24. ITG Fachtagung Mobilkommunikation – Technologien und Anwendungen

A Controller for Network-Assisted CACC based Platooning

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Agenda

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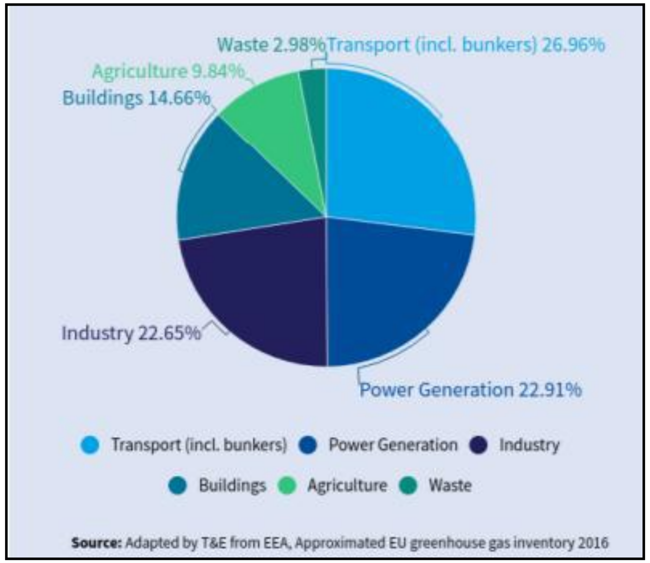
Introduction

- High number of vehicles in the transport and private sectors
- ITS technologies – Focus towards vehicle safety (ADAS) and efficiency (start-stop system)
- Usage of V2V and C-V2X technologies can further improve vehicle safety – increased communication range, can be tailored to specific applications (commercial/safety)
- C-ITS enables vehicle-safety and traffic management technologies
- Beneficiaries (major) of C-ITS services:
    - Reduced travel times (66%)
    - Reduced accident rates (22%)
    - Reduced fuel consumption (11%)

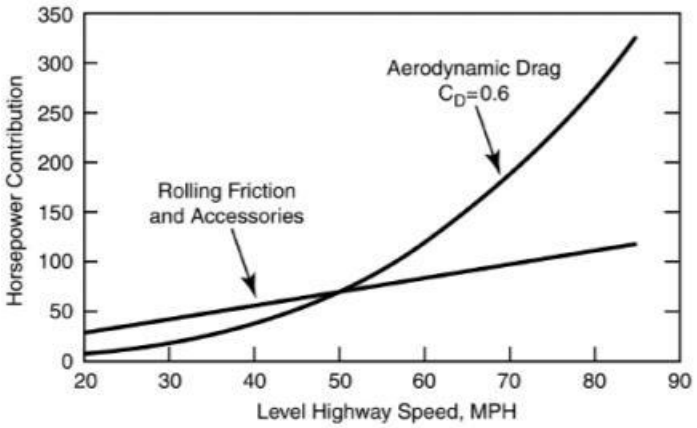


Goals

- Implementing a controller based on CACC principles
- Portray the impact of wireless communication for low latency, high reliability application such as platooning (at low inter-vehicular distances) – DSRC, LTE-V2V sidelink
- Simulations/Scenarios highlighting the controller's capabilities:
  - Creating a platoon with suitable vehicles
  - Maintaining platoon stability (main focus) – reducing vehicle instability (locally and globally)

