Analysis of Message Generation Rules for Collective Perception in Connected and Automated Driving

Gokulnath Thandavarayan, Miguel Sepulcre, Javier Gozalvez

gthandavarayan@umh.es, msepulcre@umh.es, j.gozalvez@umh.es

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TransAID

Introduction

- Automated Vehicles are equipped with multiple sensors
  - Sensors limitations degrade perception capabilities
- Connected and Automated Vehicles perform V2X communication
  - Improve perception by exchange sensor information
  - Commonly referred as collective perception
- ETSI draft standard for collective perception
  - Defines message format and structure
  - Defines message generation rules
- Analyze impact of different message generation rules
  - Study trade-offs between perception and channel load

ETSI collective perception standard

- Share sensor information as object descriptions
  - Basic information about position, speed and size of detected objects
  - Reduce message size

- Collective Perception Message (CPM) format:
  - Management & Station Data Container: information about transmitter
  - Sensor Information Containers: sensing capabilities
  - Perceived Object Containers: dynamic state and properties of objects

ETSI collective perception standard

- CPM generation rules (checked every *T*)
  - Only a CPM is generated & detected objects included:
    1. If: New detected objects
    2. If: Previously detected Vulnerable Road Users (VRU) or animals
    3. If: Previously detected objects whose position changed > 4m
    4. If: Previously detected objects whose speed changed > 0.5m/s
    5. If: Previously detected objects included in CPM 1 second ago
  - Sensor Information Containers included in CPM once per second
  - If no object is detected: generate CPM once per second

CPMs generated with variable size and rate

Simulation set-up

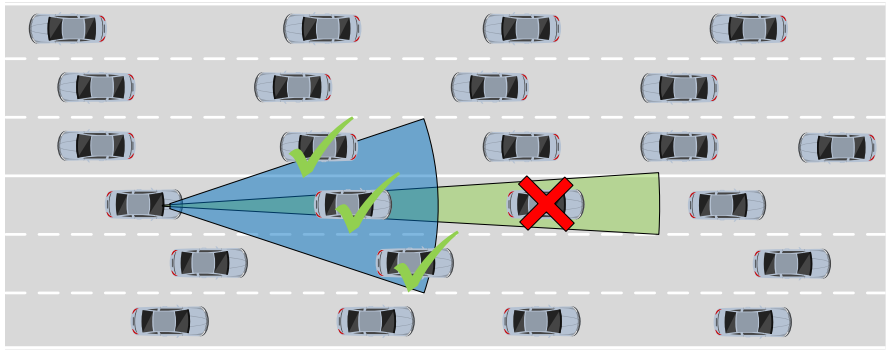
- Simulation tools:
  - ns3 (ITSG5 communications)
  - SUMO (vehicle mobility)

- Traffic parameters: (6 lane highway scenario)
  - High traffic density: 120 vehicles/km, 70km/h-59km/h speed
  - Low traffic density: 60 vehicles/km, 140km/h-118km/h speed

Simulation set-up

- Evaluated CPM generation policies
  - DYN: dynamic CPM generation following ETSI standard draft
  - P2: periodic CPM generation at 2Hz
  - P10: periodic CPM generation at 10Hz

