Executive Summary

At the core of this first meeting on Decentralised Congestion Control (DCC) were two presentations that provided the current state of play on DCC in Europe with respect to the current ETSI standard (TS 102 687 v1.1.1) and also highlighted some of the more prominent features of DCC. Throughout the discussion that followed the presentations, it was generally agreed that the currently approved DCC standard is suitable for day 1 applications but improvements will need to be made for day 2 applications. The working group agreed to draft a document addressing open technical issues and the scope of DCC for C-ITS deployment in Europe.

Action List

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<tr>
<th>Nr.</th>
<th>Action</th>
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<tbody>
<tr>
<td>1</td>
<td>Document with proposals on DCC for C-ITS deployment. Deadline for the 1st draft: March 15, 2015.</td>
<td>All WG members</td>
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1. Opening of the meeting and adoption of the agenda (DG MOVE)

DG MOVE welcomed all participants and invited them to briefly present themselves. There has been a modification to the draft agenda with one presentation being removed after mutual agreement due to content overlap with the other two. The agenda was adopted by all the participants and is included in ANNEX I.

2. Presentations on several DCC topics of the agenda.

2.1 Presentation 1: "Decentralised Congestion Control from A to Z"

The first presentation was given by a member of WG6. Some of the key points of the presentation were the following:

On the necessity of DCC:
- C-ITS based on ITS-G5 is an ad hoc network and the number of users cannot be restricted
  - All network users are peers
  - Roadside units exist but these are not granting channel access or distributing resources among network members
  - The network must be scalable, you never know from time to time how many vehicles you have in your vicinity → vehicles need to adapt the C-ITS applications to the available channel resources
- We need to be on the same frequency channel
Decentralized network topology and moving network members
  - Must agree upon which channel to use for position message dissemination (e.g., BSM and CAM)
  - When everyone meets on one channel congestion can arise if no countermeasures are taken
  - Frequency re-use as done in cellular systems is not possible

Frequency spectrum is a scarce resource
The medium access control (MAC) method selected for ITS-G5 (being a blueprint of the US IEEE 802.11p) is a carrier sense multiple access (CSMA) algorithm
  - CSMA \(\Rightarrow\) first listen to the channel for a predetermined listening period \(\Rightarrow\) no activity \(\Rightarrow\) transmit directly \(\Rightarrow\) if activity on the channel \(\Rightarrow\) perform backoff procedure (wait a randomized time which is only decremented when the channel is perceived as free)
  - CSMA can cause severe performance degradation when there is a high number of users in the system
  - Many simultaneous transmissions due to, e.g., nodes reaching a backoff time of zero at the same time within radio range, or are out of carrier sense range of each other
  - Excessive Channel access delays
  - To this end, CSMA is an unreliable MAC method when the number of users in the system is large

On the goal of DCC:
  - Avoid unstable network behaviour due to the MAC method – CSMA
  - Divide the channel resources in a fair manner between the different network members
  - Make C-ITS applications aware of the current channel status and adapt them to existing circumstances
    - E.g., at a very high network load maybe disable certain C-ITS applications and inform the driver

On the different knobs to use for DCC:
  - Transmit power control (TPC)
    - Change output power on a packet-per-packet basis
  - Transmit rate control (TRC)
    - Generate message with specific inter-arrival time between packets (i.e., Hz)
  - Transmit datarate control (TDC)
    - Change datarate per packet
  - DCC sensitivity control (DSC)
    - Change the sensitivity of the transmitter to be more aggressive or more restrictive

On the input to the DCC algorithm:
  - Channel busy ratio (CBR) is the primary and currently the best input to the DCC algorithm
    - Day one applications are using broadcast as primary communication mode implying that traditional automatic repeat request (ARQ) methods are not possible as in unicast transmissions (i.e., there exist no feedback channel between sender and receiver)
    - The CBR is calculated as the time the channel has been busy divided by a predefined listening period, e.g., typical listening period is 100 ms
  - However, GeoNetworking provides the possibility to, e.g., include the used power of the packet

