Effects of Dynamic Weight Distribution and Communication Delay on Connected and Autonomous Vehicle Platoon Dynamics

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Short summary

Connected and autonomous vehicles depend on inter-vehicular communications to perform cooperative driving tasks. Hardware failures and malicious attacks can cause communication disruptions, potentially affecting traffic efficiency and safety. In this paper, we proposed a multi-anticipative IDM with a range-based communication topology under delay. Information from multiple predecessor vehicles weighted through an exponential distribution incorporating cumulative distance and signal decay parameter. We derived stability conditions under communication delay to evaluate model stability under different parameter variations. The critical communication delay $\tau_c(v_e)$ is derived, beyond which the platoon becomes unstable. Also, the model is evaluated under clustered communication failure, where consecutive vehicles lost communication ability due to a malicious attack. Simulations show improved oscillation dampening and reduced velocity error than baseline IDM. Safety impact evaluated over a range of failure durations through multiple runs of simulations.

Keywords: Connected and autonomous vehicles, Traffic flow theory, Automated and connected driving, V2V communication, DSRC communication, Stability analysis

1 Introduction

Connected and Autonomous Vehicles (CAV) offers improvements in traffic efficiency, safety, and fuel economy. Vehicle-to-vehicle (V2V) communication or vehicle-to-anything (V2X) allows CAVs to share real-time data regarding their movement, thereby fostering cooperative driving and enhancing traffic flow. Cooperative driving in CAV leverage information from multiple predecessors to enhance string stability and achieve smaller time headways (Z. Wang et al., 2018). Usually the complete reliability of V2V/V2X communication is assumed during several autonomous driving (AD) tasks such as merging (Xu et al., 2019), isolated and network-wide traffic control (L. Li et al., 2014), motion planning in urban and free way traffic (Claussmann et al., 2020; Katrakazas et al., 2015), manuever planning in signalized and non-signalized intersections (Z. Wang et al., 2022; Gholamhosseinian & Seitz, 2022), cooperative perception (Ngo et al., 2023), lane changing control (Ma et al., 2023; T. Li et al., 2020) and collision avoidance (Zhang et al., 2022). However, in practice, V2V communication among CAVs could experience different kinds of communication loss or uncertainties (Garg & Bouroche, 2025). There are several factors, such as cyber attacks (P. Wang et al., 2020), random packet loss (Halder et al., 2022), communication delays (Petrillo et al., 2021), and hardware-related issues (Khattak et al., 2021), that result in communication disruptions.

In the existing literature, single-vehicle communication failures have been mostly studied. Malicious attacks can cause consecutive vehicle failures for prolonged duration. Communication failure in vehicle clusters and the impact of communication delay in a range-limited vehicular communication topology is less explored despite its very likely occurrence in urban or highway traffic scenarios. This paper introduces a dynamic range-limited multi-anticipative intelligent driver model with time-varying communication topology (DRMIDM-C). We modelled a range-based exponential weight distribution and studied the impact of communication delay on stability. Local and string stability conditions are derived under V2V communication delay. The critical communication delay was derived to evaluate model robustness. Studying under different delays shows transition of

the model from stable to marginally stable regime.

The paper is organized as follows. In Section 2, the mathematical description of the model and communication topology is provided. Local and string stability conditions are derived to assess the impact on traffic flow due to cluster communication failures under delays. The experimental design and required simulation configurations are described. Section 3 reports how stability varies due to different communication delays and model stability, followed by Section 4 to conclude the paper.

2 Methodology

In this section, CAV dynamics with a dynamic range-limited communication topology are presented. The exponential weight distribution and stability analysis considering communication delay are presented. Also, from the local stability analysis, an expression for the critical communication delay is derived for the given parameter set.

DRMIDM-C Model

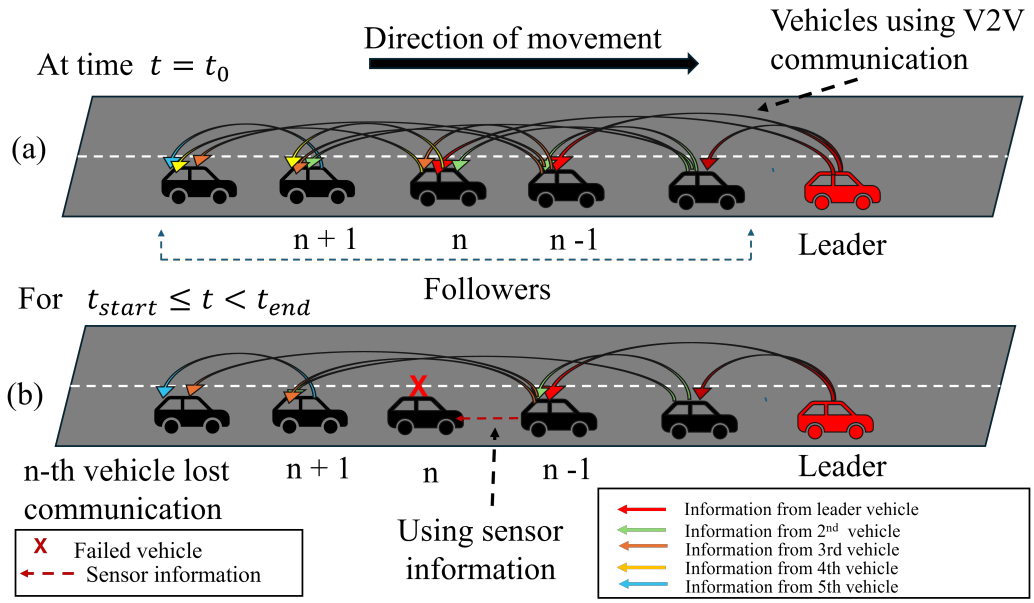


Figure 1: (a) CAV traffic using V2V communication, (b) Single vehicle failure scenario.

