

Context-based Broadcast Acknowledgement for Enhanced Reliability of Cooperative V2X Messages

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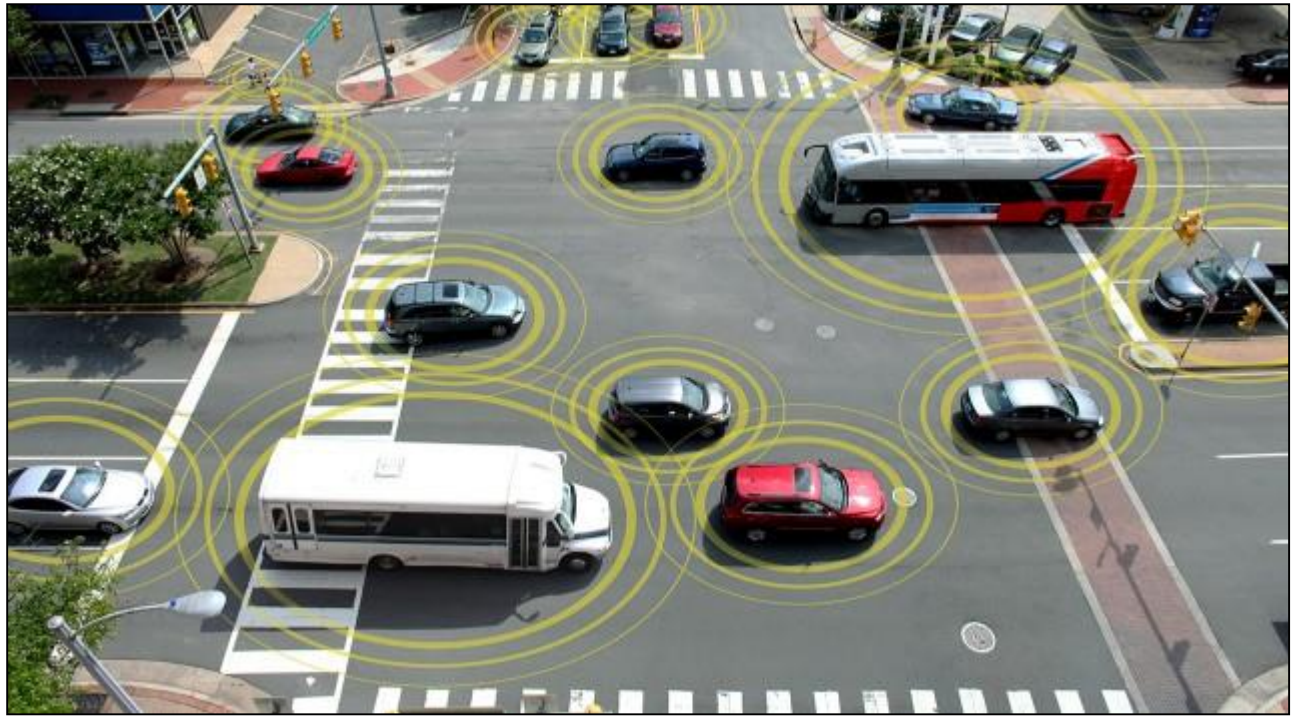
Contents

- Introduction
- Context-based Broadcast Acknowledgement
- Scenario of Evaluation
- Results
- Conclusions

Introduction

- Most V2X services are supported by the exchange of broadcast messages
  - Expand the perception capabilities of the vehicles beyond their sensing range
  - Day 1: Cooperative Awareness and Decentralized Environment Notification
  - Day 2: Collective Perception



Introduction

Broadcast V2X Messages

Benefits

+ Transmitted info is of interest to nearby vehicles

+ Do not require identifying the neighboring vehicles

+ Fast exchange of information

… but

– There is no mechanism to ensure the correct delivery

This motivates our work:
Design of a mechanism that contributes to increasing the reliability of V2X broadcast messages

Contents

- Introduction
- Context-based Broadcast Acknowledgement
- Scenario of Evaluation
- Results
- Conclusions

