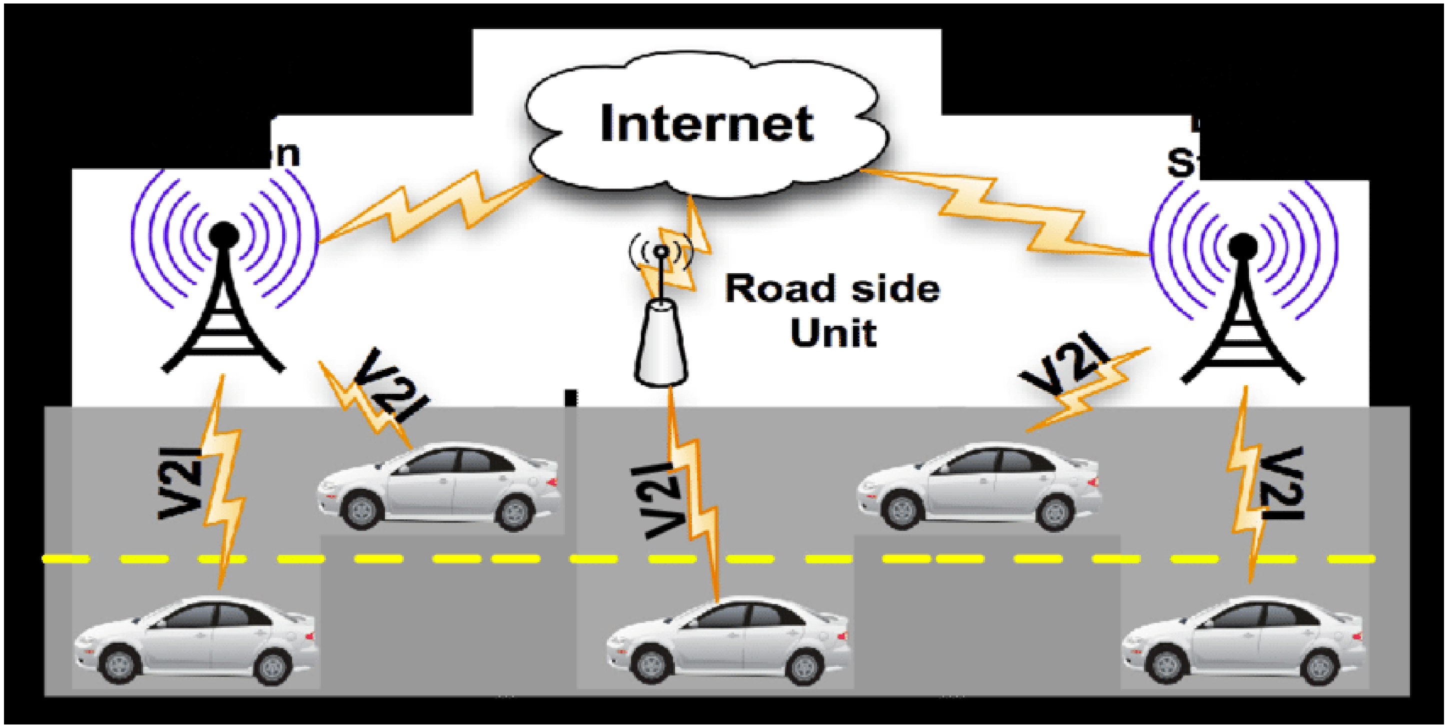
AVS2018

Integrating Freeway and Arterial Traffic Control under Vehicle-to-Infrastructure Communications Environment