The dynamics of a CAV platoon were described by a multi-anticipative IDM-based model with dynamic range-limited communication topology (DRMIDM-C) where each CAV receives information from $n-k+1$ vehicles using V2V communication within a limited range. The longitudinal acceleration $\dot{v}_n(t)$ of CAV n given by

$$\dot{v}_n(t) = a_{\max}\left[1 - \left(\frac{v_n(t)}{v_0}\right)^{\delta} - \left(\frac{s_n^*(v_n(t), \Delta v_n(t))}{\sum_{k=1}^{M_n(t)} w_{n,n-k}\, s_{n-k+1}(t-\tau)}\right)^2\right] \tag{1}$$

and the desired spacing s_n^* defined as,

$$s_n^*(t) = s_0 + T v_n(t) - \frac{v_n(t)}{2\sqrt{a_{\max} b}} \sum_{k=1}^{M_n(t)} w_{n,n-k}(t)\Delta v_{n-k+1}(t-\tau) \tag{2}$$

where $a_{\max}$, b, v_0, s_0, T, δ, τ represent the maximum acceleration, maximum comfortable deceleration, free traffic velocity, minimum safe distance, desired time headway, acceleration exponent, and communication delay respectively. $v_n(t)$, $s_n(t)$ and $\Delta v_n(t)$ represent the velocity, actual spacing from vehicle $n-1$, and relative velocity of the CAV n at time t. The number of neighbouring

vehicles constrained by the communication range R.

$$M_n(t) = \max\left\{ m \;\middle|\; \sum_{j=1}^{m} s_{n-j+1}(t) \le R \right\} \tag{3}$$

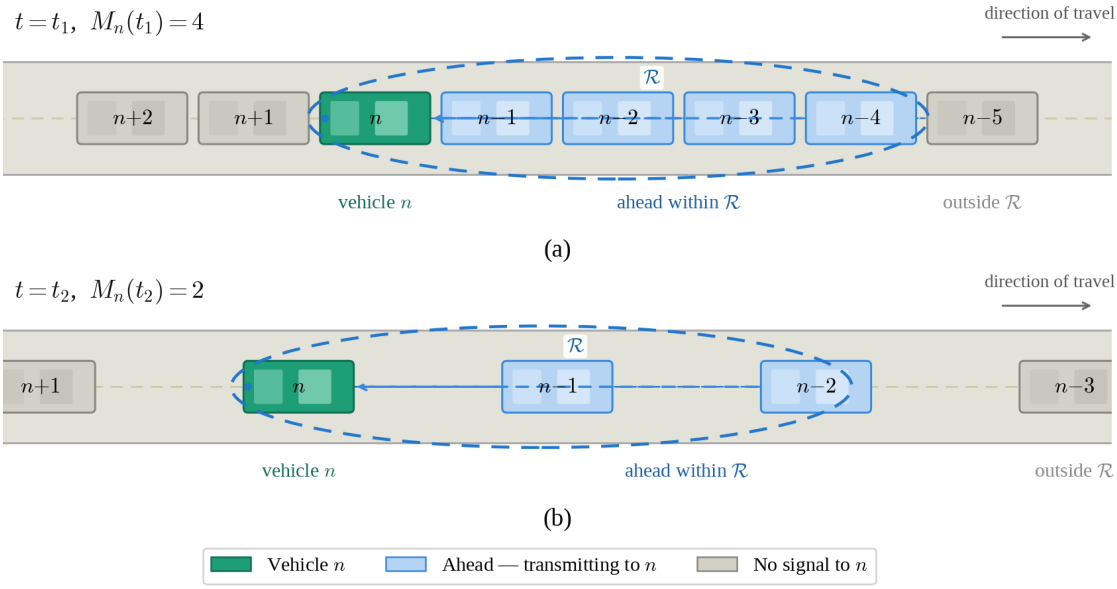


Figure 2: Range based communication with neighbouring vehicles

In a homogeneous platoon, the lengths of all vehicles are taken to be identical, L. $w_{n,n-k}$ represents the weights of the information received by a vehicle n from its neighbouring vehicles $(n-k)$. The actual spacing $s_n(t)$ and relative velocity $\Delta v_n(t)$ defined as

$$s_n(t) = \begin{cases} x_{n-1}(t) - x_n(t) - L, & \text{if } n \notin F(t) \text{ (with V2V)} \\ x_{n-1}(t) - x_n(t) - L + \xi_n(t), & \text{if } n \in F(t) \text{ (without V2V)} \end{cases} \tag{4}$$

$$\Delta v_n(t) = \begin{cases} v_{n-1}(t) - v_n(t), & \text{if } n \notin F(t) \text{ (with V2V)} \\ v_{n-1}(t) - v_n(t) + \psi_n(t), & \text{if } n \in F(t) \text{ (without V2V)} \end{cases} \tag{5}$$

where $F(t)$ represents the set of failed vehicles. During the communication failure any CAV will degraded to AV and gather information using its onboard sensor only. The sensor noise in measuring the position and velocity given by

$$\begin{aligned} \xi_n(t) &\sim \mathcal{N}\left(0, \sigma_p^2\right) \\ \psi_n(t) &\sim \mathcal{N}\left(0, \sigma_v^2\right) \end{aligned} \tag{6}$$

In Eqn.(6), $\xi_n^{(s)}$ and $\psi_n^{(s)}$ represent the measurement noise from the onboard sensor data (LIDAR, Radar, IMU, GPS, etc.) in position and velocity drawn from the normal distribution $\mathcal{N}(\cdot)$ during the communication failure, respectively. During the normal operating condition, the information exchange between CAVs using V2V communication is free from any noise.