Context-based Broadcast ACKnowledgement

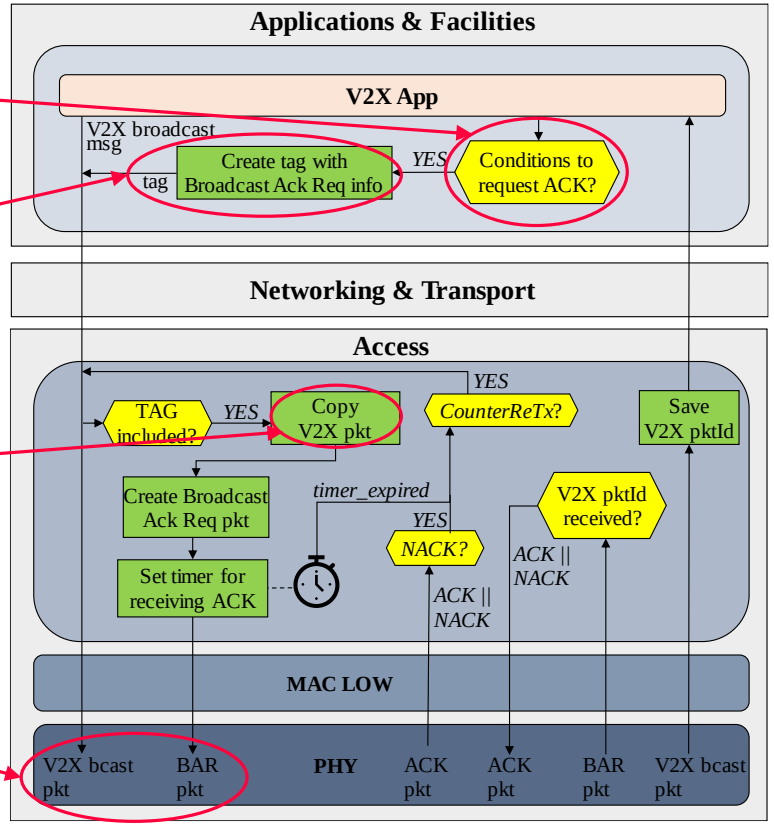
- The concept:
  - Establishing feedback loops between the transmitter and the receiver(s)
  - It informs about the delivery status of the transmitted V2X broadcast messages
  - ACK pkts: traditionally used in IEEE 802.11 for unicast transmission

- Design aspects:
  - Multiple vehicles receiving the V2X broadcast message could transmit the ACK
    - This might cause packet collisions and interference if not properly coordinated
    - This could compromise the network load and scalability

Context-based Broadcast Acknowledgement

- Integration of the proposed mechanism in the ETSI ITS protocol stack:
  - Controls what V2X broadcast messages need a feedback
  - Limits the receiving vehicle(s) to whom a feedback should be requested

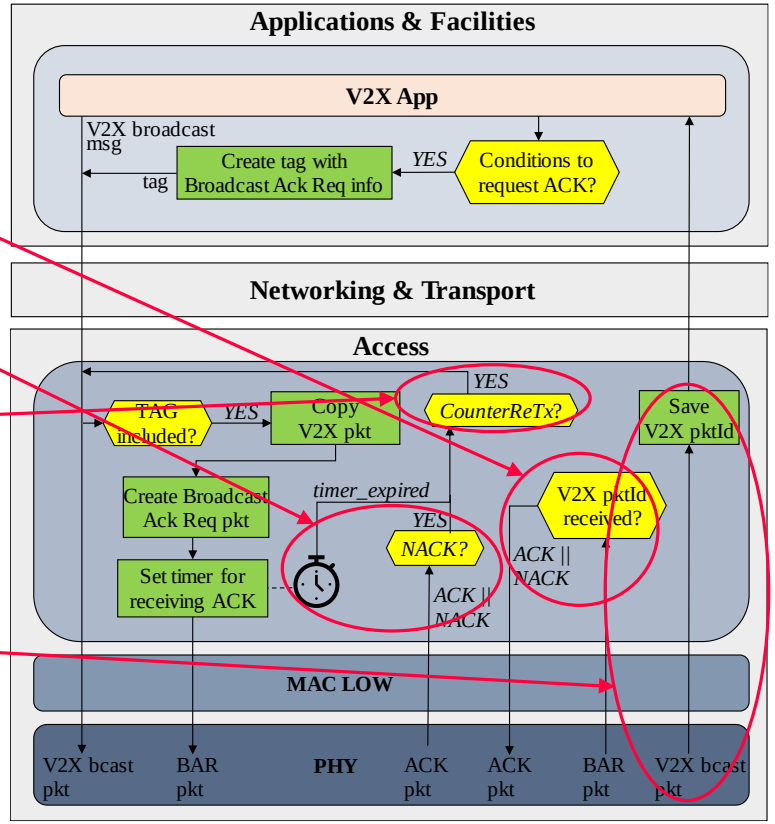
1. The 'V2X App' checks whether the conditions to request an ACK are met
2. A tag is added with the ID of the receiver that will be requested to reply with the ACK pkt
3. A copy of the V2X pkt that it was tagged is made
4. Both the V2X broadcast message and Broadcast ACK Request (BAR) are transmitted