- Onboard sensors:
  - 65m range and ±40 degrees
  - 150m range and ±5 degrees

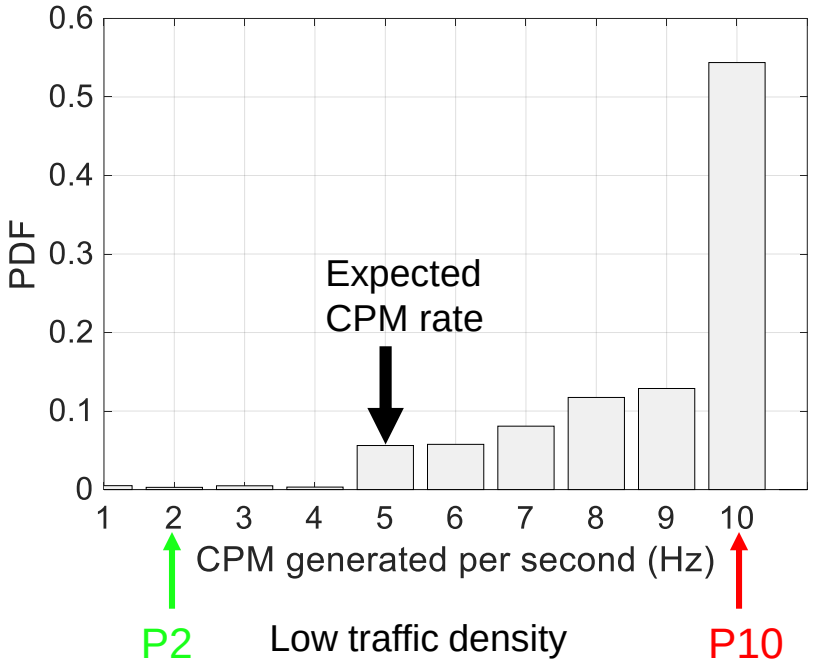


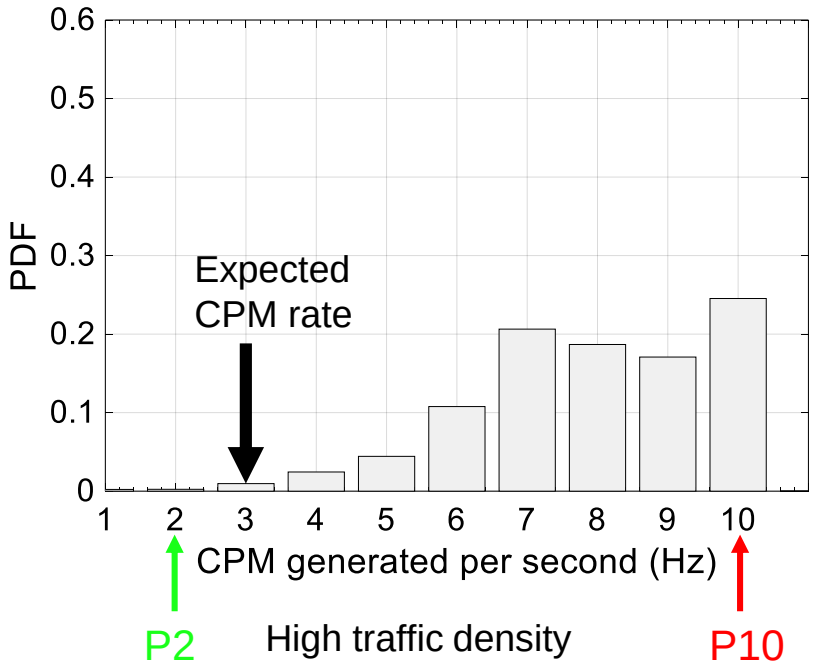
Only vehicles in Line of Sight can be detected

Evaluation results

- Number of CPM transmitted per second
  - Depends on vehicle speed and traffic density
  - CPM rate higher than expected: mobility of objects
    - 3. If: Previously detected objects whose position changed > 4m

