Clear Roads Development of Interface Specifications for Mobile Data Platforms on DOT Vehicles in Cooperation with Clear Roads

Concept of Operations for Specification

April 8, 2010

Prepared for:

Purchasing
Wisconsin Department of Transportation
Attn: Kim Linsenmayer
4802 Sheboygan Avenue, Room 104
P.O. Box 7915
Madison, WI 53707

Prepared by:

Thompson Engineering Company

3830 Rustic Place
Saint Paul, MN 55126
Tel: 651 260-0116

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Saint Paul, MN 55126
Tel: 651 260-0116

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Wisconsin Department of Transportation
Attn: Kim Linsenmayer
Research and Library Unit
4802 Sheboygan Avenue, Room 104
P.O. Box 7915
Madison, WI 53707

Dear Kim Linsenmayer,

Please find attached the draft fourth deliverable CONCEPT OF OPERATIONS (SPECIFICATION BASED) for the project entitled "Clear Roads & Wisconsin DOT's Development of Interface Specifications for Mobile Data Platforms on DOT Vehicles".

Please review as needed. Comments, suggestions, and recommendations received from the Clear Roads staff will be incorporated in the final version.

Please contact me if you require additional information. Thank you for your consideration.

Sincerely,

Gregory E. Thompson

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Concept of Operation

I. INTRODUCTION

A. Background. The Clear Roads pooled fund research program (www.clearroads.org), in coordination with the Wisconsin Department of Transportation, seeks to develop communication and data format specifications to support mobile data platforms used by State DOT's. The mobile data platforms could be equipment such as, snow plows, end-loaders, supervisor trucks, paint trucks, herbicide sprayers, trailers, oil distributors and other similar equipment used in roadway maintenance operations. Agencies that are considering adding GPS/AVL to support the mobile data platform need a set of specifications that will allow them to purchase a variety of different sensors that all use a common communication protocol and data format.

B. General. This document defines the user needs and affirms the approach used to form the basis for the ensuing specification. This document will form the foundation that subsequent sections within a specification will amplify.

Accepted system engineering processes detail that requirements should only be developed to fulfill well-defined user needs. The first stage in this process is to identify the ways in which the system will be used. In the case of this specification, this entails identifying the various ways in which transportation operations personnel may use mobile asset information (Global Positioning System (GPS), Automatic Vehicle Location (AVL), & on-board sensors) in order to fulfill their duties.

This concept of operations provides the reader with:

1. A detailed description of the scope of this specification;
2. An explanation of how an AVL/GPS/Sensor Data Collection System is expected to fit into the larger context of an ITS network;
3. A starting point in the procurement process; and
4. An understanding of the perspective of the designers of the specification.

C. Administrative. A concept of operations describes a proposed system from the users' perspective. Typically, a concept of operations is used on a project to ensure that the system developers understand the users' needs. It also serves as the starting point for users to select which features may be appropriate for their project.

The concept of operations then discusses key aspects about the proposed system, including the:

1. Physical architecture – The physical architecture defines the overall context of the proposed system and defines which specific interfaces are addressed by this specification. The reference physical architecture may be supplemented with one or more samples that describe how the reference physical architecture may be realized in an actual deployment.
2. Architectural needs – The architectural needs clause discusses the issues and needs relative to the system architecture that have a direct impact on this specification.

3. Features – The features identify and describe the various functions that users may want the device to perform. These features are derived from the high level user needs identified in the problem statement but are refined and organized into a more manageable structure.
4. Architecture scope – The architecture scope for this document is confined to the on-board vehicle equipment and sensor interfaces. A complete AVL/GPS/Sensor Data Collection System consists of the on-board vehicle subsystem, a wireless communications subsystem, and a host end subsystem.