Context-based Broadcast Acknowledgement

- Integration of the proposed mechanism in the ETSI ITS protocol stack:
  - Controls what V2X broadcast messages need a feedback
  - Limits the receiving vehicle(s) to whom a feedback should be requested

5. The receiver sends an ACK/NACK if it has/has not received the V2X broadcast pkt
6. The transmitter waits a while for the ACK
7. If the timer expires or NACK is received, a retransmission is performed
8. When the V2X broadcast pkt is correctly received it is passed to upper layers



Contents

- Introduction
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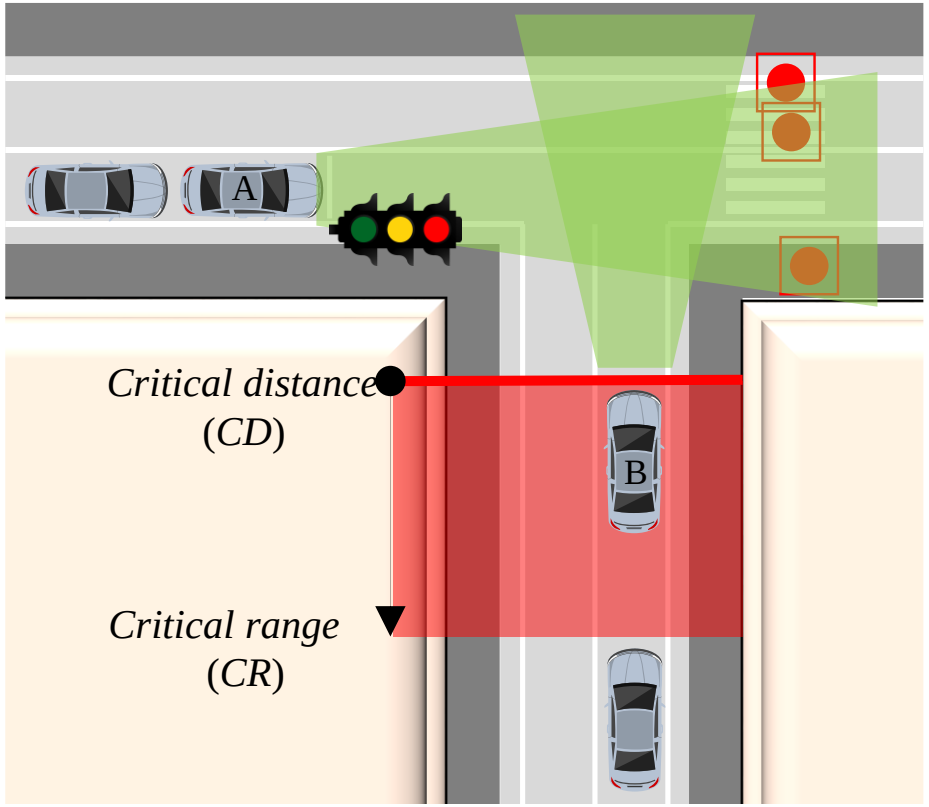
- Scenario of Evaluation
- Results
- Conclusions

Scenario of Evaluation

- Ns-3 simulation over urban intersection scenario
  - There is a risk that the vehicles approaching to the intersection from the vertical lane do not detect the pedestrians that are crossing the street

- Vehicles frequently transmit CPM broadcast messages with the detected objects
  - Pedestrians are only detected by vehicles stopped at the traffic light



Scenario of Evaluation

- Vehicles stopped at the traffic light transmit Broadcast ACK Request (BAR) messages to the vehicles driving on the vertical lane when one of the detected objects is a pedestrian
  - The vehicle addressed in the BAR message is the one closer to the *Critical Distance* (*CD*) and within the *Critical Range* (*CR*):

