Developing Next-Generation Work Zone Merge System Enabled by Connected/Autonomous Vehicle Technologies

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Majeed Algomaiah

Department of Civil & Environmental Engineering

University of Louisville

Introduction

- The Problem
- Proposed Solution
- Benefits
- Objectives
- Methodology
- Expected Results

The Problem

- Work Zone
- Early Merge

The Problem

- Late Merge

All Pictures free to use, share and modify

The Problem

- Compliance Rate!
- Trust!

All Pictures free to use, share and modify

The Problem

COMMUNICATION!

Promising Technology

- Connected Vehicles (CV)
  - Vehicle-to-Infrastructure (V2I)
  - Vehicle-to-Vehicle (V2V)
- Autonomous Vehicles (AV)
- Cooperative Late Merge
- Zipper Merge

Benefits

- Utilizes closed lane
- Reduce the length of traffic backup by
- Reduces differences in speeds between lanes
- Increases throughput

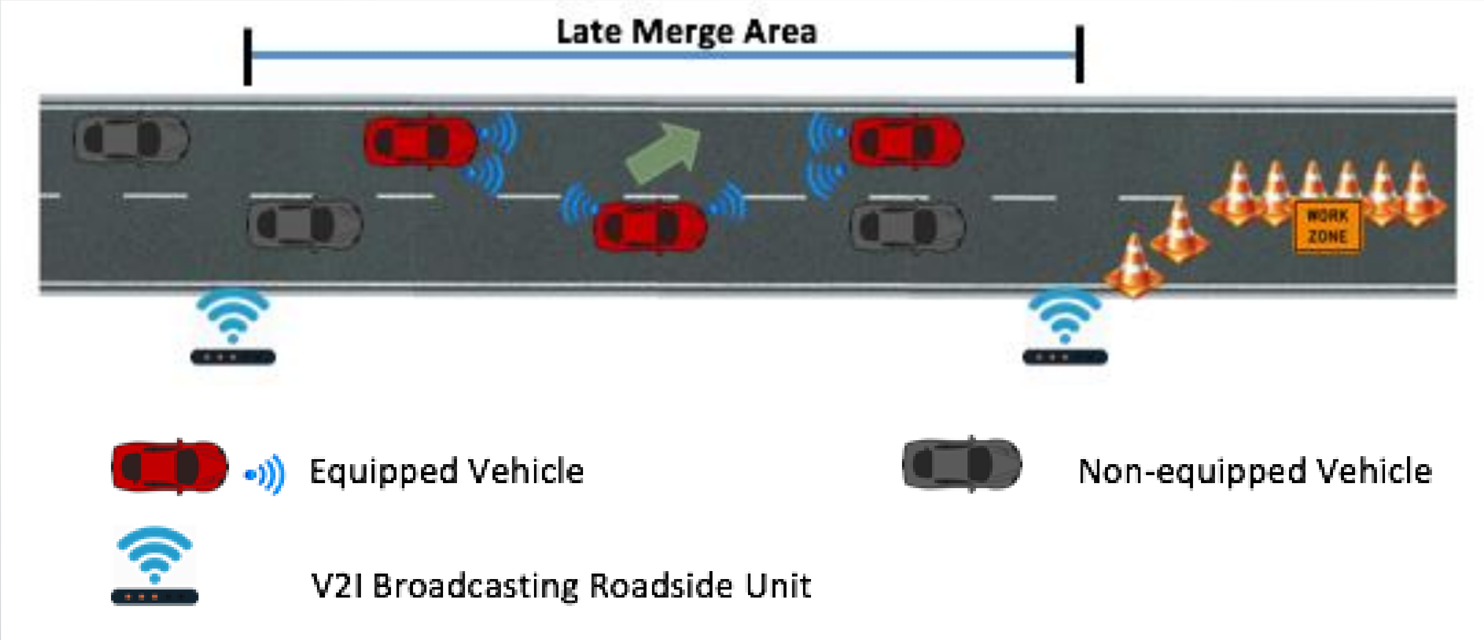
Objectives

- Develop late merge system that implements CAV and updated lane-changing and car-following microscopic models
- Test different compliance rate and market penetration rate to identify the sweet spots

