Is Packet Dropping a Suitable Congestion Control Mechanism for Vehicular Networks?

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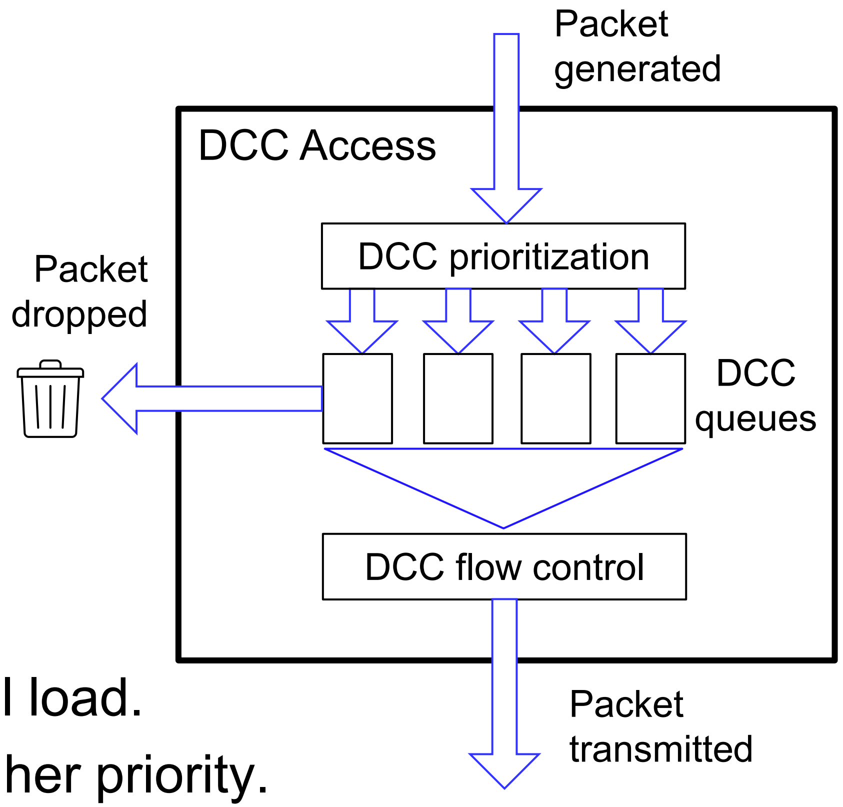
Introduction

- Vehicular networks based on V2X exchange of information.
  - Radio channel has limited bandwidth and channel load needs to be controlled.
- ETSI Decentralized Congestion Control (DCC).
  - DCC Access: packet tx rate control based on packet dropping.
  - Reduction of interference: improvement of performance at radio level.
  - Packets dropped are not transmitted and hence lost from the application perspective.
- Objective: study impact of DCC Access V2X performance.
  - Analysis at radio and application levels.
  - Different DCC Access approaches, varying packet priorities and mixed traffic scenarios.

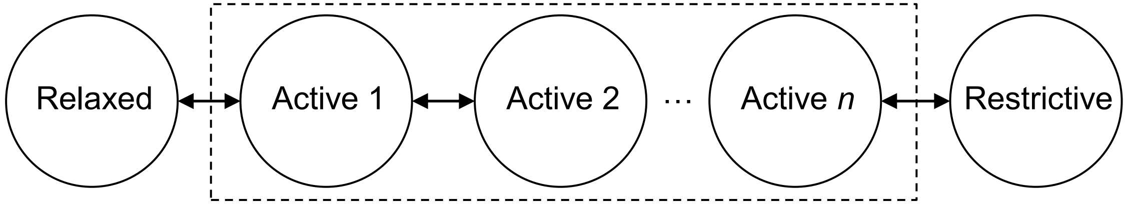
ETSI DCC Access

- Prioritization:
  - Packets classified in 4 different DCC Profiles (DP).
- Queuing:
  - Packets must wait until a new tx is allowed.
  - If a queue is full, packets are dropped.
- Flow control:
  - Adapts time between tx packets (T_{off}) based on channel load.
  - Low priority packets tx when there is no packet with higher priority.
  - Two approaches defined: Reactive and Adaptive.



ETSI DCC Access

- Reactive approach:
  - Based on a state machine, where the current state depends on the channel load.
  - Each state has a maximum packet rate (minimum interval T_{off}).