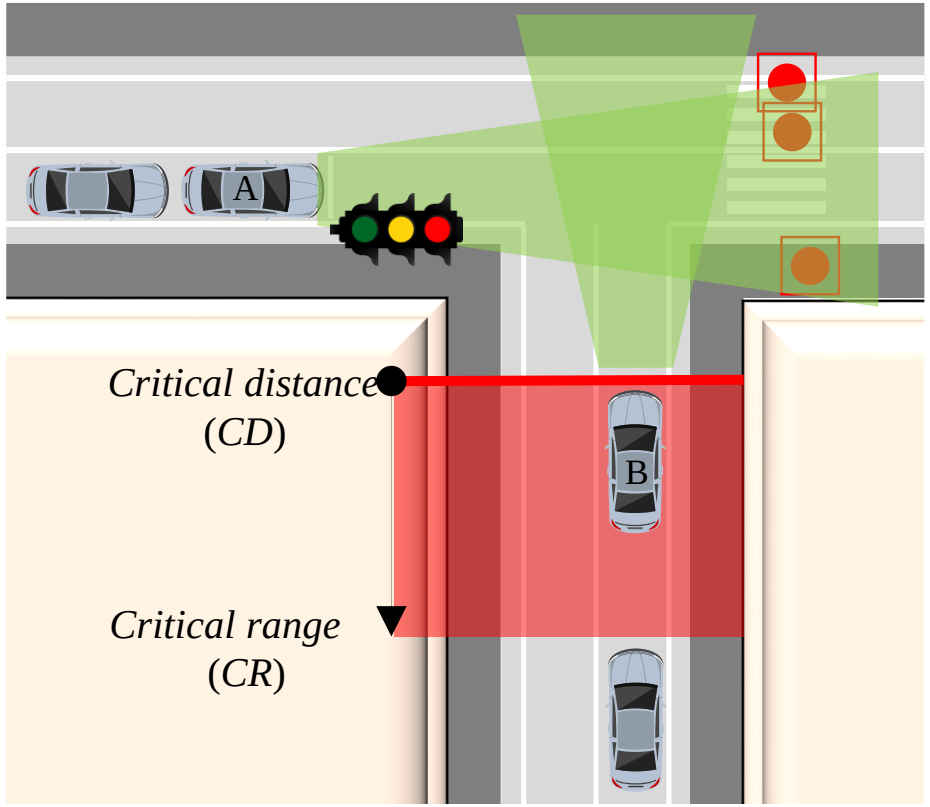
$$CD = v \cdot RT + v^2/(2 \cdot a_{max})$$

where:

$v \equiv$ vehicle's speed

$RT \equiv$ Reaction Time

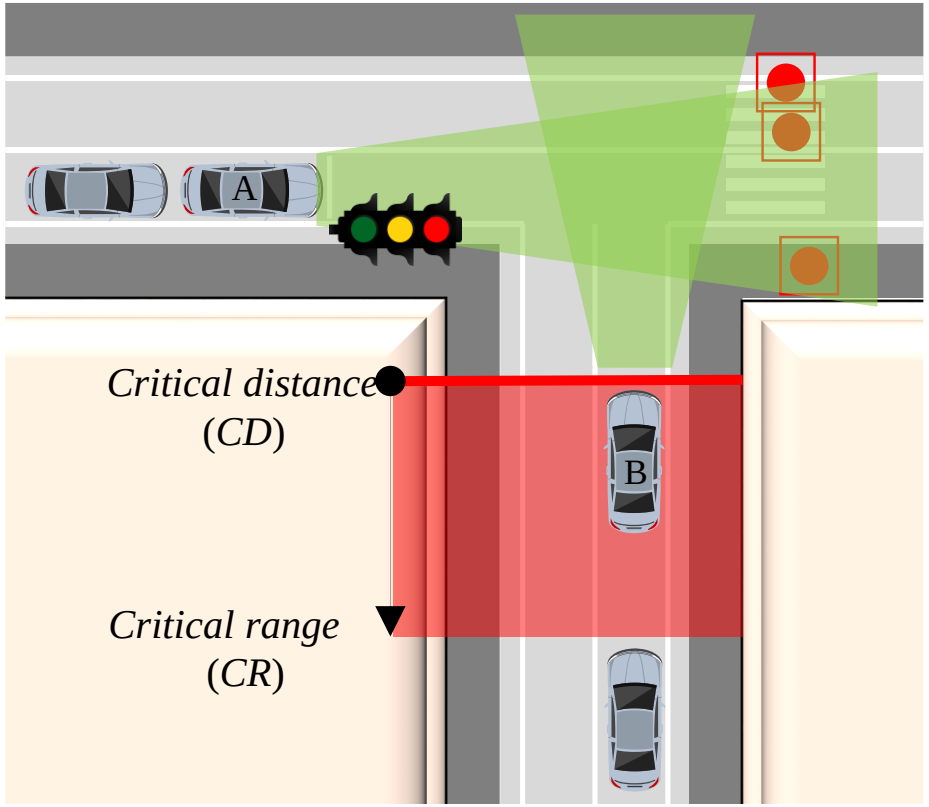
$a_{max} \equiv$ Vehicle's emergency acceleration