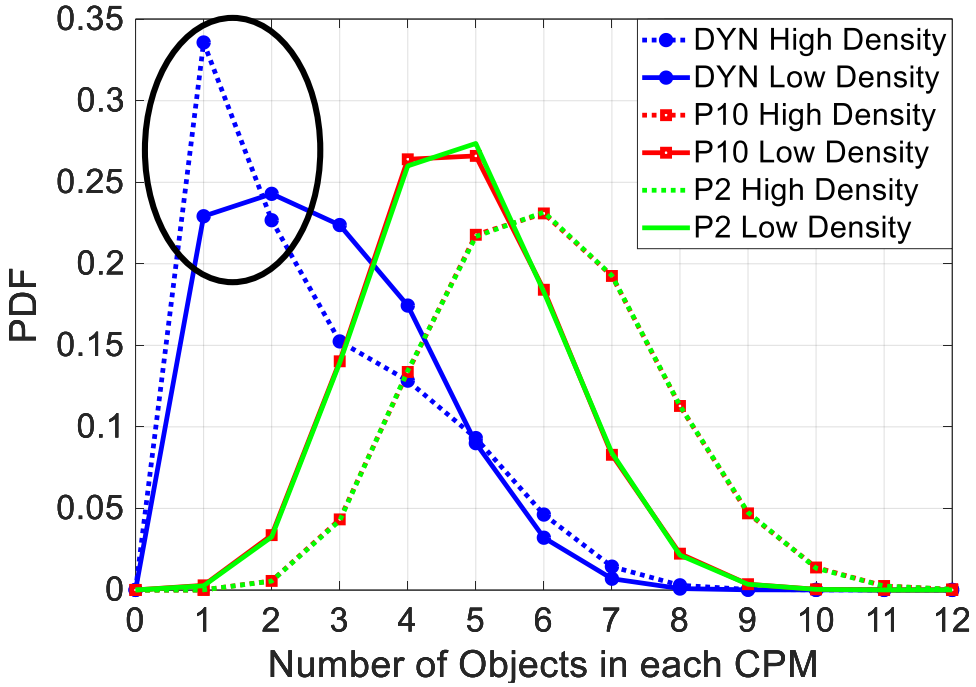
Periodic rate: constant





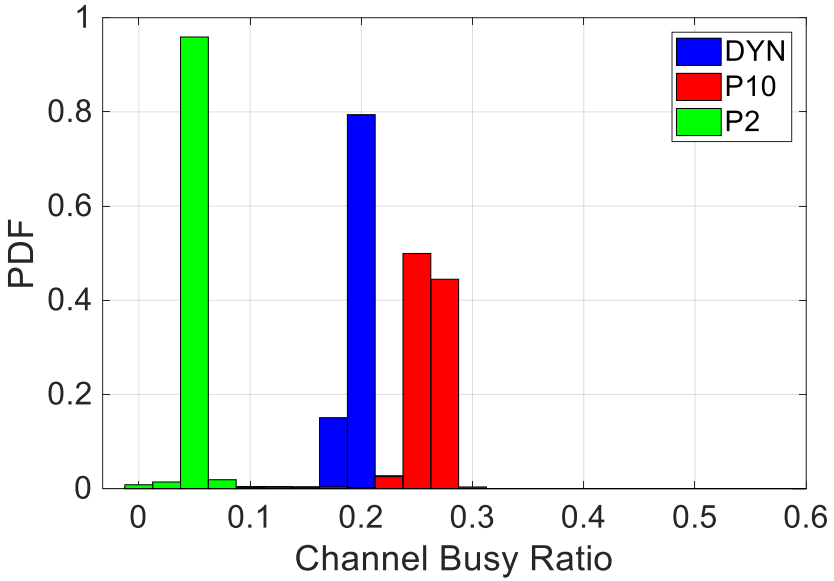
Evaluation results

- Number of objects transmitted in each CPM
  - P2 and P10: higher densities increase number of objects
  - DYN: lower number of objects, i.e. small CPMs
    - Trade-off: speed decrease with higher density

