Reduced Delay for DENM Dissemination in IEEE 80211p-Based Platooning Applications

Annette Böhm
Magnus Jonsson
Elisabeth Uhlemann

Presentation Overview

”Reduced Delay for DENM Dissemination in IEEE 802.11p-Based Platooning Applications”
[submitted to WiVeC 2013]

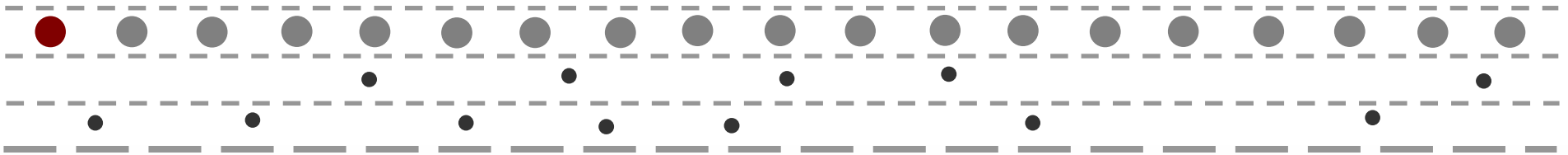
- Background and assumptions
- Proposed enhancements to the standard regarding DENM dissemination within a platoon
  - DENM send rate
  - DENM dissemination models
  - Prioritization through added offsets
- Simulation results

The platooning scenario

- Platoon of trucks sharing e.g. a highway with other 802.11p-enabled vehicles
- Leading vehicle with special, coordinating responsibilities
- Overall goal
  - Reduce vehicle spacing to gain fuel efficiency
  - Still maintain reasonable level of safety both for platoon and non-platoon vehicles

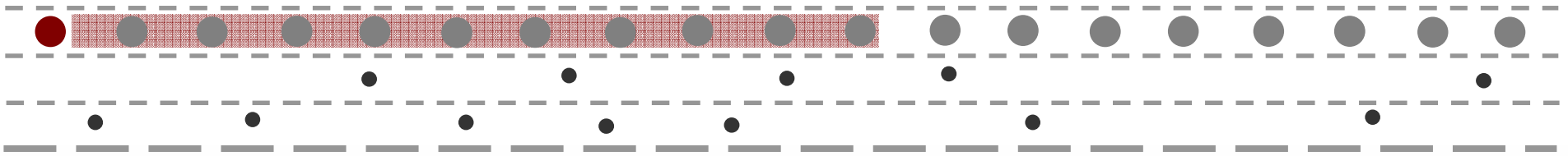
→ fast and reliable inter-platoon communication

→ context awareness

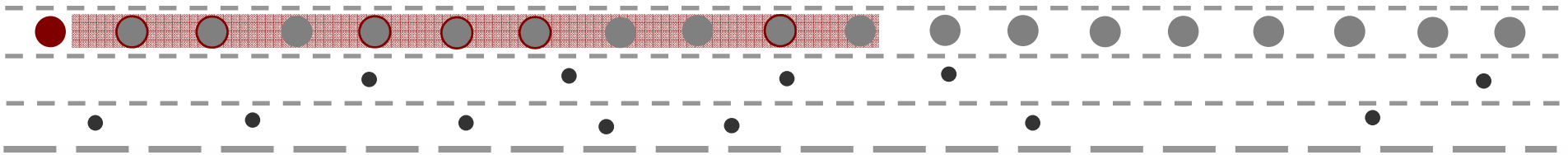


Assumptions

- General
  - IEEE 802.11p MAC with CSMA/CA and 4 priority levels
  - DENM and CAM message types
  - Single control channel shared by DENMs and CAMs
  - Data rate 6 Mbit/s
  - Packet size 800 byte
- Scenario specific
  - Platoon of 10-20 vehicles
  - Antenna-to-antenna spacing 30 m
  - Radio range of 500m (Rician fading + shadowing model)

