Broadcast Reception Rates and Effects of Priority Access in 802.11-Based Vehicular Ad-Hoc Networks

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Problem statement

- Broadcasts emergency message

- What is the probability of reception for this car?

But:

- All vehicles send data → contending for the channel
- Hidden terminal problem
- Channel characteristics
Channel modeling: the standard way …

Unit Disc Graph Model

If no interference:
• Cars inside communication range receive the packet
• Cars outside communication range do NOT receive the packet
In reality …

**Reality**

If no interference:
- Cars inside “communication range” CAN receive the packet
- Cars outside “communication range” MAY receive the packet

Reception Probability (d)?
Structure of this talk

» VANET – Key Issues
» 802.11-Priority Access applied to VANETs
» Simulation Setup
» Results: Basic Scenario (understanding the mechanism)
» Results: Dynamic Scenario (getting closer to reality)
» Summary
» Future Work
VANET – Key Issues

VANET differs from usual ad hoc network by its vehicular environment, distributions, movement and applications

- Key usage: safety applications → broadcast
- There is a deployment problem but eventually there will be saturation conditions (high penetration rates)

» What is the probability of reception of a broadcast message at an arbitrary distance to the sender?

» How to give priority access and an improved reception rate for important warnings?

» How are the above two results affected by signal strength fluctuations caused by radio channel fading?
IEEE 802.11

» Why 802.11? Interests in U.S.A. (DSRC/WAVE), Europe (Fleetnet/NOW)

» Access method: CSMA/CA

![Diagram of CSMA/CA access method]

» DIFS = SIFS + 2*SlotTime \hspace{1cm} (SIFS = 32us, SlotTime = 13us)

» CWmin = 15

» Broadcast → no RTS/CTS, no ACK, CW = CWmin
Priority Access

» Mechanism of EDCA of IEEE 802.11e

» Two main changes:
  – AIFSD[AC] = SIFS + AIFS[AC]*SlotTime
  – CWmin[AC]

<table>
<thead>
<tr>
<th>AC</th>
<th>CWmin[AC]</th>
<th>AIFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>CWmin</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>CWmin</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>(CWmin+1)/2 -1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>(CWmin+1)/4 -1</td>
<td>1</td>
</tr>
</tbody>
</table>
Simulation Set Up

» Tool: Network Simulator ns-2

» Changes to original code:
  - Some bug fixing at 802.11 module
  - Adjust values to 802.11a at 5.9GHz with 10MHz Channels (DSRC/WAVE)
  - Changes in both MAC and Physical Layer
  - Nakagami radio propagation model
Basic Scenario (static and two-ray ground)

» How CSMA/CA works in a saturated broadcast scenario?

» How AIFS and CWmin affect broadcast performance?

- 8 lanes with 75 static cars
- 20m between cars
- 500 bytes packets
- 10 packets/s
- 200m comm. range
- “Receiver” at 100m
### Basic Scenario – Results

<table>
<thead>
<tr>
<th>Result</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIFS/CW</strong></td>
<td><strong>RcvPkts</strong></td>
</tr>
<tr>
<td>2/15</td>
<td>27.7%</td>
</tr>
<tr>
<td>2/7</td>
<td>31.1%</td>
</tr>
<tr>
<td>1/7</td>
<td>54.5%</td>
</tr>
<tr>
<td>1/3</td>
<td>59.4%</td>
</tr>
</tbody>
</table>

- Car with highest priority: best probability of reception

- Why is a packet not received?
  - Hidden node
  - Car inside range chooses the same time slot to send

- For error analysis new parameters were needed: SntBTx, RcvBTx
Dynamic Scenario (mobile and TRG or Nakagami)

- 8 lanes, 2 directions (912 cars)
- Constant speed different lanes
- Distance between cars: 20m
- Comm. Range: 100m, 200m
- Packet size: 200B, 500B
- 10 pckts/s

Nakagami received power distribution
Dynamic Scenario – Metrics

Safety Applications
Broadcast Scenario

Delay
Effectiveness

Metrics:
- Channel access time
- Probability of reception
**Dynamic Scenario – Channel Access Time**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Channel Access Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Com. Range</strong></td>
<td><strong>Pckt Size</strong></td>
</tr>
<tr>
<td>100m</td>
<td>200 B</td>
</tr>
<tr>
<td>100m</td>
<td>500 B</td>
</tr>
<tr>
<td>200m</td>
<td>200 B</td>
</tr>
<tr>
<td>200m</td>
<td>500 B</td>
</tr>
<tr>
<td>200m (Nak)</td>
<td>500 B</td>
</tr>
</tbody>
</table>

» Clearly the Priority node has always shorter Channel Access Time!
Dynamic Scenario – Probability of Reception

Two Ray Ground

Nakagami

- 500 bytes packets
- 200 m intended communication range
Effect of Realistic Propagation Model - Metrics

With Non-Deterministic Radio Propagation model:

- Channel Access Time \( \uparrow \uparrow \)
- Probability of Reception \( \downarrow \downarrow \) (worse effect on priority node)

**WHY !?**

New metrics:
- Sensed Packets per second
- Channel Idle Time Ratio
### Effect of Realistic Propagation Model - Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Priority</th>
<th>Non-Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>200m, 500B</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TRG</td>
<td>TRG</td>
</tr>
<tr>
<td></td>
<td>Nak</td>
<td>Nak</td>
</tr>
<tr>
<td>Ch. Acc. Time</td>
<td>3.6 ms</td>
<td>16.4 ms</td>
</tr>
<tr>
<td></td>
<td>9.0 ms</td>
<td>26.5 ms</td>
</tr>
<tr>
<td>Sens. Pkts/s</td>
<td>3325.2</td>
<td>3324.6</td>
</tr>
<tr>
<td></td>
<td>3093.2</td>
<td>3096.8</td>
</tr>
<tr>
<td>Ch. Idle Time</td>
<td>10.8%</td>
<td>10.6%</td>
</tr>
<tr>
<td></td>
<td>4.4%</td>
<td>4.4%</td>
</tr>
</tbody>
</table>

* Same average number of packets sent by all nodes

- Less packets sensed **but** less Channel Idle Time with non-deterministic radio propagation model !!!
Summary

» Target: reliable reception of important messages in a saturated broadcast network (VANET):
  – Probability of reception and channel access time
  – Prioritization
  – Received power fluctuations

» Results
  – When saturation occurs, nodes experience severe performance degradation (probability of reception can be as low as 20% at half com. range)
  – Priority access provides improvement in both channel access time and probability of reception (AIFS and CW can be adjusted to reduce channel access time and collisions)
  – Non-deterministic radio model degrades performance of both types of nodes (worse effect on probability of reception of the prioritized ones)

» Conclusions
  – Need better understanding of distributed MAC on global scale
  – Priority access methods as well as relay/repetition strategies are very important aspects of future safety-critical applications
Future Work

» More than 1 prioritized nodes
» Relay/Repetition strategies
» Topology control
» Realistic radio models
» Spatial and temporal correlations
» Traffic modeling
Thank you very much for your attention!