Demonstration of an Advanced Public Transportation System in the Context of an IVHS Regional Architecture

D.J. Dailey, M.P. Haselkorn

University of Washington
Seattle, Washington U.S.A.

1. INTRODUCTION

In previous papers,¹ we have presented an overview of an architecture for a regional IVHS network. Numerous benefits were associated with the IVHS development strategy presented in those papers, including:

(1) easy sharing of interagency and multi-jurisdictional data without disruption of existing operations.
(2) support of existing investment in IVHS technology and system development.
(3) easy expansion of sensor technologies and user applications in a straightforward, principled manner.
(4) encouragement of future innovation.
(5) interoperability among local, regional, and national IVHS development efforts.

This paper describes a concrete demonstration of this architectural concept - a prototype Advanced Public Transportation System (APTS) that displays on a single GIS screen (1) real-time bus locations from an AVL system owned and operated by Seattle Metro, the seventh largest transit company in the U.S.A., and (2) real-time freeway congestion data from inductance loops, obtained from the Traffic Systems Management Center (TSMC) operated by the Washington State Department of Transportation (WSDOT). We call this APTS BusView.

We first describe the current implementation of BusView within the context of Washington State's IVHS regional architecture, and then present both the realization of the benefits predicted in our earlier papers as well as issues encountered during the development of the prototype system.

2. BACKGROUND AND ARCHITECTURE

In this section we present as background the architecture for Washington State's expanding IVHS regional network. This geographically distributed traffic management and information system is the environment within which our real-time transit location and congestion application lives.

The central thrust of Washington State's regional network is to provide a fertile and efficient environment for the development and deployment of IVHS services. This environment is based on a client-server relationship between consumers of traffic information and traffic information sources. Specifically, the architecture provides: (1) an efficient mechanism for scaling individual developments to a regional deployment, (2) the ability to flexibly support various sensor and application technologies, (3) easy extendibility to new clients and to new or improved data sources, (4) a guarantee that existing agencies retain autonomous use of the sources they presently control while gaining access to information previously unavailable to them, and (5) support for collaborative development and deployment at geographically and politically distributed sites.

Washington State's regional IVHS network is a distributed computing environment that can best be viewed from two perspectives: (1) information flow and (2) communication architecture. From the information flow perspective, our environment can be divided into three principle types of systems: (1) data source systems, (2) data fusion systems, and (3) information delivery/display systems. Data source systems include roadway sensors and the devices required to place sensor data on the network, as well as more static sources such as map databases. Data fusion systems include devices that gather and merge similar types of data, as well as devices that combine different types of data in useful ways. Information delivery/display systems include the applications which provide IVHS services and the devices required to place these applications on the network.

As seen from this information flow perspective, BusView consists of an odometry based AVL system (operated by Seattle Metro the transit carrier), an AVL instance server which puts the AVL odometry data on the regional backbone, an AVL positioning server which converts the AVL odometry data to latitude and longitude pairs, and a GIS application that displays, in real time, bus locations on a digital map (see Figure 1).

![Diagram showing information flow in BusView](image-url)

Figure 1. Information flow in BusView.
Another perspective from which to view BusView is as an instantiation of a communication architecture consisting of components that rely on distributed computing abstractions. The principal abstractions are: (a) a communications backbone, (b) a peer to peer communication paradigm, (c) a client server transaction model, and (d) a distributed name space. The communications backbone provides connectivity among all components; the peer to peer paradigm assures common communication while supporting geographic independence; the client server model provides data security and agency autonomy within the common communication model; and the distributed name space provides a mechanism for locating any system component. 

