Simulation Evaluation of Distributed Congestion Control -Reactive DCC-

Oyunchimeg Shagdar

Inria, FRANCE

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Report overview
-- Study of different implementations of Reactive DCC --

• Motivation:
  • What is the “optimal” behavior of Reactive DCC?

• Implementation & Simulation setting

• Results & Discussion
DCC Reactive rate control

- DCC Access
- PHY channel monitoring
- DCC Facilities
- Rate control

Table A.1: Reactive DCC - DCC states and corresponding CL

<table>
<thead>
<tr>
<th>States</th>
<th>CL (%)</th>
<th>$T_{off}$ (ms)</th>
<th>$R^*$ (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>relaxed</td>
<td>0 % ≤ CL ≤ 19 %</td>
<td>60</td>
<td>16.7</td>
</tr>
<tr>
<td>active_1</td>
<td>19 % ≤ CL &lt; 27 %</td>
<td>100</td>
<td>10.0</td>
</tr>
<tr>
<td>active_2</td>
<td>27 % ≤ CL &lt; 35 %</td>
<td>180</td>
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<td>260</td>
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<td>43 % ≤ CL &lt; 51 %</td>
<td>340</td>
<td>2.9</td>
</tr>
<tr>
<td>active_5</td>
<td>51 % ≤ CL &lt; 59 %</td>
<td>420</td>
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</tr>
<tr>
<td>restricted</td>
<td>CL ≥ 59 %</td>
<td>460</td>
<td>2.2</td>
</tr>
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Controlling the CAM generation interval

• Periodical message transmission
  • Timer triggered message generation ➔ Set Timer and send data when the timer is expired

• Upon being informed with a new CBR value, the CAM generator may
  • Wait the expiration of the ongoing timer then change the parameter table ➔ Wait-and-Go
  • Cancel the ongoing timer and set the timer following the parameter table ➔ Cancel-and-Go

• Considering that the neighbors have the “same” information update, generate a message with a “random” interval before following the parameter table
  • Do not consider: Synchronous
  • Consider: Asynchronous

4 Possible Approaches!
Approaches to “realize” Reactive DCC

- Approach 1: Synchronous & Wait-and-Go
- Approach 2: Synchronous & Cancel-and-Go
- Approach 3: Asynchronous & Wait-and-Go
- Approach 4: Asynchronous & Cancel-and-Go
Implementation and simulation setting details
DCC Implementation Overview

- NS3 version ns-3.21 coupled with SUMO
  - 802.11p module is implemented

- Implementation of channel load measurement on PHY
  - Channel activity monitoring:
    - Monitoring period: 100ms
  - Calculation of CBR (busy period / total period)
  - Notification to the CAM generator (and any other module, which needs the info)

\[
\text{CBR} = \frac{\sum T_{busy_i}}{T_{monitor}}
\]

- Implementation of Transmission Rate Control at CAM
  - Rate adaptation following the provided rule
  - DCC Reactive Control
DCC Reactive Control

- PHY Channel Activity Monitor notifies the channel state (CBR)

- Compares CBR with DCC Reactive parameter table and adjusts the Toff period

### Table A.1: Reactive DCC - DCC states and corresponding CL

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</table>
Simulation Scenario

### Table 16: Scenario Descriptions

<table>
<thead>
<tr>
<th>Category</th>
<th>Testing Objectives</th>
<th>Conditions</th>
<th>Scenarios</th>
<th>Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scalability</td>
<td>Homogeneous ITS-S density</td>
<td>1-D highway</td>
<td>Static</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2D Parking Lot</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Adaptability</td>
<td>Heterogeneous ITS-S density</td>
<td>Highway, One direction dense, one empty</td>
<td>Exponential Inter-distance (low on direct flow, high on contra-flow)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Elevated Highway</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Resilience</td>
<td>NLOS</td>
<td>Blind Intersection</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>One vehicle arriving at constant speed at each corner</td>
</tr>
<tr>
<td>4</td>
<td>Responsiveness</td>
<td>Variable Traffic</td>
<td>Cluster/Platoon on one direction, single vehicle on the opposite direction</td>
<td>Platoons of dense vehicles, sparse conditions in-between</td>
</tr>
</tbody>
</table>