D. Current Situation. Transportation system managers use AVL/GPS/Sensor Data Collection Systems in a variety of ways to improve transportation system operations. The primary uses of AVL/GPS/Sensor Data Collection System data support the following:

1. Increased efficiency for fleet mobile assets while performing road maintenance activities during all seasons; especially during hazardous road conditions due to weather, environmental, and/or emergency conditions.
2. Provide better vehicle maintenance to enhance safety, reduce costs, improve vehicle availability, and limit environmental impacts.
3. Sharing the data with the greater transportation community, public, and media
4. Improved highway maintenance operations
5. More accurate traveler information, which can result in better route planning by travelers and more effective, safer transportation system use
6. Improved management of facilities maintenance resources, leading to more timely facilities clearance and improved traveler safety
7. More effective use of advisory and regulatory mechanisms to ensure public safety
8. Enhanced monitoring of potential hazardous conditions, to improve transportation system security and traveler safety

One of the most common Information Collection System deployed by transportation system managers is the AVL/GPS/Sensor Data Collection System. These AVL/GPS/Sensor Data Collection Systems are used to collect information about road maintenance conditions, such as vehicle health, road treatments and surface temperatures. When travel is becoming hazardous due to snow and/or ice, transportation system managers can dispatch road maintenance crews to treat the roads and remove snow and ice if possible. Integrating with other systems such as road weather information (RWIS) or dynamic message signs (DMS) are also useful features of these data collection systems. Icy conditions on bridges or roadways can also lead to the triggering of a spraying device that sprays anti-icing or de-icing chemicals on bridge or roadway surfaces to improve driving conditions. High water or high wind conditions could trigger a DMS to display a message either recommending that travelers choose a different route or that they reduce their speed to protect themselves against the potential hazard.

II. DISCUSSION & DESCRIPTION

A. Problem Statement. AVL/GPS/Sensor Data Collection System are typically deployed within transportation maintenance fleets but any public works fleet is a candidate for these types of systems. The work completed on specifications from this project will benefit highway maintenance engineers significantly. Recent events have shaped the world's approach to transportation safety and the marshalling of resources to respond to several potentially damaging scenarios. Paramount to successfully managing these situations is the ability to react in real-time over a wide geographic area using a variety of communications means and a host of emergency and environmental services.

All too often, highway maintenance engineers invest resources into automatic vehicle location and global positioning systems along with several types of sensors, only to find that the systems are proprietary, they are stuck with one type of system, can't leverage new technology, etc. It's not just the AVL/GPS system that may be stagnant, once invested, because of the constant uniqueness of various sensors from salt spreaders to temperature sensors, to plows, hydraulic systems, tilt meters, engine buses, etc. - they are all different. The highway maintenance engineer is faced with one system, no way to compete amongst vendors, for all of these pieces of equipment. Developing a set of standards becomes essential for the success of these systems and the place to start is with the vehicle hardware.

B. Clear Roads Approach. This situation is complex encompassing many facets of technology implementation; however, the need is clear – that is, standardization of the equipment, processes, and interfaces is required in order to leverage the competitive nature of the marketplace, allow users to build on previous inventories without unnecessary trade-ins or scrapping previous systems including valuable data and software interfaces for legacy systems and databases.

Clear Roads has begun this process by contracting for a list of specifications that are generic for the in-vehicle equipment and allow several vendors to compete price-wise and performance-wise for the customer community. The initial literature search and industry survey (conducted in 2009 as part of this project) has demonstrated that it is not feasible to create a set of specifications that will encompass all vehicles, situations, and previous implementations; nor foresee the future as well as retro-fit the existing systems that encompass on-board equipment as well as embrace sophisticated sensors (salters, engine bus) and original equipment manufacturers (OEM) that build road maintenance vehicles.

Thus, in order to continue the specification development process, the following statements are used to describe the Clear Roads approach to a solution. These statements and suppositions help to narrow the concept of operations focus to include recently manufactured vehicles, latest trends in data collection, and leverage advances in supplemental systems such as wireless networks, cellular networks, internet breadth and speed, web services, engine or CANbus capabilities, and potential global positioning system enhancements.

Further, this approach builds on previous standardization efforts in process at the Society of Automotive Engineers (SAE) and National Transportation Communications for ITS Protocol (NTCIP).

C. Methodology. The following suppositions and statements will form the basis for a detailed set of specifications suitable to begin a standardization process for data collection for road maintenance fleets.