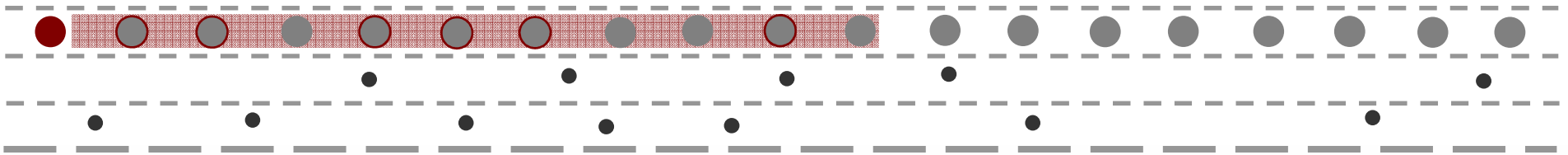


- Scenario specific assumptions (cont.)
  - CAMs sent out periodically by platoon and non-platoon vehicles (send rate 2 Hz)
  - DENMs used for dissemination of warning and control data from leading vehicle backwards in the platoon (variable send rate)
    - Event triggers DENM generation in platoon leader
    - DENMs are relayed/rebroadcasted by platoon members



Fast DENM dissemination

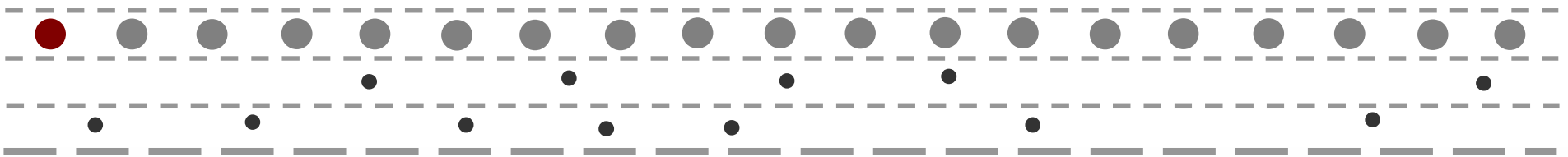
- With what frequency should a DENM be rebroadcasted periodically by a vehicle after initial reception?
  - Standard: 1-20 Hz
- When should the dissemination process seize?
  - Standard: no acknowledgements to tell who successfully received the packet
- Who should take part (be prioritized) in the dissemination process?
  - Standard: after reception a vehicle immediately tries to access the channel for rebroadcasting



Send rate

- With what frequency should a DENM be rebroadcasted periodically by a vehicle after initial reception?
  - Increase send rate beyond 20 Hz

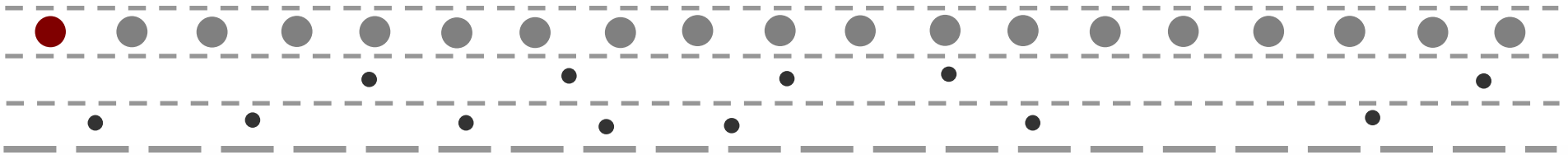
    (depending on the nature of the event, the relative speed of the vehicles, the number of platoon members and the current channel load)



Dissemination model

- When should the dissemination process seize?
  - Flooding with x repetitions
    - Depending on radio conditions and platoon lenght this number can be adjusted

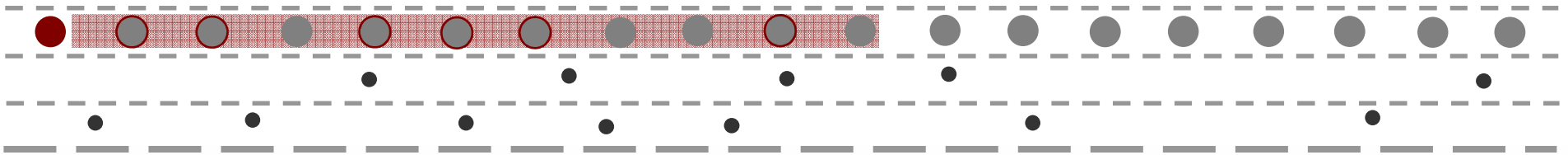
    vs.
  - Flooding until DENM is received from a vehicle behind
    - As soon as a vehicle receives a DENM from a vehicle situated further back in the platoon it assumes that the dissemination process to the back of the platoon will continue without its help