This perspective emphasizes the nature of the communication within our APTS transit application (compare Figure 2 and Figure 1). In addition, this perspective emphasizes the

![Figure 2. Communication architecture in BusView.](image)

![Figure 3. Overall IVHS communication architecture.](image)
potential for similar communication with the other components in our architecture (compare Figure 2 and Figure 3). The protocols and interfaces that create the peer to peer relationships are such that a new application can communicate directly with an existing component for its own purposes. For example, a new application could communicate with BusView's AVL instance server to obtain odometry information for the purpose of tracking bus maintenance needs, rather than providing latitude and longitude coordinates (as BusView's positioning server does). Thus in this framework, a clear paradigm exists for adding new components, and new IVHS applications are designed by selecting components from the communication architecture (Figure 3) and defining the information flow (as in Figure 1).

3. HOW BusView WORKS

The BusView application is a good example of the development strategy described above. We obtain real time transit vehicle locations by interfacing with an existing automatic vehicle location system (AVL) owned and operated by Seattle METRO, and we obtain freeway congestion information by interfacing with an existing loop data system owned and operated by the Washington State Department of Transportation (WSDOT). METRO's AVL system consists of several components including a data acquisition control system (DACS) and a set of GIS command and control consoles. The data acquisition system polls each of the coaches to obtain an odometry based distance along planned routes. The DACS then broadcasts, on an Ethernet, the bus route number, vehicle ID and distance along one of 3000 patterns from which the routes are constructed. The GIS/Display system receives information about the routes assigned to each console operator and provides a graphical display. It is at the juncture of the DACS and the METRO GIS/Display system that we have placed an instance server which eavesdrops on the network and obtains the information about each of the coaches. (See Figure 4.)

METRO's AVL system is extremely complicated, but in Figures 1, 2, & 3 it is represented only by a box labeled "AVL System." This is because from the point of view of the IVHS architecture it simply represents another data source and is connected to the network in the same principled manner as a single GPS receiver would be connected. The AVL data is tapped by attaching the AVL Instance Server to the Ethernet interconnecting the components of the AVL system and in effect eavesdropping on the odometry information. In this way, METRO's information is made available to approved participants on the network without impacting METRO's use of the data. In return, METRO gains access to the data of others (e.g. WSDOT loop data) as well as to various network services and applications.

One class of network services are called fusion servers and the type server is an example of this generic category. Once the instance server has placed the AVL information on the network, it is reencapsulated and sent to a type server process running on a computer at the University of Washington (UW). The type server performs several functions:

(1) it receives the coach data and, through a series of coordinate transformations and extended data structure searches, translates the location of the coach from the distance along a route pattern (a proprietary system) to latitude and longitude coordinates suitable for comparison and display on a GIS system,
(2) it provides a connection service that negotiates the addition of the client to the list of clients presently receiving the coach information, and

(3) it transfers the coach data to each of the clients as the real time data becomes available.

Figure 4. Implementation of BusView.

All of these communication tasks take place over Internet style interprocess communication ports. The AVL data fusion server (physically located at the UW) is shown in the upper right of Figures 2 & 3 and called "positioning server." This component acts as the fusion and redistribution point for the AVL positioning data. It initializes a connection to the AVL instance server and requests the real time odometery information. This odometery information is combined with the routing information to produce a latitude and longitude position value for each of the buses as they are polled. The position information for each of the coaches is then available to clients for a number of uses. The first of these is a map display of real time bus locations.

To present the probe vehicle location information in a useful way, our implementation includes a traffic management type display of traffic information. In our example implementation a locally developed GIS display application accesses a set of map data derived from TIGER files, the USGS 1:100,000 scale digital maps (augmented by local
measurements.) These maps can be displayed on Xterminals located anywhere on the backbone. These maps are used to give context to the probe vehicle information just developed. Access to vehicle location data, vehicle information (implemented as a network database), and congestion data (implemented by the Loop Instance Server) is handled in the same client/server way used to establish communication between the AVL fusion server and instance server. The GIS application (BusView) makes a request for data from the server and then uses this data to build the display.

