive lost beacons

Razvan Stanica
University of Toulouse
SECON 2012

VANET Congestion Control: Do Not Forget the Carrier Sensing
Loss Reasons Distribution

Distance from sender

<table>
<thead>
<tr>
<th>Protocol Evaluation</th>
<th>Safety V2V</th>
<th>Types of Losses</th>
<th>Safety Range CSMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Razvan Stanica</td>
<td>University of Toulouse</td>
<td>SECON 2012</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>VANET Congestion Control: Do Not Forget the Carrier Sensing</td>
<td>21.06.2012</td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

- The communication range in IEEE 802.11p is too long under high density.
- Collisions are unavoidable (the load is larger than 1).
- Collisions with close neighbours have deeper consequences.
- Force collisions with vehicles situated farther away to increase spatial reuse.
Future Work

- Study of Special Notifications
- Impact of ranging techniques
- Implementation on real hardware
Congestion Control in CSMA-based Vehicular Networks: Do Not Forget the Carrier Sensing

Razvan Stanica, Emmanuel Chaput, André-Luc Beylot
Institut National Polytechnique de Toulouse

IEEE 9th Annual Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON)

Seoul – 21 June 2012