Scenario of Evaluation

- Other simulation parameters

Variable	Value
Scenario	
Vehicles speed on the vertical lane (*v*)	20m/s
Traffic density on the vertical lane	50veh/Km
Critical Range (*CR*)	40m
Reaction time (*RT*)	{0.75, 1, 1.25}s
Vehicles' emergency acceleration	8m/s^2
V2X communications	
Antenna gain	0dBi
Data rate	6Mbps (QPSK ½)
Noise figure	9dB
Energy detection threshold	-85dBm



Scenario of Evaluation

- CPM content and generation rules (follow ETSI ITS CPS service)
  - Content: Perceived Object Containers (POCs) of 35 bytes each
  - Generation rules: Checked every *T_GenCpm* (100 ms)
    - New objects are always transmitted
    - Previous detected objects only transmitted if:
      - More than 0.5 seconds without reporting the detected pedestrian
      - More than 1 second without reporting other than pedestrian
      - Absolute position has changed by more than 4m since the last reported time
      - Absolute speed has changed by more than 0.5 m/s since the last reported time
      - Absolute velocity has changed by more than 4º since the last reported time

Contents

- Introduction
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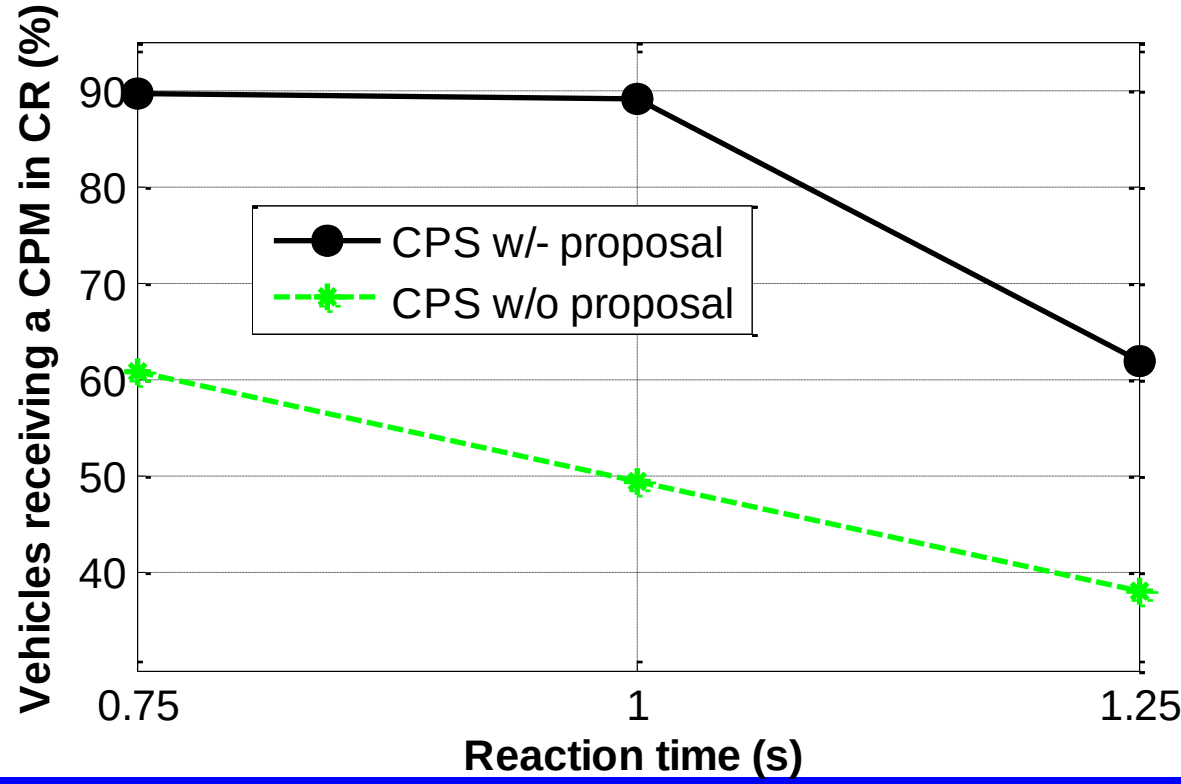
- Scenario of Evaluation
- Results
- Conclusions

