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

Dongyan Su, GSR
John Spring, PATH
XY Lu, PATH, Project Manager and Principal Researcher

Alex Skabardonis, Project PI

PATH, U. C. Berkeley
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Outlines

• Freeway Onramp Metering
• Intersection Signal Control
• Queue Estimation
• Coordination Strategy
• System Integration
• Next Step
Freeway Onramp Metering

• Ramp metering algorithm
  – ALINEA
  – I control based on occupancy
    \[ r(k) = r(k - 1) + K_R[\hat{o} - o_{out}(k - 1)] \]
  – Update rate -- 30sec; highest rate -- 900vphpl; lowest rate -- 600vphpl.

• Occupancy estimation at merge area
  – Need to estimate occupancy from upstream measurement.
  – UP ALINEA (Appendix I)
Intersection Signal Control

Previous EB RT overlap with phases 6&7

Proposed EB RT overlap with phases 6&3

[Diagram showing signal control at an intersection with arrows indicating traffic flow and signal phases.]
Intersection Signal Control

- Keep the current control, actuated control.
- Give priority to WB left-turn to avoid queue spillovers.
  - Change the overlap of EB right-turn, connect EB right-turn to phase 3 (over lap 6&7 → 6&3).
  - Regulate maximum green of phase 3 to indirectly change green length of EB right-turn.
  - Regulation algorithm is a queue-overwrite-like design. (Appendix II)
  - Ramp metering rate and ramp queue length are used in the regulation algorithm.
  - Need to estimate queues at intersection and onramp.
Queue Estimation

- Onramp queue estimation
  - Available detectors: exit detectors, intersection stop-line detectors.
  - Estimate based on the vehicle counts, metering rate, occupancy during green.

- Intersection queue estimation
  - Available detectors: stop-line detectors, approach detectors.
  - Estimate based on vehicle counts, occupancy, signal.
Coordination Strategy

- Coordination logistics (dependencies)
  
  Based on freeway traffic situation (occupancy measurement)
  determines RM rate (RM algorithm)

  ➔ determines onramp queue length

  ➔ determines space available at onramp

  ➔ determines how many vehicles can get into onramp in each cycle

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

Ramp meter computer
- Uses Interconnect channel to send URMS polls and metering rate changes to 2070 running URMS, via TCP on port 10011
- Receives traffic data (e.g. mainline and metered lane volume, occupancy, and speed) from RM 2070 and forwards them to intersection computer, via the internet, for metering rate and maximum green calculation
- Receives new metering rate(s) from intersection computer and forwards them to 2070 controller
System Integration - Intersection

Intersection computer

- Uses AB3418 protocol (a subset of NTCIP) over COM1 serial port
- Uses ATX host in place of field master
- Uses our publish/subscribe database (db_slv©) to interface to send timing from optimal control algorithm
- Can change max green for phase 3 only
- Receives mainline and metered lane data from ramp meter computer and calculates new metering rate
- Sends new metering rate to ramp meter computer via internet
**Interface with Taylor Intersection 2070 Controller running TSCP**, Functional Diagram

**Intersection Traffic Control Cabinet**
- 2070 Controller Running TSCP
- Receive traffic data
- Calculate green distribution
- Control traffic signal
- Monitoring systems fault
- Communicate with PATH computer through AB3418(E)

**TMC Ramp Meter Computer**
- Receiving detector data
- Calculating RM rate
- Sending RM rate to onramp
- Monitor PATH RM rate
- Stop PATH RM rate in case necessary

**Local RM Cabinet**
- Pulling detector data
- Receiving RM rate command from TMC computer
- Communicating with PATH computer through AB3418(E)
- Activating RM signal

**PATH Computer**: As Master at intersection cabinet
- Communicating with 2070 controller through AB3418
- Polling and Retrieving detector and signal data from 2070
- Communicating with PATH computer in RM cabinet with secured network
- Calculate phase 3 maximum green
- Send 3 max green to 2070

**PATH Computer in RM cabinet**
- Communicating with 2070 controller through AB3418
- Polling and Retrieving detector and signal data from 2070
- Communicating with PATH computer in RM cabinet with secured network
- Calculate RM rate
- Executing coordination strategy
- Sending RM rate to RM controller

**Serial Interface**

**Secured Wireless Connection**

**Caltrans network comm.**
Interface with Taylor Intersection 2070 Controller running TSCP – Data Flow Diagram

**Intersection Traffic Control Cabinet Running TSCP**

- 2070 Traffic Controller
  - Offset
  - Cycle length
  - Max/Min Green
- Traffic detector

**PATH Computer: As Master at intersection cabinet**

- Traffic signal control algorithm
- Traffic data processing
- 3G modem

**TMC Ramp Meter Computer**

- Ramp metering rate
- Traffic data server

**Local RM Cabinet**

- 2070 Running URMS
  - Ramp metering rate
- Traffic Detector

**Serial Interface**

- Secured Wireless Connection

**PATH Computer in RM cabinet**

- Ramp meter algorithm
- Coordination algorithm
- Traffic data processing
- 3G modem

Intersection Signal

Wireless or cable comm.
Technical Details: UP ALINEA

• Estimate downstream occupancy from upstream measurement.

\[
\tilde{\rho}_{out} = \alpha o_{in}(1 + \frac{q_r}{q_{in}}) \frac{\lambda_{in}}{\lambda_{out}}, \text{ if } o_{in} \leq o_{cr}
\]

\[
\tilde{\rho}'_{out} = o_{in} \frac{\lambda_{in}}{\lambda_{out}} + 100 \frac{L}{w_{\lambda_{out}}} q_r, \quad \tilde{\rho}_{out}(k) = \gamma \tilde{\rho}'_{out}(k) + (1 - \gamma) \tilde{\rho}'_{out}(k - 1), \text{ else.}
\]
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 more than half of the storage, activate the regulation.
    ➢ if onramp queue or the WB left-turn queue grows, reduce max green of phase 3 by 2 sec per cycle to limit the discharge of EB right-turn.
    ➢ Otherwise, increase max green of phase 3 by 2 sec 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 12~24sec.
  – 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 12sec, phase 3 vehicles can be discharged (phase 3 has a very low demand).