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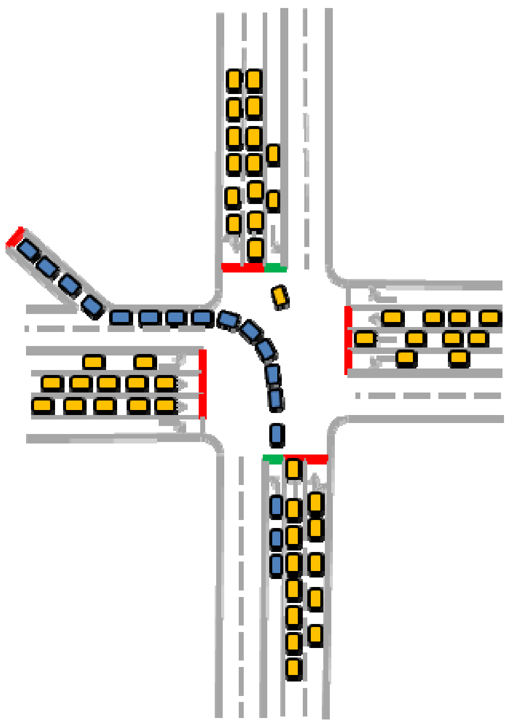
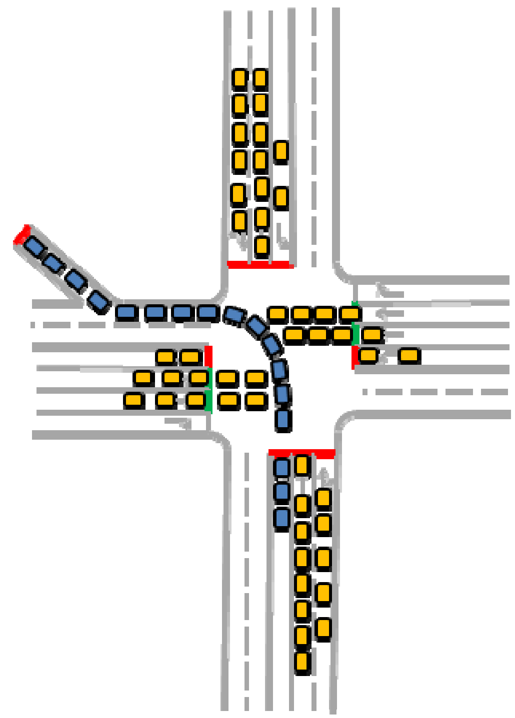
Problem Statement

- **Ramp metering: common strategy to manage freeway congestion and prevent "capacity drop" [1]**
- **Independent signal control: cause of queue spillback**

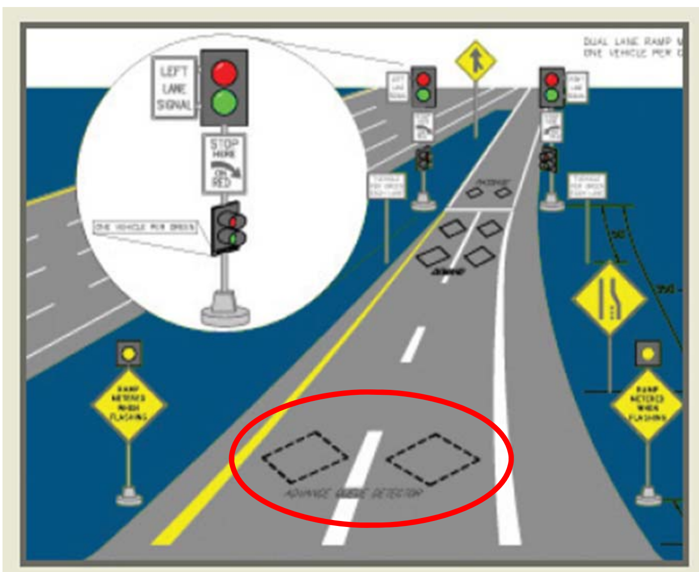


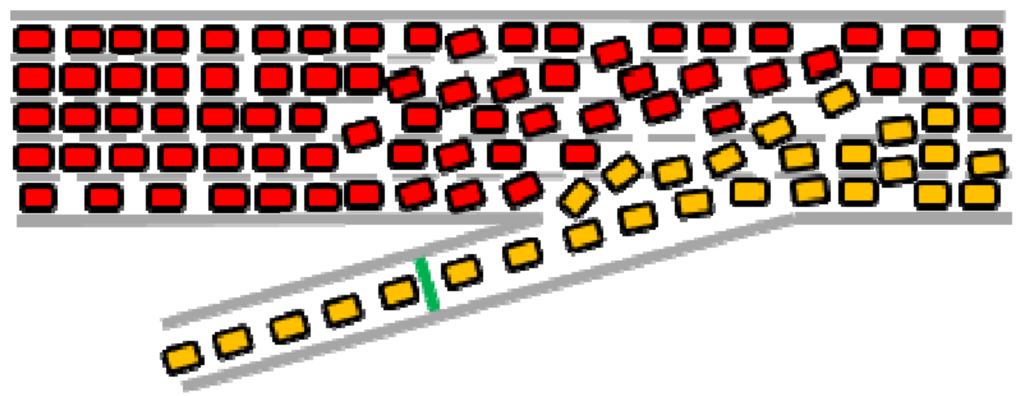


[1] Cassidy and Rudjanakanoknad, 2005; Zhang and Levinson, 2010; Kim and Cassidy, 2012

