IntelliDrive[SM] Traffic Signal Control Algorithms

Task 1: Report on the Investigation of IntelliDrive[SM] Data Sources

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Prepared for
IntelliDrive[SM] Pooled Fund Study

December 31, 2010

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OBJECTIVE AND SCOPE OF THE DOCUMENT

This task report investigates the data sources available in an IntelliDrive[SM] environment, as defined by the SAE J2735 DSRC Message Set Dictionary, and suggests a limited number of new data elements that are not part of the latest standard, but would be useful for signal control.

CURRENTLY DEFINED INTELLIDRIVE[SM] DATA SOURCES

IntelliDrive[SM] allows for information exchange using several different communications platforms, including:

- Dedicated short range communications (DSRC)
- Wi-Fi
- Worldwide Interoperability for Microwave Access (WiMAX)
- Cellular
- Bluetooth
- 3G/4G

Of the communications media, only DSRC has latency of less than one second. The US Department of Transportation has committed to DSRC as the primary platform for safety applications, and one of several platforms for mobility applications. The advantages of DSRC over Wi-Fi, as determined by USDOT, are as follows:

- It operates in a licensed frequency band
- It is primarily allocated for vehicle safety applications by FCC Report & Order – Feb. 2004 (75 MHz of spectrum)
- It provides a secure wireless interface required by active safety applications
- It supports high speed, low latency, short range wireless communications
- It works in high vehicle speed mobility conditions
- Its performance is immune to extreme weather conditions (e.g. rain, fog, snow, etc.)
- It is designed to be tolerant to multi-path transmissions typical with roadway environments
- It supports both inter-vehicle and vehicle-to-infrastructure communications (RITA, 2009)

The traffic signal control applications developed in Tasks 2 and 4 of this report were based primarily around DSRC. Given that DSRC is expected to be heavily used for safety applications on signalized arterials, this work assumed that DSRC, and associated standards, would be the primary data source for signal control. Thus, all traffic signal control algorithms developed in this project require data to be transmitted once per second, which may be difficult with non-DSRC communications with 1.5 to 5 second latencies. In contrast, DSRC's latency is 0.002 seconds.

SAE J2735 DSRC STANDARD

The vast majority of data required for effective implementation of the proposed signal control algorithms is available through the Society of Automotive Engineers (SAE) J2735 DSRC

Message Set Dictionary (SAE, 2009). This standard, which is still in draft form and most recently updated in November 2009, specifies the types of information that would be included in any safety and mobility messages sent and received with DSRC in an IntelliDrive[SM] environment. The standard defines specific information that may be exchanged between vehicles and the infrastructure as "data elements." These elements are then further grouped into "data fields," and also further grouped into messages. There are several messages, but two most directly pertain to traffic signal operations. These are the Basic Safety Message Part I and the A La Carte Message.

Basic Safety Message Part I

The most common message is the Basic Safety Message (BSM) Part I, which transmits a vehicle's position, heading, and speed. This message is often referred to as a ***Here I Am*** message. The BSM Part I is transmitted ten times per second, much more frequently than is required by the traffic signal control algorithms developed in this project. Latency is estimated to be less than one second, and typically between 10 and 20 milliseconds. The BSM Part I consists of the following data elements:

- MsgCount
- TemporaryID
- DSecond
- PositionLocal3D
  - Latitude
  - Longitude
  - Elevation
  - PositionalAccuracy
- Motion
  - TransmissionAndSpeed
  - Heading
  - SteeringWheelAngle
  - AccelerationSet4Way
- Control
  - BrakeSystemStatus
- VehicleBasic
  - VehicleSize

As the research team investigated new signal control algorithms, it became clear that this Here I Am message is sufficient to support innovations in control. A limited number of additional data elements were identified as desirable – particularly for performance measurement. These are described below.

A La Carte Messages

Several potential signal applications may require data beyond what is in the Basic Safety Message, and would instead require an "a la carte" message (ACM). The ACM can use any data elements listed in the J2735 standard, but are encouraged to limit extraneous information as bandwidth is a sometimes scarce resource.