The communication topology among CAVs represented by a directed graph $\mathcal{G} = (\mathcal{V}, \mathcal{E})$, where the set of nodes $\mathcal{V}$ represents the platoon vehicles and the directed edge set $\mathcal{E} \subseteq \mathcal{V} \times \mathcal{V}$ represents the communication links between them. The dynamic communication topology between N vehicles described by the adjacency matrix $\mathcal{A}(\mathcal{G}) = [d_{ij}]_{N\times N}$, where $d_{ij} = 1$ if $(i,j) \in \mathcal{E}$ and $d_{ij} = 0$ otherwise. The entries in $\mathcal{A}(\mathcal{G})$, for the leader vehicle (1st row) will be 0 as it moving independently. In case of communication failure, any failed vehicle (r) cannot receive or transmit information, resulting in degradation from CAV to AV. The corresponding row and column entries in $\mathcal{A}(\mathcal{G})$ for degraded AVs will be 0, $d_{r,i} = d_{i,r} = 0\ \forall i$. $M_n(t)$ be the number of neighbouring vehicles in front from which any vehicle n will receive information at time t. The contribution of the information from the different preceding vehicles is scaled by the weights $w_{n,n-k}$, so that the closer vehicle has

the higher precedence. Hence $w_{2,1} > w_{2,2} > \cdots > w_{2,k}$ (Ngoduy, 2015; Sun et al., 2018) which satisfy $\sum_{k=1}^{M} w_{n,n-k}(t) = 1$ whenever at least one upstream link exists(i.e. $d_{n,n-k} = 1$ for some k). The adjacency map-based weights are represented as a weight matrix for the entire platoon $\mathcal{W}(\mathcal{G})$. In case of communication failure, both $\mathcal{A}(\mathcal{G})$ and $\mathcal{W}(\mathcal{G})$ update accordingly in real time. On communication failure, the corresponding entries in $\mathcal{W}(\mathcal{G})$ will be 0, and the corresponding weights will be dynamically redistributed so that the information from the closer vehicle has higher weights. The weights $w_{n,n-k}$ expressed as

$$w_{n,n-k}(t) = \frac{d_{n,n-k}(t) \cdot \exp\left(-\frac{D_{n,n-k}(t)}{\lambda}\right) \cdot (M_n(t) - k + 1)}{\sum_{j=1}^{M_n(t)} d_{n,n-j}(t) \cdot \exp\left(-\frac{D_{n,n-j}(t)}{\lambda}\right) \cdot (M_n(t) - j + 1)}, \qquad k = 1, \ldots, M_n(t) \tag{7}$$

where $d_{n,n-k} = 1$ if V2V communication exists between vehicles n and $n-k$, and 0 otherwise. The signal decay parameter is λ and cumulative distance to the n-th leader $D_{n,n-k}(t)$ given by

$$D_{n,n-k}(t) = \sum_{j=1}^{k} s_{n-j+1}(t), \qquad k = 1, \ldots, M_n(t) \tag{8}$$

In Fig. 1, a platoon of N CAVs moving on a single lane straight highway configuration. The communication topology among the vehicles is described by a multi-predecessor following (MPF) topology, where each vehicle receives relative velocity Δv_i and spacing s_i information from M number of vehicles ahead using DSRC. The leader vehicle is assumed to be moving independently, without any information from vehicles ahead. Suppose a vehicle n lost its communication ability at time t, since then the vehicle n neither receives nor transmits information from or to other vehicles. Let CAV n receive information from 3 vehicles ahead of it, $M_n = 3$ (from eqn. 3). Then during the communication failure, other vehicles won't receive any information from CAV n, it is considered degraded to AV. During the communication failure it will be driven by the information obtained from its immediate leading CAV $n-1$, through its onboard sensors only. In Fig. 2, the operation of range-based communication topology represented. Any vehicle i can receive information from another vehicle j if $j \in M_i(t)$, i.e. $x_j(t) > x_i(t)$ and $(x_j - x_i - L) \leq \mathcal{R}$. At t_1, vehicle n was receiving information from the 4 vehicles ahead which satisfies the condition given in Eqn. 3, whereas at time t_2, the number of neighbouring vehicles changed to 2.

Stability Analysis

The local stability of the DRMIDM-C governed by the characteristic equation (Laplace transform)

$$s^2 + \alpha s + w_{n,n-1} e^{-s\tau}(\gamma + \beta s) = 0 \tag{9}$$

where α, β and, γ given by

$$\begin{aligned}
\alpha &= a_{\max}\left[\frac{\delta}{v_0}(\frac{v_e}{v_0})^{\delta-1} + \frac{2T(s_0 + Tv_e)}{s_e^2}\right], \\
\beta &= \frac{v_e\sqrt{a_{\max}}(s_0 + Tv_e)}{s_e^2\sqrt{b}}, \\
\gamma &= \frac{2a_{\max}(s_0 + Tv_e)^2}{s_e^3} w_{n,n-1}.
\end{aligned} \tag{10}$$

To maintain the asymptotic stability, all real roots of the Eqn. 9 need to satisfy $\mathcal{R}(s) < 0$.
For $\tau = 0$, from Routh-Hurwitz criterion, the local stability condition

$$a_{\max}\left[\frac{\delta}{v_0}(\frac{v_e}{v_0})^{\delta-1} + \frac{2T(s_0 + Tv_e)}{s_e^2}\right] + \frac{v_e\sqrt{a_{\max}}(s_0 + Tv_e)}{s_e^2\sqrt{b}} w_{n,n-1} > 0 \tag{11}$$