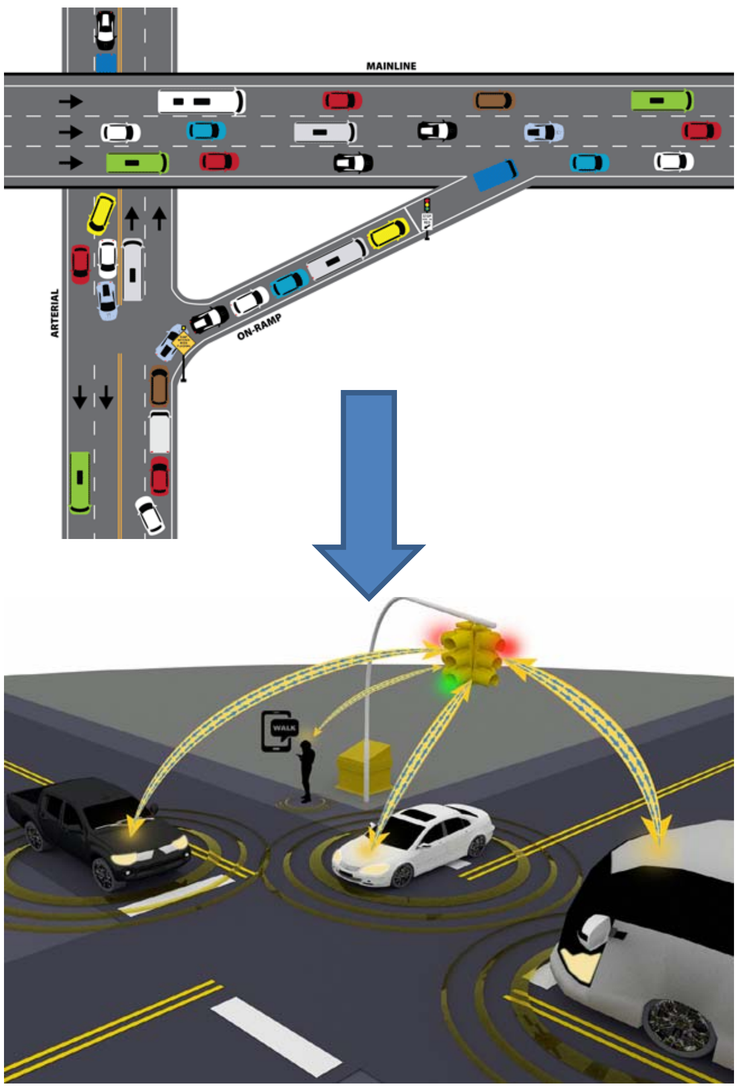
Queue Override

- **Prevents on-ramp queue spillback**
  - **Suspends or adjusts ramp metering**
  - **Freeway congestion/capacity drop ~ 10%**