Offset model

- Who should take part (be prioritized) in the dissemination process?
  - Built-in rebroadcast order due to slight differences in propagation delay
    - Vehicle closest to the sender (here: platoon leader) access channel first and force the remaining vehicles into backoff
    - Counterproductive to fast dissemination to the back of the platoon

  → Reverse offset
    - Add additional offset to reverse that built-in send order
    - Offset depends on position in platoon
    - Offset calculated as: (nbr_veh – veh_ID) * slottime
      - Slottime = 13 µs



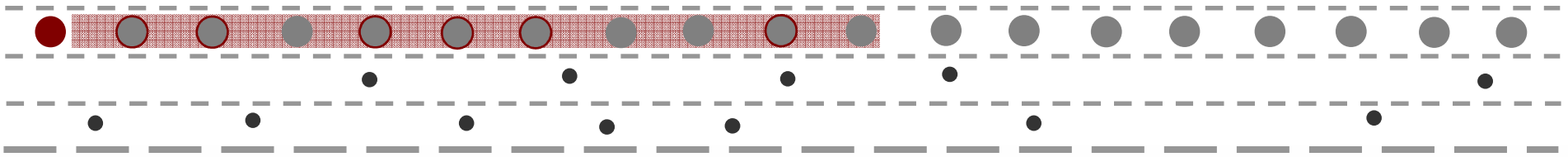
Offset model

- Reverse offset chances the ”send order” but does not prevent channel access attempts while the channel is busy by another DENM rebroadcast

→ Slotted offset

  - Adjust offset time so that a transmission is just finished when the next vehicle attempts its channel access
  - Can be calculated based on platoon length, transmission delay and propagation delay
  - A certain (reoccuring) time slot is assigned to an individual vehicle based on its position in the platoon (again enforcing a reverse send order)
  - A time slot is calculated as: $L_{timeslot} = L_{AIFS} + D_{trans} + D_{prop\_max}$.

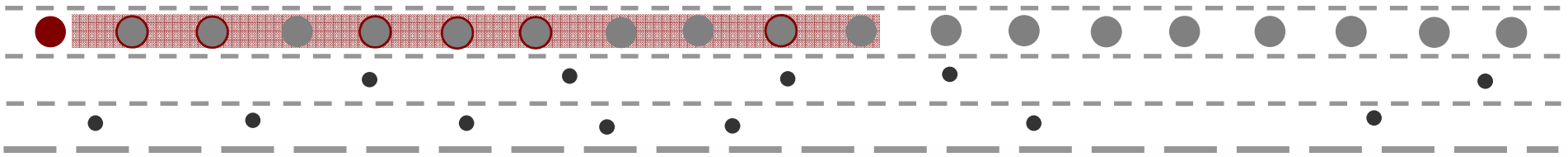
    L_{AIFS} : Lenght of an AIFS
    D_{trans} : Transmission delay of 1 packet
    D_{prop_max}. : Max propagation delay



Offset model

→ Slotted offset

- Distributed
  - Each vehicle knows its slot based on knowledge of its own position within the platoon and a time stamp send with the initial DENM
- ”Send rate” concept obsolete
  - Each vehicle uses its reoccuring time slot until dissemination process seizes
  - i.e., periodicity depends on actual platoon size



Simulation results

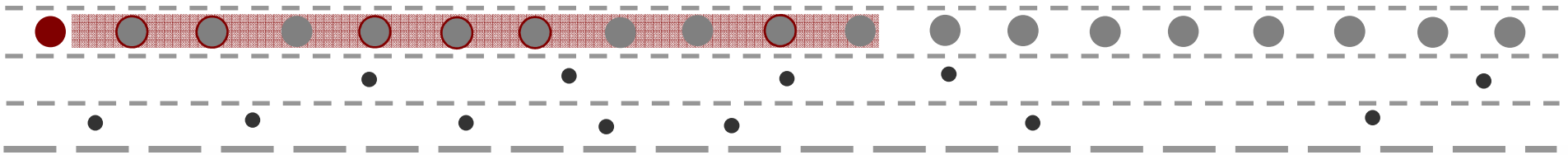
- Matlab simulator
- Monitor effect of different combinations of
  - Send rate
  - Dissemination model
  - Offset model