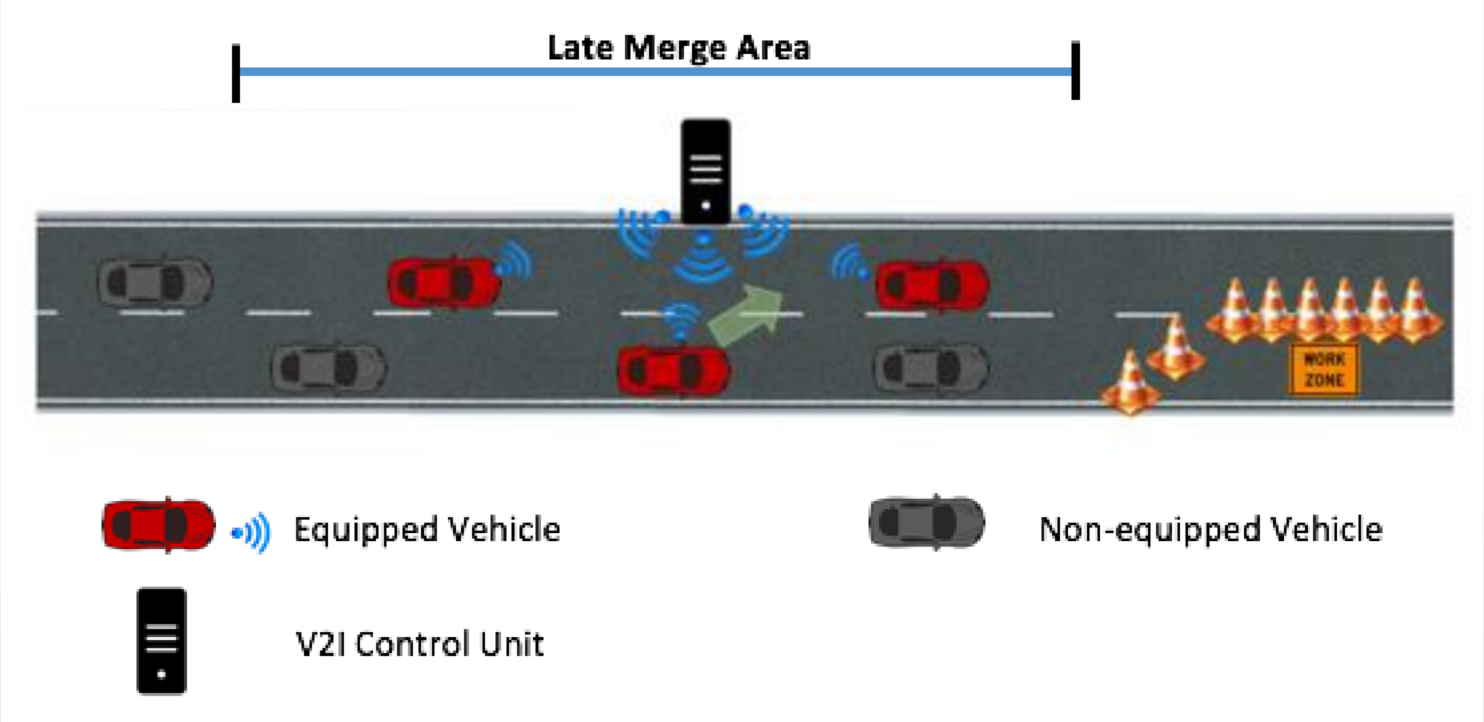
Considered Control Systems

1. Decentralized control via V2I broadcasting and V2V
2. Centralized control via V2I
3. Centralized control via V2I and V2V

