Coordination of Freeway Ramp Meters and Arterial Traffic Signals (FOT)

End of Project Presentation

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Outlines

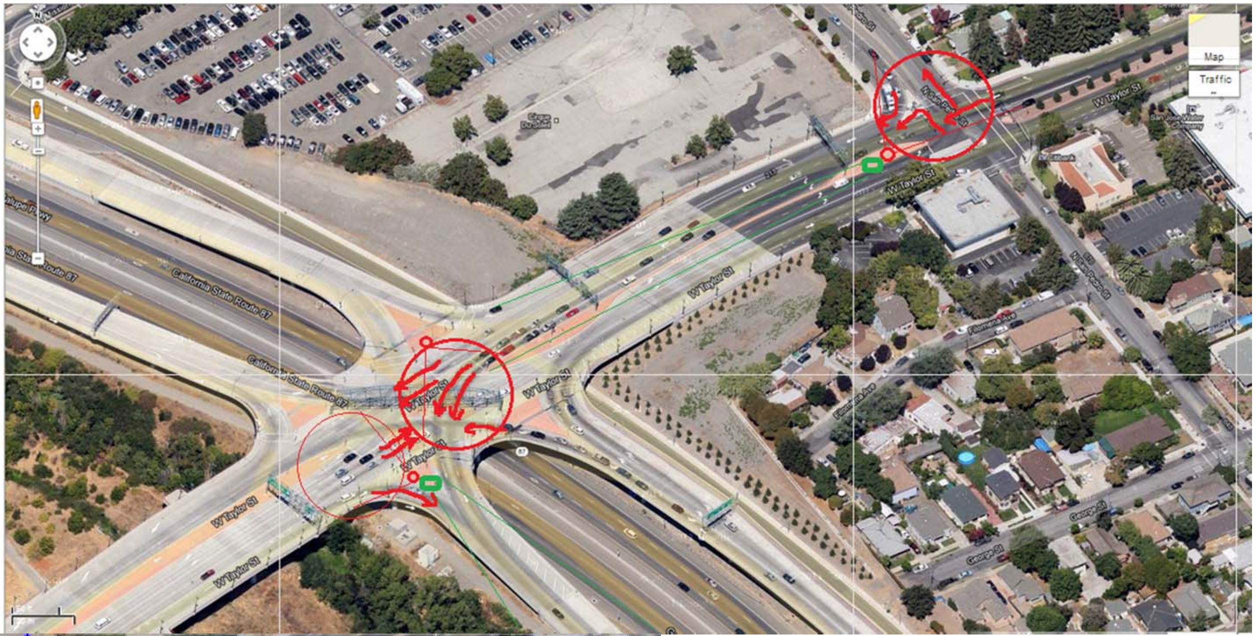
- Site Selection
- Data Collection for Modeling
- Modeling and Simulation
- Freeway Onramp Metering
- Intersection Signal Control
- Coordination Strategy
- System Integration
- Test Results
- Next Phase of the Project