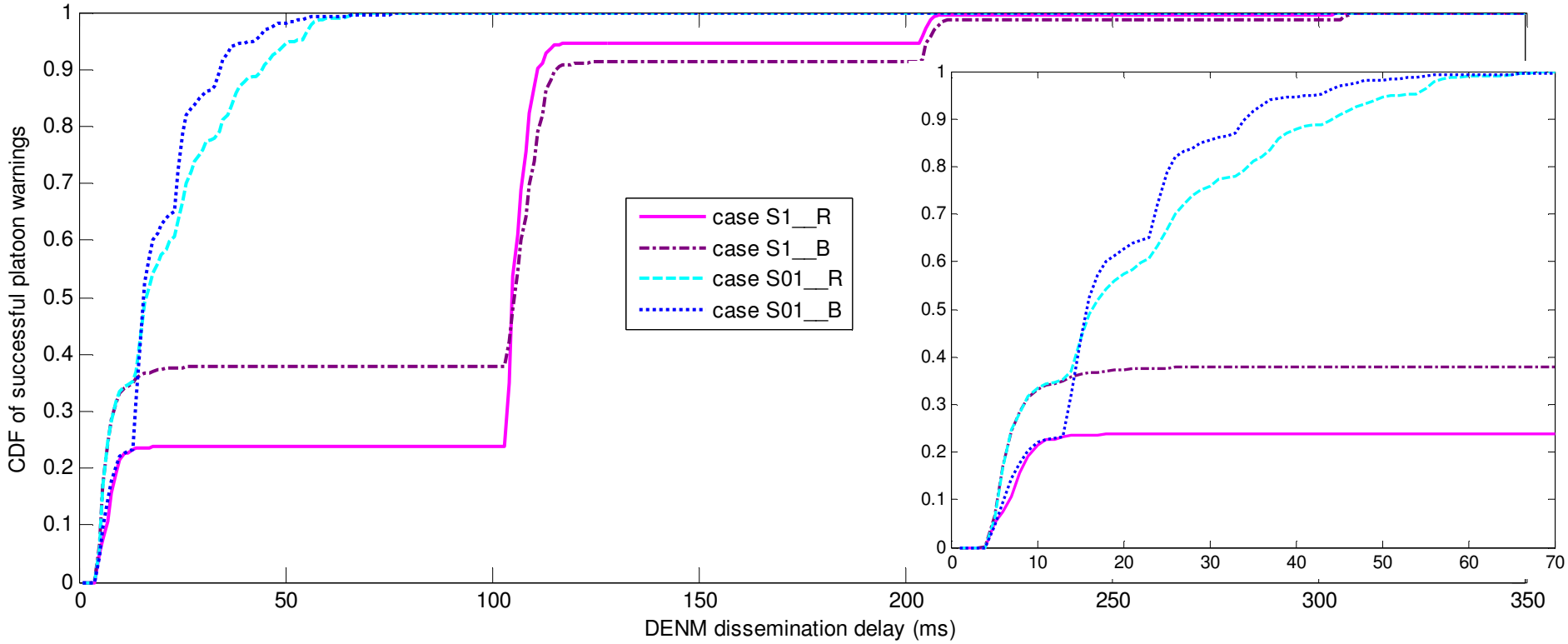
  on the
  - Delay until the entire platoon received a warning

    (***DENM dissemination delay:*** How much time has passed from the generation of the first event-triggered DENM by the platoon leader until the entire platoon received a ”copy”)
  - Performance of other traffic classes

    (***CAM up-to-dateness:*** how old is the CAM-based information from e.g. the in-front neighbor a vehicle holds when a new CAM from the same neighbor arrives)