1. The survey results and examination of recent solicitation documents reveals that 50% of today's users (those collecting or proposing to collect fleet data) are interested in vehicle maintenance data (that is, data available on the controller area network (CAN) bus). This trend is growing AWKWARD; vehicle health is tied to vehicle performance which is tied to functional sensors tagged with date, time, location, and activity. The CANbus has recently been standardized using SAE J1939 and other interface specifications. This includes most vehicles manufactured after 2007. Requesting that future equipment be backward compatible prior to this date is not cost effective. Thus, this document will provide specifications that interface with the latest CANbus documents.

2. Continue to include the location sensor (usually a GPS module, differentially corrected or not) with the communications modem (cellular or wi-fi). There is movement to add a GPS receiver to every vehicle (e.g. GM's Onstar system), however it is now commonplace to have a GPS chip in every cellular phone, thus continuing that trend for cellular data modems is practical and logical. This will be referred to as the modem/GPS unit in discussing the concept of operations.

3. Require the modem/GPS connect to CANbus in the vehicle as long as there is data desired from the vehicle that is not provided by the modem/GPS (date, time, latitude, longitude, speed, heading, etc.). This standardizes the modem/GPS unit external connections to namely one NINE PIN CANBUS CONNECTOR. There is some concern that the engine bus would become saturated and bog down, however, the OEMs are improving the CANbus each year because this has become the central data feed for diagnostic systems, usage data, and fuel or "going green" calculations. It also promotes sensor incorporation and installation at the factory level, knowing that the sensor portion of AVL/GPS data collection systems is often the most expensive and most difficult to install.

4. CANbus interfaces have placeholders for the addition of third party sensors such as pavement temperature sensors, salt spreaders, and others. Thus, all sensors used in data collection systems can be connected to the CANbus. Because this is an existing standard that several vendors have already implemented, it takes advantage of standardizing the multitude of additional sensors to one interface. It also reduces the number and length of wires needed to connect sensors when installed individually and connected separately to the modem/GPS unit. It uniquely identifies each data field with a parameter group number (PGN) and suspect parameter number (SPN). These unique identifiers are important for selecting what data to collect and where to store the data in the database.

5. The modem/GPS unit is programmed to "listen" for desired data on the CANbus, extract it, and tag it with date, time, latitude, longitude, speed, heading, etc. and other sensor information and then package it for transmission or on-board data storage. The modem/GPS unit must have some type of intelligent agent that can be remotely programmed to configure the modem/GPS unit for this customizable feature. One of the facts learned in the literature search and survey portions of this study is that no two customers or users want the exact same data. Thus, the on-board modem/GPS unit needs to be configurable or customizable. The intelligent agent does not need to be standardized because this allows modem/GPS manufacturers to be

performance and feature competitive. Users of a small amount of data collection may elect to turn this feature off. See figure 1 below.