On TS 102 687 V1.1.1 for day one applications:
• Current approved version of TS 102 687 V1.1.1 is selected as the DCC for day one applications
• Based on an open loop principle (or table look-up)
• Above a certain channel load the control is once again handed over to the MAC layer
• Unpredictable for applications having higher demands on the communication
• Transmit rate control (TRC) will mainly be used for day one applications and the output power will be fixed
• However, transmit power control (TPC) will be used when approaching a toll plaza to guarantee co-existence between CEN DSRC at 5.8 GHz and C-ITS at 5.9 GHz (also the message rate might be affected in certain cases)
• CAM generation can be restricted via a parameter exposed to the management plane
• Decentralized Environmental Notification Messages (DENMs) cannot be controlled
  • No mechanism currently to restrict or inform applications on top of the facilities when the channel is very busy...
  • To this end, if DCC currently allows 5 Hz (5 packets/second) at the access layer, applications might generate more packets than this
    • Implying that packets will be dropped at the access layer
    • High priority DENMs will be transmitted

On DCC in the USA
• CAMP (C2C-CC’s counterpart in the US) has for several years investigated two different DCC algorithms X & Y through
  • simulations (the results have been published at prestigious IEEE conferences and journals, i.e., X & Y have been scrutinized)
  • real-world testing with 130 vehicles
• Only DCC on channel 172 where the basic safety messages (BSM), i.e., position messages, are going to be transmitted to guarantee timely channel access and low delays
• They have the possibility to build the DCC directly into the message generation

On connected automation, cooperative adaptive cruise control (CACC) and platooning
• Day one applications intend to inform the driver
• Day two – marriage between active safety systems and C-ITS
  • Connected automation, e.g., platooning, cooperative adaptive cruise control (CACC)
    • Lateral and longitudinal control of the vehicle (automated vehicles)
    • Information received wirelessly from other vehicles is input to the sensor fusion
  • Requirements on a more predictable DCC behaviour is required by these applications!
    • Otherwise the safety of the system cannot be guaranteed

Summary
• DCC is required by regulation (EN 302 571)
• DCC will kick in once we have many C-ITS equipped vehicles on the roads
• No European projects so far have elaborated on DCC in a real deployment scenario
• DCC in Europe needs to address several Facilities layer protocol (e.g., CAM, DENM) and must support at least two different networking & transport protocols
• Day one DCC is already in place → let’s deploy
• Day two applications have much more stringent requirements on the communication
  • It needs to be predictable!
  • Current DCC solution can never be part of connected automation due to its unreliability at high channel loads
2.2 Presentation 2: "DCC for ITS-G5 communication systems"

The second presentation was also given by a member of WG6. Some of the key points of the presentation are the following:

**On channel load:**
- High radio channel loads cause long access delays and packet collisions, which cause radio degradation.
- For safety relevant systems, critical radio channel loads must be avoided.
- DCC avoids channel overload by message rate control and in the future
  - by additional transmit power control and later on
  - by offloading data traffic to other channels

**On 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

**Summary**
- For safety related applications the network load has to be controlled by a 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.

3. Discussion on various DCC related topics

During and after each of the presentations the floor was open for discussion and the following points were raised by the participants:

**On performance, reliability and effectiveness of the current DCC mechanisms:**
- One participant stated that we need to ensure that certain messages are always transmitted. A reasonably busy channel ensures transmission every couple of milliseconds. When a message is dropped, DCC can give feedback to the application that a message has been dropped. One participant remarked that what is being thrown away is comparable to what you lose through radio transmission. When a channel gets full, it can happen that 2 stations are transmitting at the same time, and thus the receiver cannot decode. In that case, transmission without reception occurs, something that is undesirable. DCC can avoid having two stations emitting at the same time.
- DCC has a built-in message prioritization and always transmits the high priority messages.
The timeout in the physical layer can be very long and it should be avoided. This is why DCC is necessary.

One participant mentioned that the power control mechanism can cause sharing problems if C-ITS backs down because of Wi-Fi being present in the band. Wi-Fi LAN is very tricky to handle.

DCC simply provides a limit, in case the channel is free, users can use more of its resources.

The length of a transmitted message can be decided by the application.

Different algorithms and of various effectiveness can co-exist.

On the differences between ETSI and IEEE implementations:

One participant asked why DCC in Europe is implemented on the access layer while in the USA is located on the facilities layer. It was answered that the main reason is the existence of the Geonet protocol with forwarding. Forwarded messages load the channel and DCC in the access layer aims to limit the forwarding of the messages. In the USA there is no forwarding of messages and therefore the DCC was put on the facilities layer, which knows what applications exist. Another advantage of having DCC at the lower layer is that it guarantees the transmission of the packet.

DCC in Europe is more or less protocol agnostic and everybody can use a different algorithm.