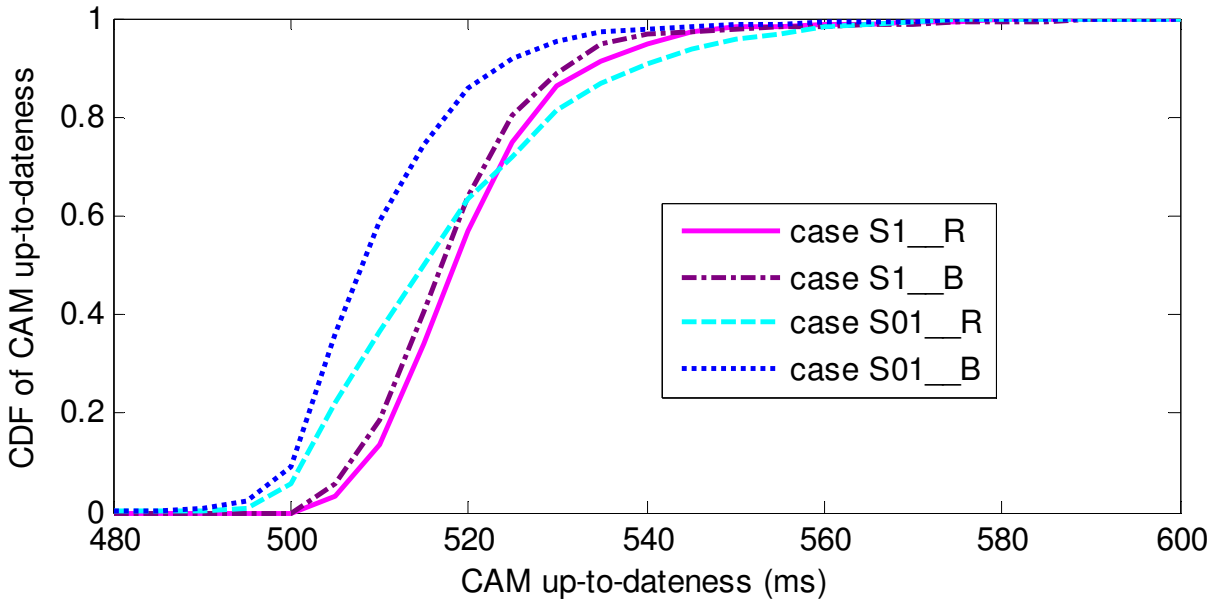
  over 1000 simulated runs





DENM dissem. delay for different send rates and dissem. models.

case	send rate	dissemination	offset	platoon
S1_R	0.1s	'5 repetitions'	no offset	20 veh.
S1_B	0.1s	'until DENM fr. behind'	no offset	20 veh.
S01_R	0.01s	'5 repetitions'	no offset	20 veh.
S01_B	0.01s	'until DENM fr. behind'	no offset	20 veh.