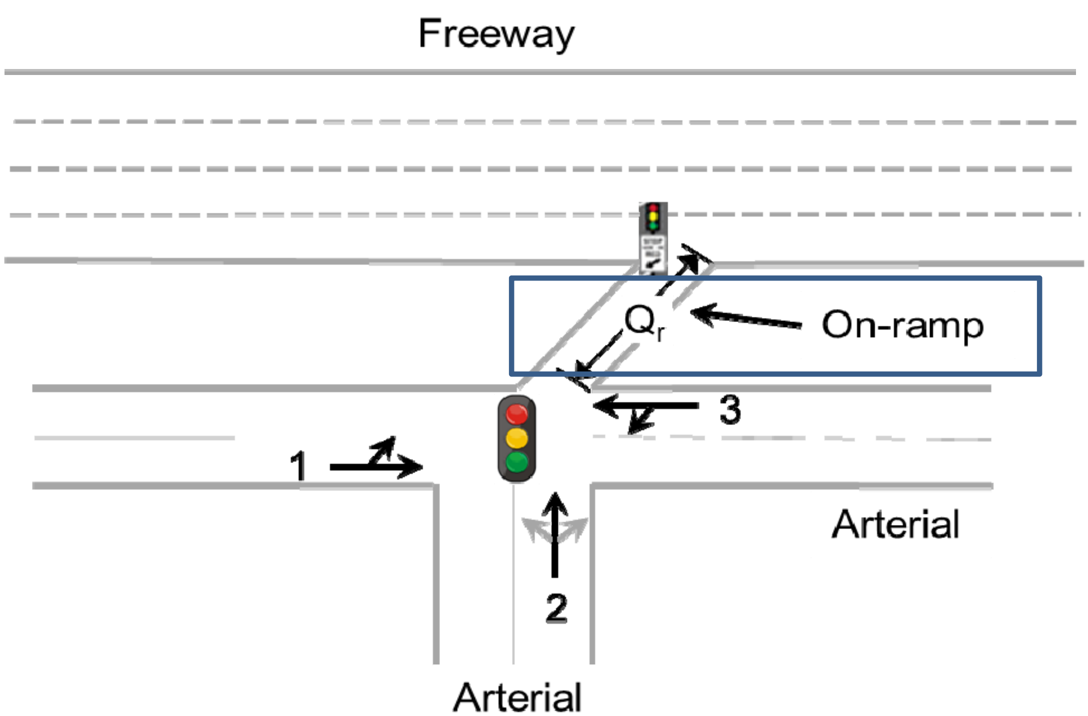
Vehicle to Infrastructure Communication



- **Vehicles can send real-time on-ramp queue length data to the traffic signal**
- **Traffic signals can adjust the cycle length in real-time**
  - **Avoid long platoons entering the freeway on-ramp from the nearby arterials**
  - **Prevent queue spillback**

Proposed Signal Control Strategy (1)

- Ramp metering control unchanged
- Integrate ramp metering controllers
- Reduced and variable cycle length
- Mitigate both on-ramp and arterial spillback
- Example signalized intersection near freeway on-ramp

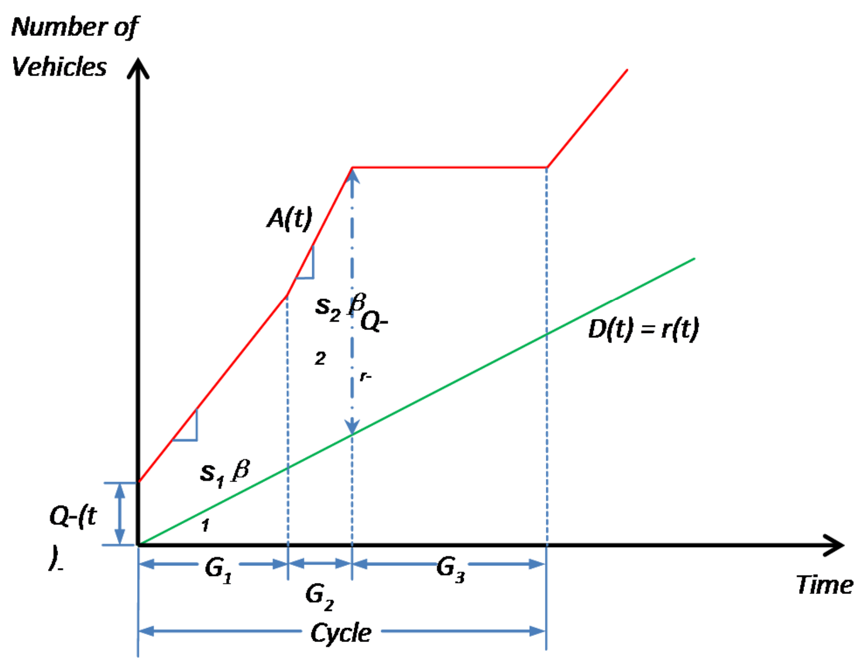


Proposed Signal Control Strategy (2)

On-ramp excess accumulation

- $Q(t) + G_1 \cdot s_1 \cdot \beta_1 + G_2 \cdot s_2 \cdot \beta_2 - G_1 \cdot r(t) - G_2 \cdot r(t) \leq Q_r$

