

On-ramp Merging on Highway for Cooperative Automated Vehicles based on an Online Reconfigurable Formation Control Approach

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Context:

On-ramp merging on highway performed by Autonomous Vehicles (AVs)

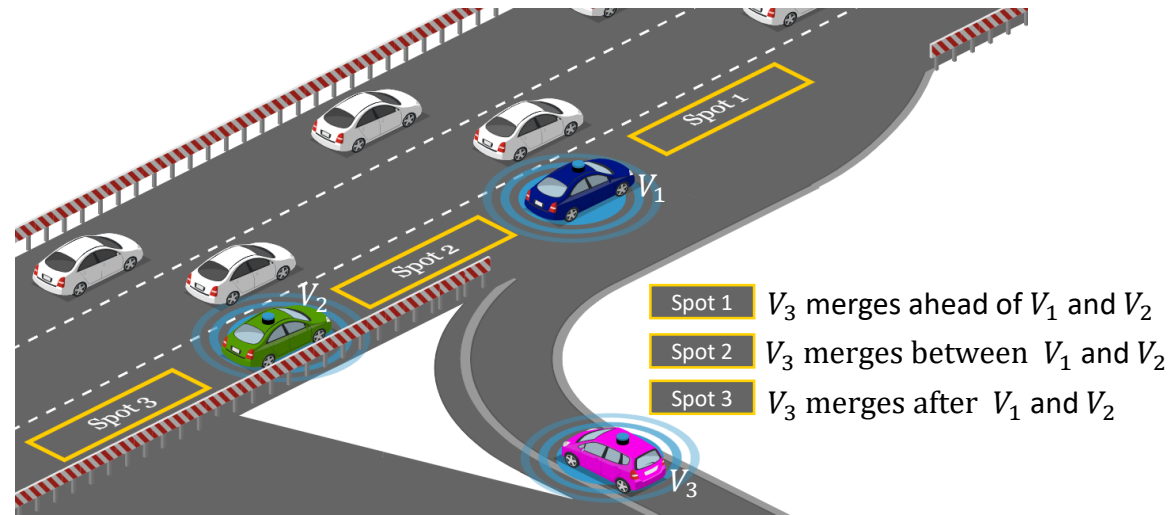


Fig 1. On-ramp merging on highway performed by AVs

- **Ego-centered** resulting merging maneuver,
- Lack of **anticipation** and **synchronization**,
- Not **efficient** in terms of **energy consumption**.

Goals:

- The **online adaptation** of the **inter-target distance matrix** proposed in [1] [2] for open world to on-road constrained environment,
- Ensure **safe and smooth on-ramp merging on highway maneuver** for CAVs.

On-ramp merging on highway performed by Cooperative and Automated Vehicles (CAVs)