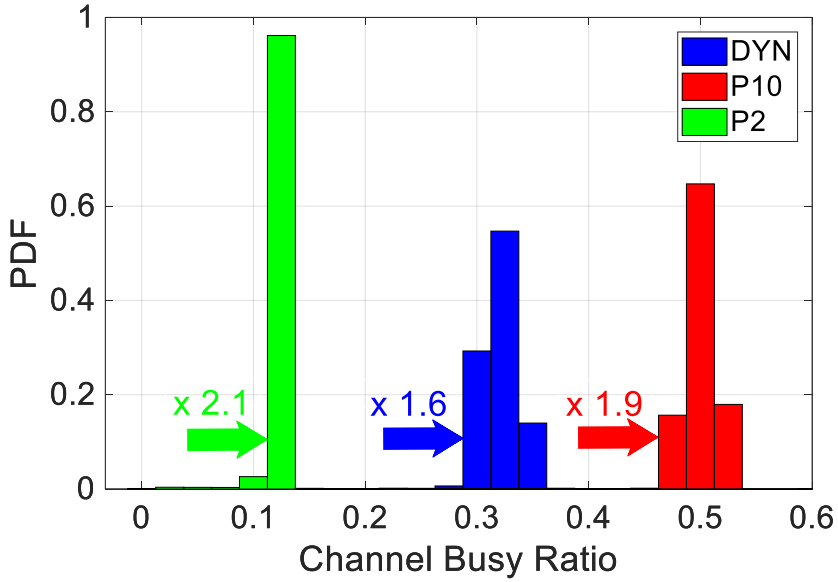


Evaluation results

- Channel Busy Ratio: % of time that the channel is busy
  - DYN: intermediate channel load between P2 and P10
  - Same trends for high traffic density
    - Smallest relative increase for DYN due to lower speeds



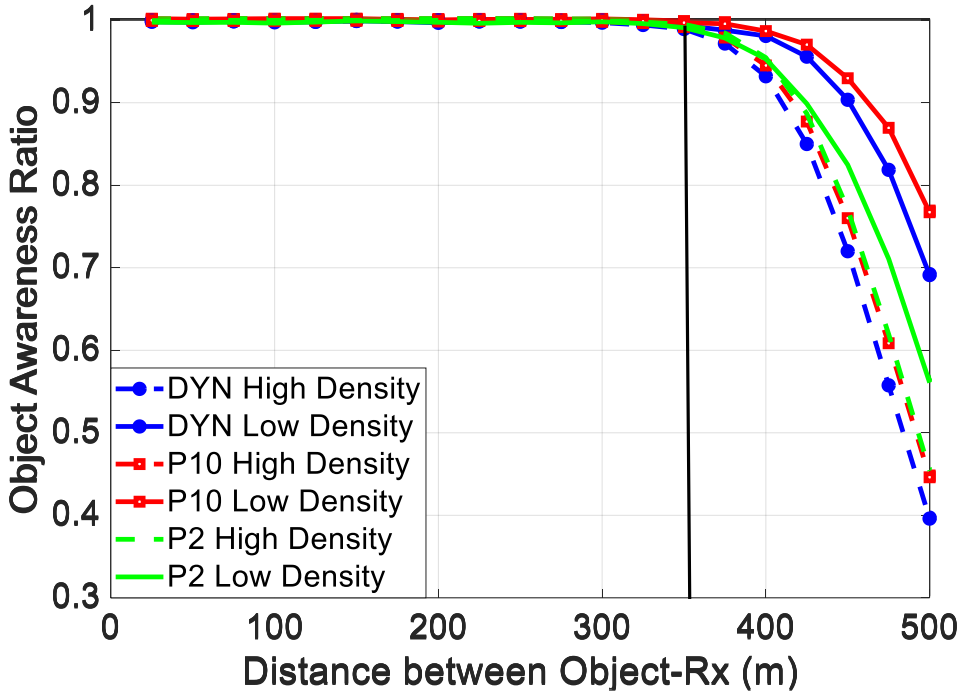
Low traffic density



High traffic density

Evaluation results

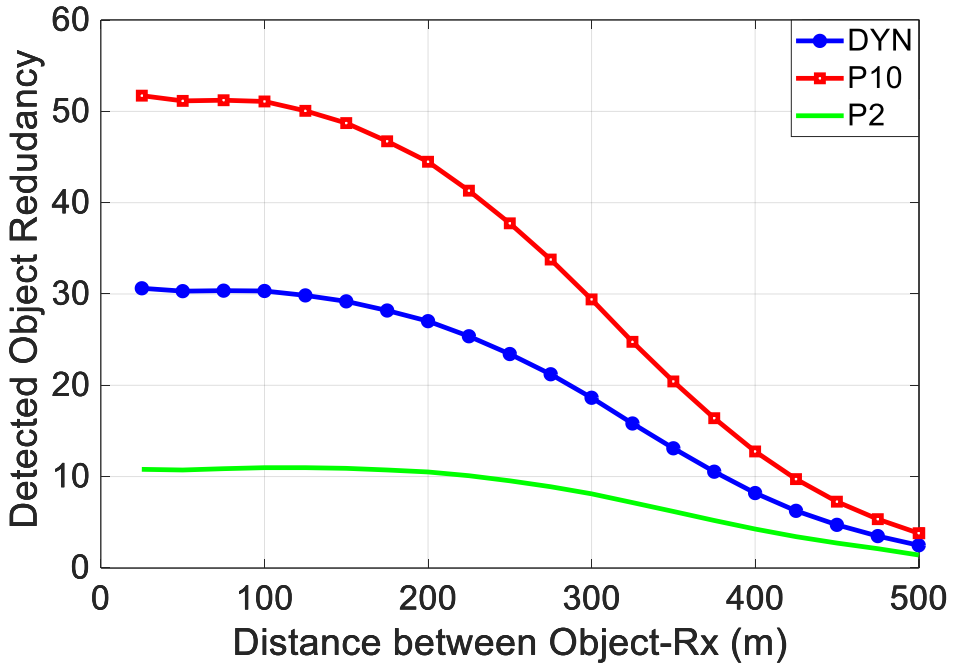
- Object Awareness Ratio: probability of detecting an object
  - All configurations: awareness ratio higher than 0.98 up to 350m
  - Beyond 350m: degradation due to propagation and interferences



