IETF-117
IPMON Context-Aware Navigator
(draft-jeong-ipwave-context-aware-navigator-08)

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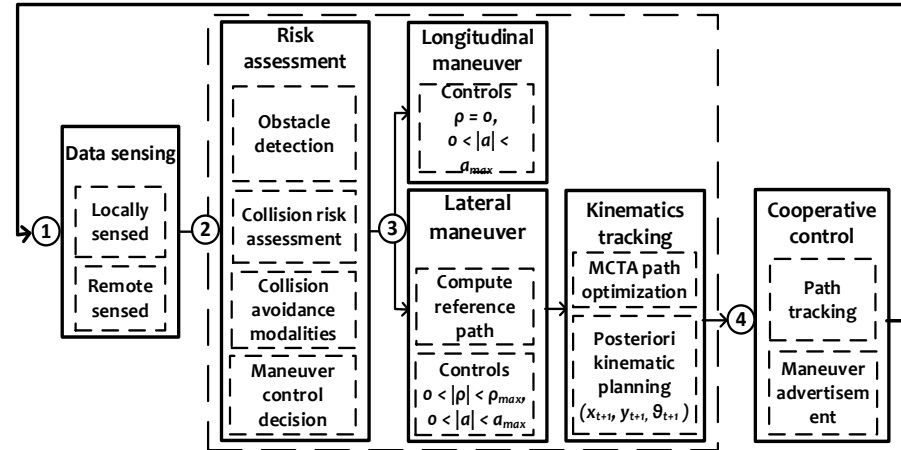
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Motivation

- **Road injury is one of top 10 causes of death,**

  – More than 1.2 million people are killed.

  – Up to 50 million are injured every year.

  – 94% crashes are caused by human.

  – Environment, vehicles and unknown reasons share 6%.

  – Autonomous vehicles can eradicate human errors.

- **Emergency Scenario**

  – Abrupt vehicle stop

  – Safety preserving handling mechanisms are needed.

- **CNP's Aims**

  – Collision Avoidance mechanism

  – Collision mitigation
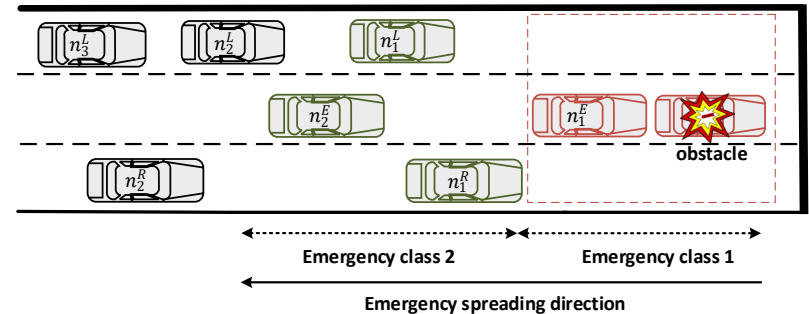
[Source] Bien Aime Mugabarigira et al., "Context-Aware Navigation Protocol for Safe Driving in Vehicular Cyber-Physical Systems", IEEE Transactions on Intelligent Transportation Systems, Vol. 24, No. 1, January 2023.

Cooperative Collision Avoidance (1/2)

- Sensing:
  - Local: Onboard sensors for self track
  - Remote: Share with other its kinematics
- Risk Assessment
  - Cluster Head (CH) analyzes sensed data to detect risks.
- Maneuver:
  - Lateral maneuver: when doable
  - Turn right or left
  - Longitudinal : Slow down, allow collision
- Tracking Mechanism
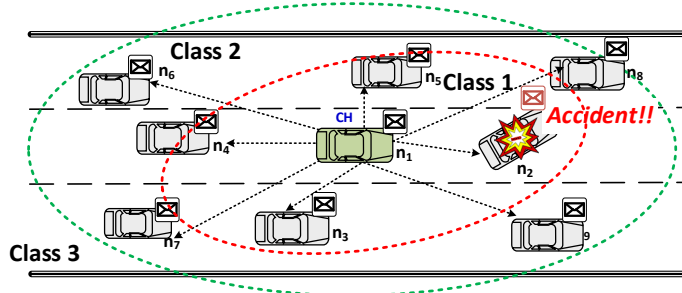
- Maneuver of vehicles which are in danger
  - Exit from emergence : Safely drive through
- Motion planning for the Emergence vehicles
  - Collaborative vehicle trajectory planning via msg exchange
  - based on neighboring vehicles in Clusters