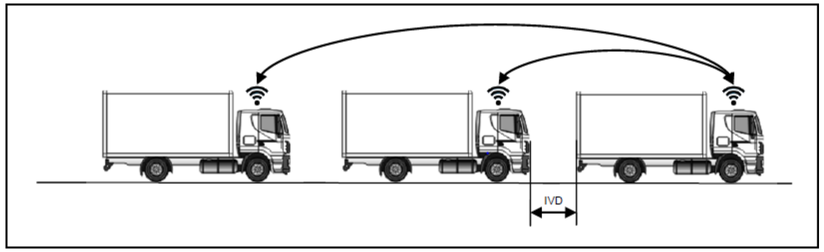
Platooning

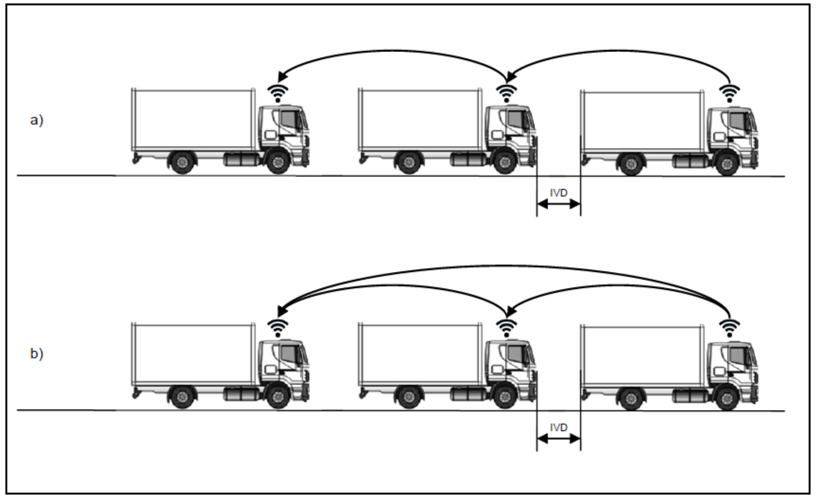
- Distance reduction effects:
  - Increased base pressure (leader)
  - Decreased drag (follower)
- Forming Strategies:
  - Scheduled/Static – vehicles are pre-decided
  - Real-time – vehicles are decided en-route
  - Opportunistic – vehicles are decided based on vicinity to one another
- Control Strategies:
  - Variable spacing – speed based control (ex. ACC) – headway defined in time
  - Constant spacing – distance based control (ex. CACC) – headway defined in distance



Vehicle power consumption to overcome resistances

Platooning – CACC Control Strategies





- Centralized
  - Platoon leader micro-manages every platoon member – speed, distance, acceleration, etc.
  - Controller is "installed" in the leader – so only a predefined vehicle can be used as a leader

- Decentralized
  - Every vehicle is responsible to maintain IVD/speed
  - Can be attained by obtaining information of
    - Only the preceding vehicle
    - The preceding vehicle and the leader

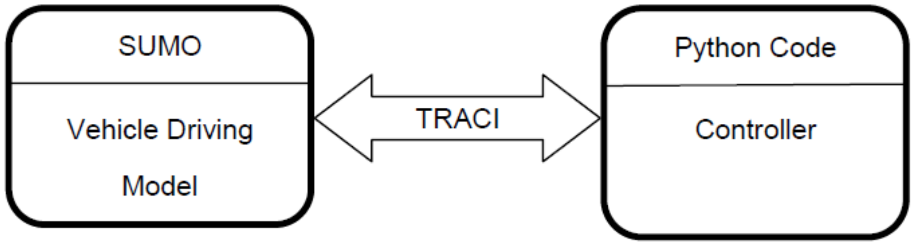
Controller

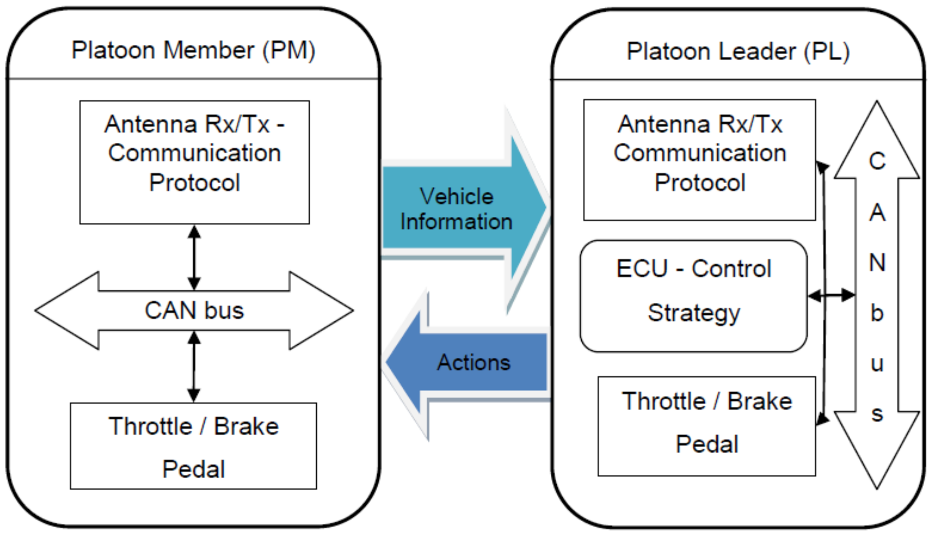
- Requirements:
  - Ability to form platoons on the go
  - Maintain platoon stability
  - Adapt to vehicles in front of the platoon
  - Conform to road's/user's specified speed limits

