Architectures of Map-Supported ADAS

Sinisa Durekovic[#1], Nic Smith[*2]

[#]NAVTEQ
Otto-Volger-Str. 1, 65843 Sulzbach, Germany
[1]sinisa.durekovic@navteq.com

[*]NAVTEQ
Unit 7 Athena Court Athena Drive, Tachbrook Park, Warwick CV34 6RT, UK
[2]nic.smith@navteq.com

Abstract— **This document describes possible architectures of a map-supported Advanced Driver Assistant Systems. It also explains the advantages of a standardized Application Programming Interfaces and Protocol with special emphasis on the ADASIS v2 Protocol and API standard.**

***Keywords*— ADAS, ADASIS v2, Electronic Horizon**

I. Introduction

With respect to the use of Digital Map data, Advanced Driver Assistance Systems can be categorized into three groups:

- *Non-map ADAS* neither uses digital map data nor can the map bring any advantages in functionality to the system. An example of a non-map ADAS is Ultrasonic Parking Distance Control.
- *Map-Enhanced ADAS* works without Digital Map information; however its functionality and reliability can be improved with the addition of Digital Map data. For instance, BMW introduced the second generation of BMW Adaptive Cruise Control in 2004 which uses data from the Navigation System for functional enhancements [1]. Another interesting example is Speed Limit Info (SLI) whereby images of traffic signs are recognized by an onboard camera and fused with Speed Limit information from the Digital Map to achieve greater reliability.
- *Map-Enabled ADAS* uses the Digital Map as one of the principal inputs to the system and without it the function would not be possible. Curve Speed Warning is an obvious example and Dynamic Pass Predictor (DPP), described in [2] is another such application.

We will use the term *Map-Supported ADAS* to refer to all Map-Enabled and Map-Enhanced ADAS applications.

II. Logical Structure of the Map-Supported ADAS

As shown in Figure 1, all Map-Supported ADAS applications share a need for four main components: Digital Map, Vehicle Positioning Module, Electronic (or ADAS) Horizon and ADAS functionality itself.

Digital Map is of course the source of vector map data. Navteq Digital Map, for instance, distinguishes between content used in classical and advanced navigation (such as Street Names) as well as content used for ADAS (most notably Road Slope and Curvature attributes). Software modules, however, do not make a clear distinction between these categories. Vehicle Positioning algorithms, for instance, mostly use attributes that fit into the Navigation Content category since those data are available on most navigation systems. To improve positional precision, advanced Vehicle Position modules can use ADAS data too. For instance, one may combine road curvature data, which is an ADAS attribute, with car gyroscope information to improve longitudinal position accuracy.

Core ADAS functionality is even less restricted to ADAS attributes and all possible information from the map may be required.

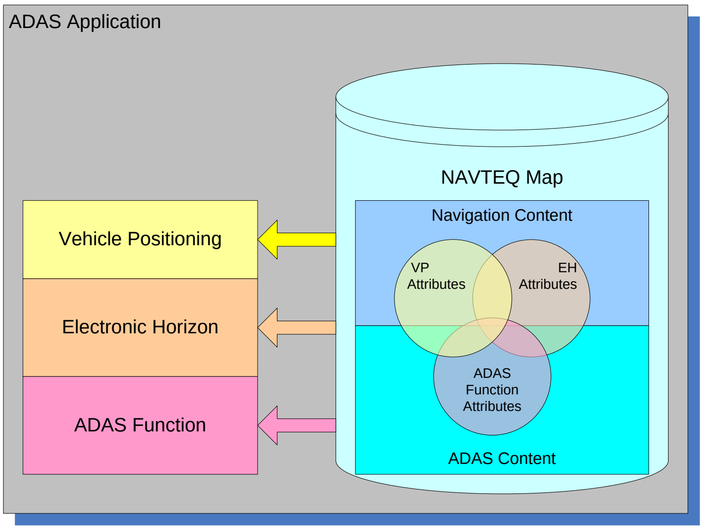

Figure 1 Main Components of the Map-Supported ADAS

Vehicle Position module uses GPS, Gyroscope and other sensors to determine the position of the vehicle in respect to the digital map.

Electronic Horizon is an extract of the Digital Map that contains data relevant to ADAS applications. Electronic Horizon takes the current position of the car from the Vehicle Positioning module and predicts the possible paths the vehicle may travel along.

Figure 2 Vehicle Position (Green triangle) on the Digital Map

Figure 3 Electronic Horizon (red) in the Digital Map

More information about Electronic Horizon can be found in [3]. eHorizon, ADAS Horizon, ADASIS Horizon and Advanced Driver Horizon are alternate names for the same concept.

ADAS Function module encapsulates the worker algorithm of the ADAS application. The Electronic Horizon module provides it with information about the current road the vehicle is on as well as information about the path ahead. This is used as the basis for all calculations. The “Depth” of the Electronic Horizon is strongly dependent on the nature of the application. Whilst Speed Limit Info will only need to know about the current road, a Curve Speed Warning application will require the road geometry a few hundreds of meters ahead of the vehicle. Further, a predicted path of several kilometers or even tens of kilometers will be required for Energy-Management ADAS applications.