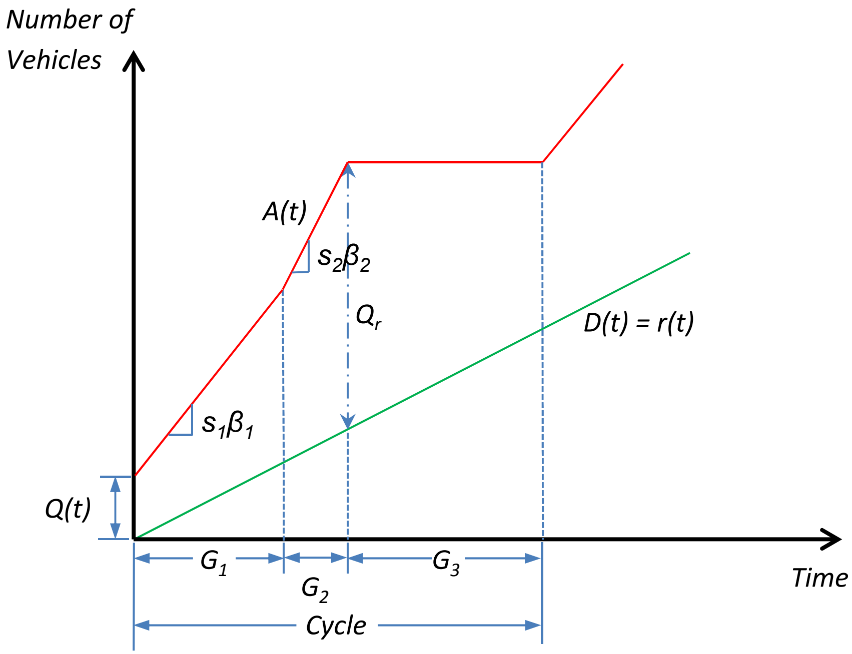
$Q(t)$	$G_1 \cdot s_1 \cdot \beta_1 + G_2 \cdot s_2 \cdot \beta_2$	$G_1 \cdot r(t) - G_2 \cdot r(t)$	Q_r
Residual on-ramp excess accumulation	Upstream arrival	Downstream departure	Available queue storage



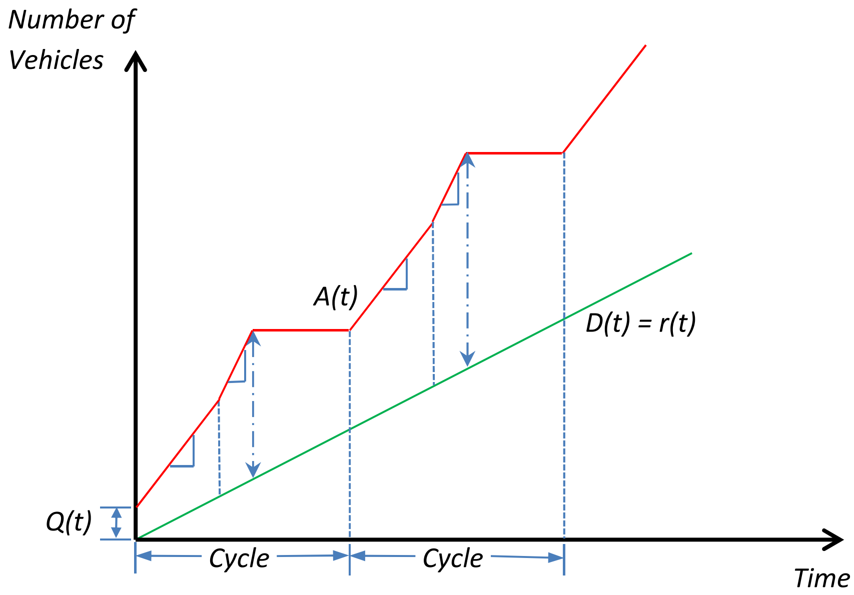
Proposed Signal Control Strategy (3)

- Phases 1 and 2: shorter green times
- Clear on-ramp queues in phase 3

Before



After



Proposed Signal Control Strategy (4)

- On-ramp residual excess accumulation can be determined by tracking vehicles entering and leaving the on-ramp:

$$Q(0) = 0$$

$$Q(1) = Q(0) + A(1) - D(1)$$

$$\vdots$$

$$Q(t) = Q(t-1) + A(t) - D(t)$$

- Maintain the same green time distribution:

$$g_1 = \frac{y_1}{Y} \cdot (C - 3l)$$

$$g_2 = \frac{y_2}{Y} \cdot (C - 3l)$$

Proposed Signal Control Strategy (5)