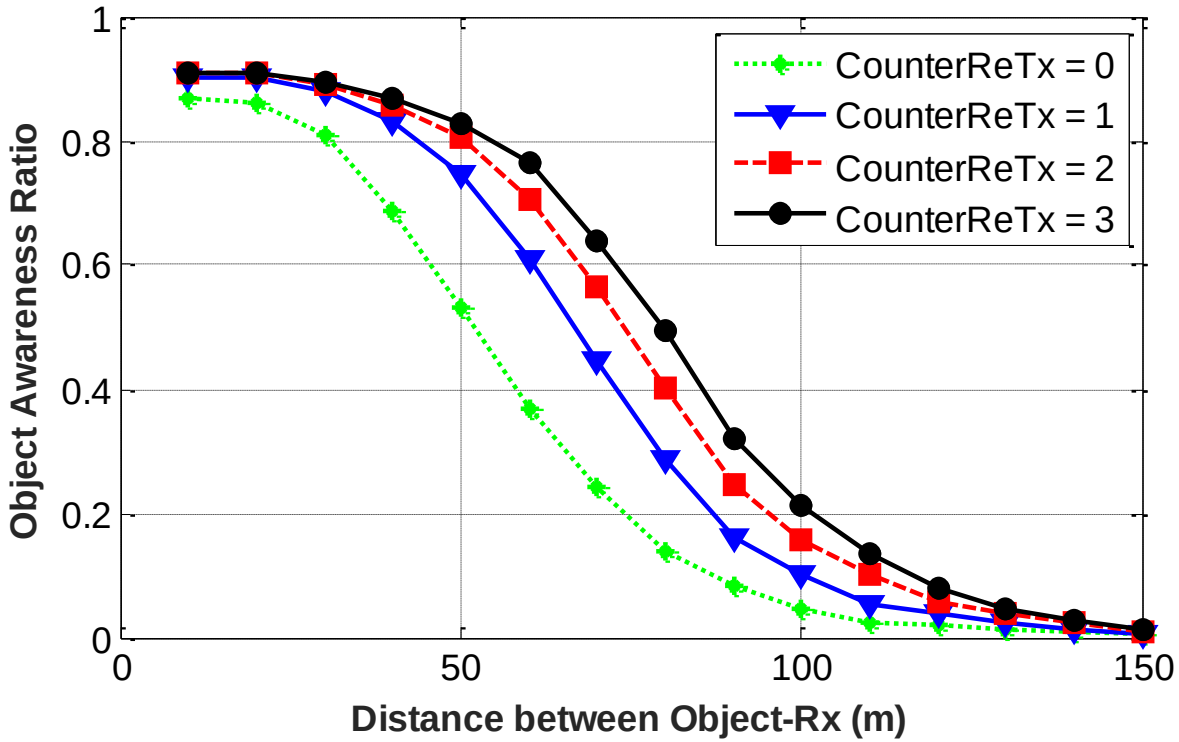
Results

- % of vehicles that receive a CPM within the Critical Range (CR) as a function of the Reaction Time (RT)
  - If RT increases, the CR moves away from the intersection:
    - Less vehicles receive correctly a CPM due to the worse propagation conditions
  - The proposal increases the reliability of CPM messages:
    - Retransmissions of CPM if the addressed vehicle does not respond with an ACK



