



Latest Findings on CPM Generation Rules: Combination of Redundancy Mitigation and Look-Ahead

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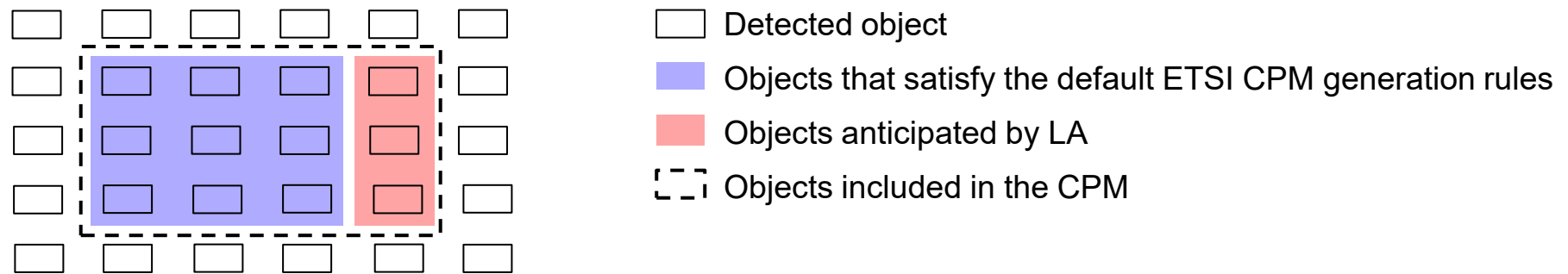
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- Introduction
- Standalone techniques: redundancy mitigation and look-ahead
- Proposed combinations
- Simulation results
- Conclusions

- Default ETSI CPM generation rules have mainly two inefficiencies:
 - They can generate many small CPMs that contain a low number of objects.
 - They generate significant redundancy that could not be necessary.
- TR 103 562 and TS 103 324 introduced two mechanisms to solve them:
 - Look-Ahead (LA) includes in the current CPM the objects that will be included in the next one.
 - Redundancy Mitigation (RM) avoids the transmission of an object if e.g. it has been recently transmitted by a nearby vehicle.
- There are multiple options to combine LA, RM and the default ETSI CPM generation rules
 - This study analyzes the combination included in the TR and TS, and other potential options.

- Look Ahead (LA): an object is included in the current CPM if it is predicted to be included in next CPM (section 4.3.4 of the TR)

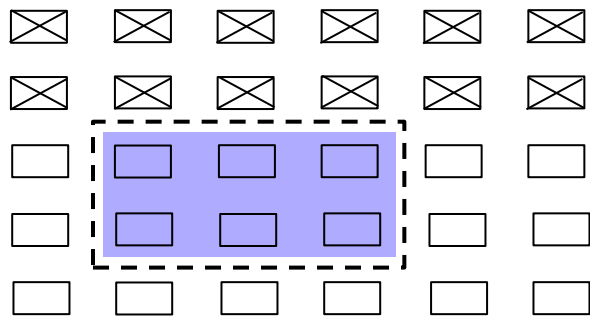


- For objects that do not currently satisfy the default ETSI CPM generation rules:
 - Predict the object dynamics for the Next TGenCPM since the last tx CPM.
 - Include it if predicted position or predicted speed changed more than 4m or 0.5m/s.
 - Include it if it was included 1 - TGenCPM (or more) seconds ago.

- Look Ahead (LA): an object is included in the current CPM if it is predicted to be included in next CPM (section 4.3.4 of the TR)
 - Advantages:
 - Increases the number of objects in each CPM (approx. double)
 - Reduces the number of CPMs transmitted per second, i.e. amount of headers
 - Reduces the CBR (10%-24%)
 - Improves object perception ratio, especially at large distances (approx. 200-300m)
 - Disadvantages:
 - Increases object redundancy

G. Thandavarayan, M. Sepulcre and J. Gozalvez, "[Generation of Cooperative Perception Messages for Connected and Automated Vehicles](#)," in IEEE Transactions on Vehicular Technology, vol. 69, no. 12, pp. 16336-16341, Dec. 2020, doi: 10.1109/TVT.2020.3036165.

- Dynamics-based redundancy mitigation (section 4.5.3 of the TR)
 - An object is not included in a CPM if its position has changed less than $P_Redundancy \leq 4$ m and its speed less than $S_Redundancy \leq 0,5$ m/s since the last time it was received in a CPM.
 - With $P_Redundancy = 4$ m and $S_Redundancy = 0,5$ m/s, multiple transmitters perceiving the same object generate a reporting rate similar to that of a single transmitter.
 - It is applied on all detected objects, i.e. before the default ETSI CPM generation rules.