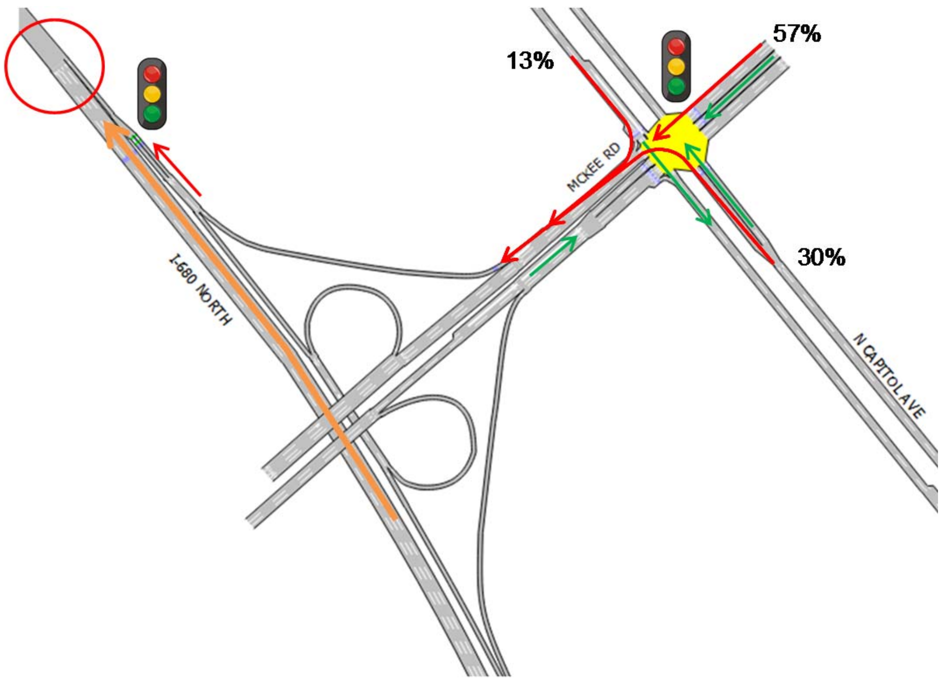
- Cycle length upper limit:

$$C \leq \frac{[Q_r - Q(t) + r(t) \cdot 2l] \cdot Y + 4l \cdot \left[\sum_{i=1,2} s_i \beta_i y_i - \sum_{i=1,2} r(t) y_i\right]}{\left[\sum_{i=1,2} s_i \beta_i y_i - \sum_{i=1,2} r(t) y_i\right]}$$