Cooperative Collision Avoidance (2/2)

- Coordinated Maneuvers
  - Kinematics information are shared in real time.
  - Cluster Heads assess risks associated with sensed data.
  - Plan Maneuver Path & tracking
  - To centralize the computation : minimize computation burden
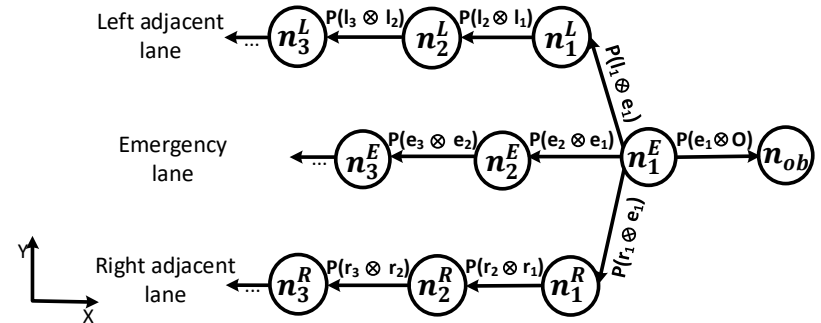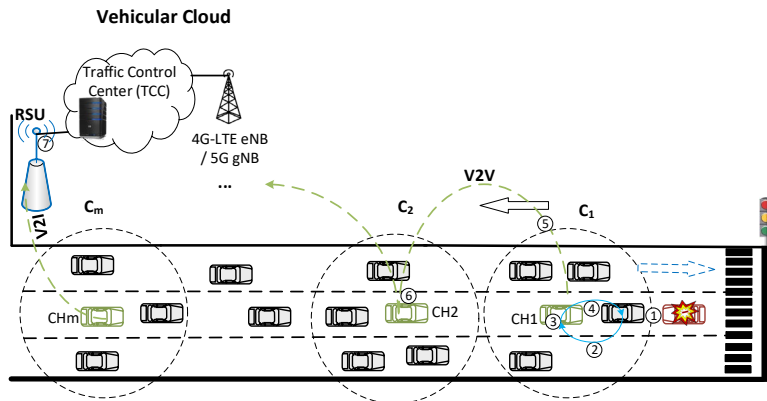
- Collision probability:
$$P_{c,p} = 1 - \left(\frac{T_c - T_{cmin}}{T_{cmax} - T_{cmin}} \right)$$
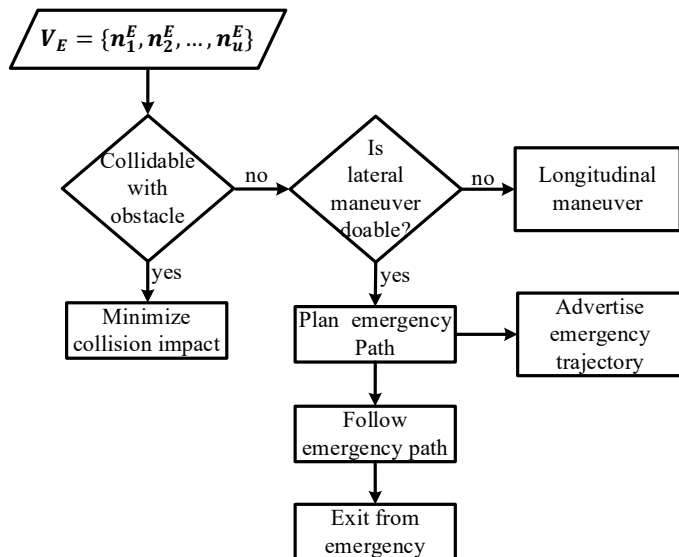
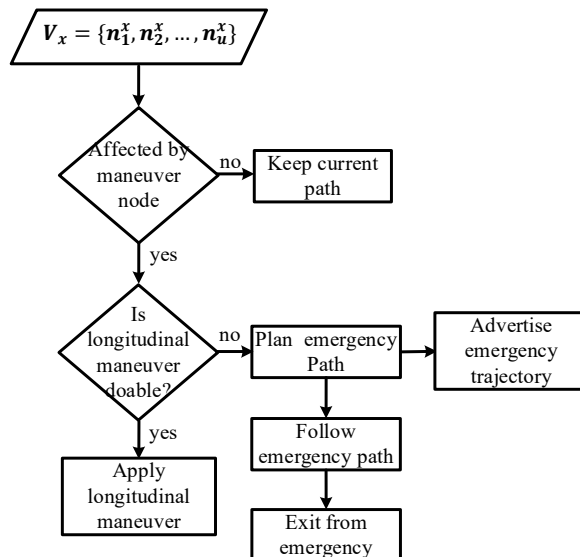- Safe Probability
$$q_i = 1 - P_{c,p}$$