State	CBR	Packet rate	T_{off}
Relaxed	< 30%	20 Hz	50 ms
Active 1	30% to 39%	10 Hz	100 ms
Active 2	40% to 49%	5 Hz	200 ms
Active 3	50% to 65%	4 Hz	250 ms
Restrictive	> 65%	1 Hz	1000 ms

- Adaptive approach:
  - Linear control process to adapt the packet transmission rate (or interval T_{off}).
  - Designed to converge to a target channel load value of CBR_{target} = 68%.

Simulation set-up

- Simulation tool: ns-3
  - DCC Access module available: https://github.com/msepulcre/DCC-ns3

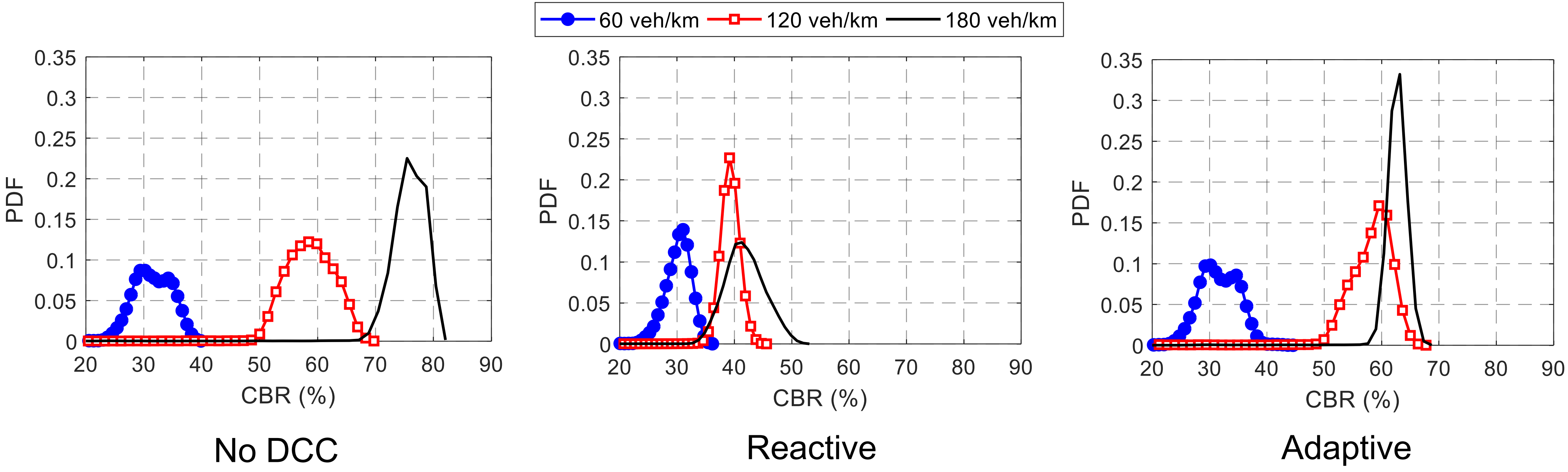
- Traffic parameters: 6 lane highway scenario.
  - Traffic densities: 60, 120 and 180 vehicles/km.
  - Vehicle speed: 100 km/h (for all densities).

- Message generation rate:
  - CAM rate: 3 Hz; CAM size: 350 bytes; DCC profile: DP2.
  - CPM rate: 8.5 Hz; CPM size: 261 bytes; DCC profile: DP2 or DP3.

- DCC Access:
  - Reactive and Adaptive approaches implemented and evaluated.
  - Queue length: 10 packets; Packet Time to Live: 1 second.