Since a DCC penetration rate of 100% is not expected at Day 1, gradual penetration (10%, 50%) of ITS-S is also considered, first for 4-wheels motor-vehicles and also for vulnerable traffic users. The penetration rates to be considered for each type of ITS-S are given in Table 17.
Table 18: Scenario Parameter for Scalability Test

<table>
<thead>
<tr>
<th>Class</th>
<th>Vehicular Density</th>
<th>Corresponding 1D parameters</th>
<th>Corresponding 2D parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sparse</td>
<td>50 vehicle/km$^2$</td>
<td>100 m inter-distance / 3 lanes / 2 directions</td>
<td>1.5 m inter-distance, 2D</td>
</tr>
<tr>
<td>Medium</td>
<td>100 vehicles/km$^2$</td>
<td>45 m inter-distance / 3 lanes / 2 directions</td>
<td>0 m inter-distance, 2D</td>
</tr>
<tr>
<td>Dense</td>
<td>250 vehicles/km$^2$</td>
<td>20 m inter-distance / 3 lanes / 2 directions</td>
<td>-</td>
</tr>
<tr>
<td>Extreme</td>
<td>400 vehicles/km$^2$</td>
<td>10 m inter-distance / 3 lanes / 2 directions</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 19: Specific highway configurations for scalability tests

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway Length</td>
<td>1 000 m to 50 000 m</td>
<td>10 000 m (1 000 m if static)</td>
</tr>
<tr>
<td>RSU Inter-Location</td>
<td>50 m to 500 m</td>
<td>100 m</td>
</tr>
<tr>
<td>Vehicle size</td>
<td>2 m × 5 m</td>
<td>2 m × 5 m</td>
</tr>
<tr>
<td>Flow density class</td>
<td>Sparse/Medium/Dense</td>
<td>Dense</td>
</tr>
<tr>
<td>Contra-flow density class</td>
<td>As Flow</td>
<td>Dense</td>
</tr>
</tbody>
</table>
Communication parameters

Table 22: Default communication parameters for all scenarios

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAM transmission ranges (in Time)</td>
<td>[0.6 ms - 0.8 ms - 1 ms]</td>
</tr>
<tr>
<td>CAM 'minimum' Tx Rate ($R^x$)</td>
<td>1 Hz</td>
</tr>
<tr>
<td>CAM default Tx Rate ($R^{tx}$)</td>
<td>10 Hz</td>
</tr>
<tr>
<td>CAM triggering conditions: changes in position - speed - acceleration</td>
<td>5 m - 2 m/s - 1 m/s²</td>
</tr>
<tr>
<td>Default Tx Power ($P^x$)</td>
<td>23 dBm</td>
</tr>
<tr>
<td>Tx Power approaching CEN DSRC Toll Booth</td>
<td>10 dBm</td>
</tr>
<tr>
<td>CAM Routing</td>
<td>SHB</td>
</tr>
<tr>
<td>EDCA Queue / TC</td>
<td>1 DENM / 3 CAM</td>
</tr>
<tr>
<td>En threshold</td>
<td>-95 dBm</td>
</tr>
<tr>
<td>Modulation Schema</td>
<td>QPSK ½ 6 Mbit/s</td>
</tr>
<tr>
<td>Antenna Pattern</td>
<td>Omnidirectional, gain = 1 dBi</td>
</tr>
<tr>
<td>Access Technology</td>
<td>ITS G5A</td>
</tr>
<tr>
<td>ITS G5 Channel</td>
<td>CCH</td>
</tr>
</tbody>
</table>

Table 23: Scenario 1 and scenario 2 - communication scenario - no-hidden node

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tx Power</td>
<td>Fixed 23 dBm</td>
</tr>
<tr>
<td>Fading</td>
<td>LogDistance, Exponent: 2</td>
</tr>
<tr>
<td>Target CL</td>
<td>65 %</td>
</tr>
</tbody>
</table>
Results: Packet delivery ratio and Packet Inter-Reception Time