We consider that an object is successfully detected if at least one CPM is received within a second with info about it

Evaluation results

- Detected Object Redundancy: no. of times same object rx per sec
  - All policies provide a high number of updates / sec
  - Is this redundancy needed for connected and automated driving?



Low traffic density

Conclusions

- Collective perception
  - Designed to improve perception capabilities
- Evaluation of ETSI collective perception msg generation rules
  - Balance between perception and communication
- Open discussion
  - High detected object redudancy observed
  - Can it be further optimized?

Thank you for your attention

Gokulnath Thandavarayan, Miguel Sepulcre, Javier Gozalvez
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Backup: configurations

CPM Container	Size
ITS PDU header Management Container Station Data Container	121 Bytes
Sensor Information Container	35 Bytes
Perceived Object Container	35 Bytes

Parameter	Values	
	Low traffic density	High traffic density
Highway length	5km	
Number of lanes	6 (3 per driving direction)	
Traffic density	60 veh/km	120 veh/km
Speed per lane	140 km/h 132 km/h 118 km/h	70 km/h 66 km/h 59 km/h

Parameter	Values
Transmission power	23dBm
Antenna gain (tx and rx)	0dBi
Channel bandwidth/carrier freq.	10MHz / 5.9GHz
Noise figure	9dB
Energy detection threshold	-85dBm
Data rate	6Mbps (QPSK 1⁄2)

Policy	Traffic density	CBR
Periodic at 2Hz	Low High	5.6 % 11.9 %
Periodic at 10Hz	Low High	25.6 % 49.6 %
Dynamic	Low High	19.2 % 31.7 %