The demonstration display consists of the street network displayed on an Xterminal (the traffic workstation in Figure 3), along with the real time location of any probe vehicles and real time freeway congestion data from WSDOT. The user of this display can make selections to tailor the information. The maps can be scaled from a regional presentation to the individual street level and various layers of the cartographic information can be turned on or off (e.g. political boundaries, streams, lakes, streets, arterials and freeways). In future implementations, information about each probe vehicle will be obtained by pointing to the icon representing that vehicle and clicking a mouse button. Figure 5 is a snapshot of the current map display. The transit vehicle locations are represented by the route number placed on the map.

![Display of Real Time Bus Locations](image.png)

Figure 5. Display of Real Time Bus Locations
4. INSTITUTIONAL ISSUES

In addition to providing a rich development environment, the architectural framework described above also addresses institutional issues that in the IVHS arena often overshadow technical issues. Independent agencies are unwilling to share data for joint development if it means they must adjust their current procedures or sacrifice the security and integrity of their data. Our IVHS architecture is a political as well as a communication entity, since it encourages regional cooperation of transportation agencies through a principle of "enlightened self-interest." In other words, the cost of making data available on the network is minimal; the benefits are considerable.

4.1 Benefits

In the case described here, we were able to make transit data from Seattle METRO and traffic congestion information from WSDOT available on a wide area network without impacting the operations, philosophies, or integrity of the agencies whose mission it is to gather this information. For example, Seattle METRO's system is set up in a command and control model, while WSDOT's is less hierarchical. In addition, these two units do not have a history of joint development efforts. Nevertheless, a prototype of BusView was constructed with components and cooperation from these two large and complex agencies, despite the fact that they are geographically separate, philosophically distinct, and highly conscious of data integrity.

With future implementation, we anticipate benefits for both the transit operator and the traveling public. On the transit operator side the ability to generalize the geographically limited command and control AVL systems will allow the transit carrier to make real time coach information available to a range of internal users beyond the six consoles constructed for the command and control center. This should allow planners to use the real time coach information in positioning stops and planning routes, as well as allow systems personnel to evaluate the accuracy of the AVL information and install or reposition communications infrastructure to guarantee the desired level of accuracy. These functions are unavailable in the closed command and control environment.

As for the traveling public, a range of possible benefits are possible, including:

(1) **Increased productivity**: If the transit rider can be told when the coach will be at their stop in real time, they are less likely to leave their work site earlier than necessary to allow for the perceived wait time needed to assure catching the coach of their choice.

(2) **Reduced stress**: If the transit user can be assured that the coach she/he is planning to ride has not passed their chosen stop and that it will be arriving in a timely manner, the stress level associated with the lack of information will be reduced.

(3) **Increased public safety**: Providing timely information to transit riders will allow them to spend less time in potential dangerous waiting situations.

(4) **Increased ridership and mode change**: The above benefits would lead to a perception that transit is responsive to public needs and that transit is an attractive
alternative to SOV travel. This would reduce congestion as well as have a beneficial impact on environmental pollution.

### 4.2 Additional Issues

An additional issue which complicated the design and development of a *BusView* prototype was the fact that the AVL system purchased by METRO is a closed proprietary system. Using the eavesdropping technique described above, we were able to obtain coach distance along planned routes as well as some rudimentary status information. However, the proprietary arrangement made it difficult to fine tune the system. For example, when a coach is off route for any reason (e.g. the driver is lost, static rerouting as a result of weather conditions or planned events, or dynamic rerouting in response to congestion or incidents) the present AVL system is unable to place the vehicle geographically. This limitation also applies to non routed para-transit such as that used in response to the ADA legislation. In addition METRO has not as of yet had a real time validation of location on a large scale. Until issues like these can be dealt with, METRO is understandably reluctant to broadcast real time coach location information to the general public for fear of bad publicity or liability from mis-information.

Another issue, yet to be fully addressed, is one of usability. The scope of a test of real time transit location information has been limited to users at the University of Washington who have agreed to participate in an experiment in delivery of APTS information. We are just embarking on obtaining user feedback in a controlled environment at the University of Washington. It is hoped that through iterative design techniques and user feedback, we will produce a prototype that effectively delivers transit information capable of achieving the benefits enumerated.