- Safe Lane quality
$$SL = \prod_{i=1}^{u} q_i$$

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Emergency Maneuver

Front Vehicles

$V_E = \{n_1^E, n_2^E, \ldots, n_u^E\}$

Collidable with obstacle
- no → Is lateral maneuver doable?
  - no → Longitudinal maneuver
  - yes → Plan emergency Path → Advertise emergency trajectory
- yes → Minimize collision impact

Plan emergency Path → Follow emergency path → Exit from emergency

Rear Vehicles

$V_x = \{n_1^x, n_2^x, \ldots, n_u^x\}$

Affected by maneuver node
- no → Keep current path
- yes → Is longitudinal maneuver doable?
  - no → Plan emergency Path → Advertise emergency trajectory
  - yes → Apply longitudinal maneuver

Plan emergency Path → Follow emergency path → Exit from emergency

$$L_x^* = \max_{L_x \in \{L,E,R\}} (S_L, S_E, S_R)$$

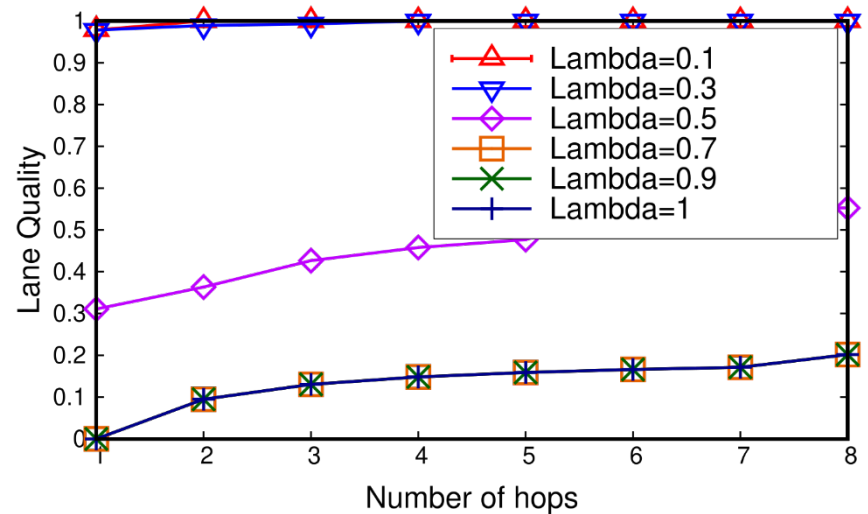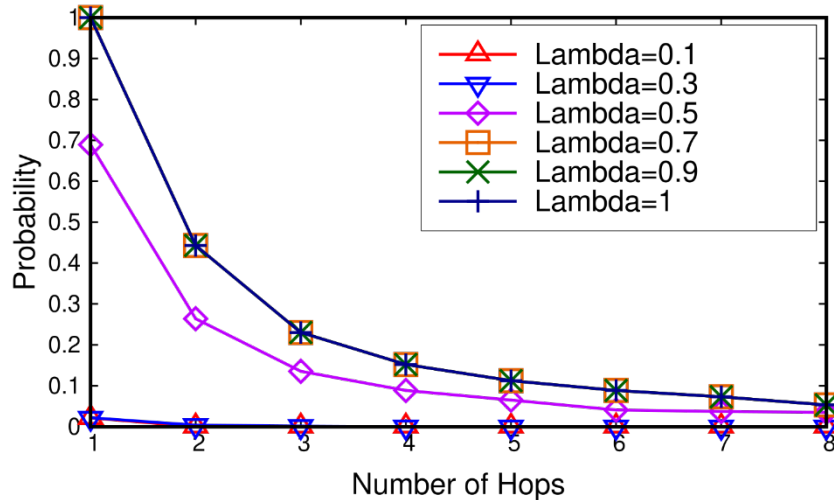The decision of the lane for maneuvering emergency vehicles in adjacent lanes

$$u = [\rho \quad a]^T$$

trajectory control input

- The directly affected vehicles are the first to be maneuvered.
- The rear vehicles affected by maneuvers are also maneuvered.