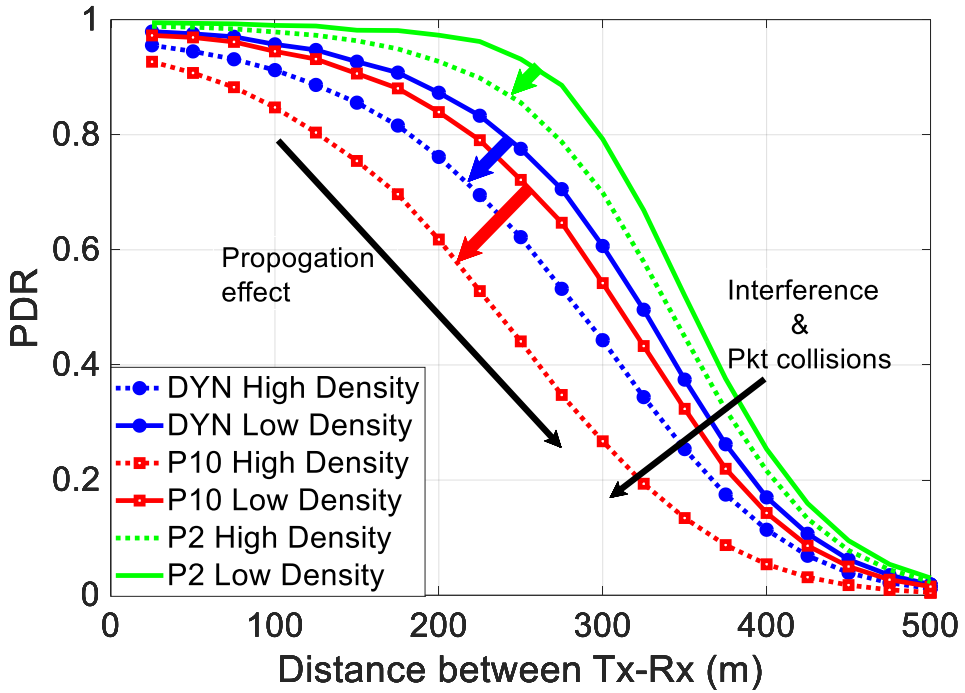
Backup: Configurations

- Vehicles measure 5m x 2m
- Objects detected from two sensors are fused
- Traffic scenario is a six-lane highway with 5km length
- Lane width 4 meters
- Shadowing effect (sensor masking) implemented in XY-plane
- Statistics taken from 2km center of the simulation scenario
- All vehicles with ITS-G5 transceiver (100% penetration)
- All vehicles operate in the same channel
- The speeds have been selected based on statistics of a typical 3-lane US highway obtained from the PeMS database

- Communication parameters:
  - Transmission power: 23dBm
  - Antenna gain (tx and rx): 0dBi
  - Channel bandwidth/carrier freq.: 10MHz / 5.9GHz
  - Data rate: 6Mbps (QPSK ½)
  - Propagation model: Winner+B1 (pathloss and shadowing)

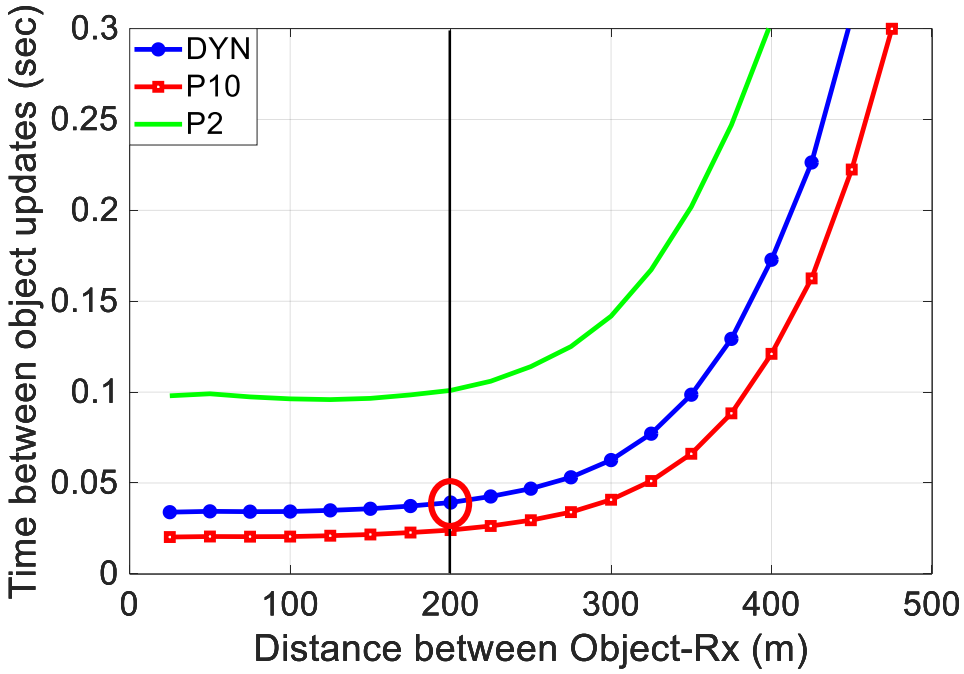
Evaluation results

- Packet Delivery Ratio: prob of successfully receiving a CPM
  - Propagation effects: degradation with distance
  - Degradation due to interference and packet collisions
    - Higher CBR results in higher degradation