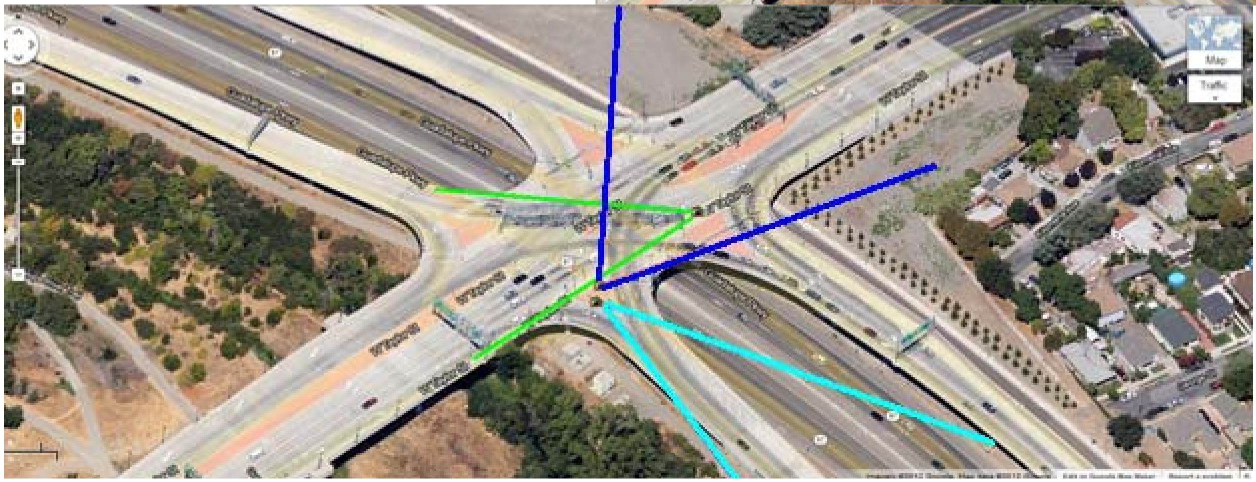
Site Selection

- Site Selection criteria development
  - Road geometry, traffic situation, sensor detection
  - Data system
  - Communication systems
  - Traffic controllers (freeway & arterial), 170 → 2070
  - Traffic control software and interface capability
  - Institutional issues
  - Small and relatively independent
- Data collection for site selection
  - 5 sites considered: I280-Saratoga, SR87-Taylor, SR85-Camden, I280-Lawrence, SR101-DeLaCruz
  - SR87-Taylor was selected with the project panel