On scalability and potential improvements:

Overall 1 Hz transmission frequency (i.e. 1 message/sec) gives a hard upper limit and at this transmission rate 700-1000 vehicles can be supported. For higher transmission frequencies that are necessary when the vehicles are moving faster as in a motorway (transmission rate about 10 Hz), the number of cars that can be supported by the channel is about 100. In a typical urban scenario, the channel load is less than 50% for receivers and transmitters.

One participant mentioned that currently on a motorway with 8 lanes, the maximum number of cars moving at normal speed is about 85, which can be supported by the channel without reaching saturation, even with a transmission frequency as high as 10 Hz. If the vehicles are driving slowly, their number can go up to 300 but since the transmission frequency is now smaller, they can still be supported by the channel.

The message rate control can work for up to 1000 stations (vehicles). Above that other mechanisms like coordinated power control should be implemented because the transmittance rate would need to be controlled.

The packet transmission around a street corner in an urban environment can occur with the presence of reflectors (buildings, windows, metal fences). In case there is an open space, the transmitted packets can go around the corner only with the presence of a passive reflector (e.g. a piece of metal).

The current DCC standard is mainly for day 1 applications. The revised version of the standard will minimise the chance of throwing away messages.

On other miscellaneous issues:

The ITS-G5C frequency band that ranges from 5,470 GHz to 5,725 GHz can be used for service announcements. We have to ensure that this lower frequency range stays covered in the ITS.

The issue of extending the DCC system to pedestrians has being raised. It was argued that the current DCC is designed for vehicles and extending it to include pedestrians is not trivial because DCC is very ITS-G5 oriented whereas for pedestrians 5.9 GHz is not very suitable (battery life issues). One participant argued that for pedestrians different technologies may be applied and to avoid congestion issues a separation between transmitters and receivers should be made with the pedestrians being restricted to the latter. Another participant raised the issue of positioning accuracy for pedestrians which, being in the order of a couple of meters is not
sufficient in an urban environment. One participant stated that despite these issues, an efficient system cannot be simply limited to vehicles.

- Regarding real world testing, it was mentioned that in the deployments performed so far, the number of vehicles was not sufficiently high in order to reach the channel saturation conditions.

4. Conclusion and further steps.

The overall consensus of the discussion was that DCC is sufficient for Day 1 applications, however for day 2-3 applications like, for example, platooning, more capacity will be needed and improvements in the standard are necessary. Taking this into consideration, it was agreed between the participants to produce a document with some recommendations on the open technical issues and the scope of DCC for C-ITS deployment in Europe. This document will also contain some background information on the topic and contributions from all the WG participants are strongly encouraged. The deadline for the first draft was set to be March 15, 2015. A conference call will be scheduled after that date where the possibility of a physical meeting for finalising the document will be considered.
Annex I: Agenda

**Agenda**

1. **Welcome and adoption of the agenda**

2. **Presentations on the current state of play in DCC**
   - Presentation I from a member of WG6
   - Presentation II from a member of WG6

3. **Discussion on DCC mechanisms**
   - Performance, reliability and effectiveness of the existing DCC mechanisms.
   - Differences between the ETSI and IEEE implementations.
   - Test results from simulations or real life deployment scenarios.
   - Potential improvements on the existing mechanisms (optimal parameterisation and mechanism/approach selection); is an update on the existing standards necessary?
   - Scalability and readiness to incorporate future applications without compromising the basic safety functions.
   - Other strategic issues.

4. **Conclusion, follow up and next steps.**
Annex II: List of participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
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<tbody>
<tr>
<td>Alain Servel</td>
<td>PSA Peugeot Citroen</td>
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<td>Angelos Amditis</td>
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<td>Bettina Erdem</td>
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<td>Kapsch</td>
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<td>Erik Olsen</td>
<td>Public Roads Administration (NO)</td>
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<td>Hennes Fischer</td>
<td>Yamaha</td>
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<td>Johanna Despoina Tzanidaki</td>
<td>Tom Tom</td>
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<td>Jose Manuel Menendez</td>
<td>Indiv Expert</td>
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<td>Katrin Sjöberg</td>
<td>Volvo</td>
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<td>Klaas Rozema</td>
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<td>Maria Paola Bianconi</td>
<td>FIAT</td>
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<td>Markus Riederer</td>
<td>FEDRO (CH)</td>
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<td>Neil Pattemore</td>
<td>FIGIEFA</td>
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<td>Niels Andersen</td>
<td>Car2Car</td>
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<td>Pär Degerman</td>
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<td>Alain Van Gaever</td>
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