- Assumptions:
  - Straight line driving is expected, i.e., no lateral movement/steering is expected
  - Platoon members do not leave the platoon
  - Controller doesn't allow for non-members to break the platoon
  - All vehicular components (brake pedals, throttle pedals, etc) work without a glitch

Controller – Architecture & Logic

- Controller is installed in the Platoon leader (centralized approach)
- Leader selection - A truck is always chosen due to its higher frontal area
- Member selection based on:
  - Distance from the last platoon member – lower the better
  - Speed of the vehicle - +/- 25% of platoon speed
- Joining manoeuvre – vehicles join in behind the current last member
- Information exchange between PMs and PL
  - Current position (PM -> PL)
  - Current velocity (PM -> PL)
  - Current distance to its preceding member (PM -> PL)
  - Actions – brake, accelerate, maintain speed (PL -> PM)
- **Platoon stability** – Saw tooth control
  - A tolerance range is given to the controller (desired IVD +/- 10%) based on which the apt PM is accelerated or decelerated
  - Prevent vehicles from being in a state of constant disarray (undershooting and overshooting)





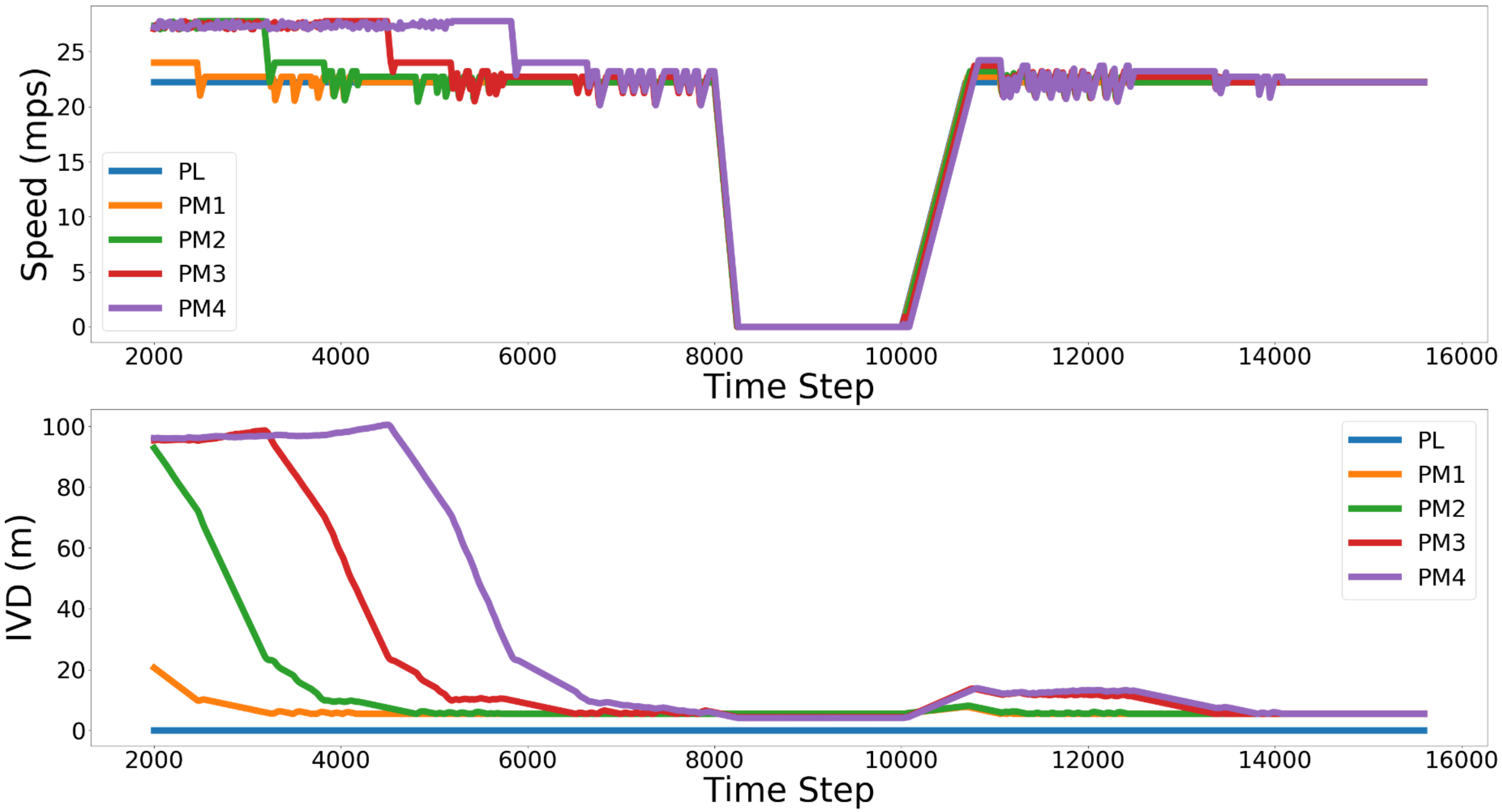
Simulation Set-up

- SUMO – microscopic traffic simulator
- 4 km of highway (single lane)
- Road speed limit = 130 kmph
- Vehicles used – trucks
- Reaction time of vehicles = 0.3 s (internal processing time for vehicles)
- Networks simulated – DSRC, LTE-V2V sidelink (Abstract implementation - PDR values)
- Message rates – 12.5 ms, 25 ms and 100 ms
- Tested IVDs – 1 m, **5 m** and 10 m
- Reaction time (τ) = 0 s
- Min gap (g) = 0 m
- Platoon speed = 80 kmph

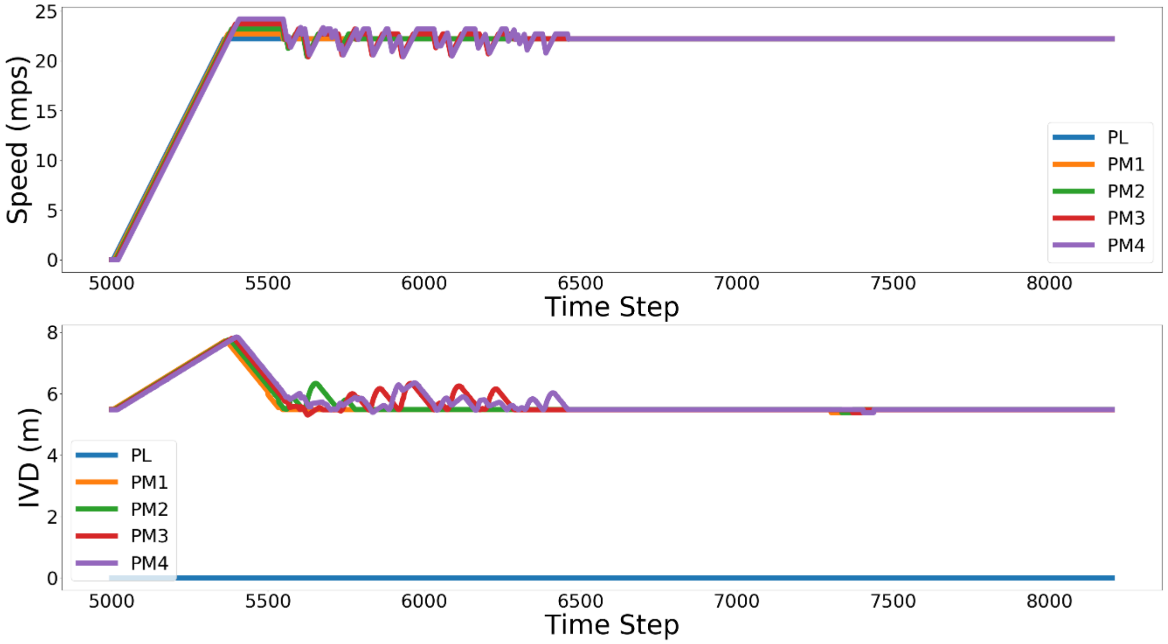
Results – Simulation Phases

- Complete simulation at a message rate of 12.5 ms or 80 Hz
- Simulation phases:
  - 2000 – ~6500: Formation
  - 8000 – 10000: Emergency braking
  - 10000 – ~11000: Acceleration