Several of the new performance measures available with IntelliDrive[SM] described in the Task 3 report would require data elements from the ACM. These performance measures, and their required data elements, are described below:

Sudden Deceleration
Sudden deceleration is a safety performance measure where a hard braking event or sudden deceleration may indicate a recent crash, congestion, or unsafe roadway. Required data elements in the ACM include:

- DE_BrakeAppliedPressure
- DE_Acceleration
- DE_AcclerationConfidence
- DE_AntiLockBrakeStatus

Change in Lateral Acceleration
This measure evaluates sharp turning movements or swerving events, which may indicate hazards in the roadway, recent crashes, ice, etc. Required data elements in the ACM include:

- DE_StabilityControlStatus
- DE_SteeringWheelAngleRateOfChange
- DE_SteeringWheelAngleConfidence

Weather Conditions
This performance measure is used to collect aggregated driver behavior data in a variety of moisture and light conditions, to better understand how saturation flow and deceleration rates change during adverse weather. Required data elements in the ACM include:

- DE_SunSensor
- DE_RainSensor
- DE_ExteriorLights
- DE_WiperRate
- DE_WiperStatusFront
- DE_WiperStatusRear

Data Elements not Included in SAE J2735

Although the SAE J2735 standard is comprehensive, there are some data elements that have been theorized during Tasks 2, 3, and 4 that were not included in the standard. These data elements would be useful either in signal timing or performance measurement.

Number of Passengers
Often the objective in signal timing is to minimize average delay of all travelers in the network. However, due to the difficulty of measuring individual travelers, the metric most often minimized is delay per vehicle. In some situations, it may be advantageous to give greater priority to vehicles with several passengers, to encourage transit use and carpooling. However, because there has never been a way to get precise passenger counts, transit signal priority has generally given equal priority to all transit vehicles, regardless of how many passengers are on board.

Although the data element DE_Transit currently provides an approximate measurement of percentage of seats occupied on transit vehicles, a more precise count of the actual number of passengers could be used to develop much more sophisticated transit signal priority systems.

Similarly, a data element providing the number of passengers in non-transit vehicles would also be useful. Real-time signal timing plans could use the number of approach *persons* instead of vehicles to minimize person-delay. Although there is currently no foolproof way to measure passengers in a vehicle, there are several concepts under development for high-occupancy toll lane applications.

Real-time Delay

In developing signal timing plans in an IntelliDrive^{SM} environment, it may be useful to know directly the delay that vehicles are experiencing second-to-second. See the Task 3 report for more information on the importance of real-time delay. Delay is not only related to a vehicle's speed, but to the speed at which a vehicle would travel unobstructed. In many situations, the speed limit is an effective substitute for a vehicle's unobstructed speed. However, when a vehicle is turning at an intersection, its maximum allowable speed is a factor of vehicle size and the radius of the turn. A vehicle's size is already listed as a data element, and turning radii are included in the Map data. By combining this information with a vehicle's speed, the second-to-second delay could potentially be determined.

By introducing real-time delay as a new data element, this information could be shared among nearby traffic signals to develop cooperative timing plans that respond immediately to changes in demand.

CONCLUSIONS

Although several communications media are available for traffic signal operation, DSRC currently has the most documentation and standardization. With its low latency and high transmission rate, it is the preferable platform for signal operations. The SAE J2735 standard contains a broad array of data elements, and its Basic Safety Message I is all that is required for the majority of the traffic signal control algorithms and performance measures described in the Task 2, 3, and 4 reports. Several new data elements are suggested here to improve the standard.

REFERENCES

Society of Automotive Engineers (SAE), J2735, Dedicated Short Range Communications (DSRC) Message Set Dictionary, November 2009.

Research and Innovative Technology Administration (RITA), "About IntelliDrive: DSRC Frequently Asked Questions." *IntelliDrive^{SM}*. http://www.intellidriveusa.org/about/dsrc-faqs.php. 2009.