For $\tau > 0$, the characteristic equation is transcendental. The marginal stability boundary found by substituting $s = j\omega$

$$-\omega^2 + j\omega\alpha + w_{n,n-1} e^{-j\omega\tau}(\gamma + j\omega\beta) = 0 \tag{12}$$

For a given model parameters, the system is locally stable for a given $\tau > 0$ iff all roots the Eqn. 12 is negative. The local stability of DRMIDM-C with communication delay τ maintained for $0 \leq \tau < \tau_c$, where critical delay τ_c given by

$$\tau_c = \frac{1}{\omega_c}\left[\arctan\left(\frac{\omega_c\beta}{\gamma}\right) + \arctan\left(\frac{\alpha}{\omega_c}\right)\right] \tag{13}$$

where oscillation frequency at stability boundary ω_c given by

$$\omega_c = \left(\frac{-(\alpha^2 - w_{n,n-1}^2\beta^2) + \sqrt{(\alpha^2 - w_{n,n-1}^2\beta^2)^2 + 4w_{n,n-1}^2\gamma^2}}{2}\right)^{1/2} \tag{14}$$

The string stability of the DRMIDM-C with communication delay τ is given by the transfer function $H(s)$,

$$H(s) = \frac{\gamma e^{-\tau s}(1 - H(s))\, P_s(H)}{s\big[s + \alpha - \beta e^{-\tau s}(1 - H(s))\, P_v(H)\big]},$$

where the weighted polynomials are defined as

$$P_s(H) = \sum_{k=1}^{M_n} w_{n,n-k} H^{-(k-1)}, \qquad P_v(H) = \sum_{k=1}^{M_n} w_{n,n-k} H^{-k},$$

with $w_{n,n-k}$ given by Eqn. 7 The parameters α, β, γ are as defined in Eqn. 10. The platoon is string stable iff

$$\sup_{\omega \geq 0} |H(j\omega)| \leq 1.$$

For the special case of only the immediate leader ($M_n = 1$), the transfer function simplifies to

$$H(s) = \frac{\beta s + \gamma}{e^{\tau s} s(s + \alpha) + \beta s + \gamma},$$

and the string stability condition reduces to $|H(j\omega)| \leq 1 \; \forall \; \omega \geq 0$.

Safety Performance Measure

The model is studied for the cluster failure scenario to evaluate the impacts on the safety performance of the model. Hence, TTC value was used to measure whether the CAVs undergo a safety-critical situation using a TTC threshold ($TTC_{\text{threshold}}$) (Minderhoud & Bovy, 2001). Below the $TTC_{\text{threshold}}$, any TTC value indicates a safety-critical situation. A shorter TTC indicates the possibility of read-end collision and directs the CAV for deceleration. Whereas a large TTC indicates that the CAV can safely accelerate towards the leading vehicle.

Communication Failure Experiments

A framework is designed to evaluate the dynamical performance of the CAV platoon under cluster failure scenarios. Impacts on safety and stability are assessed across different communication delays under V2V communication failure scenarios. The leader vehicle driven by external driving profile and the platoon moving using the DRMIDM-C control mechanism. The cluster failure scenario shows the vehicles experiencing packet loss due to correlated shadowing (Nilsson et al., 2017) or malicious attacks (P. Wang et al., 2020).

A platoon of 10 CAVs is considered to evaluate the impacts of communication failures through simulations. Each CAV gathers spacing and relative velocity data from the vehicles ahead, given by $M_n(t)$ within the DSRC communication range R at time t. The parameters used were adopted from the literature (Kesting et al., 2010; Moradi-Pari et al., 2023) except for the desired time headway T given in the Table 1. The baseline parameters are calibrated using human-driven vehicle data. Maintaining the same T might diminish the potential benefits of CAVs. Because CAVs have better response time than human drivers and improve traffic efficiency by sustaining higher throughput, adopting a lower T value is reasonable (Rahman & Abdel-Aty, 2018). In Table 2, the details of different simulation experiments are given. For multiple runs, a cluster of consecutive vehicles is chosen at random. The duration of cluster failure varied from $5s - 30s$ and the time window also varied within $[25s, 125s]$ to obtain the distribution of Min TTC with the help of multiple runs of simulations. The failure start time and duration are chosen from a uniform distribution. Time delays were kept fixed throughout the simulation.

Table 1: Model Parameters

Parameter	Description	Value	Units
$a_{\max}$	Maximum acceleration	1.4	m/s^2
b	Maximum comfortable deceleration	2.0	m/s^2
v_0	Free traffic velocity	33.3	m/s
s_0	Minimum distance	2	m
L	Vehicle length	5	m
T	Desired time headway	1.5	s
δ	Acceleration exponent	4	–
R	DSRC communication range	200	m
λ	Signal decay parameter	100	m
σ_p	Standard deviation of sensor noise in position measurement	0.1	m
σ_v	Standard deviation of sensor noise in velocity measurement	0.1	m/s

Table 2: Simulation Experiments

ID	Multi-anticipation	τ (s)	λ (m)	Failure	Description
1	$M = 1$ only	0	–	None	Baseline IDM (single predecessor)
2	Range-based	0	100	None	DRMIDM-C without delay
3	Range-based	0.2	100	None	DRMIDM-C with $\tau = 0.2$ s
4	Range-based	0.2	100	5,6,7	Clustered failure + delay
5	Range-based	0	50	None	Sharper weight decay ($\lambda = 50$ m), no delay
6	Range-based	0.2	50	None	Sharper weight decay + delay