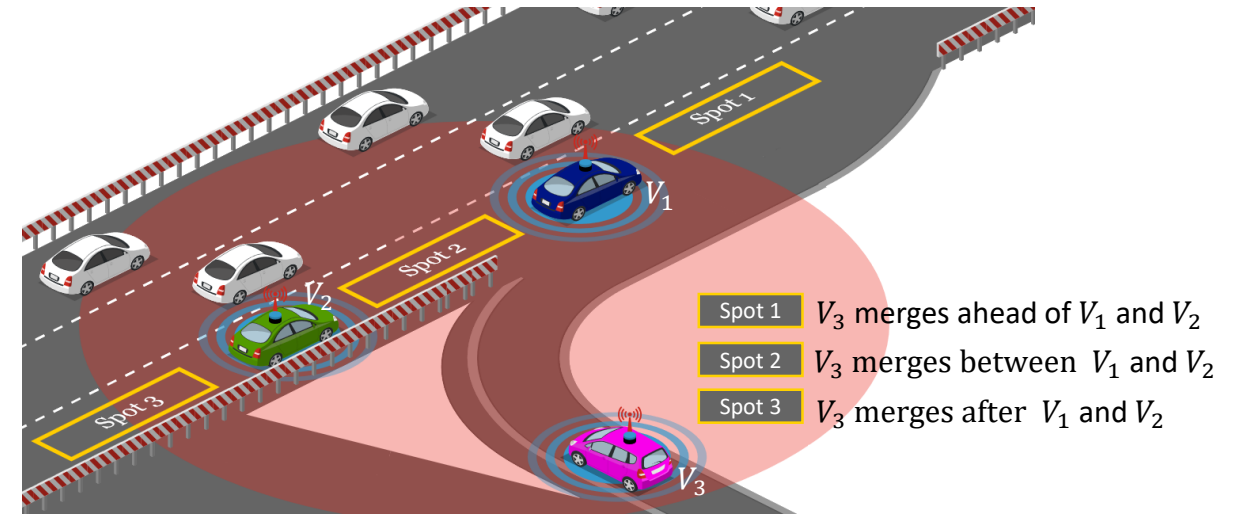


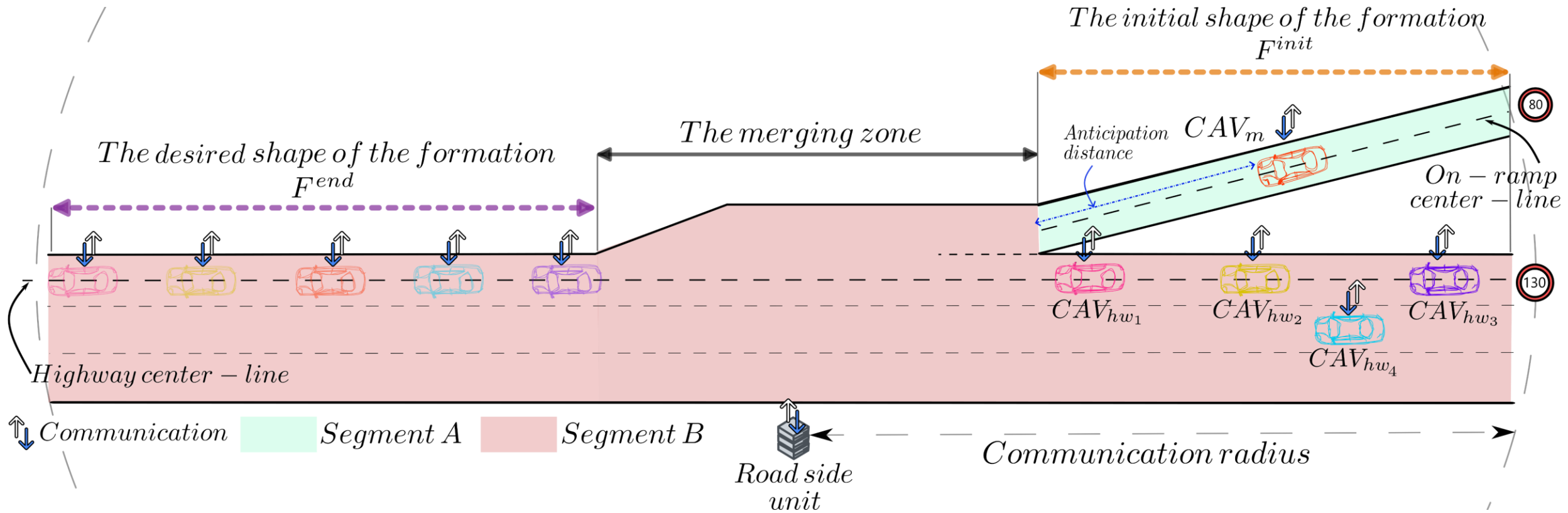
Fig 2. On-ramp merging on highway performed by CAVs

- **Cooperative** on-ramp merging maneuver,
- **Anticipation** is improved using surrounding CAVs information, shared using communication,
- Synchronization permits to improve the **energy efficiency**.

[1] L. Saidi, L. Adouane and R. Talj, CORM: Constrained Optimal Reconfiguration Matrix for Same On-Ramp Cooperative Merging of Automated Vehicles, IEEE International Conference on Intelligent Transportation Systems, Macau, China, pp. 2783-2790, 2022.

[2] J. Vilca, L. Adouane and Y. Mezouar, Stable and Flexible Multi-Vehicle Navigation Based on Dynamic Inter-Target Distance Matrix, IEEE Transactions on Intelligent Transportation Systems, vol 20, pp. 1416- 1431, 2019.