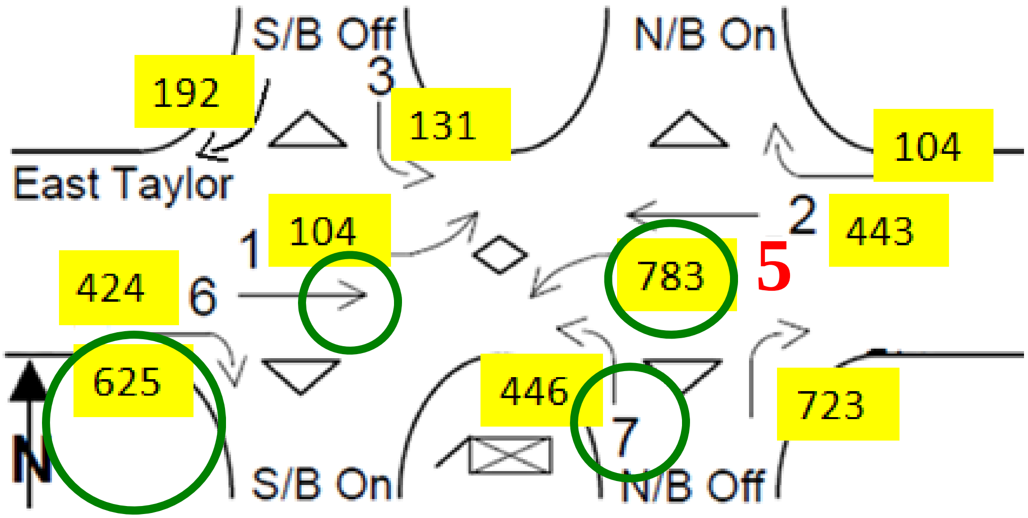
Data Collection for Modeling

- **3 Miovision VCU systems + 3 Video cameras**



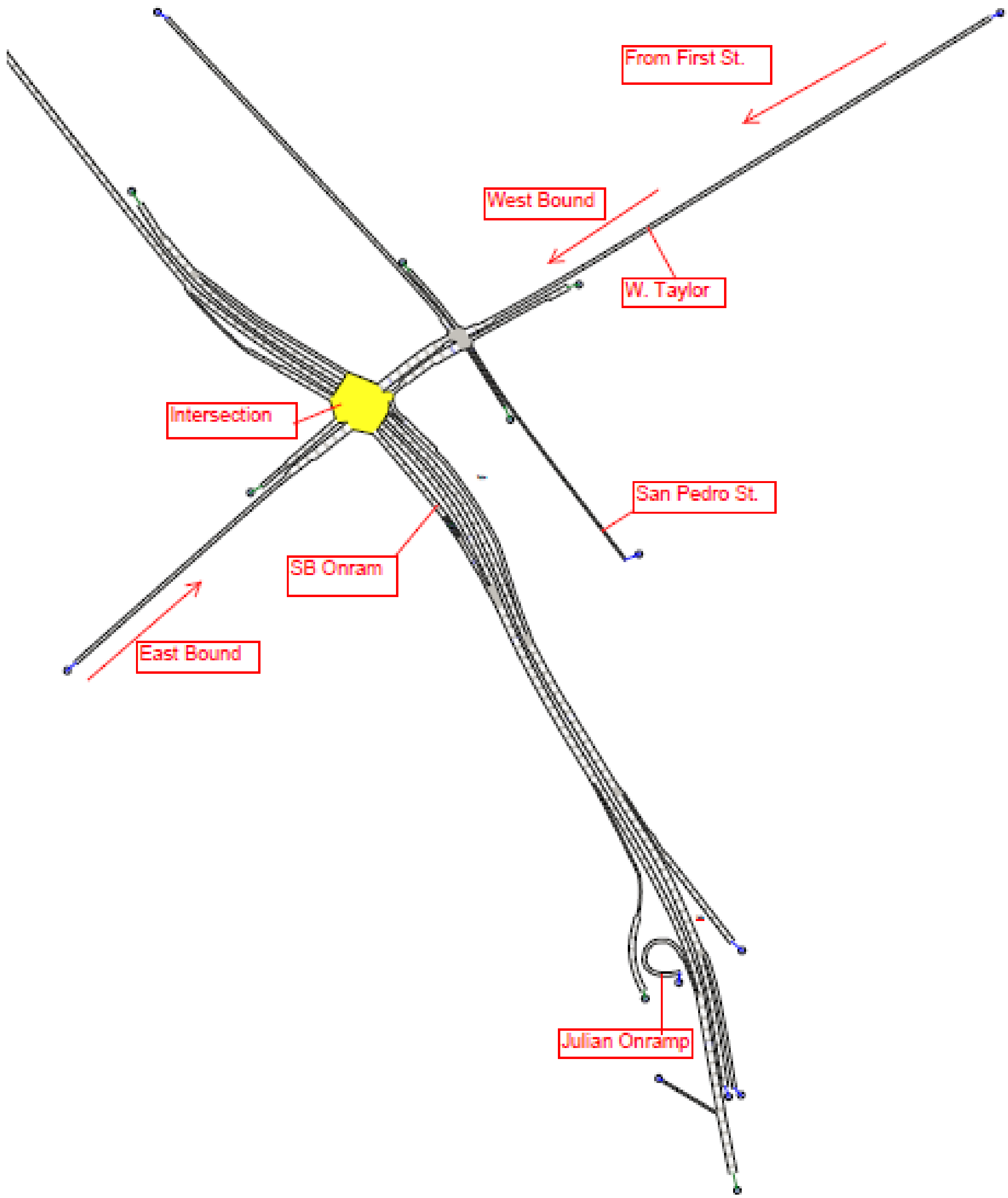


Intersection Traffic Situation



- **The Problem**
  - **EB RT green = Phase 6 Throu green + Phase 7 green ➔ too high priority to access onramp all the time**
  - **EB Phase 5 LT has large demand, but less priority to access onramp in PM Peak ➔ queue spills over to San Pedros**

Modeling and Simulation - Model Calibration



Modeling and Simulation - Model Calibration

- **Data:**
  - **Aggregated over 10min**
- **Flow**
  - **Compute the percentage of acceptable simulated flow (within acceptable error)**
  - **Aggregated flow in 10min**
  - **Freeway: detector at upstream of Taylor SB on-ramp, 1 lane available**
  - **Intersection: 8 movements**
  - **FHWA recommended flow calibration criteria**
- **Speed**
  - **Compute the percentage of acceptable simulated speed (speed error less than 5mph)**

Calibration Results

- **Intersection:**
  - **EB RT Movement**
    - **Percent of flow values within acceptable error: mean 92.1%, deviation 6.2%**
    - **Percent of flow values with GEH<5: mean 97.1%, deviation 3.9%**
  - **WB LT Movement**
    - **Percent of flow values within acceptable error: mean 89.2%, deviation 5.8%**
    - **Percent of flow values with GEH<5: mean 92.1%, deviation 4.2%**
- **Freeway Mainline:**
  - **Flow**
    - **Percent of flow values within acceptable error: mean 93.4%, deviation 1.4%**
    - **Percent of flow values with GEH<5: mean 90.3%, deviation 3.1%**
  - **Speed**
    - **Percent of speed values with error<5mph: mean 89.7%, 3.1%**