Simulation Results (1/4)

Lane quality validation

- The risk of collision is high if the CNP assesses the risk only to its neighbors.

- The greater the number of vehicles in the lane that are considered by the risk assessment is, the lower the risk of collision is.

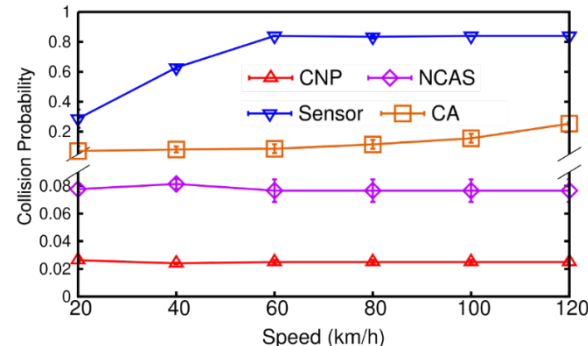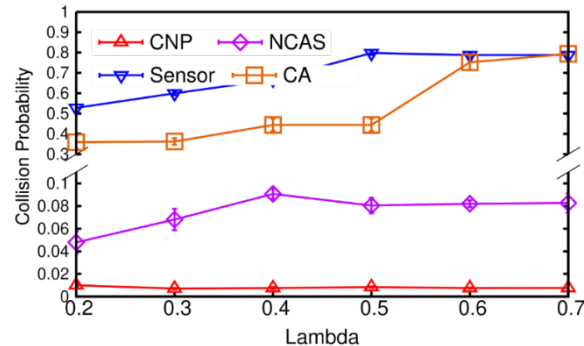- A small number of vehicles in the CNP risk assessment will result in poor safe lane quality.

Overhead & Collision Probability of CAP, NCAS and Sensors
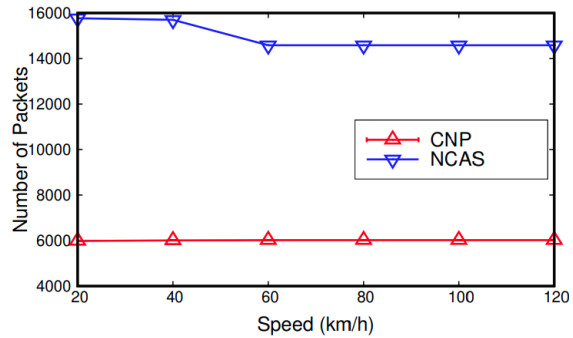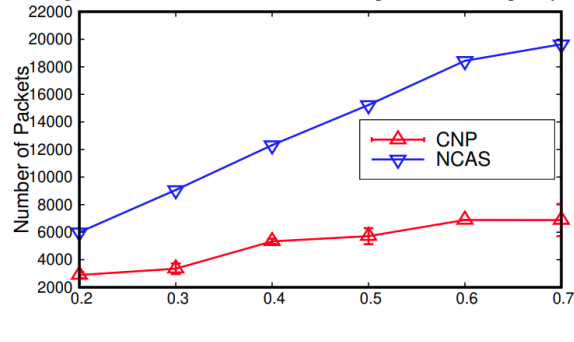
Overhead

- CNP reduces 15-60% of communication overhead caused by NCAS (Average Speed =80km/h)
- It also reduces up to 60% of communication overhead (Lambda = 0.6)

