Combination of Traffic-Responsive and Gating Control in Urban Networks: Effective Interactions

Mehdi Keyvan-Ekbatani, Xueyu Gao, Vikash Gayah, Victor Knoop
Main Contributions

• Compared the impacts of adaptive signal control and perimeter gating (only)
• Examined the impacts of combining adaptive signal control and perimeter gating
  – The improved capacity and slightly higher critical accumulations on the MFD, as a result of traffic-responsive control, implemented for a more efficient gating
• Implemented in AIMSUN microsimulation of Chania urban network
• Impacts quantified using overall urban traffic network efficiency
Introduction

- Under over-saturated traffic conditions density-based adaptive signal control schemes have little to no effect on a network (Gayah et al., 2014).
- These strategies may allow too much traffic to enter from the boundary of a network, if it is less congested, which can intensify queue spillbacks in the congested areas.
- They also tend to act only after congestion begins to occur.
- Urban traffic networks might be better controlled by limiting the vehicle rate within the busiest parts of a network (using gating/perimeter control).
- The perimeter gating strategy relies on macroscopic relationships between traffic variables measured network-wide (network accumulation vs. production; MFD or NFD)
NFD and Traffic-Responsive Control Strategies

- Adaptive signal control can have positive effects on the free flow and capacity portions of the NFD
  - Improved network capacity and higher critical accumulations can be achieved on the NFD
- These improved macroscopic measures can result in more efficient gating
Combining Gating and Traffic-Responsive Strategies

Integrated Traffic Control

Gating/Perimeter Traffic Control

Traffic-Responsive Control Strategies e.g. Simplified SCATS

Flow Control

Traffic Dynamics

Real-Time Traffic Monitoring
Traffic State estimation

Real-Time Measurement

Production
Accumulation
Gating Control (Review)

\[ q_g(k) = q_g(k-1) - K_p \left[ TTS(k) - TTS(k-1) \right] + K_i \left[ TTS - TTS(k) \right] \]

TTS: Total Time Spent (Accumulation)
Volume-Based Traffic-Responsive Control

- Fixed cycle length
- Simple proportional algorithm to allocate the available green time
- Green allocation based on traffic volume measured at upstream detectors on each approach

\[ g_i(t) = (C - L) \cdot \frac{v_i(t-1)}{\sum_i v_i(t-1)} \]

C: Cycle
L: lost time
i: approach
v: approach volume
Simplified SCATS

- Green time and total cycle lengths are variable
- Appropriate cycle length is first select based on the volume ratio observed during the previous cycle.

\[
C(t) = \begin{cases} 
STOPPER & \text{if } C(t) = MIN, R(t-1) > 0.4 \\
MIN & \text{if } C(t) = STOPPER \text{ and } R(t-1) < 0.2 \\
\min[C(t-1) + STEP, MAX] & \text{if } R(t-1) > 0.95 \\
\max[C(t-1) - STEP, STOPPER] & \text{if } R(t-1) < 0.85 \\
C(t-1) & \text{otherwise}
\end{cases}
\]

\[
g_i(t) = (C(t) - L - G_{\min}) \cdot \frac{d_i(t-1)}{\sum_i d_i(t-1)} + g_{i,min}
\]

- \( G_{\min} \): sum of minimum greens
- \( d \): approach demand

- \( MIN = 42 \text{ s} \)
- \( MAX = 132 \text{ s} \)
- \( STOPPER = 66 \text{ s} \)
- \( STEP = 6 \text{ s} \)
- \( g_{i,min} = 6 \text{ s} \)
Test-Bed (Chania Network)
Simulation Setup

• The protected network includes 28 signalized junctions and consists of 165 links.

• Measurements are collected every 90 seconds for the gating control

• 4-hour trapezoidal demand profile
• Realistic O-D flows applied.

• 15 simulation runs carried out.

• (1) Overall mean speed and (2) delay; (3) Maximum queue length applied as performance indexes
Simulation Scenarios

• Scenario 1: (no-gating) the traffic lights in the PN are controlled applying fix-time control signal plan.

• Scenario 2: (no-gating) “volume-based” traffic responsive control strategy is implemented to control all the traffic lights within PN.

• Scenario 3: (no-gating) adaptive traffic control strategy “modified SCATS” is used for controlling the signalized junctions within PN.

• Scenario 4: Gating at the perimeter and fix-time control inside PN.

• Scenario 5: Gating at the border and “volume-based” for the rest of the traffic lights in the PN.

• Scenario 6: Gating at the boundary and “modified SCATS” within PN
Traffic-Responsive Control
Benefits on NFD

No-Gating

With Gating

Shifted TTS

Higher TTD
Density Standard Deviation in all Scenarios
### Overall Network Performance

<table>
<thead>
<tr>
<th>Performance Index</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
<th>Scenario 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>delay (sec/km)</td>
<td>389</td>
<td>294</td>
<td>351</td>
<td>203</td>
<td>193</td>
<td>203</td>
</tr>
<tr>
<td>speed (Km/h)</td>
<td>8</td>
<td>10</td>
<td>9</td>
<td>13</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>vehicle out</td>
<td>12675</td>
<td>12913</td>
<td>12801</td>
<td>12924</td>
<td>12912</td>
<td>12923</td>
</tr>
</tbody>
</table>

Gating Scenarios
Maximum Queue Length

- **Fix time**
  - No gating: 700 veh
  - Gating: 1000 veh

- **Volume based**
  - No gating: 700 veh
  - Gating: 900 veh

- **Modified SCATS**
  - No gating: 700 veh
  - Gating: 1000 veh

**Challenge the future**
Conclusions

• The joint implementation of perimeter gating control and adaptive traffic signal control examined.

• Gating provides higher speeds and lower delays than adaptive signal control alone.

• Adaptive traffic control increases the critical accumulation less car metered, shorter gating queues.

• The combination offers advantages in case of multi-zone gating (less negative impact on vicinity traffic).
Thanks for listening!

Email:

M.Ekbatani@tudelft.nl