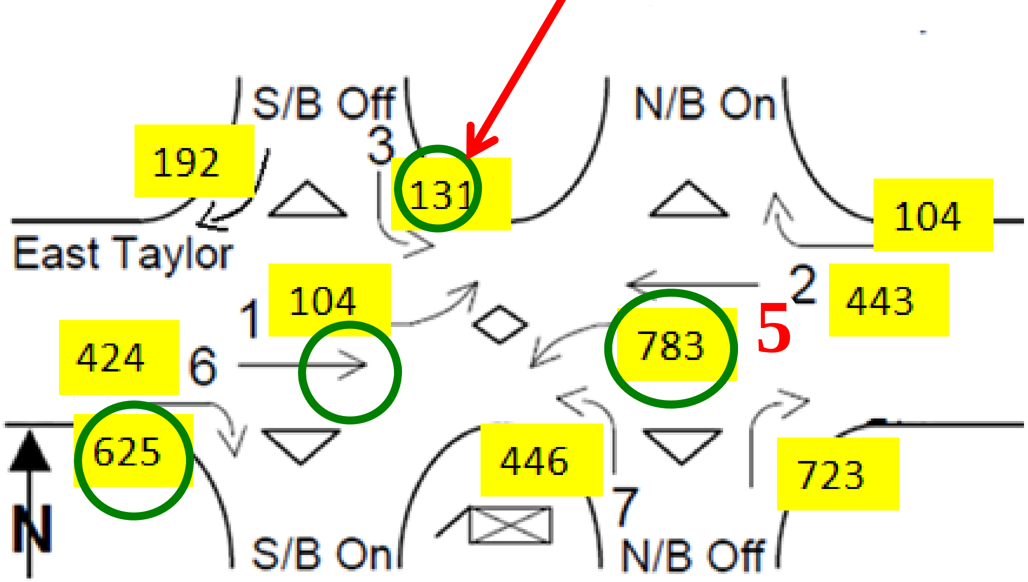
Freeway Onramp Metering

- **Ramp metering algorithm**
  - **ALINEA, control based on occupancy**
  - **Requiring detectors installed at merging area**

- **Simulated and Implemented UP ALINEA**
  - **Modified ALINEA**
  - **Need to estimate occupancy from upstream measurement.**

Intersection Signal Control

Only controls **green time** of phase 3



Intersection Signal Control

- **Initial development:**
  - **Optimization for balancing demand and supplies of all major movements and onramp**
- **Simplified Strategy for Field Implementation and Test**
  - **Keep the current control strategy: actuated control.**
  - **Limit EB RT Green to give more space at onramp to WB LT**
  - **Give more spaces at onramp to WB LT to improve throughput and to avoid queue spillovers**
    - **Change the overlap of EB right-turn, connect EB RT to phase 3 (over lap 6&7 → 6&3).**
    - **Regulate maximum green of phase 3 to indirectly change green length of EB RT.**
    - **Regulation algorithm is a queue-overwrite-like design based on occupancy instead of direct queue estimation**

Coordination Strategy

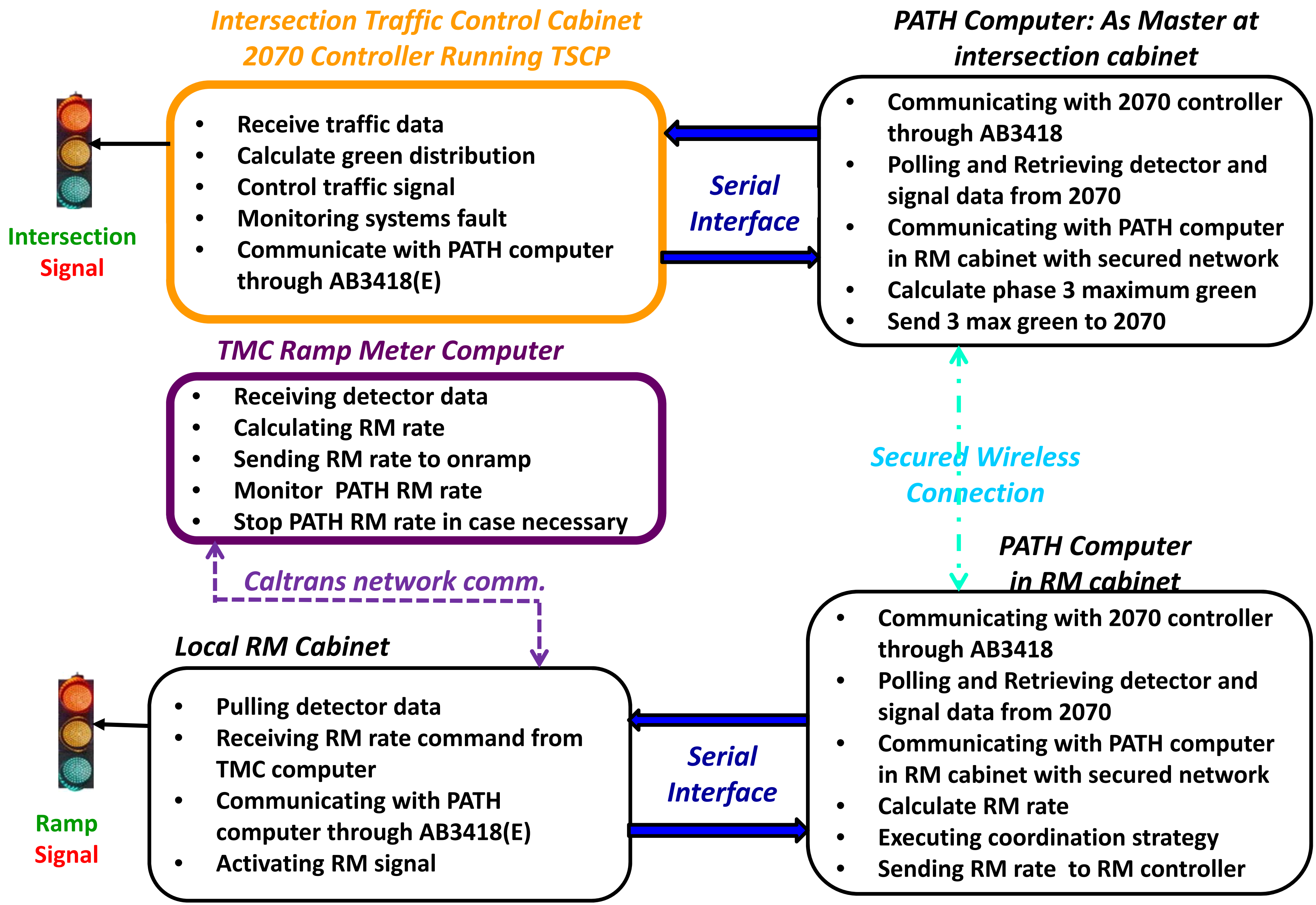
- **Coordination logistics (dependencies)**