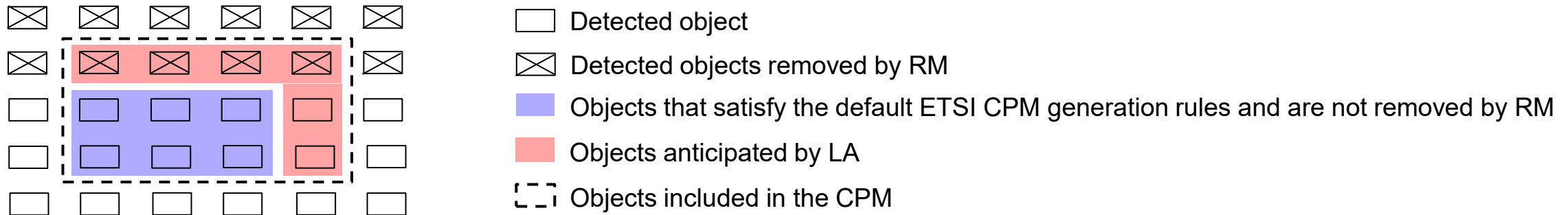


- Detected object
- ⊠ Detected object removed by RM
- Objects that satisfy the default ETSI CPM generation rules and are not removed by RM
- - - Objects included in the CPM

- Dynamics-based redundancy mitigation (section 4.5.3 of the TR)
 - Advantages
 - Significant reduction of the CBR due to reduction of redundancy
 - Up to 60%-70% with $P_{\text{Redundancy}} = 4\text{m}$
 - Up to 15%-30% with $P_{\text{Redundancy}} = 1\text{m}$
 - Improvement of the PDR due to lower interferences
 - Improvement of the object perception ratio at high traffic densities
 - Disadvantages
 - Slight degradation of the object perception ratio at low traffic densities
 - Most of the CPMs contain less than 4 objects: efficiency could be improved
 - Default generation rules 55%, LA 33% and RM 97%

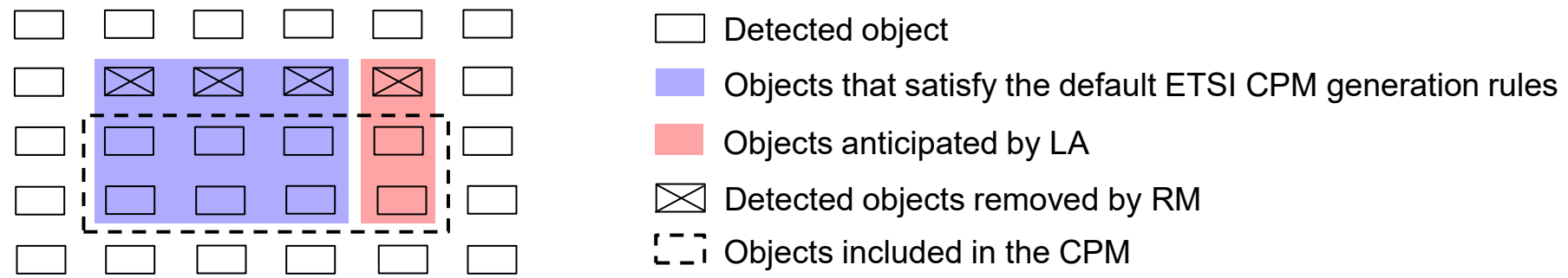
G. Thandavarayan, M. Sepulcre, J. Gozalvez, "[Redundancy Mitigation in Cooperative Perception for Connected and Automated Vehicles](#)", *Proc. IEEE 91st Vehicular Technology Conference (VTC2020-Spring)*, Antwerp, Belgium, 25-28 May 2020.

- LA and RM are combined in the TR and TS as follows:
 - Step 1: apply RM on all detected objects.
 - Step 2: include in the CPM all objects that satisfy the CPM generation rules and that have not been removed by RM.
 - Step 3: apply LA on all detected objects except the objects included in the CPM.



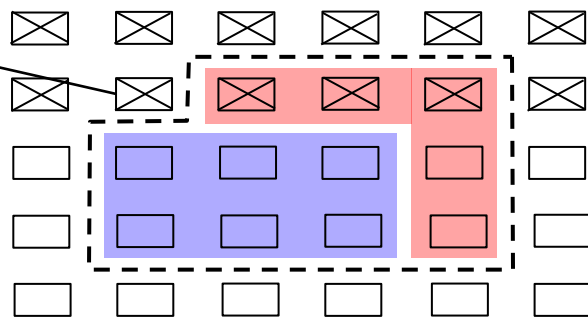
- Observations:
 - All objects removed by RM that satisfy the default CPM generation rules are added again by LA.
 - Current combination in the TR is equivalent to applying only LA: other combinations needed.