3 Results and discussion

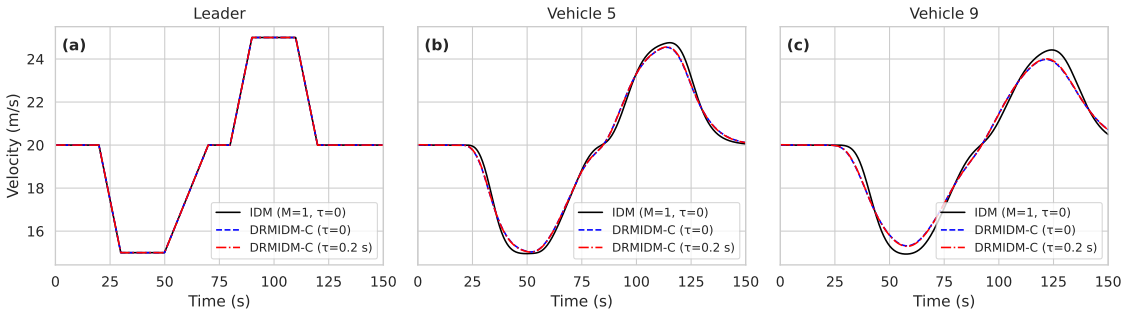


Figure 3: Velocity evolution for (a)leader, (b)vehicle 5, and (c)vehicle 9.

Fig. 3 compares how the velocity fluctuations propagate upstream. DRMIDM-C suppresses oscillations even in presence of communication delay. The performance of DRMIDM-C show better oscillations damping than the baseline model (IDM) considered.

From the acceleration profiles in Fig. 4, it is found that DRMIDM-C provides smoother acceleration with lower peak amplitude than the baseline IDM. In the presence of communication delay ($\tau = 0.2s$), it introduces sharp deceleration due to operating on stale information. when a CAV receives a spacing and relative velocity information with delay, by the time the acceleration is executed the actual traffic situation is already evolved. The exponential weighting of multiple predecessors prevent such oscillations from growing and preserve platoon stability.

Maximum velocity deviation from the equilibrium velocity v_e of all vehicles over the duration $t \in [20, 150]$, where leader velocity profile going through variations. The baseline IDM (black circles) exhibits growing error with vehicle index. In contrast, DRMIDM-C variants shows decreasing error profiles. In presence of communication delay (red triangles) or sharper weight decay $\lambda = 50m$ (green and orange inverted triangles) elevates the error but does not reverse the decreasing trend.

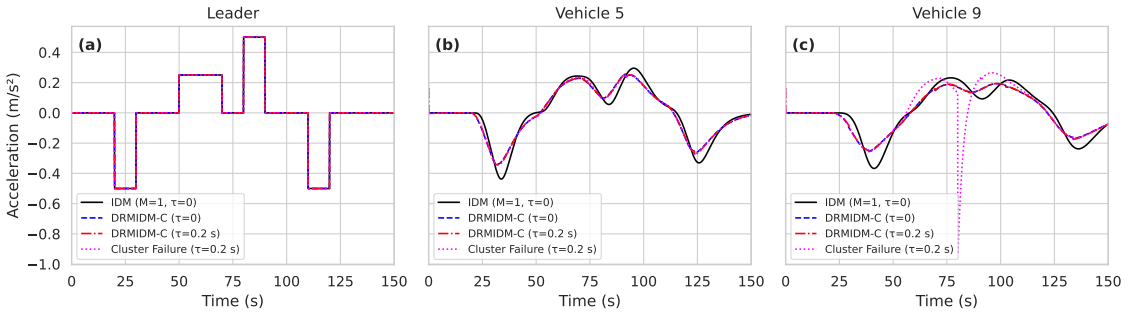


Figure 4: Acceleration profile for (a)leader, (b)vehicle 5, and (c)vehicle 9 across different scenarios.

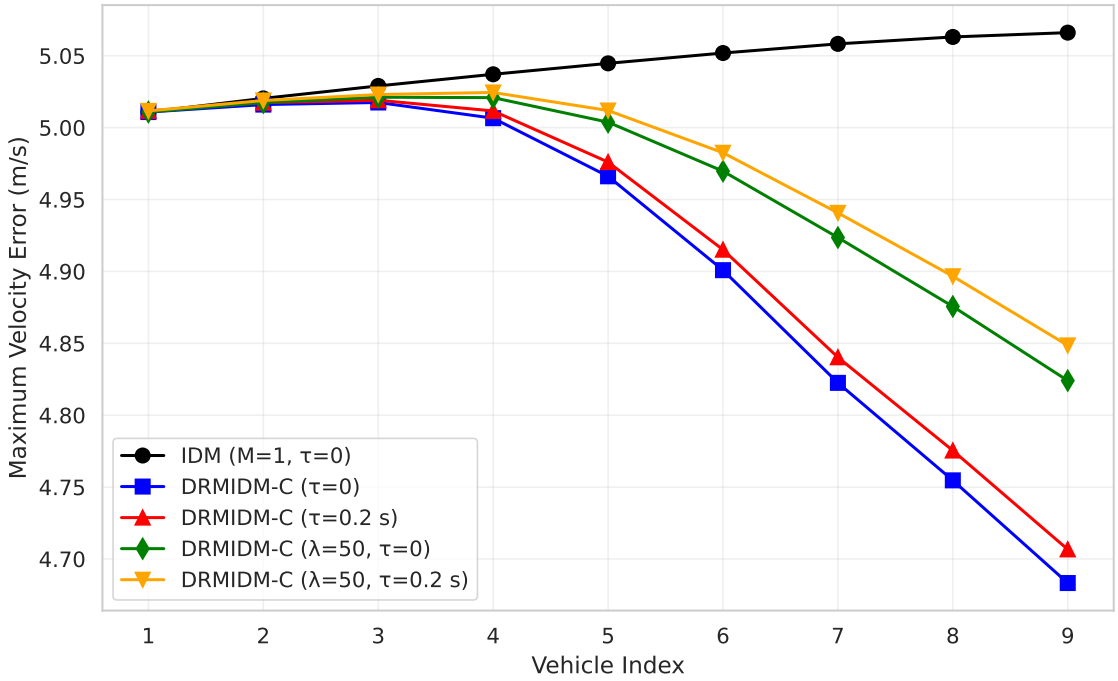


Figure 5: Maximum absolute velocity deviation from v_e over the time window $t \in [20, 150]$.