Based on freeway traffic situation (occupancy measurement) determines RM rate (RM algorithm)

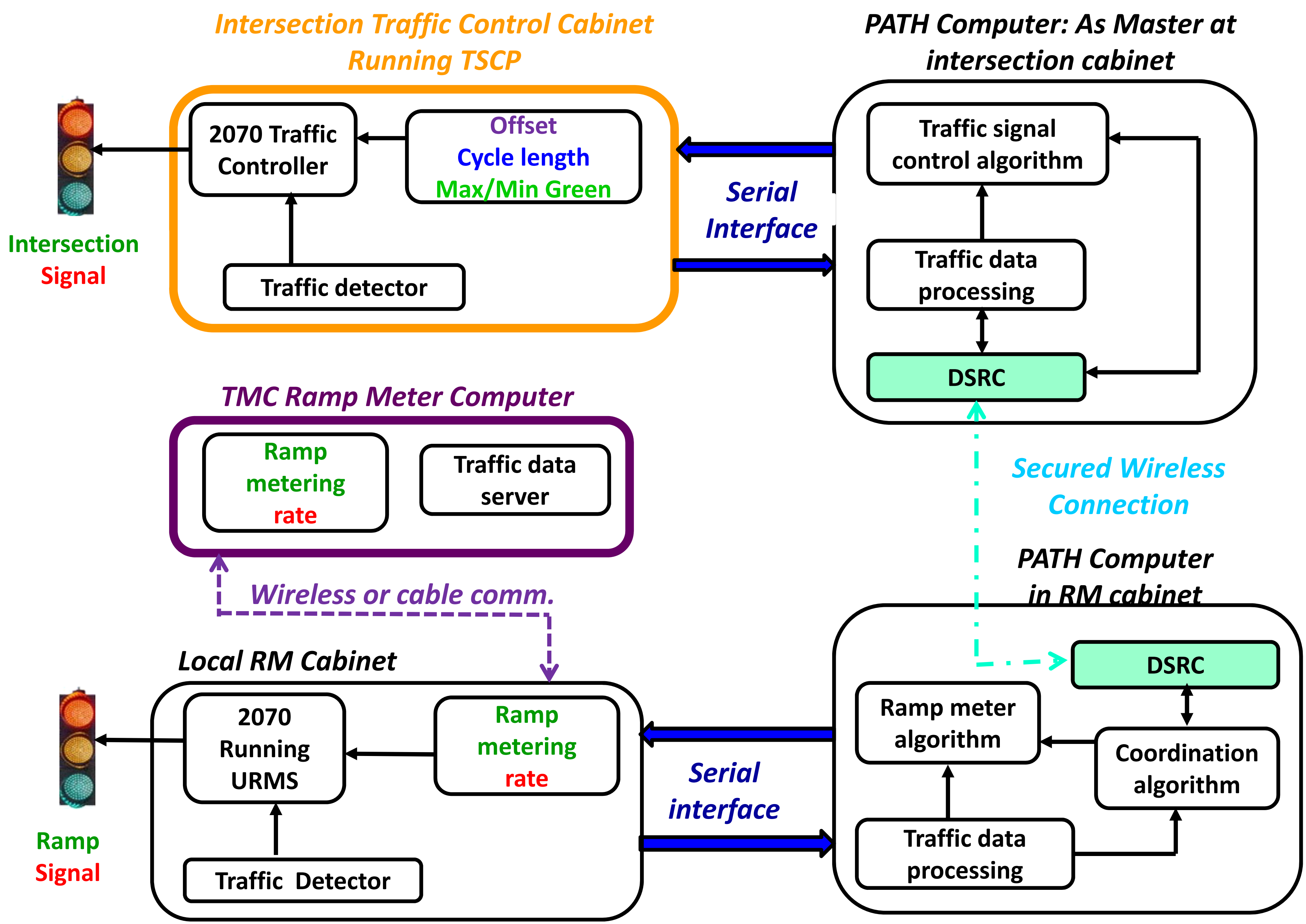
➔ estimate the condition of onramp queue