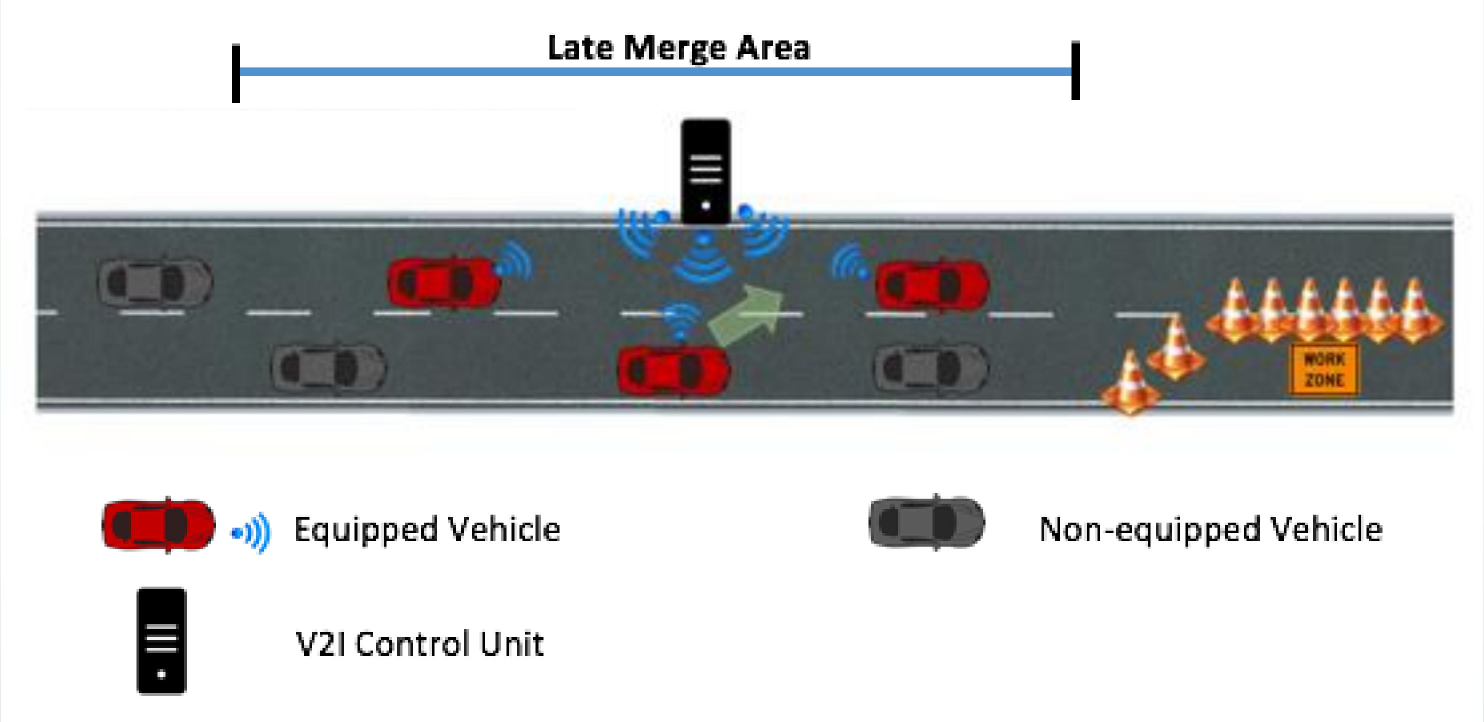
1. Decentralized control via V2I broadcasting and V2V