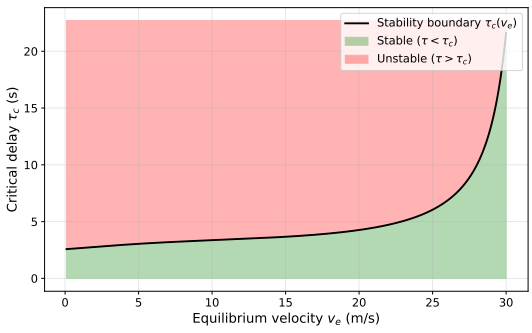


Figure 6: Local stability boundary

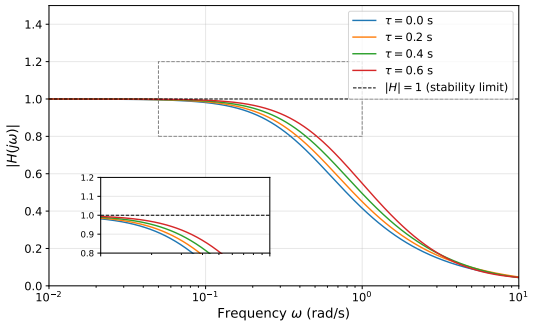


Figure 7: String stability frequency response

It shows a quantitative measure of disturbance rejection capability of DRMIDM-C.
Fig 6 shows the local stability boundary of DRMIDM-C for $T = 1.5s$. The black curve $\tau_c(v_e)$ separates the stable and unstable region. For a given equilibrium velocity, communication delays less than critical value ensures stability. The critical delay increasing with v_e for a given parameters shows multi-anticipative information and specific weight distribution allow the platoon longer delays and ensures local stability. There is sharp increase observed in critical delay in the range

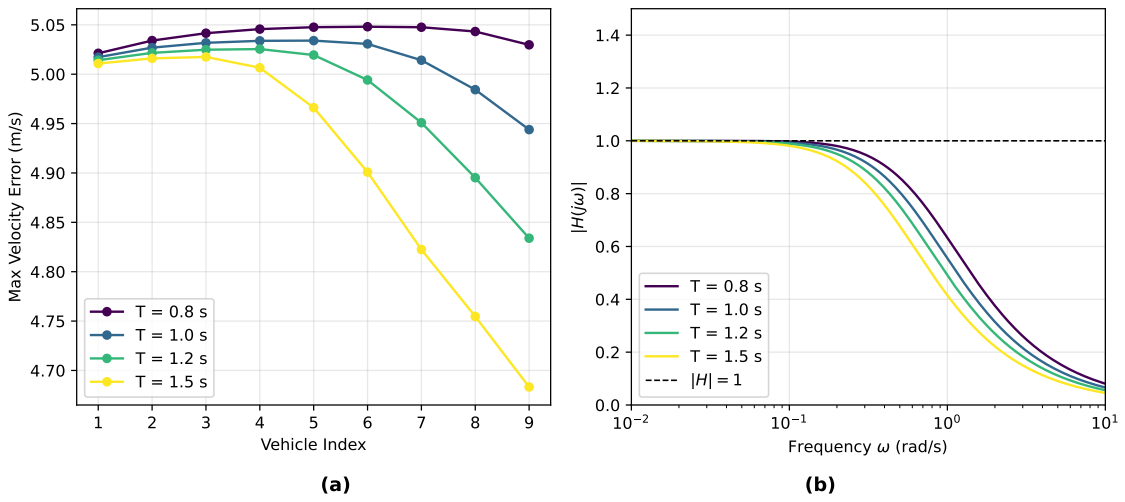


Figure 8: T variations in DRMIDM-C: (a)Max velocity error, (b)String stability.

