BLUETOOTH TRAFFIC MONITORING TECHNOLOGY

CONCEPT OF OPERATION & DEPLOYMENT GUIDELINES

September 17, 2008

Introduction to Bluetooth Traffic Monitoring:

Beginning in late 2007 the University of Maryland, with support from the Maryland State Highway Administration, developed an anonymous probe technique to monitor the travel time on highways and arterials based on signals available from the point-to-point networking protocol commonly referred to as Bluetooth. The majority of consumer electronic devices produced today come equipped with Bluetooth wireless capability to communicate with other devices in close proximity. For example, many digital cameras use Bluetooth for downloading pictures to a laptop computer. It is also the primary means to enable hands-free use of cell phones. Bluetooth enabled devices can communicate with other Bluetooth enabled devices anywhere from 1 meter to about 100 meters, depending on the power rating of the Bluetooth sub-systems in the devices.

The Bluetooth protocol uses an electronic identifier, or tag, in each device called a Media Access Control address, or MAC address for short. The MAC address serves as an electronic nickname so that electronic devices can keep track of who's who during data communications. It is these MAC addresses that are used as the basis for obtaining traffic information. The concept for deriving traffic information in this manner is illustrated in Figure 1.

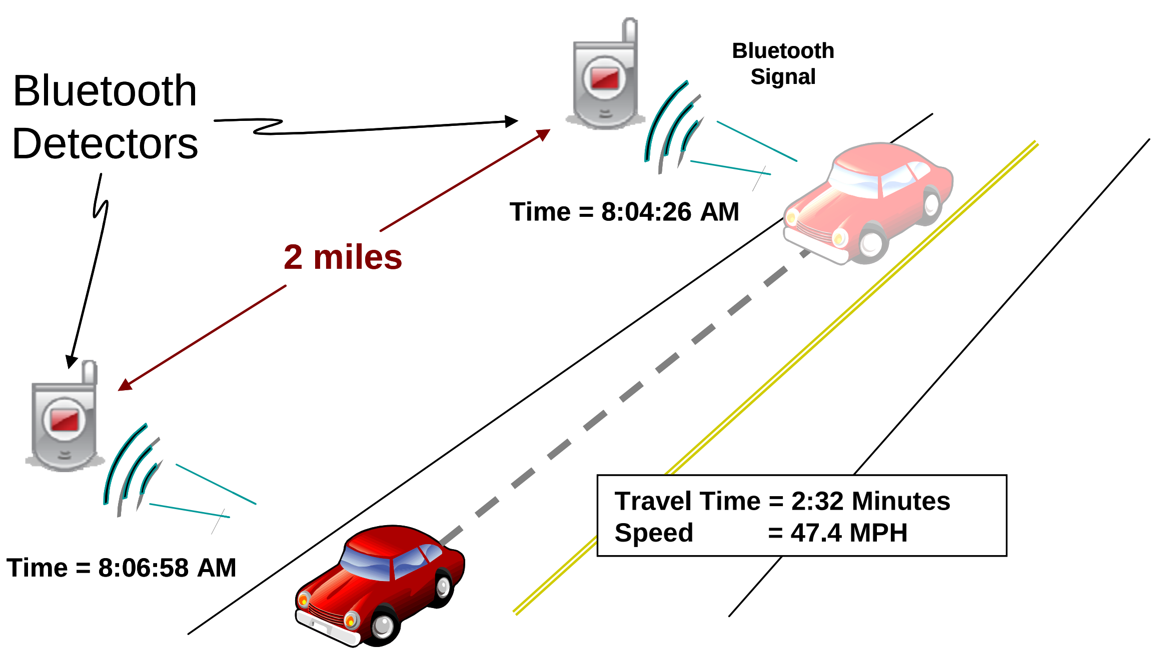

Figure 1 Bluetooth traffic monitoring operation concept

A vehicle containing a detectable Bluetooth device is observed at two stations. The MAC address and time of detection is logged, and the information used to obtain a sample travel time for the segment. Observations of multiple vehicles containing Bluetooth devices provide a highly accurate estimate of traffic conditions. Experiments have indicated that approximately one in twenty vehicles contain a Bluetooth device that can be detected.