Evaluation results

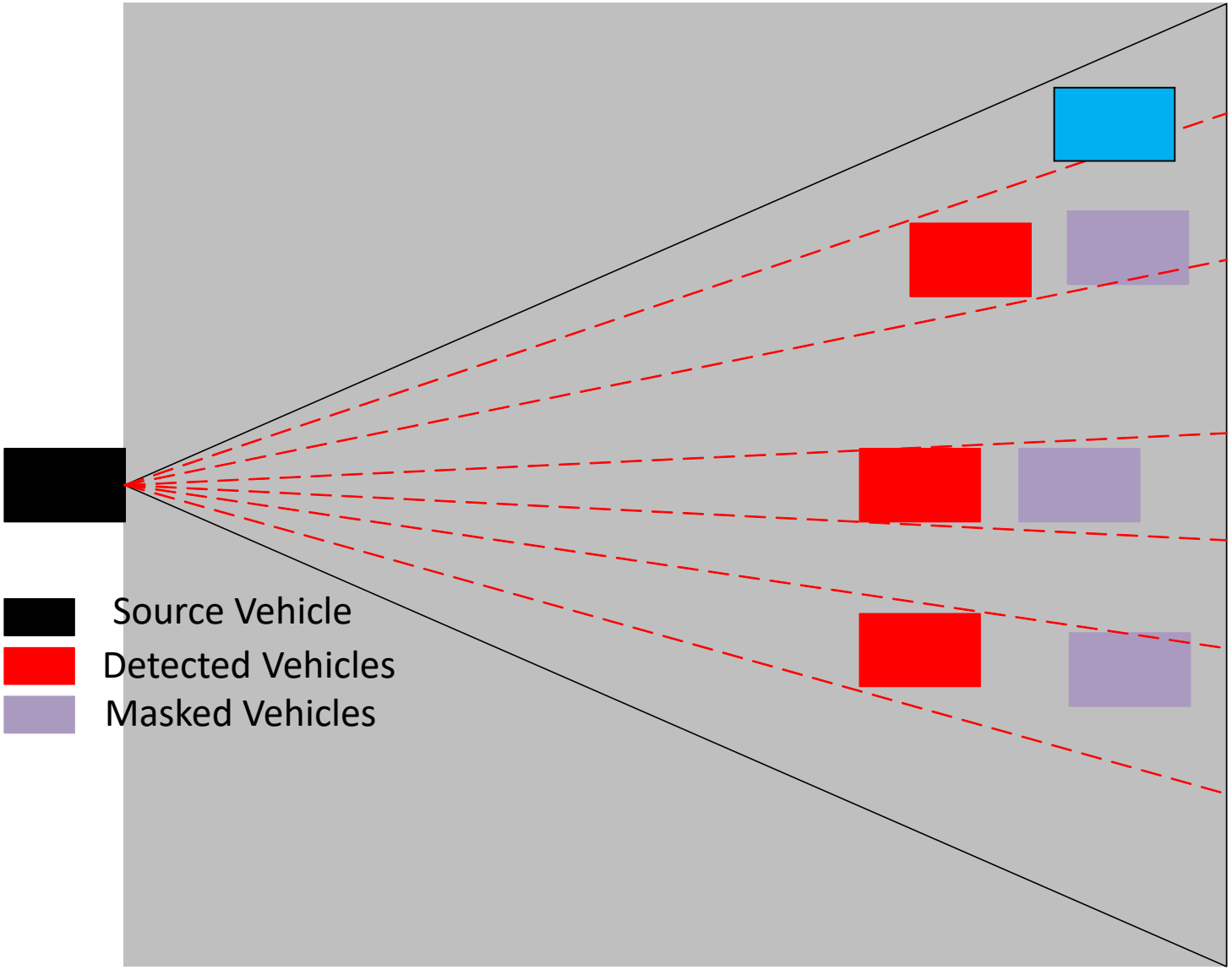
- Time between object updates: freshness of information
  - All policies: object updates below 0.1s up to 200m
  - DYN: object updates below 0.03s up to 200m



Low traffic density

DYN provide frequent updates near to P10 while better controlling the channel load

Backup: Sensor Masking



Content

- Introduction
- ETSI collective perception standard
- Message generation rules
- Simulation set-up
- Evaluation results
- Conclusions