- Combination I: avoids anticipating an object with LA if it is removed by RM
 - Step 1: include in the CPM all detected objects that satisfy the default ETSI CPM generation rules.
 - Step 2: apply LA rules on all detected objects except the objects already included in the CPM.
 - Step 3: apply RM on objects included in the CPM (steps 1 or 2) and remove the necessary ones.



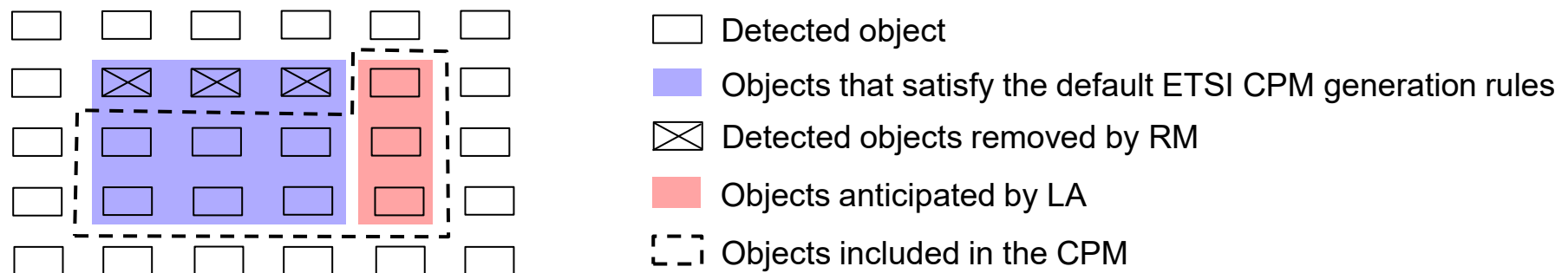
- Combination II: extends the TR by avoiding that LA adds new detected objects
 - Step 1: apply RM on all detected objects.
 - Step 2: include in the CPM all objects that satisfy the CPM generation rules and that have not been removed by RM.
 - Step 3: apply LA on all detected objects except the objects included in the CPM.
 - Do not include new detected objects that were removed by RM

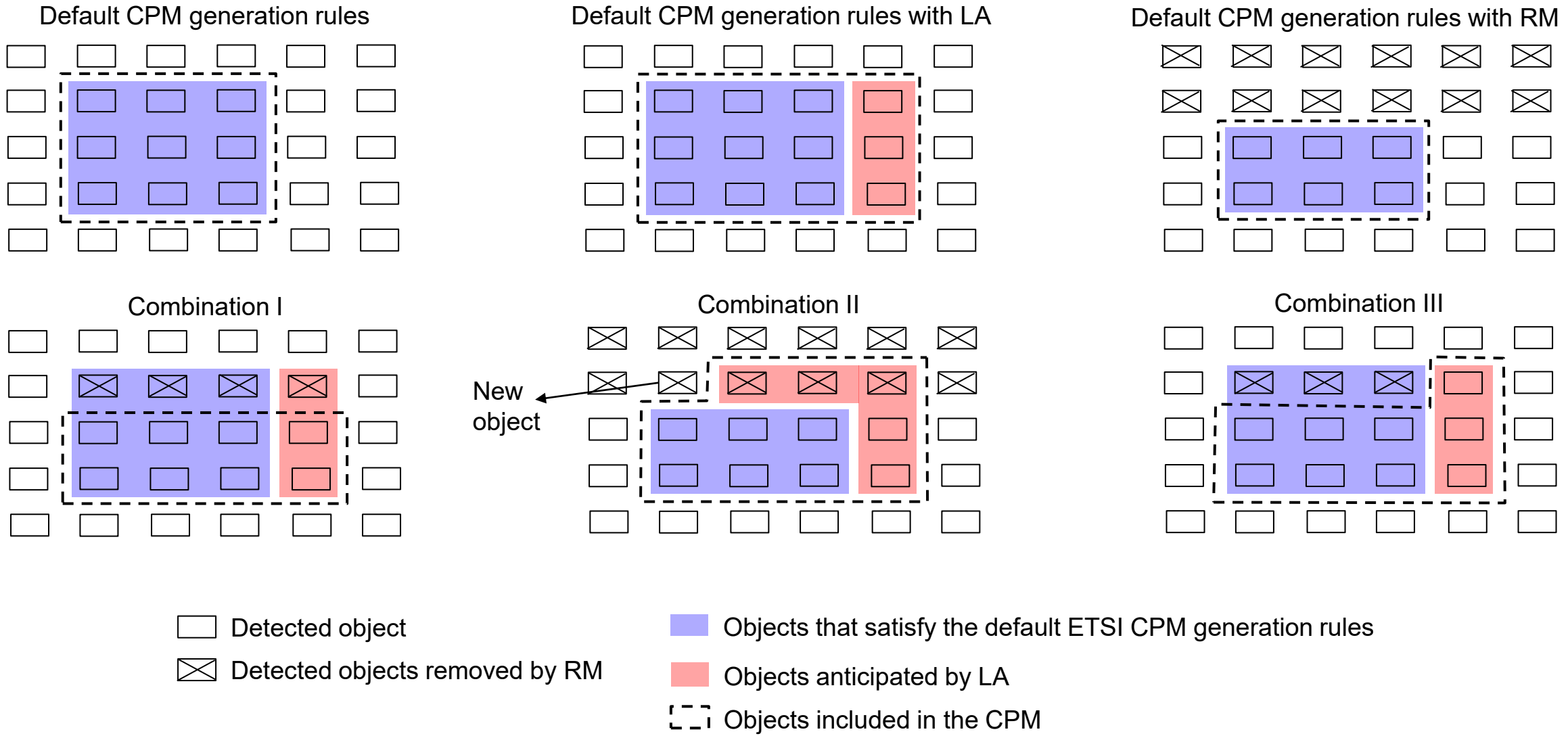
New detected object removed by RM that is not added again by LA