Privacy Concerns

The anonymous nature of this technique is due to the use of MAC addresses as identifiers. MAC addresses are not associated with any specific user account (as is the case with cell phone probes) or any specific vehicle (as with automated toll tags). The MAC address is not linked to a specific person through any type of central database, thus minimizing privacy concerns. MAC address are assigned at the Bluetooth electronic chip manufacturers, and not tracked through the sales chain. Additionally, users concerned with privacy can set options in their device (referred to as ‘Discovery Mode’ or ‘Visibility’) so that the device will not be detectable.

Concept of Operation

The University of Maryland (UMD) has developed a portable Bluetooth monitoring system consisting of field detection equipment and central processing software. The detectors are deployed on a freeway or arterial in proximity to the roadway at the base of a sign post or guard rail post. These units are the size of a large briefcase or small carry-on. A photo of the device and a sample placement next to a sign post are shown in Figure 2.

Figure 2 The Bluetooth detector is shown as it would be deployed during data collection. The unit sits on the ground and is tethered to an existing post.

Detectors need to be tethered to a secure object for security reasons. **Local transportation and security officials should be notified of the use and appearance of the devices, and the**

devices should be marked with local contact information. The units contain an internal battery and can operate for up to six days without recharging. Data is stored to a removable memory card for later retrieval. In a typical application detectors are placed from 2 to 4 miles apart along a corridor for 48 to 96 hours. At the end of the data collection period, the units are collected, data is downloaded from the memory cards and the battery is recharged. The mobile devices are equipped with an omni-direction Bluetooth antenna and a class one (highest power) transceiver. This combination provides the greatest flexibility in the field, allowing a single technician the ability to deploy a sensor in less than five minutes. One sensor can typically cover both directions of a divided freeway when it is deployed in a fashion similar to that shown in Figure 2, provided that no median barrier exists and that the median is not excessively wide. Lower power transceivers and directional antennas can spatially limit the detection area for more directed study areas.

Sample Data

Studies have indicated that approximately 1 automobile in 20 contains some type of Bluetooth device that can be detected. Not every Bluetooth device is detected at every station so the number of matched detections (a device detected at two consecutive detectors) is lower. Even so, a majority of the detected devices are seen at multiple stations. The density of matched pairs can be used not only to develop a sample of travel time for a particular segment of the roadway, but to also estimate the variance of the traffic stream. Figure 3 shows data from a segment of Interstate I-95 between Washington, DC and Baltimore, Maryland between 6:30 AM and 12:45 PM obtained with an early generation of prototype equipment. Each data point represents the travel time from a matched detection at each end of the segment. Figure 3 depicts the impact on travel time as a result of an incident that began around 10 AM, was cleared at approximately 10:50 AM and traffic returned to normal flow around 11:15 AM.

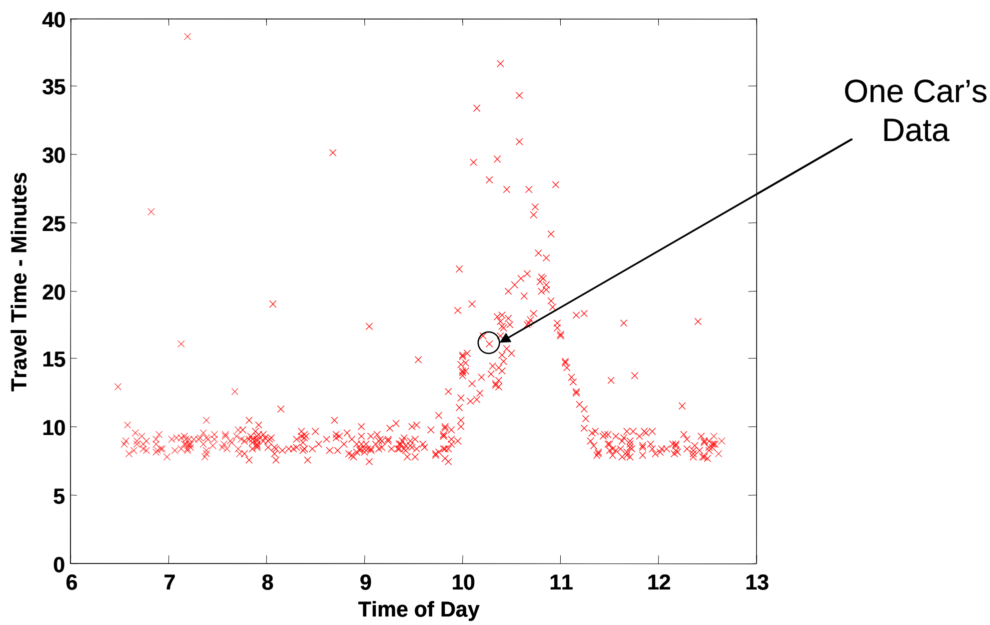

Figure 3 Sample Bluetooth data taken along a segment of I-95 between Baltimore and Washington, DC