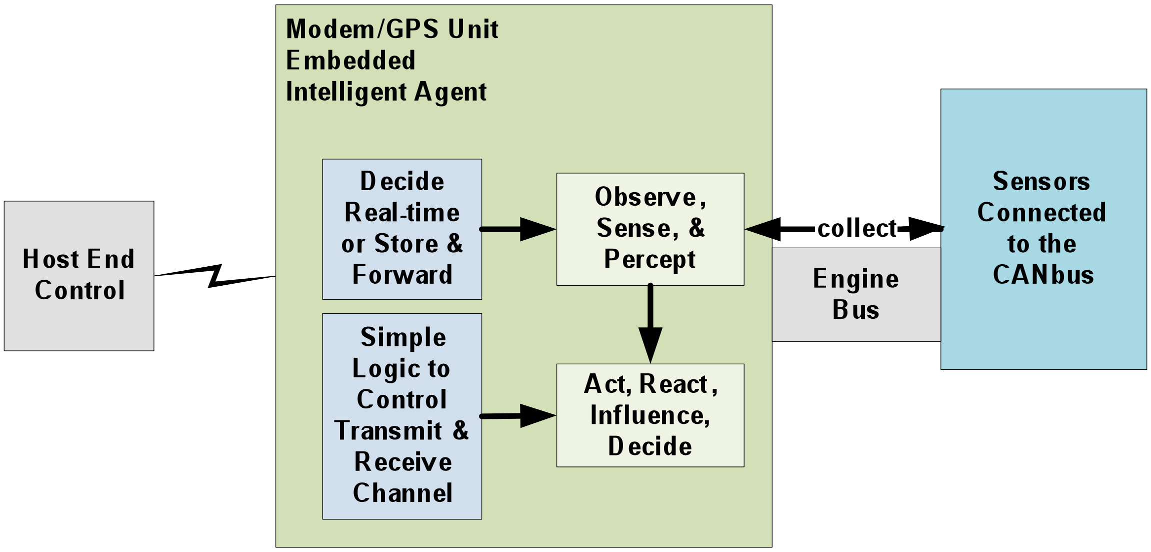

Figure 1: Intelligent Agent Example for Modem/GPS

6. The modem/GPS unit needs to employ another intelligent agent as part of its firmware that provides system recognition and can provide key interface data when queried by the host end. Thus, when a new modem/GPS unit is activated that unit is prepared to handshake with the host end to tell it model number & serial number, other identification data, which listener to use, data speed, and other parameters in order to successfully communicate its information.

7. There are several communications means available in today's marketplace, in addition to cellular (which has several modulations) and wi-fi; there are 900 Mhz radio, satellite, radio, mesh radio, and others. This document will refer only to cellular and wi-fi for the concept of operations. However, this feature cannot be standardized, only that the vendor be required to package the data and send it. Decipher the data at the other end using a listener and parser (discussed later). The best example is that within the cellular group of wireless networks, there are two major modulations time division (TDMA) and code division (CDMA). This concept of operations must accommodate that difference as well as others because each user has unique requirements for coverage area, data throughput, monthly costs, and configurations. Thus, the modem/GPS unit mechanics, data speed, encryption on/off, packaging (header), and so forth from the unit to the listener (at the host server) is transparent to the user.

8. The modem/GPS unit then requires that the data come from the CANbus, tagged with GPS, capable of sending and/or storing information, be remotely configurable to identify what to collect, how often, set triggers and thresholds, and address the data packets (messages) for delivery at the host server. The host end listener must be able to listen, decipher, and parse the data into a standardized format for a common transportation database. This allows vendors and customers to mix and match in-vehicle equipment with graphical user interfaces employing web services. The host

end listener must be provided as part of the package price of the in-vehicle equipment.

9. The host end standardization is not part of this project but is part and parcel of any AVL/GPS data collection system. There are several host end configurations that are possible with data collections systems. Local area networks with infra-structure, one desk user stations, and behind the fire-wall style legacy systems provide a variety of options. However, these tend to be proprietary, more expensive, and involve a significant investment in training and system interface. A web based user interface should be standard as it promotes monthly service (flexible billing), avoids firewall issues, and leverages the fact that most people are comfortable getting their information from the internet; i.e. they know how to use a browser. The web continues to become faster, more secure, and offer multiplier-style applications (e.g. "there's an app for that") to enhance and enrich the data to information to knowledge to wisdom paradigm.

D. Physical Architecture. This specification addresses the on-board data collection and communications equipment for road maintenance vehicles. It describes the interface between a host end server application or graphical user interface and the modem/GPS unit on-board the vehicle. The relationship between these and other logical components is depicted in Figures 2, 3, and 4. This section describes the physical architecture and linkages between the various subsystems comprising and AVL/GPS data collection system. However, one should realize that the actual physical arrangement of these components may vary from implementation to implementation.

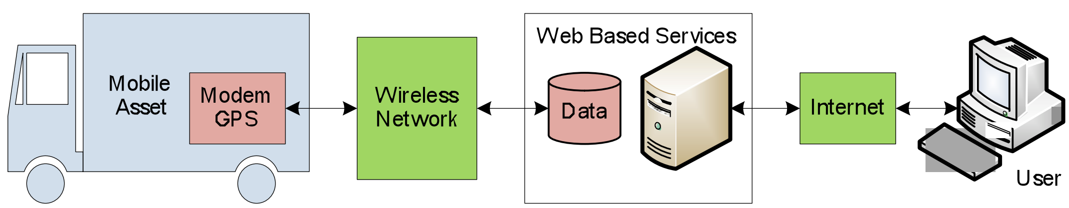

Figure 2: Block Diagram Illustrating Vehicle to User

Figure 2 shows the basic building blocks of an AVL/GPS data collection system. The modem/GPS unit on board the vehicle provides the communications connection for exporting the information off the road maintenance vehicle. The wireless network can take many forms but functions as the ubiquitous network of radio transmission and the internet and provides a seamless interface from the vehicle to the host end web based services. These can be located anywhere there is network access and provide web services that have become standard for people seeking information. That also becomes the hub of database integration to maximize the potential of AVL/GPS data collection systems by leveraging existing legacy systems such as fuel management, timecard, or repair work order systems.