III. Placement of the Electronic Horizon

The Electronic Horizon module uses Digital Map and the output of the Vehicle Positioning as its main inputs. Since both of these components are also required for the classical in-car Navigation System, Electronic Horizon can be realized as an extension of the existing software module on the Head-Unit. Note however that the Navigation System digital map database must also contain the additional map attributes required for the ADAS function.

For instance, if the system must support a Curve Warning application the on-board digital map must by necessity also contain road curvature data that it not typically used by classical Navigation Systems.

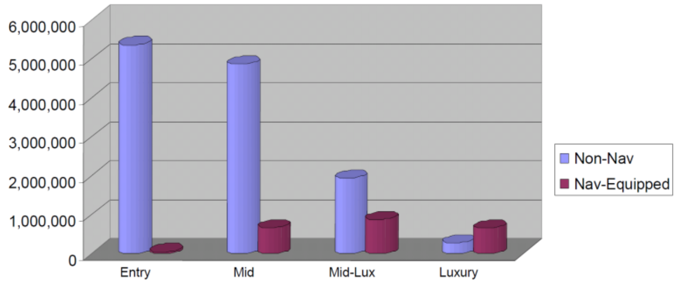

Figure 4 Navigation System penetration by vehicle category in Europe (2008)

Only a minority of vehicles are currently equipped with in-dash navigation systems that can be extended with the Electronic Horizon needed to support ADAS functions in the car (Figure 4).

To enable the introduction of map-supported ADAS without the need for a relatively expensive navigation system, specialized Electronic Horizon ECUs have been developed. From the digital map perspective, these ECUs contain only ADAS relevant map content which greatly reduces the size of the included data. Map attributes like Street Names, Administrative Areas or Points-of-interest are not included in Electronic Horizon ECUs.

From the software standpoint only Vehicle Positioning and Electronic Horizon modules are implemented. Relatively complex Geo-coding, Routing, Maneuver Generation and Guidance modules are of no use for the ADAS.

Figure 5 Credit-card sized NAVTEQ Map & Positioning Engine

One example of an Electronic Horizon ECU is the NAVTEQ MPE (Figure 5) which was introduced in 2009. This unit includes a 2 GB SD-card with digital map data (North America or Europe ADAS Map), GPS receiver, gyroscope, Vehicle Positioning and Electronic Horizon modules.

IV. Placement of the ADAS Worker Module

If the Electronic Horizon is placed on the Head-Unit together with the ADAS Worker Module, calculations required for the Adaptive Front Lighting (AFL) can be integrated on the same device as the Navigation System.

An advantage of this approach is the possibility for the AFL module to directly communicate with the Electronic Horizon. Usually the Head Unit already incorporates other software functions such as Navigation, Entertainment and Air Conditioning control and it may not be possible to accommodate another software module on that computer. This problem is even more apparent if multiple ADAS functions need to be supported. Each such function will need its own share of the CPU and storage space.

As an alternative, ADAS Worker Modules can be located on dedicated ECUs. While this brings more flexibility to the system, the challenge that needs to be tackled is the transfer of Electronic Horizon data from the Head Unit or Electronic Horizon ECU to the ADAS function ECU.

V. ARCHITECTURES OF MAP-SUPPORTED ADAS

Depending of the placement of the Electronic Horizon (EH) and ADAS Worker Modules, several architectures are possible. Those architectures can be explained in an example of Map-Enhanced Adaptive Front Lighting (AFL). Such an ADAS application will:

- Adjust the shape of the vehicle light beam depending on the current road (highway, cross-country, urban environment)
- Activate cornering lights on the crossings
- Change the beam angle depending of the road geometry ahead.

To perform the above functions the AFL module needs information about the current road type, crossings ahead of the vehicle and the road geometry on the predicted paths. This data are available from the Electronic Horizon.

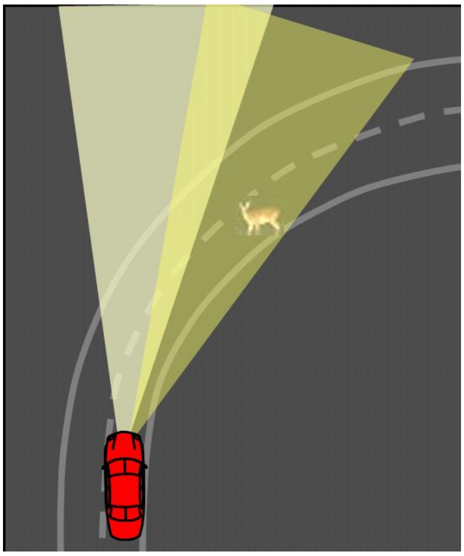

Figure 6 Map-Enhanced Adaptive Front Lightning

A. *Head-Unit integration, propriety EH API*

When the Electronic Horizon module is implemented at the Head Unit (HU) it is possible to integrate the AFL module on the HU as well. This module will make use of the EH data provided by the specialized Electronic Horizon API (Figure 7).