➔ how to distribute the available space between Right Turn (overlap with Phase 6&3) and Phase 5 Left turn (intersection traffic control algorithm)

Functional Diagram



Data Flow Diagram



Test Results – Compare "before" & "after"

- **Relevant Detector Locations**
- **Data Validation**
- **Focusing on WB LT and EB RT, Onramp and Freeway**
- **Data Analysis (10 min aggregation)**
- **Flow Comparison at WB LT Stop Line**
- **Vehicle Counts of EB RT & WB LT A-Loop**
- **Occupancy of EB RT & WB LT A-Loop**
- **Compare Average Across all Effective Days**
- **Net Benefit at Taylor Intersection**
  - **Net flow increase**
  - **Net time delay decrease**
- **Benefit at Onramp: Accumulated Passage detector Flow**
- **Affect to Freeway Upstream**

Relevant Detector Locations

Test Results

- **Data Validation: Test dates of PATH controller at SR87 Onramp and Taylor Intersection:**
  - **PATH control on date: 10/29/13- 11/08/13 (Green)**
  - **Control, Loop & Overlap changed on date: 11/12/13 (12:30pm)**
  - **PATH control off for data collection: 11/09/13 – 11/18/13 (Red)**
  - **Health check conducted; weekend were dropped (Yellow)**

PATH Control on date	PATH Control on date	Data Collection Date	Day of the Week	Comments
10/29	11/05	11/12	Tue	
10/30	11/06	11/13	Wed	
10/31	11/07	11/14	Thu	
11/01	11/08	11/15	Fri	
11/02		11/16	Sat	Weekend dropped
11/03		11/17	Sun	Weekend dropped
11/04		11/18	Mon	