- Detected object
- ⊠ Detected object removed by RM
- Objects that satisfy the default ETSI CPM generation rules
- Objects anticipated by LA
- ⌈⌋ Objects included in the CPM

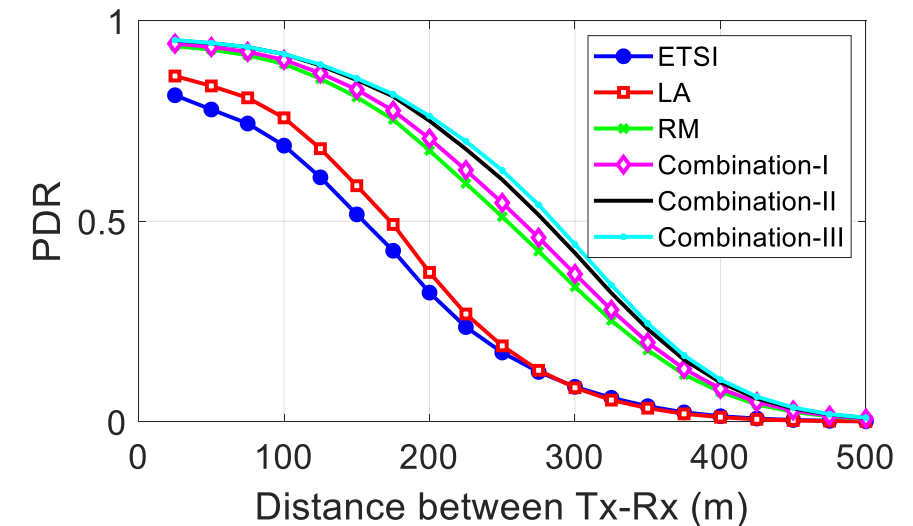
- Combination III: RM does not remove objects anticipated by LA
 - Step 1: include in the CPM all detected objects that satisfy the default ETSI CPM generation rules.
 - Step 2: apply RM on objects included in the CPM and remove the necessary ones.
 - Step 3: apply LA rules on all objects except the objects included in the CPM and removed by RM.