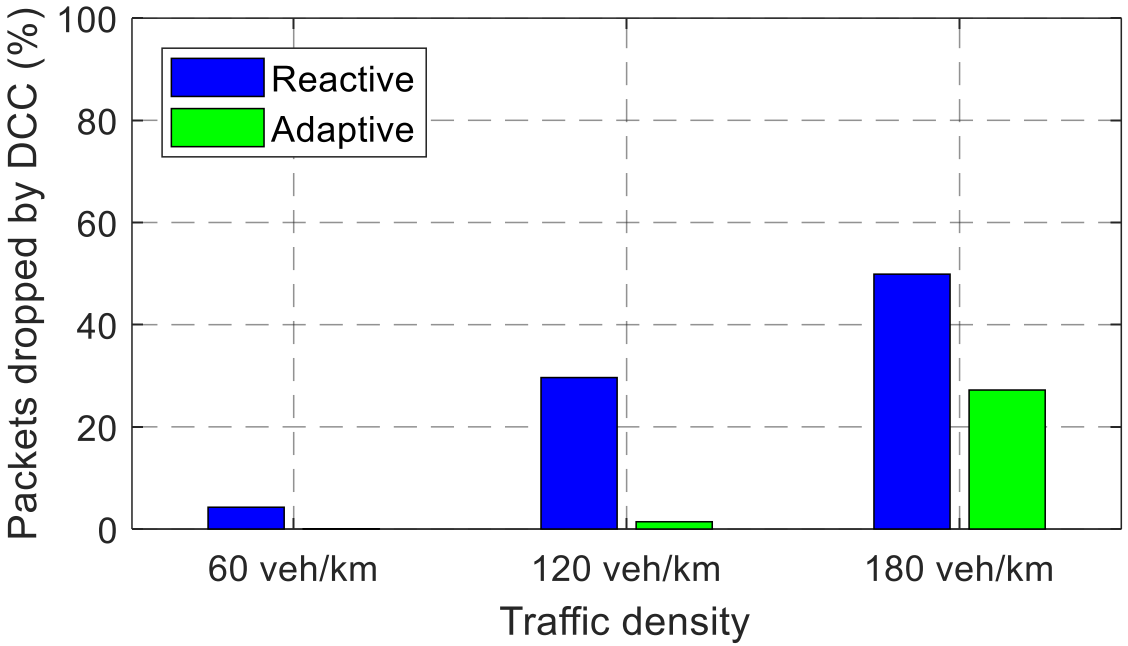
Evaluation results

- Channel load or Channel Busy Ratio (CBR).
  - Without DCC, CBR increases with density up to more than 80%.
  - Reactive approach drastically reduces the CBR below 50%.
  - Adaptive approach limits the maximum CBR to 68%.



Evaluation results

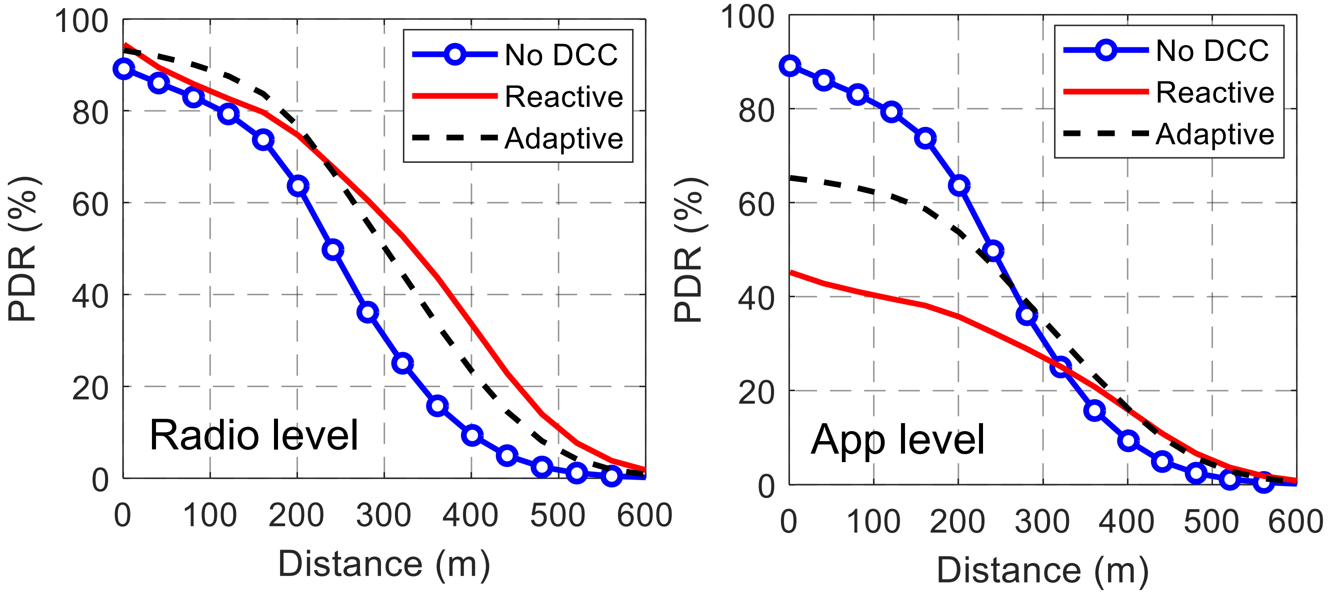
- Packets dropped by DCC at Access layer.
  - DCC drops packets to control the channel load.
  - Reactive approach increase the packet drop significantly.
  - Packets dropped are not transmitted, hence lost.