• Approach 1: Synchronous & Wait-and-Go
• Approach 2: Synchronous & Cancel-and-Go
• Approach 3: Asynchronous & Wait-and-Go
• Approach 4: Asynchronous & Cancel-and-Go
Packet inter-reception time and Delivery Ratio -- Approach 1: Synchronous & Wait-And-Go --
Packet inter-reception time and Delivery Ratio

--- Approach 2: Synchronous & Cancel-And-Go ---

![Graphs showing packet inter-reception time and delivery ratio vs distance for different scenarios.]

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Packet inter-reception time and Delivery Ratio

--- Approach 3: Asynchronous & Wait-And-Go ---

![Graphs showing Packet inter-reception time and Delivery Ratio](image)
Packet inter-reception time and Delivery Ratio

-- Approach 4: Asynchronous & Cancel-And-Go --

Distance (m)

DccOff-100m
DccReactive_4-100m
DccOff-45m
DccReactive_4-45m
DccOff-20m
DccReactive_4-20m
DccOff-10m
DccReactive_4-10m

Distance (m)

DccOff-100m
DccReactive_4-100m
DccOff-45m
DccReactive_4-45m
DccOff-20m
DccReactive_4-20m
DccOff-10m
DccReactive_4-10m

Packet inter-reception time (s)

Packet delivery ratio

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Packet inter-reception time -- Comparing the 4 Approaches --

- Cancel timer

- Cancelling the timer seems to be “BAD” idea!!

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Closer look to

- Approach 1: Synchronous & Wait-and-Go
- Approach 2: Synchronous & Cancel-and-Go
- Approach 3: Asynchronous & Wait-and-Go
- Approach 4: Asynchronous & Cancel-and-Go
Message generation behaviour at a node
Message generation behavior
- Scenario: 100m inter-vehicle distance-

- Synchronous approach:
  - Message generation interval switches between high or low values
Message generation behavior
- Scenario: 20m inter-vehicle distance-

- Synchronous approach:
  - Message generation interval switches between high or low values

Packet interval (s) vs Time (s) for synchronous approach.
Number of total transmissions during samples of time period
Number of transmissions
- Scenario: 100m inter-vehicle distance-

- Synchronous approach:
  - Nodes transmit in synchronized way
Number of transmissions
- Scenario: 45m inter-vehicle distance-

- Synchronous approach:
  - Nodes transmit in synchronized way
Number of transmissions
- Scenario: 20m inter-vehicle distance-

- Synchronous approach:
  - Nodes transmit in synchronized way

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Number of transmissions
- Scenario: 10m inter-vehicle distance-

- Synchronous approach:
  - Nodes transmit in synchronized way

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Average CBR during samples of time period
CBR vs Time
- Scenario: 100m inter-vehicle distance-

- Synchronous approach:
  - CBR fluctuates more
CBR vs Time
- Scenario: 45m inter-vehicle distance-

- Synchronous approach:
  - CBR fluctuates more
CBR vs Time
- Scenario: 20m inter-vehicle distance-

- Synchronous approach:
  - CBR fluctuates more

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CBR vs Time
- Scenario: 10m inter-vehicle distance-

- Synchronous approach:
  - CBR fluctuates more

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CBR at vehicles’ positions
CBR vs Position
- Scenario: 100m inter-vehicle distance-

![Graph showing CBR vs Position]

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CBR vs Position
- Scenario: 20m inter-vehicle distance-
Conclusion

- Depending on the behaviour of the Reactive DCC, the algorithm can or cannot perform better than non-DCC system.
- Because the control is based on a measurement of "common" channel, asynchronous control seems to be necessary.
  - Transmit first with a "random" interval before following the table parameter.
Thank you!

Oyunchimeg SHAGDAR
oyunchimeg.shagdar@inria.fr