2. Centralized control via V2I



3. Centralized control via V2I and AV

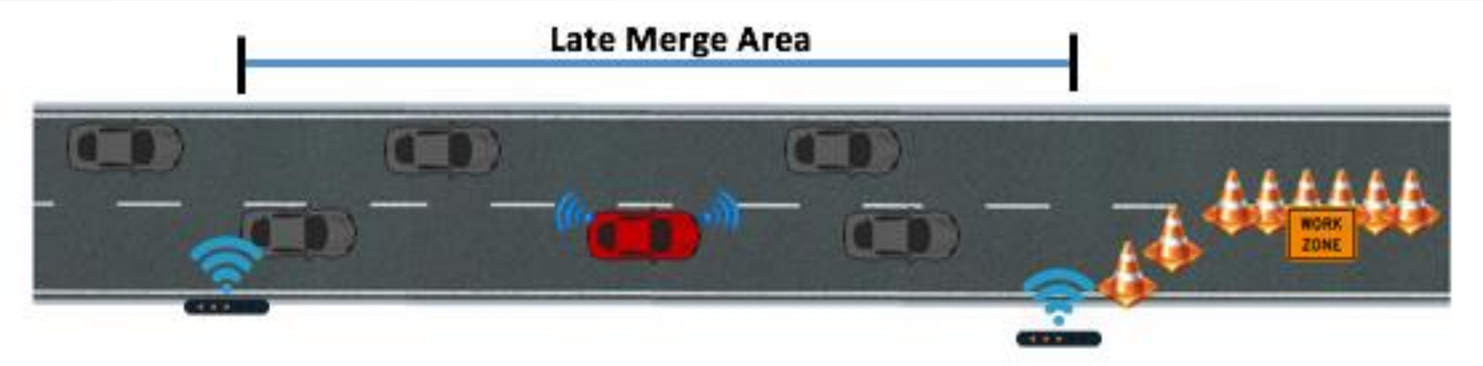


3. Centralized control via V2I and AV

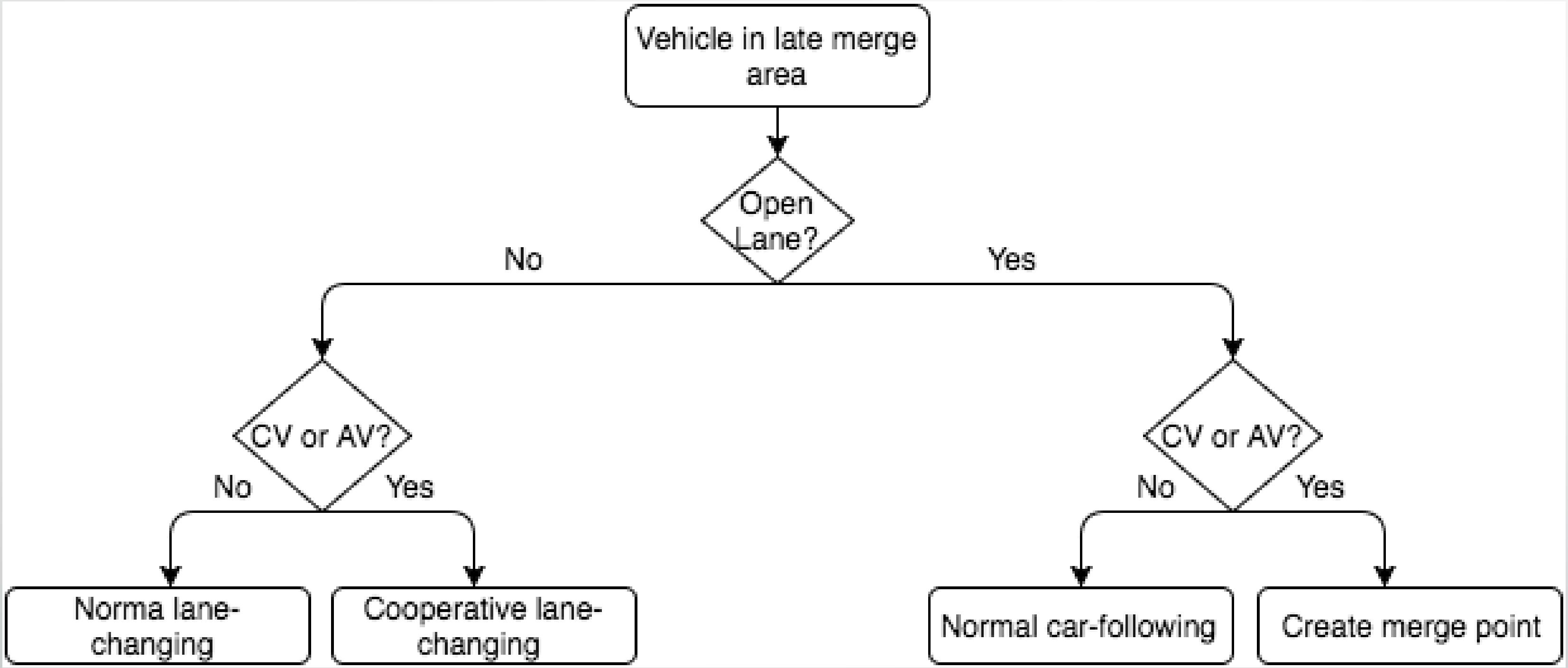
- 100% Compliance Rate
- Perception-reaction time (PRT)
- Control of speed and headway
- Cooperative Adaptive Cruise Control (CACC)

Challenges

- Unequipped Vehicles!
- Compliance Rate!
- Market Penetration Rate!