Figure 3 provides the next level of detail in showing how each subset links from the vehicle to the user. The sensors are connected to the CANbus where the data becomes available and is continuously active. The modem/GPS unit is connected to the CANbus and is programmed to collect the user defined data and transmit at user determined intervals. The wireless network functions as the link from the vehicle to the host end server. The listeners and database need to be standardized as well.

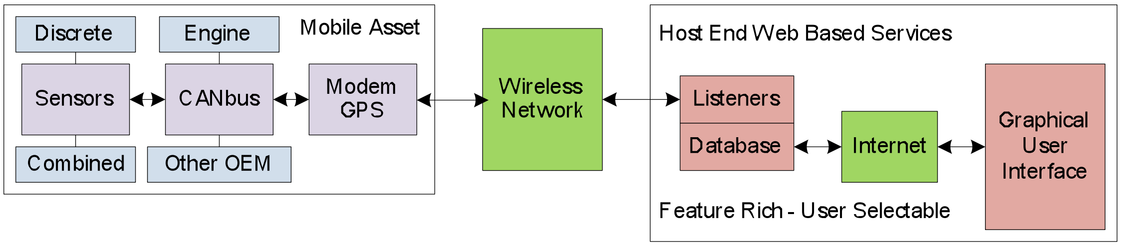

Figure 3: Block Diagram of On-board Equipment & Host End Services

Figure 4 illustrates the functional level of detail for the on-board equipment. The boxes colored in green are example sensors that could be used for road maintenance vehicles. As depicted in Figures 1 and 2, the sensors are connected to the CANbus and the data is sent to the wireless network by the modem/GPS unit.

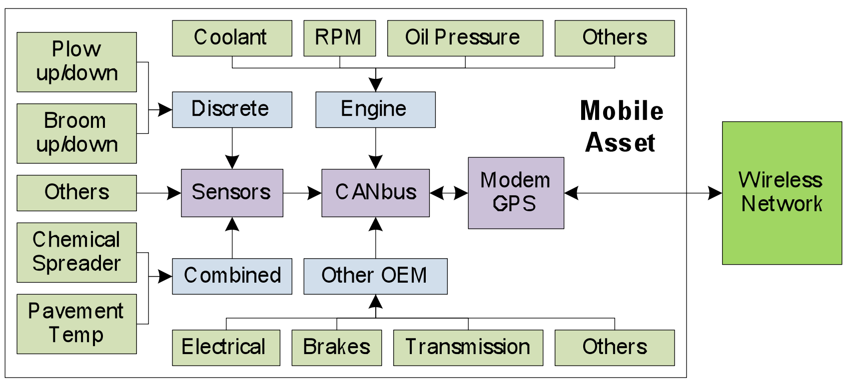

Figure 4: Functional Level for On-Board Capabilities

III. SUMMARY

A. Summary. The set of specifications will follow this approach for the on-board vehicle equipment. Examples of where this type of data collection system can be useful are numerous and are being expanded every day. Such as, it's possible to determine the effectiveness of the material distribution methods employed during the snow and ice removal process. Another function could be to calculate fuel usage based on idle time, geographic region, style of driving by an operator, and or deadhead versus operational time; this would apply to any type of vehicle fleet. Accomplishing these tasks require accurate data collection procedures, precise level of service estimation, and detailed analysis.

B. Benefits. Thus, highway maintenance engineers have seen the benefit of managing their fleet, marshalling their resources, and managing their personnel by collecting and storing real-time data; then processing this data, making decisions from it, and analyzing post-event for training, continuous process improvement, and lean enterprise.

The specifications (Section II, next deliverable) for each subsystem will follow the concept of operations (Section I of the Specification).