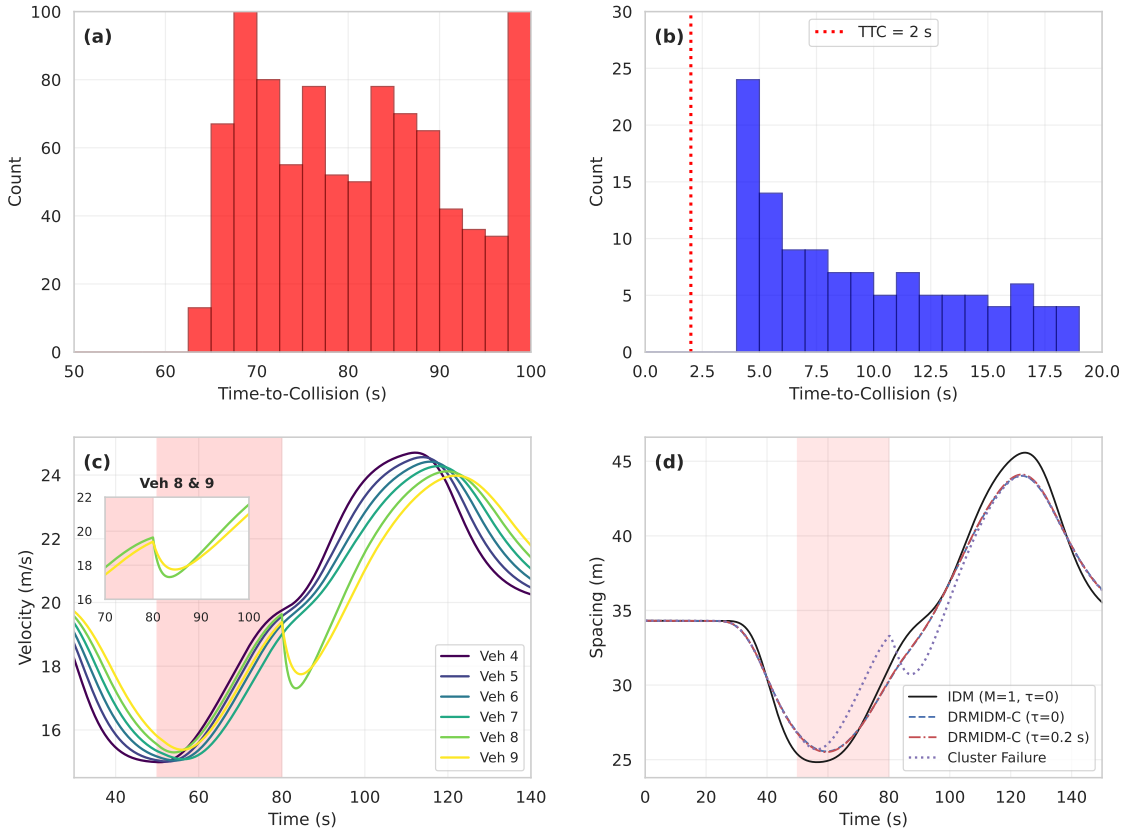


Figure 9: Cluster failure: (a)TTC distribution for failed vehicles [5,6,7], (b)TTC distribution for vehicles 8 and 9, (c)Velocity during cluster failure, (d)Spacing across all scenarios for vehicle 9.

$25 \leq v_e \leq 30$ indicates the model become more sensitive. Fig. 7, represents the transfer function $H(s)$ for various delay τ. Upto $\tau = 0.2s$ the magnitude remain below 1 satisfies $H(s) < 1$, indicating string stable behaviour. The system shows marginally string stable for $\tau = 0.6$.

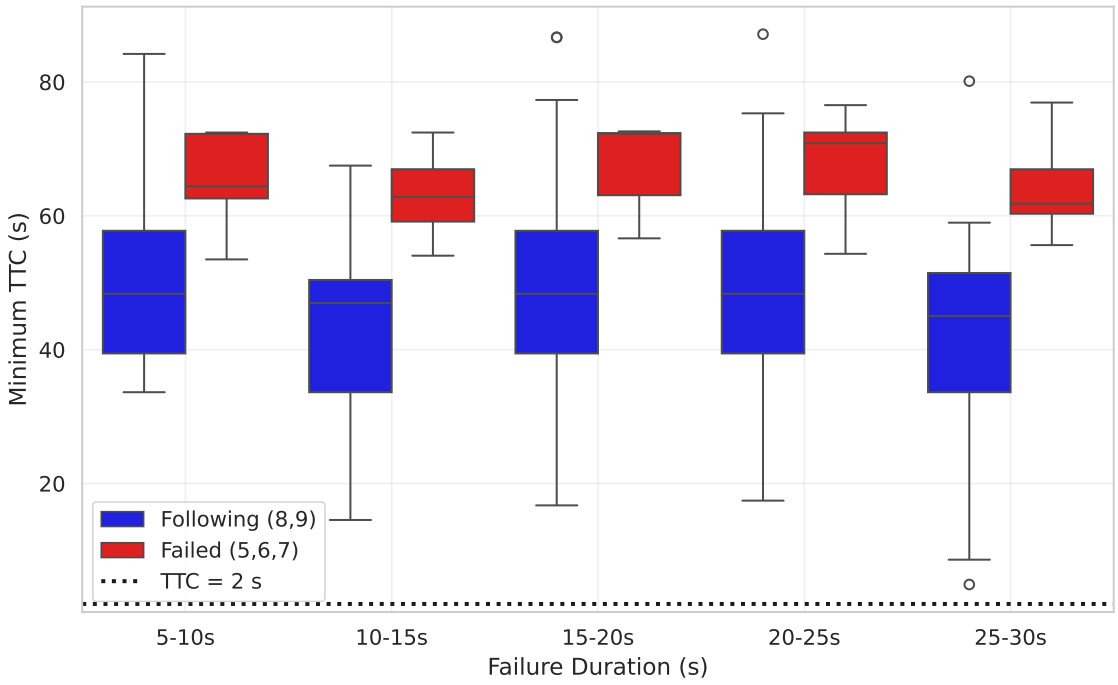


Figure 10: Minimum TTC distribution across multiple runs of cluster failure simulations

4 Conclusions

The DRMIDM-C integrates range-limited exponential weight distribution and communication delay to describe CAV dynamics. The model performance studied for a given leader velocity profile in Fig. 3. From simulations, it is observed that DRMIDM-C exhibits improved oscillations dampening and lower velocity error even under communication delay than baseline. We have derived the critical delay, below which the models remains stable. For different communication delay and time headway DRMIDM-C maintain stability. The model studied for low time headways, as CAVs are meant to increase capacity and can operate in significantly lower intra-platoon gaps than that for human driven vehicles. In case of cluster failure, it is observed that the next few perfectly operating CAVs (e.g. here vehicle 8 and 9) are heavily affected due to the oscillation created during the velocity correction on communication restore. The drop in min TTC value indicates the higher rear-end collision risk for the following vehicles than the failed vehicles. DRMIDM-C shows range-based exponential weight distribution offer resilient CAV platooning under communication failure and delays. Further calibration of DRMIDM-C for real CAV systems will provide a practical design guideline for CAV control.

