INTRODUCTION

This paper presents an evaluation of approaches to Arterial Travel Time and an assessment of the strengths and weaknesses of the GPS Fleet data approach. The importance of Travel Time information for arterial routes is widely recognised yet poorly implemented. Travel Time systems are producing reliable and accurate results for freeways, but there has been significant technical and cost challenges to overcome if similar results are to be had for arterial routes. Problems include:

- Prohibitive cost of deploying fixed-road sensors with adequate traffic network coverage
- Measuring and accommodating delays at traffic lights and intersections

Keywords: arterial travel time, wireless, GPS, intelligent transportation, real-time, congestion prediction

AN EVALUATION OF ARTERIAL TRAVEL TIME SOLUTIONS

Unlike freeway travel time solutions, arterial travel time must be measured and not inferred. The identification of the vehicle is required, and measurements taken for each vehicle at various points along a route. Arterial travel time systems fall into two categories – systems based on re-identification of the vehicle at points along a route, and GPS solutions where a vehicle broadcasts its status at specific time intervals. Re-identification approaches include Bluetooth systems, RFID capture, EM signature and license plate identification.

A comparison of the first order performance of these systems would indicate that all approaches are capable of providing similar results. However, the major difference between GPS-based and re-identification systems lies in the relationship between system lifecycle costs, timeliness of the data and the accuracy of the results (see table 1).

Re-identification requires a fixed-road sensor network to be installed and maintained. Although the sensors can be relatively cheap, the cost to deploy and then subsequently maintain is expensive and disruptive (for example, where road and lane closures or flow restrictions are required). Timeliness and accuracy requires a dense sensor network, which in many cases is prohibitively expensive.

GPS solutions are non-invasive and in contrast obviate the need for deployment and maintenance expenditure. The cost to purchase GPS Fleet data remains a consideration. However, sensor density and therefore timeliness remains significantly lower in cost when compared with the equivalent re-identification approach.
Accuracy and timeliness are also related. Assuming that the behaviour distribution of instrumented vehicles follows a normal distribution, then accuracy and timeliness both improve proportionate to the number of vehicles on the network.

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Timeliness</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot Speed based Models</td>
<td>✗</td>
<td>✓</td>
<td>✗✗</td>
</tr>
<tr>
<td>GPS Fleet</td>
<td>✓✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>EM Signature ✓</td>
<td>✗</td>
<td>✓✓</td>
<td>✓</td>
</tr>
<tr>
<td>Toll Tag</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>License Plate ID</td>
<td>✗</td>
<td>✓✓</td>
<td>✓</td>
</tr>
<tr>
<td>Floating Car</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

Table 1: Evaluation of Arterial Travel Time Solutions

Although GPS Fleet data is the only solution where a sensor network does not have to be deployed, there are a number of issues.

- The availability of (voluntary) GPS Fleet data in all areas.
- Ensuring that the GPS Fleet data is representative of the population as a whole, that is, does the driving behaviour (time of day, speed, routes for example) of the contributing vehicles representative of a ‘typical’ commuter.
- Inherent difficulties in urban canyon areas due to the nature of GPS signal transmission. (However, these errors tend to be small on average.)

**COMPUTING TRAVEL TIME WITH GPS DATA**

Vehicle speed, position and travel time is calculated by combining GPS data with a database of Road Element segments. The following formula illustrates the basic calculation for calculating Average Travel Time (ATT) for each Road Element (RE):

\[
ATT_{i,t,d} = \sum_{j} (ATT_{REj})_{i,t,d}
\]

\(ATT\) – Average Travel Time  
\(RE\) – Road Element  
\(T\) – Time between reports  
\(D\) – Distance travelled between reports  
\(L\) – Length of Road Element

The sum is taken for all vehicles per Road Element per time window. This approach enables the average speed for Road Element to be calculated over different time windows simultaneously. Typically, time windows would of the order of one minute, ten minutes and one hour.
Calculating Travel Time for any given route is then simply the sum of the average travel time for each Road Element over all Road Elements in the route:

\[ ATT_{i,t,d} = \sum_{j} (ATT_{REj})_{i,t,d} \]

\( ATT \) – Average Travel Time
\( RE \) – Road Element

The advantage of this approach is that none of the vehicles currently in the network need have travelled a complete end to end route for the system to calculate the travel time for that route. This is a significant advantage of this approach over re-identification techniques, where typically a vehicle must have travelled the entire route for the travel time to be measured.

UNDERSTANDING SYSTEM RESOLUTION AND ACCURACY

The resolution of Travel Time calculations from fixed-road sensor networks is constrained by the spacing between sensors, regardless of how many data points are available. With a GPS-based, floating sensor network, resolution at any given point in time is still limited to the distance between sensors. However, as the vehicles are moving, over time the resolution of overall network improves.

Travel time calculations will therefore be based on smaller and smaller intervals enabling accurate, high resolution travel time maps to be generated. As shown in Figure 1, the resolution can be as fine-grained as to understand the travel time through a specific intersection. Hence one of the major problems with arterial travel time can be addressed, as well as producing highly valuable planning information.

CONCLUSIONS

This paper has discussed the use of GPS data as a low cost and effective approach for arterial travel time. The approach addresses the problems with alternative solutions – high deployment and maintenance costs for sensor networks and inaccurate results due to traffic lights and intersections. A GPS-based solution offers:

- Low cost solutions by eliminating the deployment and maintenance cost overhead.
- Greater accuracy of travel time prediction due to the finer grained resolution that can be achieved by floating sensor networks over fixed sensor networks.
- A vehicle does not need to have travelled the entire route in order to contribute to the travel time calculation for that route – the information from even one Road Element in the route can be used.