General Framework



Modeling

- Time-to-collision (TTC)

$$TTC = \begin{cases} \frac{s}{\Delta V}, & v_L < v_S \\ \infty, & \text{otherwise} \end{cases}$$

Gettman et al. (2008)

- Time-to-end-of-lane (TEOL)

$$TEOL = \frac{s}{v_S}$$

Modeling

- Lane-changing

Hidas (2006)

$$g_l \geq g_{l,min} \quad \text{and} \quad g_f \geq g_{f,min}$$

$$g_{l,min} = g_{min} + \begin{cases} c_l(v_s - v_l) & \text{if} \quad v_s > v_l \\ 0 & \text{otherwise} \end{cases}$$

$$g_{f,min} = g_{min} + \begin{cases} c_f(v_f - v_s) & \text{if} \quad v_f > v_s \\ 0 & \text{otherwise} \end{cases}$$

Modeling

- Lane-changing

Hidas (2006)

$$g_l = g_{0l} - \left(v_s D_t - \frac{b_s}{2D_t}\right) + (v_l D_t)$$

$$g_f = g_{0f} - \left(v_f D_t - \frac{b_f}{2D_t}\right) + (v_s D_t)$$

$$D_t = D_v / b_{f,s}$$

Modeling

- Perception-reaction time (PRT)

Adel et al. (2011)

$$PRT_D = \begin{cases} PRT_1 = PRT_0 \left(1 - 0.1 - 0.4 \dfrac{\sigma}{100}\right), & t < \Delta t_1 \\ PRT_2 = PRT_1 + (PRT_0 - PRT_1)\, t - \dfrac{\Delta t_1}{\Delta t_2}, & \Delta t_1 \leq t < \Delta t_1 + \Delta t_2 \\ PRT_0 & \text{otherwise} \end{cases}$$

Modeling

- Desired Speed (DS)

Adel et al. (2011)

$$DS_D = \begin{cases} DS_1 = DS_0 + (V_{CV} - DS_0)\,\dfrac{\sigma}{100}, & t < \Delta t_1 \\ DS_2 = DS_1 + (V_{CV} - DS_0)\,\dfrac{t - \Delta t_1}{\Delta t_2}, & \Delta t_1 \leq t < \Delta t_1 + \Delta t_2 \\ DS_0 & \text{otherwise} \end{cases}$$

Modeling

- Desired Headway (DH)

Adel et al. (2011)

$$DH_D = \begin{cases} DH_1 = DH_0 + \left(HW_{CV} - DH_0\right)\dfrac{\sigma}{100}, & t < \Delta t_1 \\ DH_2 = DH_1 + \left(DH_0 - DH_1\right)\dfrac{t - \Delta t_1}{\Delta t_2}, & \Delta t_1 \leq t < \Delta t_1 + \Delta t_2 \\ DH_0 & \text{otherwise} \end{cases}$$

Modeling

- Car-following (Treiber, 2006)

$$\dot{v}(t) = a \left[1 - \frac{v(t)^{\alpha}}{DS_D} - \frac{s*(v(t), \Delta v(t - PRT_D))^{\beta}}{s(t - PRT_D)} \right.$$

$$s*(v, \Delta v) = s_0 + \max\left(0, v \cdot DH_D + \frac{v\Delta v}{2\sqrt{ab}}\right.$$

Simulation

- Using VISSIM
- Microscopic Simulation
- Combinations of different scenarios:
  - Compliance Rates (e.g. 90%, 75%, 50% and 25%)
  - Market Penetration Rates (e.g. 90%, 75%, 50% and 25%)

Simulation

- Simulation running example

Expected Results

- Increased throughput
- Optimal parameters
- A sweet spot of market penetration rate and compliance rate among 3 control systems

The End

Any Questions?