Code Availability

The codes for the simulations available in this Github link: https://github.com/arscode/HEART2026

Acknowledgements

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References

Claussmann, L., Revilloud, M., Gruyer, D., & Glaser, S. (2020, May). A Review of Motion Planning for Highway Autonomous Driving. *IEEE Transactions on Intelligent Transportation Systems*, *21*(5), 1826–1848.

Garg, M., & Bouroche, M. (2025). Longitudinal Car-Following Control of Connected Autonomous Vehicles in Realistic Scenarios: A Survey. *IEEE Transactions on Intelligent Transportation Systems*, 1–30.

Gholamhosseinian, A., & Seitz, J. (2022). A Comprehensive Survey on Cooperative Intersection Management for Heterogeneous Connected Vehicles. *IEEE Access*, *10*, 7937–7972.

Halder, K., Montanaro, U., Dixit, S., Dianati, M., Mouzakitis, A., & Fallah, S. (2022, May). Distributed H Controller Design and Robustness Analysis for Vehicle Platooning Under Random Packet Drop. *IEEE Transactions on Intelligent Transportation Systems*, *23*(5), 4373–4386.

Katrakazas, C., Quddus, M., Chen, W.-H., & Deka, L. (2015, November). Real-time motion planning methods for autonomous on-road driving: State-of-the-art and future research directions. *Transportation Research Part C: Emerging Technologies*, *60*, 416–442.

Kesting, A., Treiber, M., & Helbing, D. (2010, October). Enhanced intelligent driver model to access the impact of driving strategies on traffic capacity. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *368*(1928), 4585–4605.

Khattak, Z. H., Smith, B. L., & Fontaine, M. D. (2021, February). Impact of cyberattacks on safety and stability of connected and automated vehicle platoons under lane changes. *Accident Analysis & Prevention*, *150*, 105861.

Li, L., Wen, D., & Yao, D. (2014, February). A Survey of Traffic Control With Vehicular Communications. *IEEE Transactions on Intelligent Transportation Systems*, *15*(1), 425–432.

Li, T., Wu, J., Chan, C.-Y., Liu, M., Zhu, C., Lu, W., & Hu, K. (2020). A Cooperative Lane Change Model for Connected and Automated Vehicles. *IEEE Access*, *8*, 54940–54951.

Ma, Y., Liu, Q., Fu, J., Liufu, K., & Li, Q. (2023, May). Collision-avoidance lane change control method for enhancing safety for connected vehicle platoon in mixed traffic environment. *Accident Analysis & Prevention*, *184*, 106999.

Minderhoud, M. M., & Bovy, P. H. (2001, January). Extended time-to-collision measures for road traffic safety assessment. *Accident Analysis & Prevention*, *33*(1), 89–97.

Moradi-Pari, E., Tian, D., Bahramgiri, M., Rajab, S., & Bai, S. (2023). Dsrc versus lte-v2x: Empirical performance analysis of direct vehicular communication technologies. *IEEE Transactions on Intelligent Transportation Systems*, *24*(5), 4889–4903.

Ngo, H., Fang, H., & Wang, H. (2023, September). Cooperative Perception With V2V Communication for Autonomous Vehicles. *IEEE Transactions on Vehicular Technology*, *72*(9), 11122–11131.

Ngoduy, D. (2015, May). Linear stability of a generalized multi-anticipative car following model with time delays. *Communications in Nonlinear Science and Numerical Simulation*, *22*(1-3), 420–426.

Nilsson, M. G., Gustafson, C., Abbas, T., & Tufvesson, F. (2017, October). A Measurement-Based Multilink Shadowing Model for V2V Network Simulations of Highway Scenarios. *IEEE Transactions on Vehicular Technology*, *66*(10), 8632–8643.

Petrillo, A., Pescape, A., & Santini, S. (2021, March). A Secure Adaptive Control for Cooperative Driving of Autonomous Connected Vehicles in the Presence of Heterogeneous Communication Delays and Cyberattacks. *IEEE Transactions on Cybernetics*, *51*(3), 1134–1149.

Rahman, M. S., & Abdel-Aty, M. (2018, August). Longitudinal safety evaluation of connected vehicles' platooning on expressways. *Accident Analysis & Prevention*, *117*, 381–391.

Sun, J., Zheng, Z., & Sun, J. (2018, March). Stability analysis methods and their applicability to car-following models in conventional and connected environments. *Transportation Research Part B: Methodological*, *109*, 212–237. (Publisher: Elsevier Ltd)

Wang, P., Wu, X., & He, X. (2020, June). Modeling and analyzing cyberattack effects on connected automated vehicular platoons. *Transportation Research Part C: Emerging Technologies*, *115*, 102625.

Wang, Z., Han, K., & Tiwari, P. (2022, June). Digital Twin-Assisted Cooperative Driving at Non-Signalized Intersections. *IEEE Transactions on Intelligent Vehicles*, *7*(2), 198–209.

Wang, Z., Wu, G., & Barth, M. J. (2018, November). A Review on Cooperative Adaptive Cruise Control (CACC) Systems: Architectures, Controls, and Applications. In *2018 21st International Conference on Intelligent Transportation Systems (ITSC)* (pp. 2884–2891). Maui, HI: IEEE.

Xu, H., Feng, S., Zhang, Y., & Li, L. (2019, June). A Grouping-Based Cooperative Driving Strategy for CAVs Merging Problems. *IEEE Transactions on Vehicular Technology*, *68*(6), 6125–6136.

Zhang, S., Wang, S., Yu, S., Yu, J. J. Q., & Wen, M. (2022, July). Collision Avoidance Predictive Motion Planning Based on Integrated Perception and V2V Communication. *IEEE Transactions on Intelligent Transportation Systems*, *23*(7), 9640–9653.