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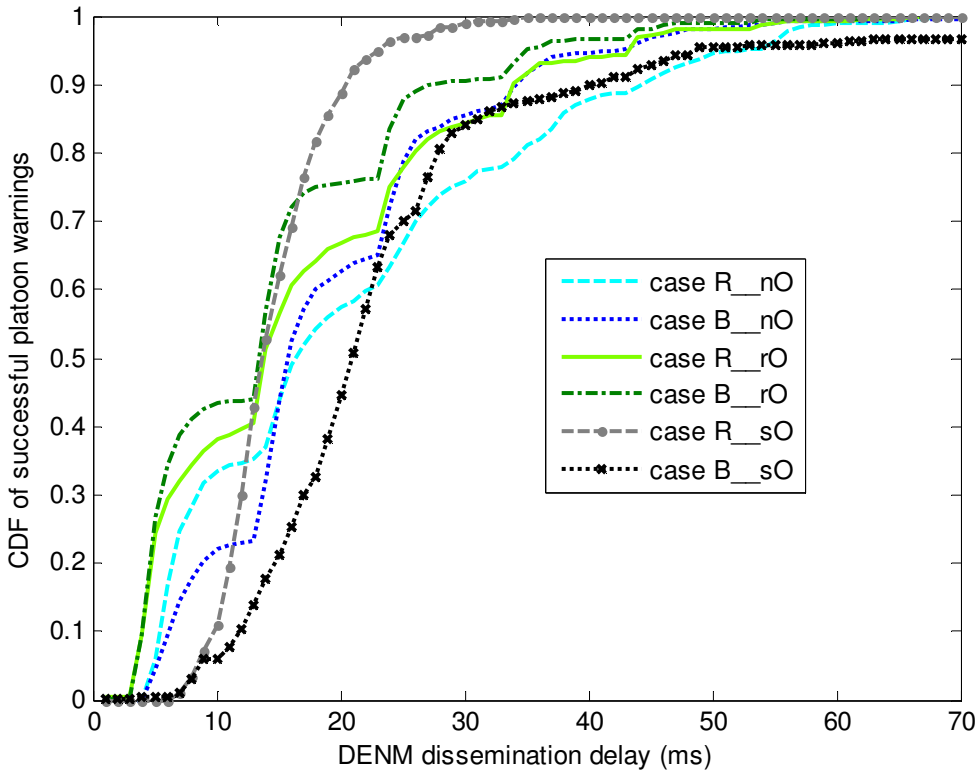
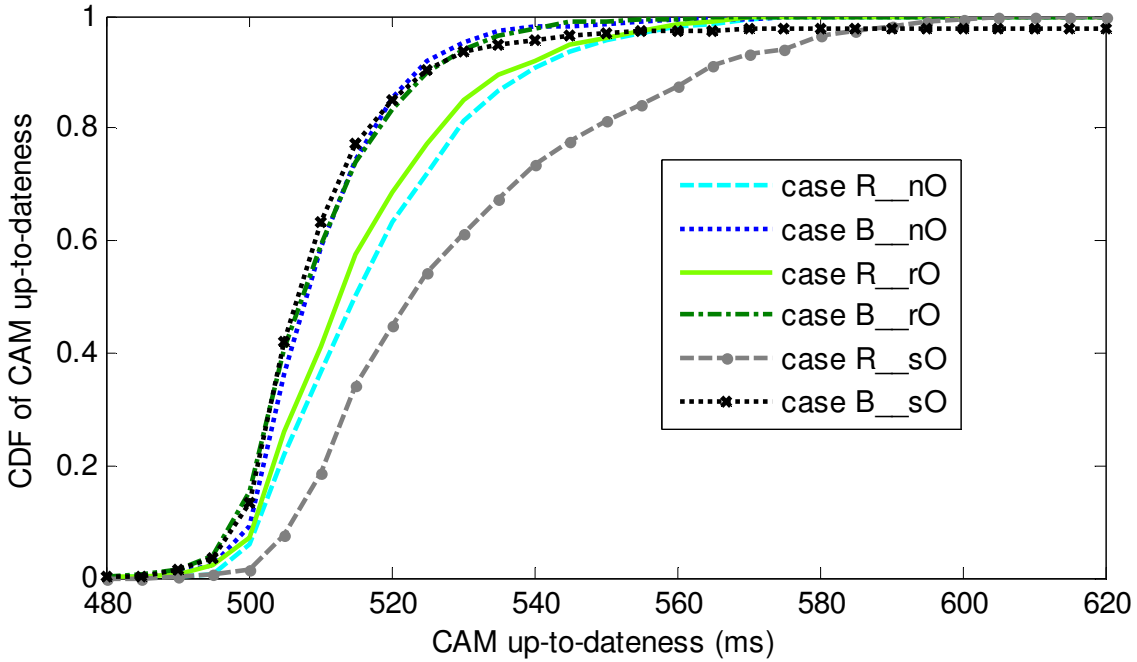


