ADVANCED TRAFFIC SIGNAL CONTROL USING BLUETOOTH DETECTORS

Jordan Hart-Bishop, Dr. Bruce Hellinga, Amir Zarinbal
Outline

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Introduction

• This research focuses on the use of Bluetooth detectors as a data source for Traffic Responsive Plan Selection (TRPS) signal control

• The proposed system would provide an additional option to traffic professionals attempting to deal with volume variation at an intersection
Introduction

- Bluetooth detectors have been used to effectively estimate the travel times that motorists would experience on arterials.
- The system has the potential to be a lower cost option than the other methods primarily due to their ease of installation and maintenance.
Objectives

- The two main objectives of this research are:
  1. To determine the accuracy by which Bluetooth data can be used to measurement arterial traffic conditions
  2. To identify how these measures can be used to improve signal timing plans in real-time.
Simulation Tools

• The first stage of this research involves the use of simulated traffic data
• PTV Vissim microsimulation software was used to generate vehicle trajectories
• BlueSynthesizer, an in-house Bluetooth detector simulation software was used to produce simulated Bluetooth data
Vissim Test Network

- The Hespeler Road Corridor in Cambridge, ON, from Highway 401 to Highway 8 was created in Vissim

(Background Image from Bing Maps)
BlueSynthesizer Tool

- BlueSynthesizer was developed to simulate the detection process using several parameters:
  - Level of Market Penetration
  - Detector Radius
  - Detector Positions
Proposed Measures of Performance

- The two MOPs that have been selected for the experiment are as follows:
  - Bluetooth Travel Time, $TT_B$, the travel time between two detectors on the roadway
  - Bluetooth Dwell Time, $\beta$, the time that a vehicle spends within one detectors detection zone
Bluetooth Travel Time

- **Distance**
- **Time**
- Upstream Detection Zone
- Downstream Detection Zone
- First-First Travel Time
- Average-Last Travel Time
- True Travel Time

$x =$ Bluetooth Hit
Bluetooth Dwell Time

- Distance
- Time
- Detector Zone
- $\beta =$ Bluetooth Dwell Time
- B = True Dwell Time
- $\times =$ Bluetooth Hit
Initial Experimentation

• Two simulation experiments were completed to assess the proposed MOPs
  • The first experiment focused on linking the Bluetooth MOPs to the true Travel Times
  • The second experiment focused on attempting to identify traffic states using the Bluetooth MOPs
Initial Experimentation

- Experiment 1 simulated a variety of traffic demands for one approach to gather travel time data for several levels of congestion.
- Experiment 2 had two constant volume cases and signal timing plans that were optimized for each case.
  - Base conditions (Base)
  - Increased Southbound Left volume (SBL)
Initial Experimentation

• The two experiments share the following settings:
  • Aggregation interval of 5-minutes
  • 10% Level of market penetration of Bluetooth devices
  • The Bluetooth detectors were assumed to have an effective radius of 100m
  • The southbound approach true travel time was measured from the centre of the Bluetooth detection zone
Experiment Layout

Simulated Direction of Travel

Upstream Detection Zone

250m

Downstream Detection Zone
Experiment 1 Results

Southbound Approach Travel Time Comparison

Travel Time (Seconds)

Simulation Hour

- Travel Time First-First
- Travel Time Average-Last
- True Travel Time
- Travel Time First-Last
Experiment 1 Results

Average-Last Bluetooth Travel Time vs. True Travel Time

\[ y = 0.99x \]
\[ R^2 = 0.93 \]
Experiment 1 Results

Bluetooth Dwell Time vs. True Dwell Time

\[ y = 0.7731x \]

\[ R^2 = 0.8165 \]

Line of Perfect Correlation
Experiment 1 Results

Bluetooth Dwell Time vs. True Travel Time

\[ y = 0.2768x + 25.604 \]
\[ R^2 = 0.6402 \]
Experiment 1 Results

• From these results, we can make the following observations:

  1. This experiment shows that, at least under ideal conditions, the Bluetooth measured travel times can accurately reflect the true travel times when the travel times are computed in an appropriate manner (i.e. in this case as average-last).

  2. Bluetooth dwell times are highly correlated with the true dwell times, but they underestimate the true dwell times.

  3. The Bluetooth dwell times are not a reliable estimate of the approach travel time when queues on the approach extend upstream of the detection zone.
Experiment 2 Results

Comparison of Southbound Approach Travel Times for Volume and Signal Plans

<table>
<thead>
<tr>
<th>Travel Times (seconds)</th>
<th>Base Volume</th>
<th>Increased Southbound Left Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>True</td>
<td>Bluetooth</td>
</tr>
<tr>
<td>Base Signal Plan</td>
<td>Mean</td>
<td>51.8</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>4.3</td>
</tr>
<tr>
<td>SBL Signal Plan</td>
<td>Mean</td>
<td>49.5</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>4.1</td>
</tr>
</tbody>
</table>
Experiment 2 Results

Comparison of True Southbound Approach Travel Times for Volume Scenarios with Base Signal Plan Plot

- Bluetooth - Base Volume
- Bluetooth - Increased SBL Volume
- True - Base Volume
- True - Increased SBL Volume
Pilot Study

- This research has selected two study intersections on Hespeler Rd in Cambridge, ON
  - Hespeler Rd and Eagle St N/Pinebush St, located at the north end of the corridor just south of Highway 401.
  - Hespeler Rd and Bishop St N, which is approximately the halfway point of the study corridor.
- The pilot study involves both Bluetooth detectors and Wi-Fi detectors from multiple vendors
Pilot Area 1

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>📦</td>
<td>Traffic Sensor</td>
</tr>
<tr>
<td>🕒</td>
<td>Puck Station</td>
</tr>
<tr>
<td>📡</td>
<td>Video Camera</td>
</tr>
<tr>
<td>📡</td>
<td>Bluetooth Detector</td>
</tr>
<tr>
<td>🧵</td>
<td>Wi-fi Detector</td>
</tr>
</tbody>
</table>

Highway 401 Eastbound Off-ramp

200 m

260 m

230 m

220 m

(Background Image from Google Maps)
Pilot Area 2

(Background Image from Google Maps)
Conclusions

• The results from the first rounds of simulation has shown that the identified Bluetooth MOPs are very closely related to the corresponding true measurements.

• Evidence was also presented that demonstrated the theoretical way that the system could detect a difference between two traffic states.

• The pilot study outlined in this presentation will allow for initial validation of simulation results, and provide information on how the system could be implemented on the Hespeler Rd corridor.
Acknowledgements

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Thank you! Questions?