Collision Probability

- CNP has the minimal collision risk on average either considering road arrival rates or speeds
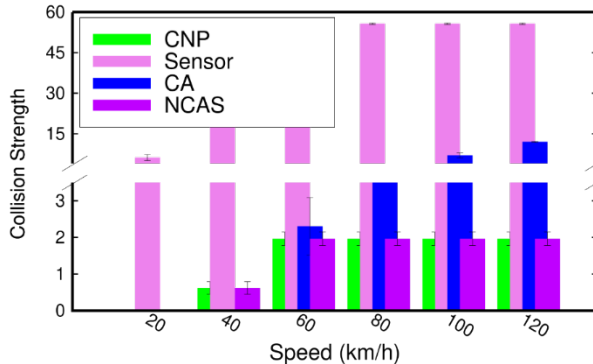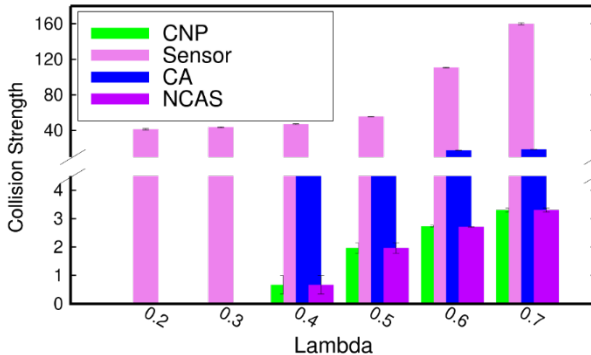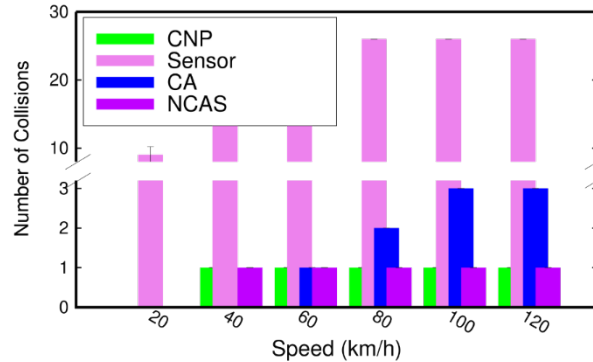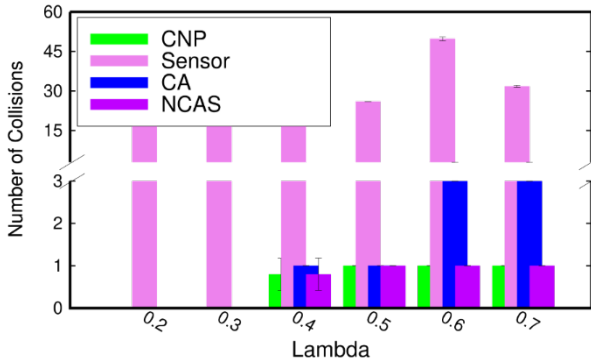
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Number and strength of collisions for CAP, NCAS and Sensors

Number of Collisions

CNP has the smallest number of collisions either when we considering road arrival rates or speeds
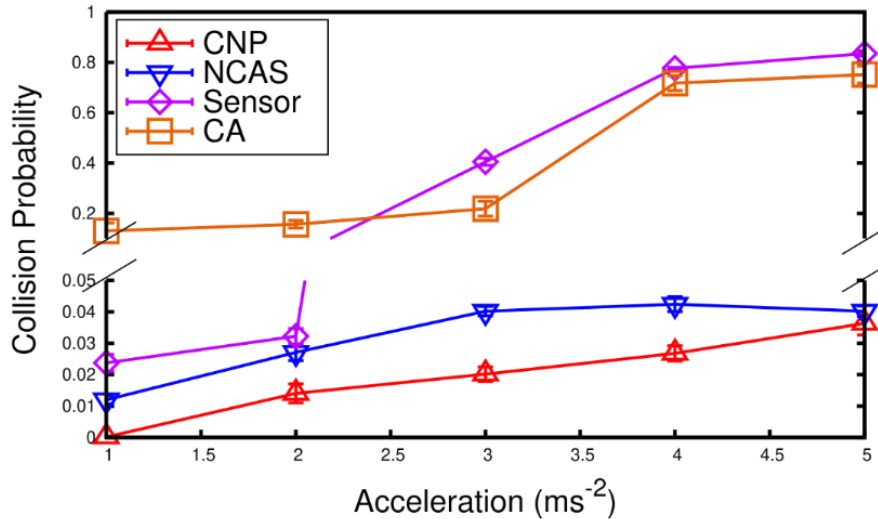

Collision Strength

The collision strength is the smallest in CNP, resulting in small damage of colliding vehicles for both road arrival rates and speeds.

Impact of Acceleration

Collision Probability

- CNP has the minimal collision risk on average for all the accelerations tested.