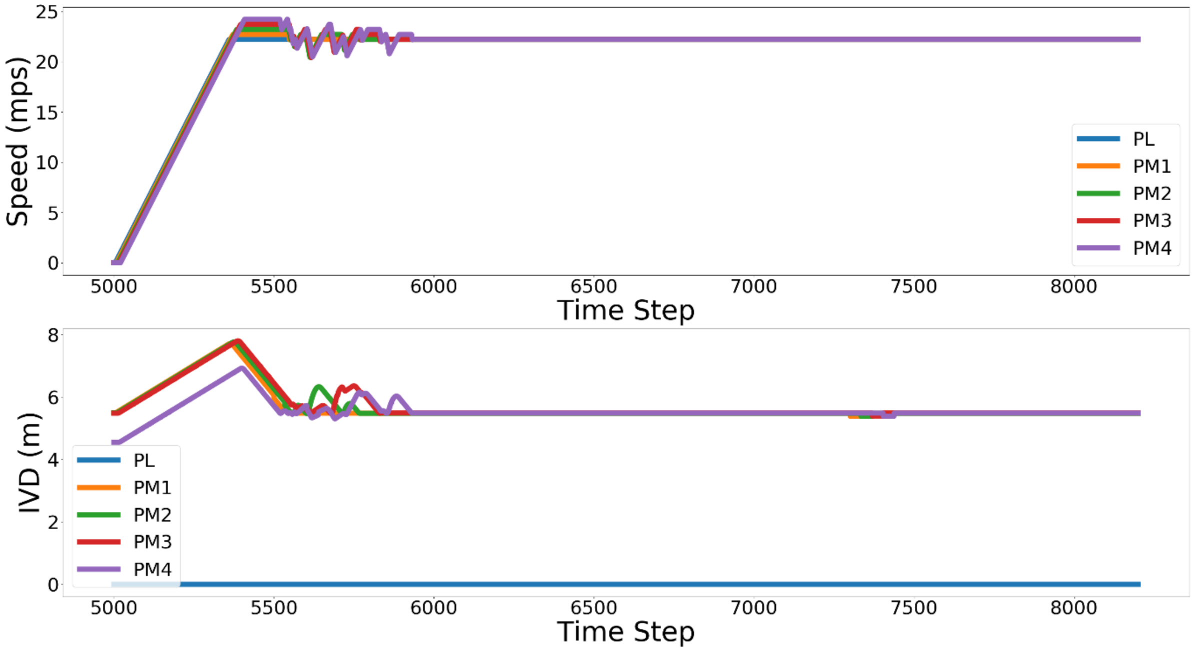
Note – A simulation time step is equal to the message rate, i.e., here a time step is equal to 12.5 ms



Results – DSRC vs LTE-V2V sidelink



DSRC @ 40 Hz



LTE-V2V sidelink @ 40 Hz

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Results

- The values for PM 1-4 are percentages (of the total time taken for the platoon to achieve stability), i.e., the amount of time each vehicle is responsible for the instability in the platoon
- The instability can be amounted to:
  - Reaction time of vehicles (300 ms) – bottleneck!
  - Messages not being received
  - Consecutive packets being dropped

Message Rate	DSRC	LTE-V2V sidelink
80 Hz	~39 seconds	~31 seconds
40 Hz	~40 seconds	~32 seconds
10 Hz	~27 seconds	~25 seconds

MR = 12.5ms, IVD = 5m	LTE	DSRC
PM1 (%)	67.46	34.19
PM2 (%)	75.88	68.54
PM3 (%)	91.58	86.71
PM4 (%)	94.01	87.65
Total Time (s)	30.8875	39.8875

24 messages

MR = 25ms, IVD = 5m	LTE	DSRC
PM1 (%)	41,48	34,63
PM2 (%)	79,69	46,19
PM3 (%)	92,75	75,08
PM4 (%)	94,23	84,42
Total Time (s)	32,125	40,425

12 messages

MR = 100ms, IVD = 5m	LTE	DSRC
PM1 (%)	82,4	52,08
PM2 (%)	78,4	80
PM3 (%)	70,8	80,38
PM4 (%)	87,2	81,89
Total Time (s)	25	26,5

3 messages

Conclusion & Future Work

Conclusion:

- Platoon stability is achieved over multiple simulations, excluding the ones in which vehicle collision was detected
- Higher the IVD, higher is the stability of the platoon
- Higher message rate leads to more redundant messages and network usage
- The vehicle reaction time should govern the frequency at which messages are received
- LTE-V2V sidelink achieves platoon stability at a faster rate than DSRC owing to its higher PDR values

Future Work:

- PID control implementation in place of saw-tooth control to provide for smoother transitions for vehicles
- Implement a detailed model of a wireless communication protocol rather than a high level abstraction (PDR)
- Introduce other parameters – latency, network congestion, resource allocation, etc.

Thank You

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