Evaluation results

- Packet Delivery Ratio (PDR).
  - DCC improves PDR at radio level due to lower interference.
  - DCC degrades PDR at application level.
    - Highest density: significant portion of packets generated are not transmitted.
    - Medium and low density: Adaptive and No DCC have similar performance.

PDR at radio level: ratio between packets received and transmitted



PDR at app level: ratio between packets received and generated

Traffic density: 180 veh/km; all packets DP2

Evaluation results

- Packet prioritization: CAM as high priority (DP2) and CPM as low priority (DP3).
  - Almost no CAMs are dropped because their higher priority.
  - Up to 70% (Reactive) and 37% (Adaptive) of CPMs are dropped.

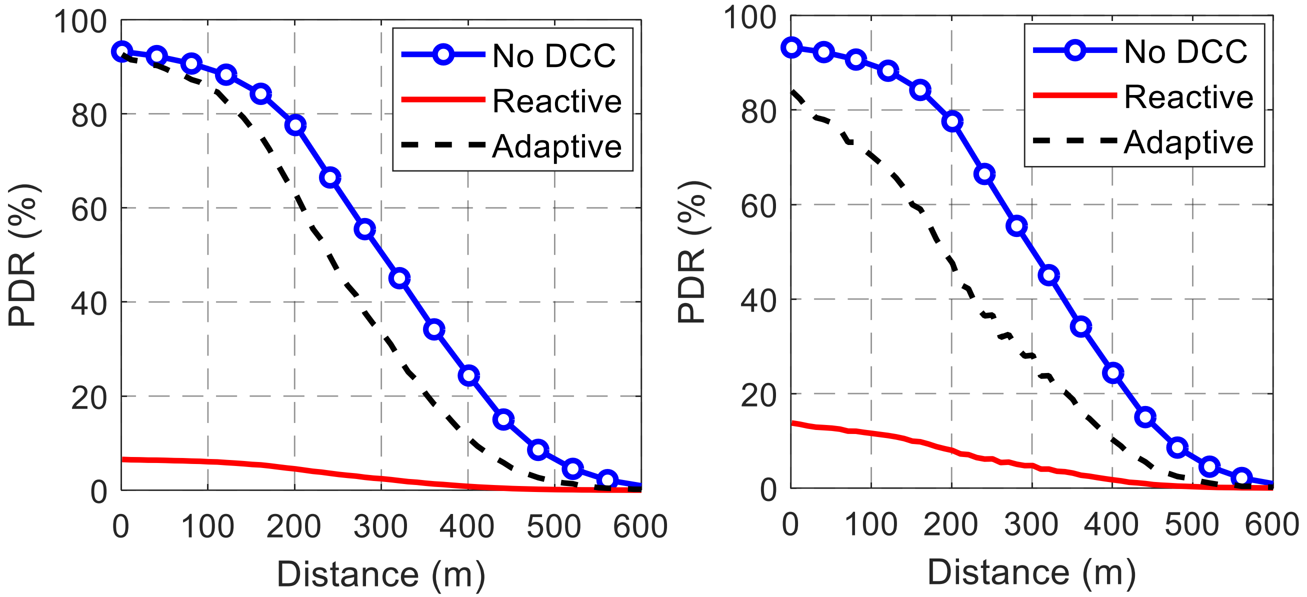
Traffic density	Reactive		Adaptive	
	CAM	CPM	CAM	CPM
60 veh/km	0.09 %	5.9 %	0.08 %	0.8 %
120 veh/km	0.05 %	40.3 %	0.03 %	2.2 %
180 veh/km	0.10 %	70.4 %	0.07 %	37.2 %

Packets dropped by DCC when CAMs are configured as DP2 and CPMs as DP3

Evaluation results

- Mixed of vehicles using Reactive and Adaptive.
  - Best performance achieved when DCC is not used.
  - Vehicles using Reactive experience a significantly low performance.
  - Increasing vehicles using Reactive decreases the performance of Adaptive.

PDR at application level for 120 veh/km and all packets DP2



25% Reactive – 75% Adaptive

50% Reactive – 50% Adaptive

Conclusions

- Congestion control based on packet dropping degrades application level performance.
  - A significant portion of packets are generated, but not transmitted.
  - Not using congestion control can provide better performance than packet dropping.
- DCC needs adequate configuration.
  - Lower priority services/applications can be highly degraded.
  - In mixed scenarios, vehicles using Reactive degrade the performance.
- Future alternatives are needed to reduce and control the load.
  - More intelligent message generation.
  - Power or data rate control.
  - V2X message compression.

Thank you for your attention

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