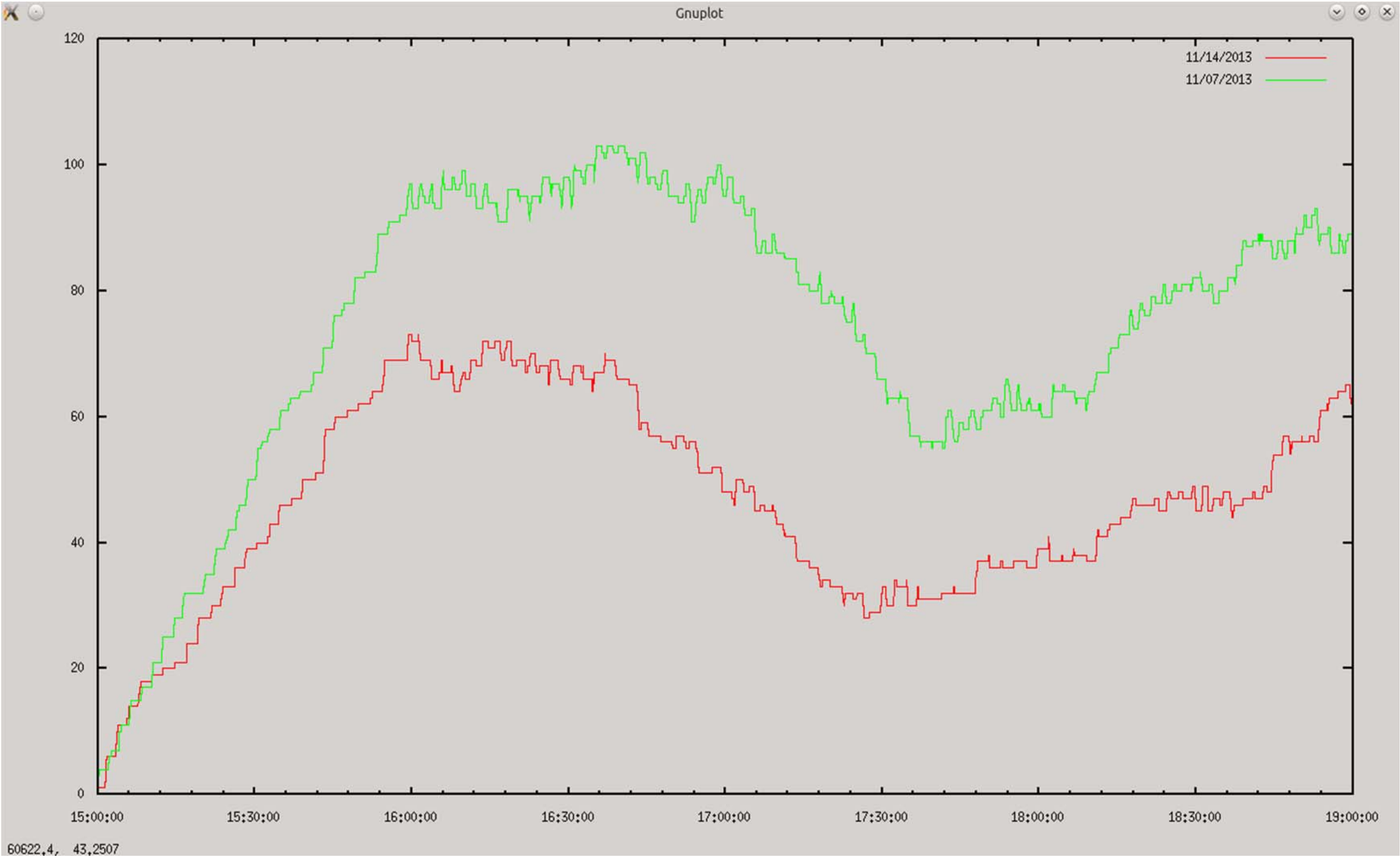
Test Results

- **Data Analysis Using: Vehicle Counts & Occupancy**
  - **Taylor intersection**
    - **Phase 5 (WB) LT Stop-line**
    - **Phase 5 (WB) LT Advance loop (A-loop)**
    - **Phase 6 (EB) RT A-loop**
  - **Onramp**
    - **Passage detector**
    - **Queue detector**
  - **Freeway SR87 mainlines immediate upstream**
    - **HOV, GPL 1, and GPL 2**
  - **Aggregation**
    - **Accumulated value for each day 2:15-8:00pm**
    - **Average of Accumulated value overall effective days**

WB LT: Vehicle Count at Stop Line (Phase 5)

After

Before



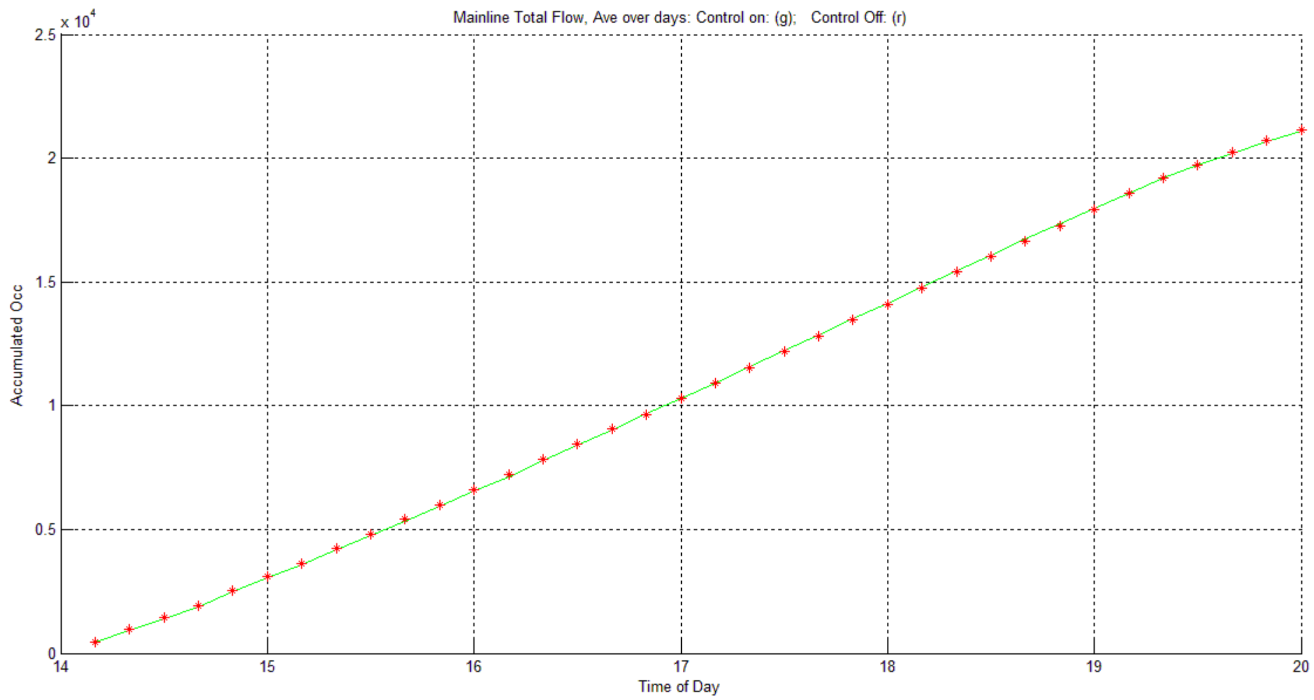
Net Benefit at Taylor Intersection (EB RT & WB LT) at Advance Loop

