Overview

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Introduction

What is Decentralized Congestion Control (DCC)?
DCC shapes the ITS-G5 ad hoc network traffic.

Why to shape the network traffic?
To ensure proper operation of safety applications.
Since high channel loads cause ...
    • ... long channel access delays and
    • ... packet collisions, which cause radio range degradation

Therefore, for safety relevant systems critical channel loads must be avoided!
How to shape the network traffic?

Decentralized Congestion Control (DCC)

- **IEEE 802.11** (MAC and PHY Layer)
  - Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
  - Enhanced Distributed Coordination Function (EDCA)
  - Quality of Service (QoS) and Access Categories (AC)

- **ETSI TC ITS**
  - Cross layer extension to IEEE 802.11
IEEE 802.11 CSMA/CA and QoS for broadcast packets

- **Arbitration Interframe Space (AIFS)**
- **Slot Time**
- **Contention Window (CW)**
- **Transmission Time**

**Message prioritization by PHY timing parameters.**

**EDCA mechanism**

<table>
<thead>
<tr>
<th>AC</th>
<th>CW_min</th>
<th>CW_max</th>
<th>AIFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC_VO</td>
<td>3</td>
<td>7</td>
<td>58 µs</td>
</tr>
<tr>
<td>AC_VI</td>
<td>7</td>
<td>15</td>
<td>71 µs</td>
</tr>
<tr>
<td>AC_BE</td>
<td>15</td>
<td>1023</td>
<td>110 µs</td>
</tr>
<tr>
<td>AC_BK</td>
<td>15</td>
<td>1023</td>
<td>149 µs</td>
</tr>
</tbody>
</table>

4 priorities (access categories)
historically called:
- VO ... voice
- VI ... video
- BE ... best effort
- BK ... background
EDCA limitations for broadcast packets

EDCA avoids most packet collisions up to moderate channel loads.
For high channel loads the probability increases that the CWs end simultaneously for several nodes.
⇒ both nodes can transmit at the same time.

ETSI TC ITS DCC

• DCC avoids this channel overload by ...
• ... message rate control, and in future
• ... by additional transmit power control, and later on
• ... by offloading data traffic to other channels.
Control input to the DCC algorithm

- **Local measurement** ⇒ simple to implement:
  - Local Channel Busy Ratio (CBR)

- **Global knowledge** ⇒ improves fairness and safety:
  - CBR dissemination
  - Message rate dissemination
  - Transmit power level dissemination
CBR determination principle* and accuracy

\[
CBR = \frac{\sum t_{\text{Busy}}}{\sum t_{\text{Clear}}} \quad \sum t_{\text{Busy}} + \sum t_{\text{Clear}} = 100 \text{ ms}
\]

*) IEEE 802.11 specifies a more complex CBR determination.
How to specify DCC?

- Specification based on a **testable** system behaviour limit.

- Proposal: **Upper CBR limit vs. node number**

- For a message length of 1 ms the **message rate limit** is:
Implementation examples ...

State Machine ($T_{off}$ proportional to CBR)

Continuous PI controller with upper and lower rate limits

Any other algorithm that matches the limit!
Single channel with local DCC information

Message generation parameters

DCC Facility

DCC parm. evaluation

CEN DSRC coexistence

DCC Access

CAM

DENM

Service

Appl.

Facilities Layer

Network and Transport Layer

Traffic class prioritization

DCC queues

Power control

Flow control

Local CBR

PHY / MAC / DRIVERS / RADIO (Chipset)

Access Layer
Multi channel with global DCC information

- Message generation parameters
- DCC Facility
- Channel DCC param.
- DCC parm. evaluation
- CEN DSRC coexistence
- DCC Access
- Global DCC TX param.
- Neighbour Table
- Global DCC RX param.
- Traffic class prioritization
- Local CBR
- DCC queues
- Power control
- Flow control
- Traffic class prioritization

Network and Transport Layer

- CAM
- DENM
- Service
- Appl.

Facilities Layer

Access Layer

PHY / MAC / DRIVERS / RADIO (Chipset)
Conclusions

IEEE 802.11 CSMA/CA plus EDCA works fine for moderate network loads.

For safety related applications the network load has to be controlled by an additional DCC algorithm.

The first implementation step will be done by a local CBR measurement, and a message rate control.

To improve fairness and safety, information sharing between the ITS-Ss will be necessary later on.

A coordinated power control will be necessary when high penetration rates are reached.

In addition, multi-channel DCC can be used.
Thank you!