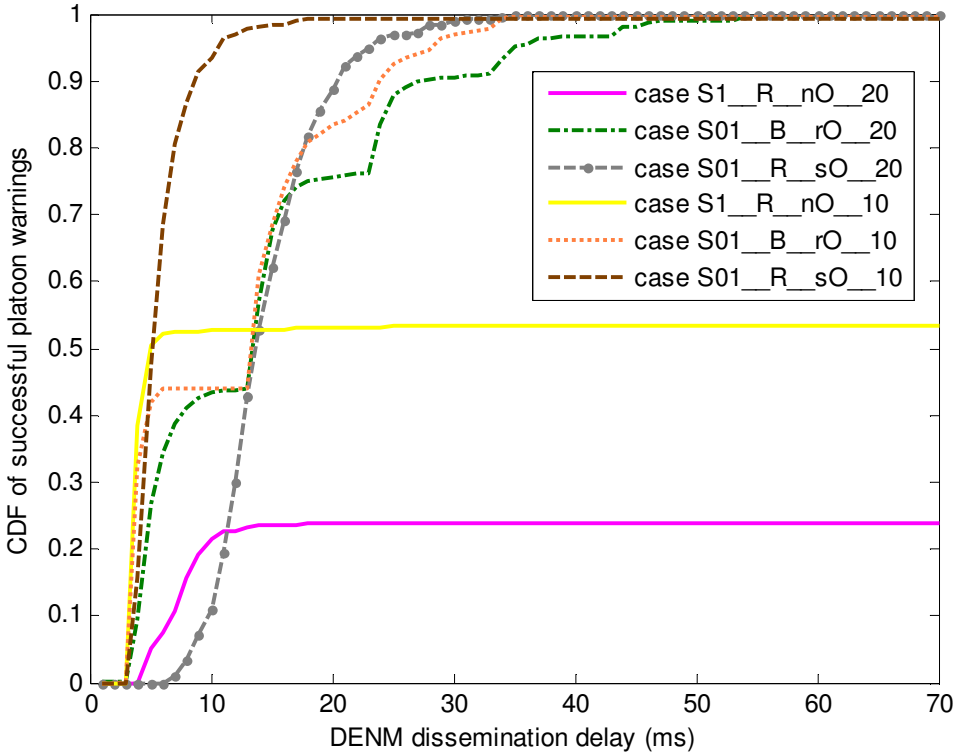
DENM dissem. delay for different dissem. and offset models.

case	send rate	dissemination	offset	platoon
R_nO	0.01s	'5 repetitions'	no offset	20 veh.
B_nO	0.01s	'until DENM fr. behind'	no offset	20 veh.
R_rO	0.01s	'5 repetitions'	reverse	20 veh.
B_rO	0.01s	'until DENM fr. behind'	reverse	20 veh.
R_sO	n.a.	'5 repetitions'	slotted	20 veh.
B_sO	n.a.	'until DENM fr. behind'	slotted	20 veh.



CAM up-to-dateness for different dissem. and offset models.

case	send rate	dissemination	offset	platoon
R_nO	0.01s	'5 repetitions'	no offset	20 veh.
B_nO	0.01s	'until DENM fr. behind'	no offset	20 veh.
R_rO	0.01s	'5 repetitions'	reverse	20 veh.
B_rO	0.01s	'until DENM fr. behind'	reverse	20 veh.
R_sO	n.a.	'5 repetitions'	slotted	20 veh.
B_sO	n.a.	'until DENM fr. behind'	slotted	20 veh.



DENM dissem. delay for different platoon sizes

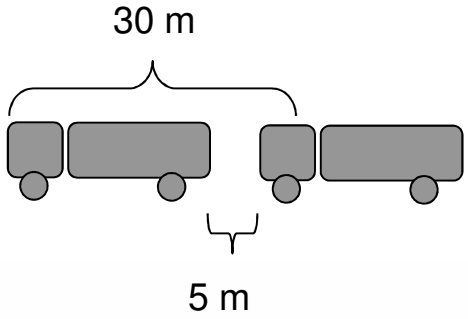
case	send r.	dissemination	offset	platoon
S1_R_nO_20	0.1s	'5 repetitions'	no offset	20 veh.
S01_B_rO_20	0.01s	'until DENM fr. beh.'	reverse	20 veh.
S01_R_sO_20		'5 repetitions'	slotted	20 veh.
S1_R_nO_10	0.1s	'5 repetitions'	no offset	10 veh.
S01_B_rO_10	0.01s	'until DENM fr. beh.'	reverse	10 veh.
S01_R_sO_10		'5 repetitions'	slottled	10 veh.

Conclusion

Through

- Simple additions/enhancements of the IEEE 802.11p standard
- Context aware choice of
  - Send rate
  - Dissemination model
  - Offset model

we achieved a reduction in DENM dissemination delay from 320ms (unaltered standard, 10Hz send rate) to 35 ms (slotted offset, 100 Hz send rate) while still maintaining service to lower priority traffic classes (e.g. CAM)



At 90 km/h:
5 m ~ 200 ms