Scenario



Plan

- The proposed control architecture
- The Formation Reconfiguration Approach based on an Online Control Strategy (FRA-OCS)
- Simulation results
- Conclusion and perspectives

The control architecture skeleton

FRA-OCS: Formation Reconfiguration Approach based on an Online Control Strategy

X_T, v : targets and velocity of the CAV,

Γ, δ : torque and steering wheel

X_M : vehicle state

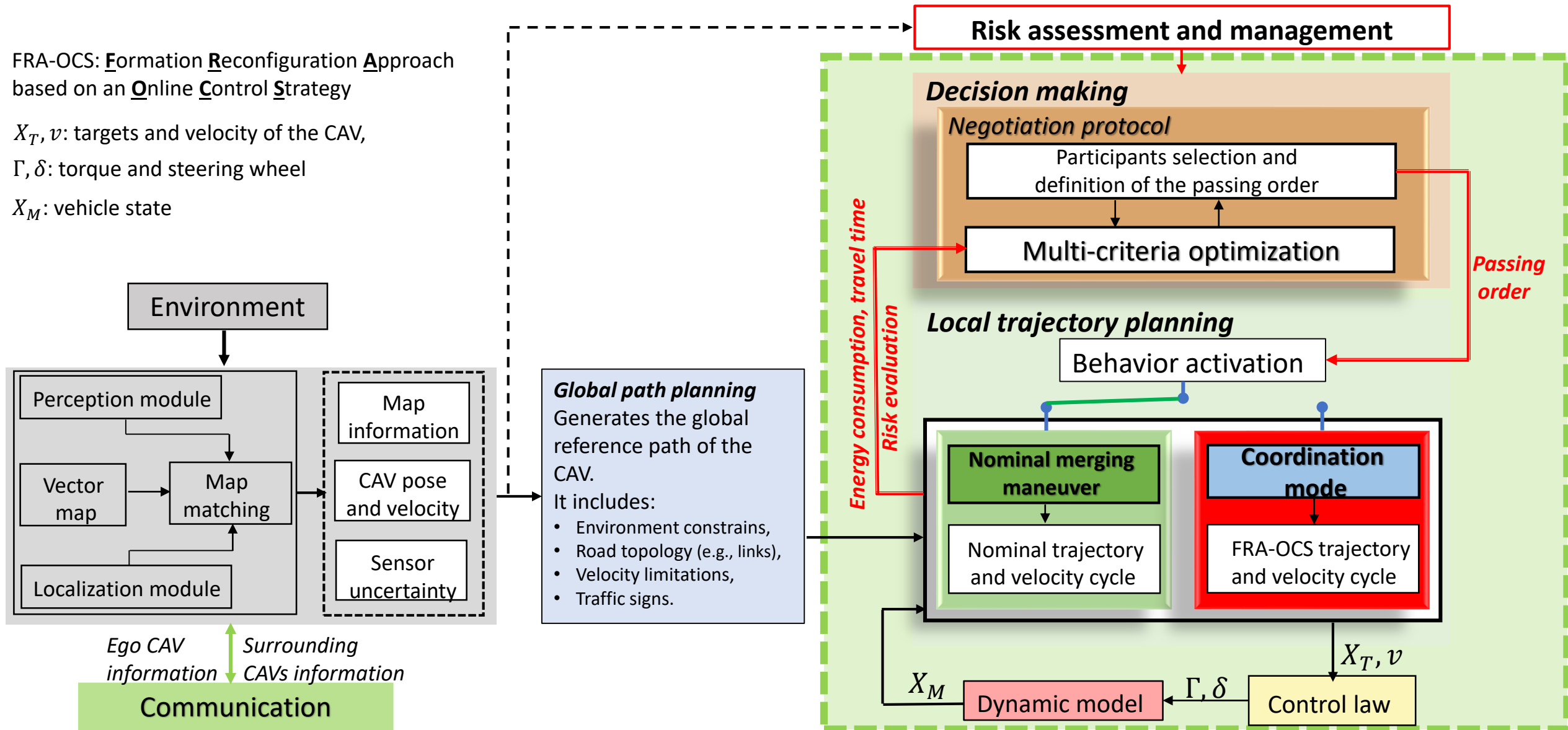
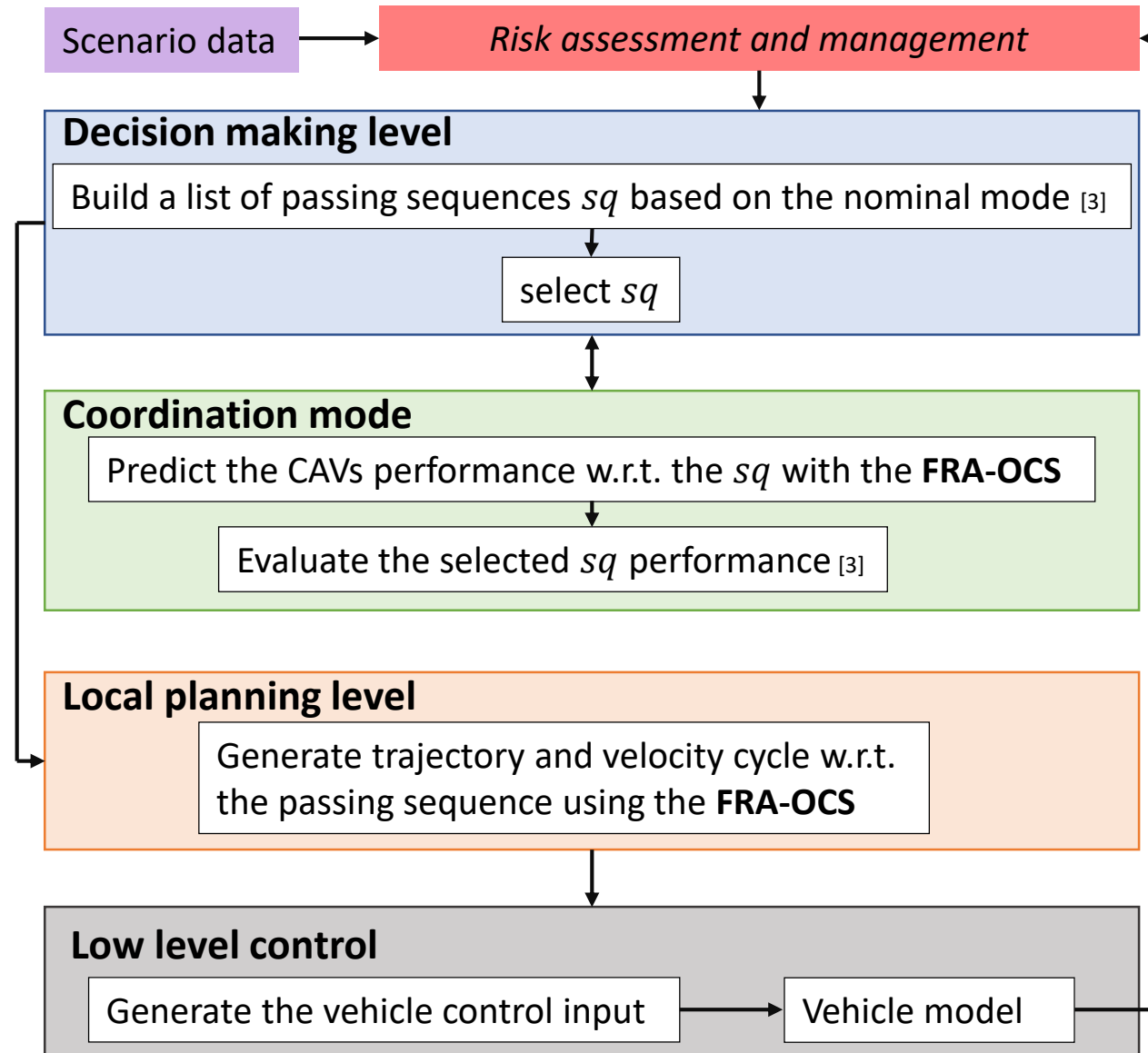
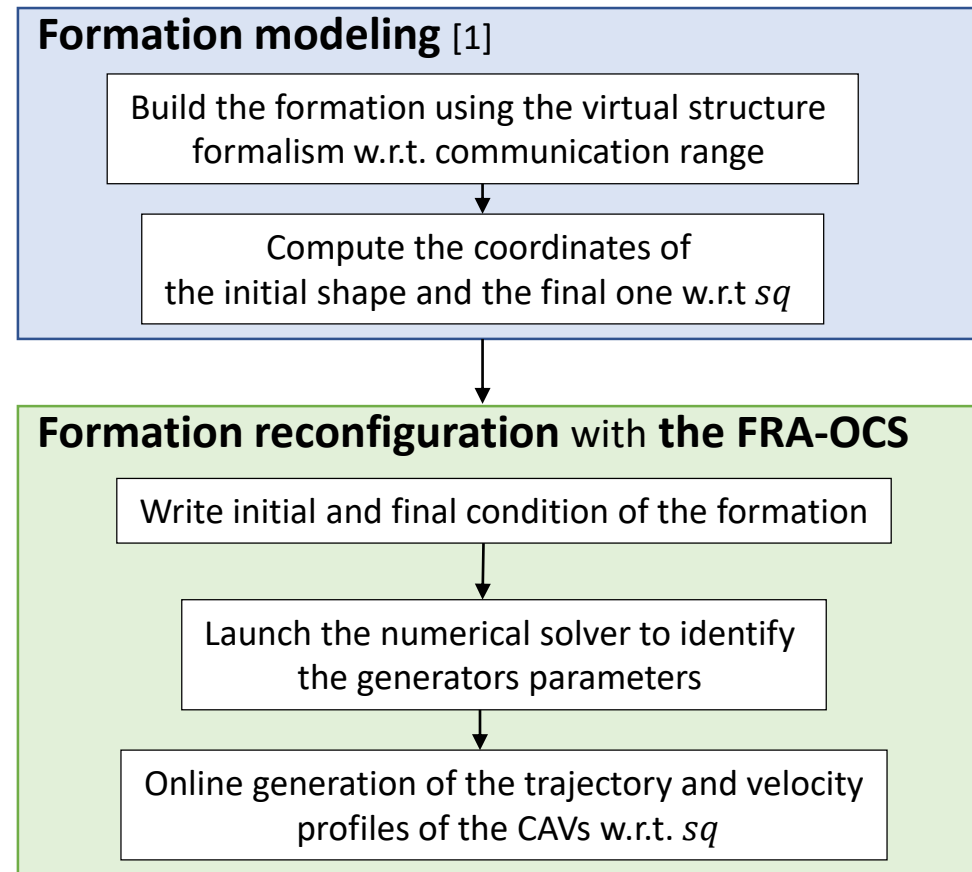