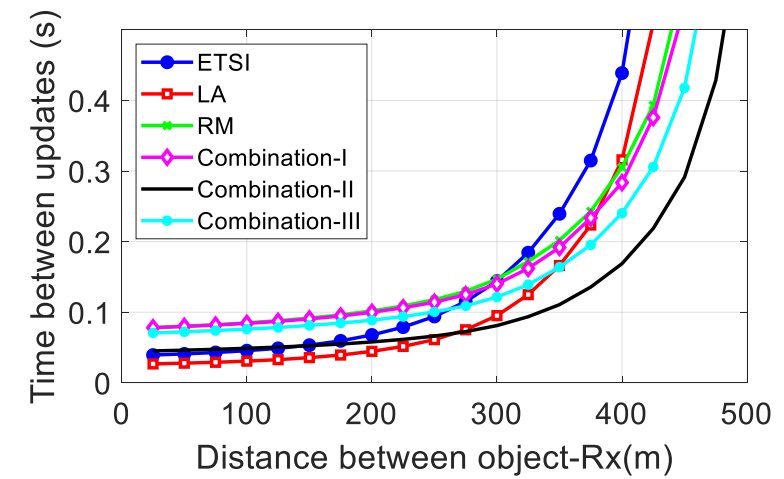
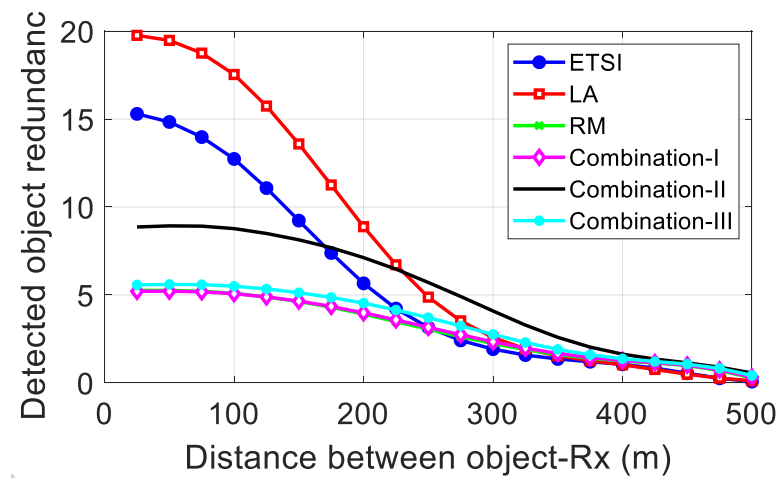
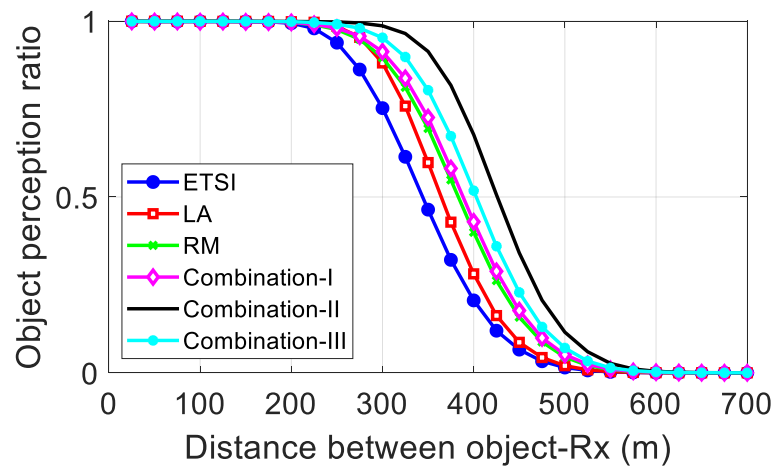


- Analysis of V2X communications performance
 - Combination II produces the lowest CPM rate and almost the largest CPM size
 - Important effect of RM to reduce the load and improve the PDR
 - RM alone or in any of the proposed combinations

	Avg. CPM rate	Avg. # objects	CBR (%)
ETSI	9.6	6.4	82
LA	6.2	12.3	82.7
RM (1m)	6.7	1.8	49
Combination I	6.1	2.0	46
Combination II	2.8	10.6	40.2
Combination III	4.3	3.7	38.3



- Analysis of object perception
 - Combination II improves object perception significantly at large distances.
 - The other two combination techniques also outperform the standalone solutions
 - Combinations I and III achieve the lowest redundancy (similar to RM)
 - Combination II achieves a low redundancy compared to ETSI and LA
 - Combination II achieves lower time between object updates at large distances
 - At short distances it achieves similar results than the default ETSI CPM gen. rules.



- Different combination of LA and RM and the default CPM generation rules are possible
 - The one included in the TS and TR may be misleading and equivalent to only applying LA
- Three different combinations proposed and evaluated.
 - All of them improve the performance of LA and RM when applied alone.
 - Combination II provides a reasonable balance between channel load and performance.
- Next steps
 - Propose new text to define the combination in the TS
 - Evaluate the solution in combination with DCC Access and DCC Facilities

Thank you for your attention



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- Simulation platform: ns3 + SUMO
 - Highway with 8 lanes
 - 240 vehicles/km, 50km/h
 - 360° sensor, 100% penetration
- Transmission parameters:
 - Transmission power: 23dBm
 - Channel bandwidth: 10MHz
 - Carrier frequency: 5.9GHz
 - Energy detection threshold: -85 dBm
 - Data rate: 6Mbps (QPSK $\frac{1}{2}$)