Comparing LIMERIC and DCC Approaches for VANET Channel Congestion Control

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Outline

• Background
• Adaptive Control - LIMERIC Algorithm
• Reactive Control – European DCC
• Comparison Results
• Conclusions
Background

• Wireless V2V communication holds great promise for significantly improve the traffic efficiency.
  – collision avoidance
  – road hazard awareness
  – route guidance

• 802.11p based DSRC technology
  – specify MAC and PHY protocols
  – VANENT is moving rapidly toward deployment
    • US government recently announced an intention to require DSRC devices in new cars within a few years
    • Twelve members of the Car2Car-Communication Consortium at Europe have pledged to begin equipping their new vehicles with communication devices by 2015
Background

- **Common Characteristic of V2V communication**
  - periodically broadcast safety messages including information: e.g. location, speed, heading; timing message
  - Channel load increases with node density

- **DSRC uses 802.11 Medium Access Control**
  - Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA): listen before sending; backoff when sense busy

- **Frame collisions still occur**
  - Field tests show 79.5% packet loss for links with RSS between -80 to -85 dBm with 360 vehicles [1]

- **High load on the DSRC Safety channel**
  - reduce the successful communication rate
  - compromise the mission of increasing road safety
Safety Messages

• Basic Safety Message (BSM) in US, Cooperative Awareness Message (CAM) in Europe
  – position information, time stamp, heading, speed, driving direction, path history, vehicle type

• BSM generation
  – have not specified
  – 10 BSM/second rate in most tests and trials

• CAM generation
  – time condition: message interval, provided by DCC, expires
  – dynamic condition: (i) heading changed > 4°, (ii) position changed > 4 meters, or (iii) magnitude of speed changed > 0.5 m/sec
  – After 1 second even above two conditions are not met
Message Rate Control

Each vehicle computes its message rate $r_i(t)$ adaptively based on channel load (Channel Busy Ratio).

Goals: controlled load, convergence, fairness
Adaptive Control: LIMERIC[2]

\[ r_j(t) = (1 - \alpha)r_j(t - 1) + \beta(CBR_g - CBR(t - 1)) \]

- **Goal aggregate load**
- **Current Aggregate load**

\[ 0 < \alpha < 1 : \text{contraction parameter,} \quad \beta > 0: \text{linear gain adaptive parameter,} \]

- **Achieves goals of controlled load, convergence, fairness**

- Impacts fairness, convergence speed

- Impacts stability, convergence speed
Reactive Control – European Decentralized Congestion Control (DCC) [3]

Table Look-Up for Congestion Control

<table>
<thead>
<tr>
<th>Channel load</th>
<th>Packet Tx interval</th>
<th>Packet rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 30 %</td>
<td>100 ms</td>
<td>10 Hz</td>
</tr>
<tr>
<td>30-39%</td>
<td>200 ms</td>
<td>5 Hz</td>
</tr>
<tr>
<td>40-49%</td>
<td>300 ms</td>
<td>3.33 Hz</td>
</tr>
<tr>
<td>50-59%</td>
<td>400 ms</td>
<td>2.5 Hz</td>
</tr>
<tr>
<td>&gt;59%</td>
<td>500 ms</td>
<td>2 Hz</td>
</tr>
</tbody>
</table>

Only Reacting to Congestion
Does not achieve goals of controlled load, convergence, fairness
## Comparison

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Hz</td>
<td>There is no congestion control algorithms present and all vehicles transmit CAM/BSM 10 times per second.</td>
</tr>
<tr>
<td>LIMERIC</td>
<td>The vehicles’ generate and transmit BSMs when LIMERIC algorithm allows.</td>
</tr>
<tr>
<td>10Hz with DCC</td>
<td>The vehicles generate CAM/BSM with 10 Hz and at the access layer the DCC will act as a gate-keeper according to the current allowed rate.</td>
</tr>
<tr>
<td>CAM with DCC</td>
<td>The vehicles generate CAMs based on vehicle dynamics and at the access layer the DCC will act as a gate-keeper according to the current allowed rate.</td>
</tr>
</tbody>
</table>
Simulations

Set-up a Road Topography in SUMO
Length of the highway = 4 Km

- We conducted NS-2 simulations
  - Number of Cars = 500, 1000, 1500
  - Power = 500 m transmission range
  - Message rate = 10 Hz, LIMERIC, 10 Hz with DCC, CAM with DCC
  - CBR measured every 100ms synchronously over all nodes
  - LIMERIC target CBR=79, $\alpha = 0.1$, $\beta = 0.033$
Channel Busy Ratio (CBR)

CBR measured in the winding part of the road v.s. time
total number of nodes: 1000 nodes

<table>
<thead>
<tr>
<th></th>
<th>10 Hz</th>
<th>LIMERIC</th>
<th>10 Hz with DCC</th>
<th>CAM with DCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean CBR</td>
<td>92%</td>
<td>68%</td>
<td>61 %</td>
<td>50 %</td>
</tr>
</tbody>
</table>

Huge oscillations in CAM with DCC Approach
Packet Error Ratio (PER)

Due to oscillations LIMERIC has much lower PER as compared to CAM with DCC, even though LIMERIC converges to higher CBR.
Inter-Packet Gap (IPG)

LIMERIC has the best Inter Packet Gap (IPG) Performance
Performance – 1500 Nodes

LIMERIC outperforms other schemes for 1500 node case as well.
Number of Transmissions

(a) The distribution of transmissions in one second for LIMERIC approach
   total number of nodes: 1000

(b) The distribution of transmissions in one second for 10Hz_DCC approach
   total number of nodes: 1000

(c) The distribution of transmissions in one second for CAM_DCC approach
   total number of nodes: 1000

Message transmission in CAM with DCC approach happens in clusters
Asynchronous CBR Implementation reduces oscillations only by a little amount.
Conclusions

• Adaptive control has controlled load, convergence, fairness properties

• Reactive control does not have these properties
  – Significantly suffers from oscillation in the channel load
Thank You
Reference