Fig 3. The control architecture skeleton

The formation reconfiguration control architecture skeleton



[3] L. Saidi, L. Adouane and R. Talj, Altruistic Coordination Strategy for On-Ramp Merging on Highway of a Formation of Cooperative Automated Vehicles, International Conference on Methods and Models in Automation and Robotics, Międzyzdroje, Poland, 2023.



[1] L. Saidi, L. Adouane and R. Talj, CORM: Constrained Optimal Reconfiguration Matrix for Same On-Ramp Cooperative Merging of Automated Vehicles, IEEE International Conference on Intelligent Transportation Systems, Macau, China, pp. 2783-2790, 2022.

Simulation scenario:

Context:

The simulation presents an on-ramp merging on highway scenario of Cooperative Automated Vehicles (CAVs). The scenario is performed using the FRA-OCS. Under the communication range of the road side unit, the merging of CAV_m is operated using the cooperative mode of the proposed control architecture.

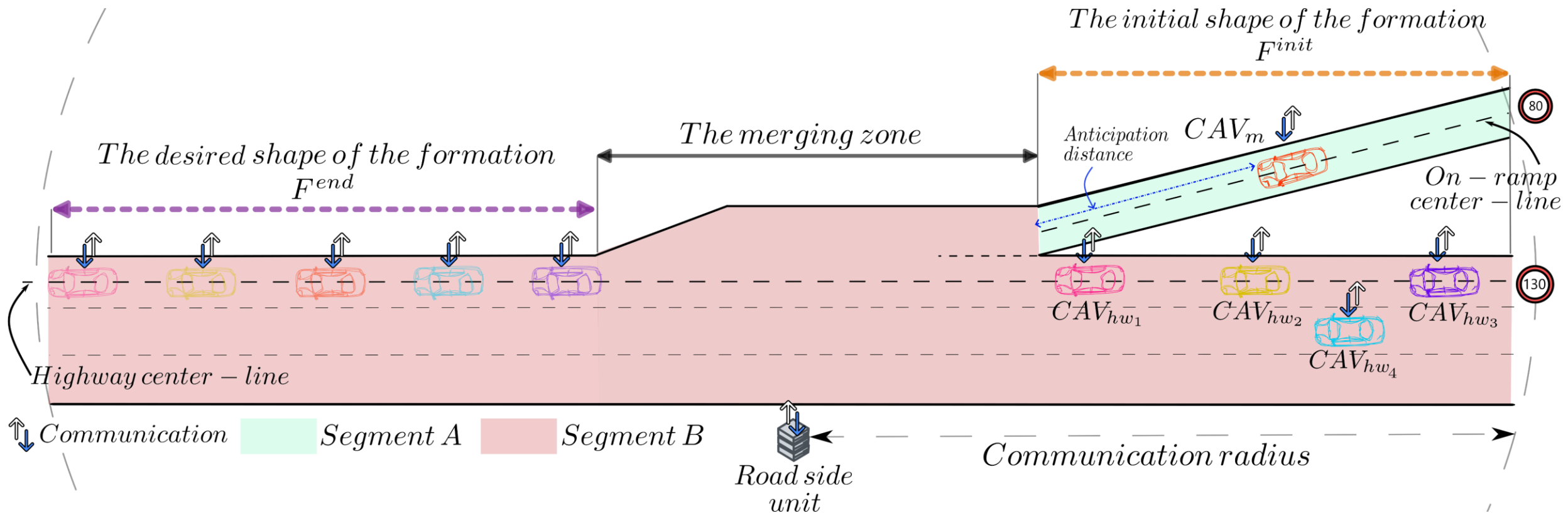
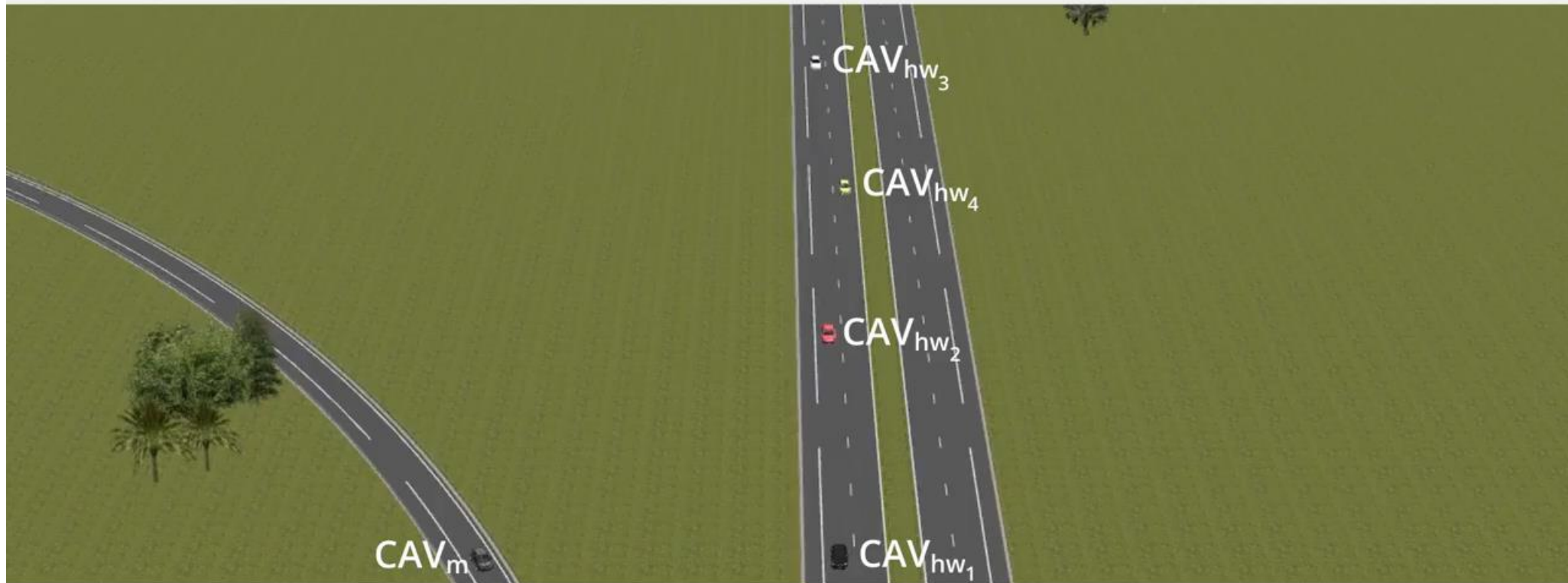