The Bluetooth sensors and software developed at UMD are being used to collect ground truth data to validate the I-95 Traffic Monitoring System. The travel times obtained from the Bluetooth sensors are compared against the travel times reported in the commercial traffic data feed provided by Inrix corportation. An example of this is shown in Figure 4. This data was collected in June of 2008 on the Washington Beltway and compared against the pre-production data provided by Inrix corporation. Also included in the plot are four floating car sample data points. This illustrates the contrast between the volume and quality of traditional means of ground truth testing with floating car data, and that provided by Bluetooth equipment.

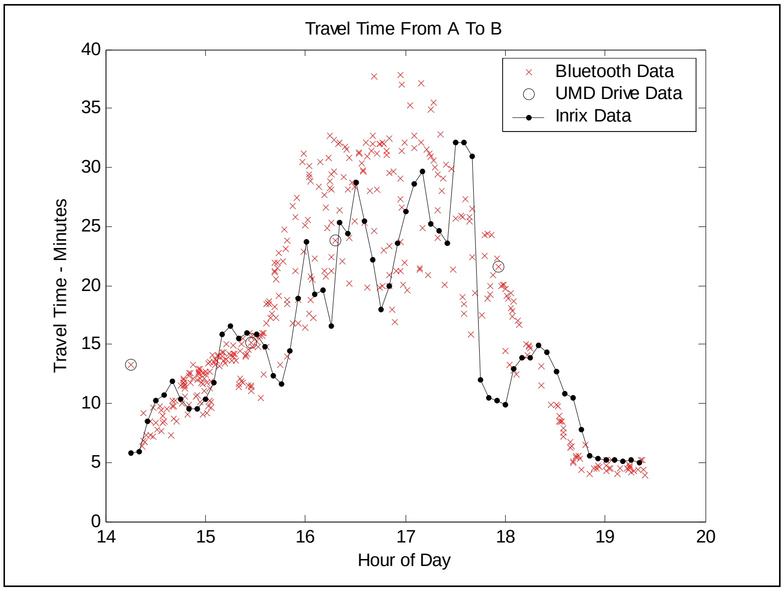

Figure 4 Sample validation data from June 2008 on I-495 in Northern DC

Future Direction

The University of Maryland (UMD) is continuing to develop and refine this technique in cooperation with the Maryland State Highway Administration. Current initiatives include analyzing the penetration rate of the Bluetooth receivers by co-locating detectors in proximity to Automated Traffic Recorders. Also planned in 2008 is a demonstration up-linking the data via a cellular modem and processing the data in real-time and effectiveness of the Bluetooth data for Origin-Destination studies. The UMD is cooperating with Purdue University in exploring the uses and applications of the data. In a joint data collection project with Purdue, the Indiana Department of Transportation and UMD, Bluetooth sensors were deployed during the Brickyard 400 in 2008. The data was used to evaluate the effectiveness of the traffic management scheme, the results of which will be presented at the 2009 Transportation Research Board (TRB) annual meeting.

In order to get this technology commercially viable as quickly as possible, the UMD through its Office of Technology Commercialization has licensed the its technology to Traffax Inc. A portable version (similar in functionality to that used to validate the I-95 Traffic Monitoring project) is scheduled to be available in 2008, with permanent mount versions available in 2009.

Cost comparisons contrasting a Bluetooth approach and driving testing have been analyzed based on a 20 mile corridor. Depending on assumptions, the cost-per-data-point ratio between floating car data collection and Bluetooth is estimated to be 500:1 to 2500:1.

Conclusion

Bluetooth Traffic Monitoring provides an opportunity to collect high quality, high density travel times by anonymously sampling a portion of actual travel times from the traffic stream. By matching MAC addresses at two different locations, not only is accurate travel time measured, but privacy concerns typically associated with probe systems are minimized. Bluetooth traffic monitoring is estimated to be 500 to 2500 times more economical than drive testing on a cost per data point basis. This technique is being utilized to collect ground truth data to validate the I-95 Traffic Monitoring System, and to date ground truth data has been collected in multiple states. Continued development is planned at UMD to explore applications and uses of the data.

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