Results

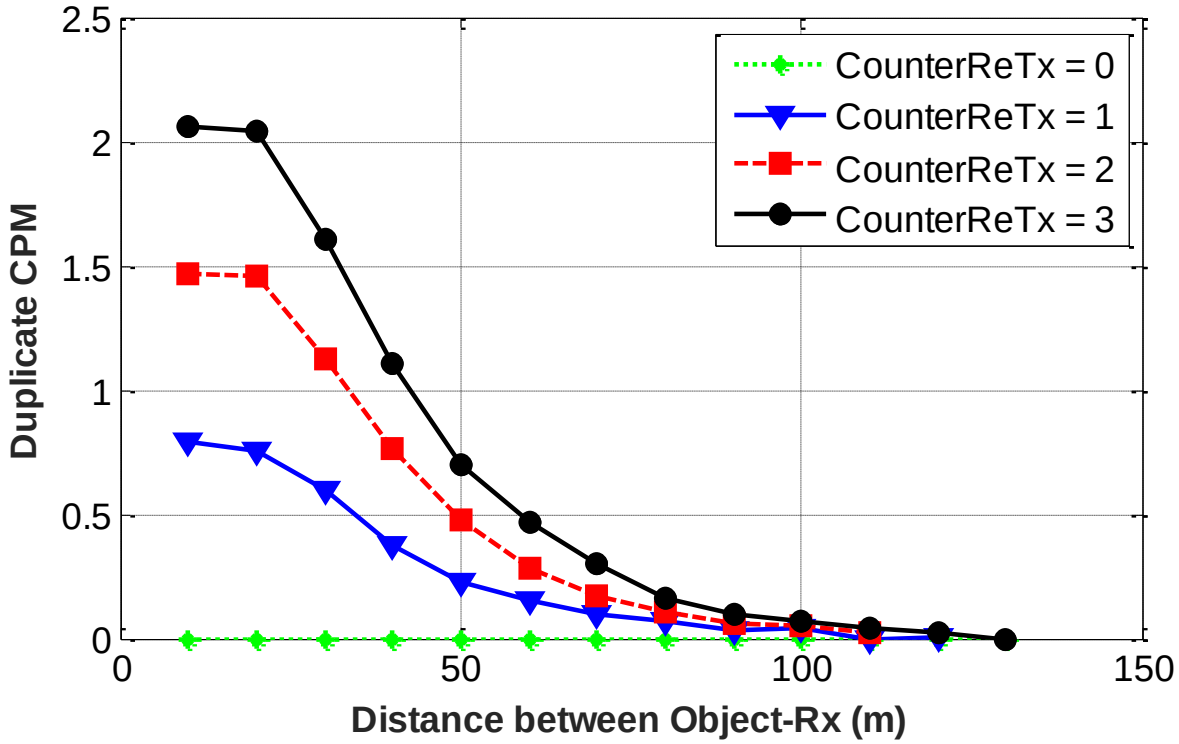
- Object Awareness Ratio as a function of the distance between the object and the receiving vehicles
  - Probability to detect a crossing pedestrian within a 0.5 s time window
  - w/o proposal (i.e. *CounterReTx* = 0):
    - 50% @ 50 meters to intersection
  - w/- proposal (e.g. *CounterReTx* = 3):
    - 82% @ 50 meters to intersection
  - What is the cost of the reported benefits?



$RT = 1$s

Results

- Duplicate received CPM
  - The proposal performs up to *CounterReTx* retransmissions if the addressed vehicle does not ACK the CPM
  - Retransmissions might be because:
    - Failure in the CPM, BAR, ACK/NACK
    - Some CPMs might be unnecessary



The efficiency of the proposed mechanism is ensured by controlling the number of vehicles and situations where an ACK is requested

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- Introduction
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- Conclusions

Conclusions

- This paper has proposed a context-based mechanism to improve the reliability of V2X broadcast transmissions
  - @ tx vehicle:
    - Selectively requests the ACK of specific/critical V2X broadcast messages
    - Performs retransmissions at the MAC level if they are not correctly received
  - @ rx vehicle:
    - Replies with ACK/NACK upon request
- The proposal is valid for any broadcast V2X message
- This paper demonstrates its high potential considering the Collective Perception Service

Thank you for your attention!!

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