Fig 10. Illustration of the on-ramp merging on highway scene

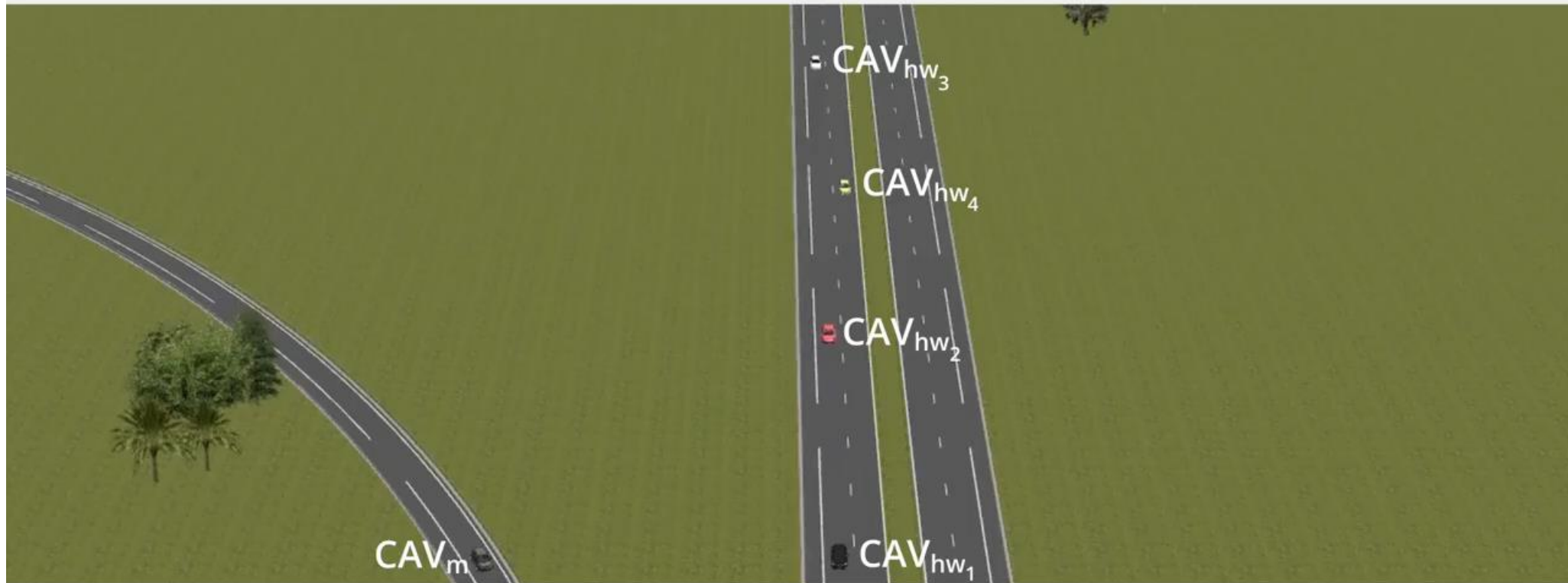
Online formation reconfiguration:

The FRA-OCS computes with the help of the velocity generator the needed formation dynamic to perform the passing sequence selected by the cooperative mode.



Online formation reconfiguration:

The highway CAV in yellow decides to join the formation what causes a configuration switch. FRA-OCS computes the needed dynamic to perform the new passing sequence, while ensuring the continuity of the CAVs dynamics.



- Safe and smooth on-ramp merging approach for Cooperative and Automated Vehicles (CAVs).
- A two steps strategy:
 1. Formation modeling using the virtual structure,
 2. Formation reconfiguration: online computation of the trajectory and velocity generator parameters w.r.t. sq .
- Several simulations were conducted in order to test the performance of the proposed strategy.

Future work:

- Compare the performance of the proposed FRA-OCS to other on-ramp merging approaches.
- Include communication delays and deal with uncertainty.