Time interval for evaluation	4:00-6:00pm	4:00- 6:30pm	4:00-7:00pm
Total Flow of WB RT & EB LT increased	6.98%	7.64%	8.18%
Time delay reduced	7.15%	5.24%	3.06%

Onramp Benefit: Accumulated Flow

Time interval for evaluation	4:00-6:00pm	4:00- 6:30pm	4:00-7:00pm
Passage detector flow change (after meter)	0.73%	1.2%	1.8%
Queue detector flow change	11.01%	11.12%	11.28%

Effect on Freeway Upstream Traffic Flow



- **Freeway mainline throughput unchanged**
- **To improve freeway traffic, it is necessary to consider a freeway corridor and relevant arterial(s) in next project phase**

Performance Improvement Summary

- **Intersection**
  - **WB RT flow significantly increased by 7% in PM Peak**
  - **Total delay reduced by 7% in PM Peak**
- **Onramp**
  - **Passage detector flow increased about 1%**
  - **Queue flow increased by 11% ➔ better use of onramp storage in PM Peak**
- **Freeway mainline upstream**
  - **End even, not affected in PM Peak**

Next Phase of the Project

- **To consider a freeway corridor with relevant arterial(s)**
- **Coordinated ramp metering (developed in another project)**
- **Coordinated arterial intersection signal control**
- **For both freeway RM and arterial intersections**
  - **Centralized data systems**
  - **Centralized signal control**
  - **PATH computer interface with TMC computer**
- **Systematic coordination of the two subsystems**
- **Secured communication between two PATH computers running a special OS to avoid virus**
- **Objective: to achieve system-wide performance improvement**

Questions and Comments?

- **Please Contact:**

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Technical Details: UP ALINEA

- **Estimate downstream occupancy from upstream measurement.**
  - $\tilde{o}_{out} = \alpha o_{in}(1 + \frac{q_r}{q_{in}})\frac{\lambda_{in}}{\lambda_{out}}$, if $o_{in} \leq o_{cr}$
  - $\tilde{o}'_{out} = o_{in}\frac{\lambda_{in}}{\lambda_{out}} + 100\frac{L}{w\lambda_{out}} q_r$, $\tilde{o}_{out}(k) = \gamma\tilde{o}'_{out}(k) + (1 - \gamma)\tilde{o}'_{out}(k - 1)$, else.

Technical Details: Intersection design

- EB right-turn is connected to phase 3. (phase 3 still has SB left-turn, no conflict between them.)
- Design and set max green of phase 3 every cycle, indirectly change EB right-turn green.
- Detectors associated with EB right-turn are assigned to phase 3, so they can actuate phase 3.
- Queue overwrite like design
  - When the onramp queue is estimated to be, activate the regulation.
    - if onramp queue or the WB left-turn queue grows, reduce max green of phase 3 by 2sec per cycle to limit the discharge of EB right-turn.
    - Otherwise, increase max green of phase 3 by 2sec to allow more vehicles to get into onramp.
    - Release EB right-turn when its queue exceeds a limit.
    - Lower bound and upper bound of the max green.
  - Deactivate.

Technical Details: Intersection design (cont.)

- **range of the max green**
  - **Max green is within 15~24sec.**
  - **Original max extension is 15sec, min initial is 4sec.**
  - **Max extension of phase 7 is 20sec, min initial is 4sec.**
  - **By choosing 24sec, phase 3 and phase 7 are possible to terminate at the same time (yellow and red clear are different).**
  - **By choosing 15sec, phase 3 vehicles can be discharged (phase 3 has a very low demand).**
  - **Phase 3 use max green every 4 cycle to release Phase 6 RT queue**

Modeling and Simulation - Model Calibration

- **Data: Aggregated over 10min**
- **Flow**
  - **Compute the percentage of acceptable simulated flow**
  - **Aggregated flow in 10min**
  - **Freeway: detector at upstream of Taylor SB on-ramp, 1 lane available**
  - **Intersection: 8 movements**
  - **Criteria**
    - **Link flow quantity**
      - **700vph < Flow < 2700vph, within 15%;**
      - **Flow < 700vph, within 100vph;**
      - **Flow > 2700vph, within 400vph;**
    - **Link flow GEH**
      - $GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$
- **Speed**
  - **Compute the percentage of acceptable simulated speed (error<5mph)**

Delay Estimation

- **Assuming an average queue release speed**
- **Estimate queue length based on occupancy of single loop detector**
- **➔ Determine density from flow measurement**
- **➔ Determine the number of vehicles in the queue**
- **➔ Accumulate per cycle to get total delay**
- **➔ Apply to WB RT and EB LT to get total delay**
- **➔ Apply this method to both “before” and “after” situation**