- Updated every cycle
- Does not provide progression/maximum bandwidth

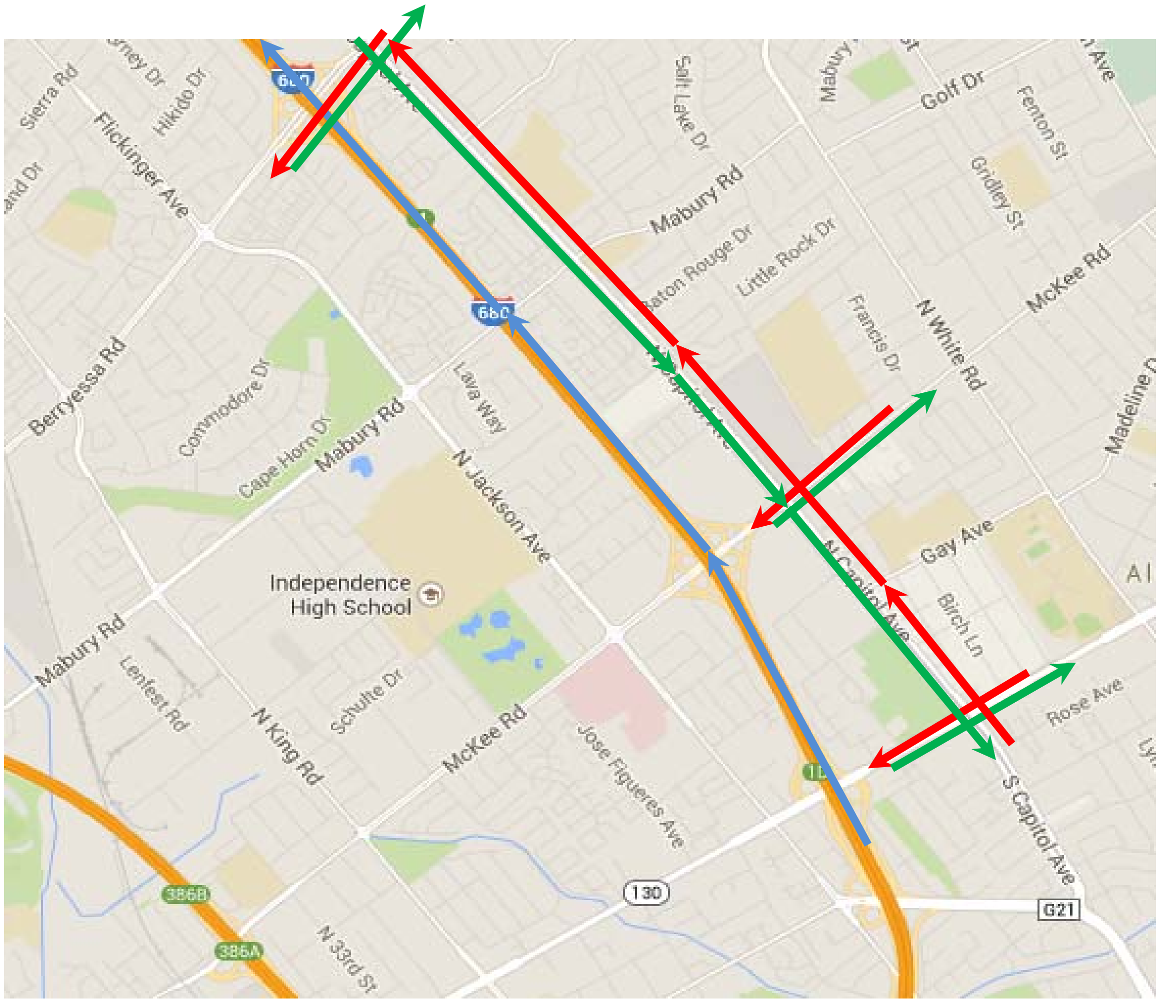
Simulation Test

- **Test site: NB I-680/Capitol Ave Corridor, San Jose, CA**
  - **Recurrent bottleneck –AM peak (7:00AM – 9:30AM)**
  - **Aimsun Model**
    - **Enhanced driving behavior model [1]**
  - **Calibrated to replicate field data**
  - **Before: metering <u>with</u> queue override, <u>long</u> cycle lengths**
  - **After: metering <u>without</u> queue override, <u>short</u> cycle lengths**
  - **20 replications**



[1] *Lu, Kan, Shladover, 2017*

Simulation Results: Test Corridor (1)



Simulation Results: Test Corridor (2)

I. Freeway

	Before		After		% Difference	
Freeway Mainline						
	Total Delay (veh-hr)	Total Distance Traveled (veh-mile)	Total Delay (veh-hr)	Total Distance Traveled (veh-mile)	Change in Total Delay	Change in Total Distance Traveled
I-680 NB	833.41	43104.13	740.64	44792.95	**-11.13%**	**3.92%**

II. Arterial

Average Delay on Main Parallel Arterial (min/veh)			
Capitol Ave NB	8.63	10.51	**21.84%**
Capitol Ave SB	5.72	5.91	**3.33%**
Average Delay of Cross Street (sec/veh)			
Alum Rock WB	48.05	47.33	-1.43%
Alum Rock EB	37.27	37.82	1.47%
McKee WB	56.76	52.34	**-7.79%**
McKee EB	28.92	16.51	**-42.91%**
Berryessa WB	47.27	39.26	**-16.73%**
Berryessa EB	50.50	37.55	**-34.48%**

III. Total System

	Total Delay (veh-hr)	Total Delay (veh-hr)	Change in Total Delay
Freeway & Arterial	2881.37	2727.19	**-5.65%**

Summary

- **Vehicle-to-infrastructure communication allows for traffic signals to adjust cycle lengths based on on-ramp queue length**
- **Improved arterial signal timing can reduce arterial and freeway delay**
- **Sensitivity analysis: similar improvement when peak (7:30 AM – 8:30 AM) demand increases by 5-10%.**