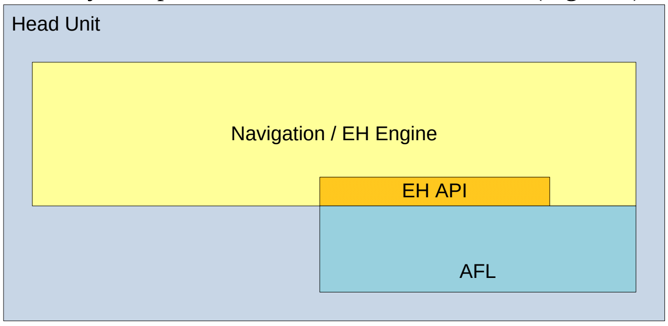

Figure 7 AFL on HU, system-specific API

B. *Head-Unit integration, standardized APIs*

While the main advantage of the above approach is its simplicity, issues arises when the AFL module needs to be re-integrated into another system that uses a possibly different EH Engine and EH API. To overcome that challenge, it is advisable to standardize the Electronic Horizon Application Programming Interface.

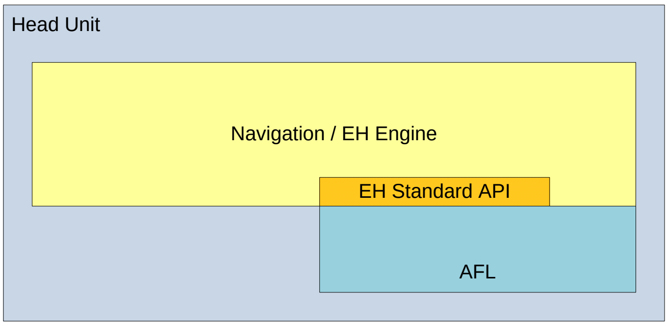

Figure 8 AFL on HU, standardized API

C. *AFL ECU, AFL-specific communication protocol*

When multiple ADAS applications are to be supported, a single HU may not be capable of performing all of the calculations. In that case the AFL module may be located on a separate unit. Electronic Horizon data will be transferred to the AFL ECU over the CAN or some other communication channel using a special protocol that contains only the data of interest for the AFL (Figure 9). CAN is still a dominant automotive bus and we will use it in our illustrations.

A special module, *AFL Electronic Horizon Provider* takes AFL relevant data from the Electronic Horizon and sends it over the CAN bus. Another module on the AFL ECU, *AFL Electronic Horizon Reconstructor*, receives that data and effectively creates a specialized copy of the Electronic Horizon on the client side. The protocol used between the AFL EH Provider and AFL EH Reconstructor may be highly optimized because it targets just one function. If the AFL EH Provider accesses the Electronic Horizon using a standardized

API, migration of the system to different Head-Units is simplified.

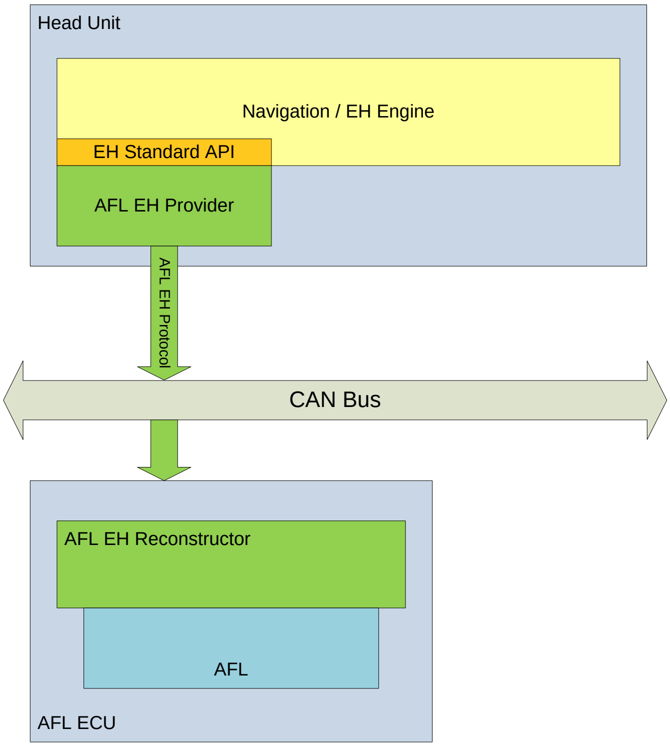

Figure 9 AFL on ECU, AFL-specific protocol

D. AFL ECU, Standard Protocols and APIs

Using the architecture described previously several ADAS ECUs with different ADAS functionalities would require several specialized Electronic Horizon Provider modules, as well as the design and implementation of different communication protocols. In addition, each ECU needs an Electronic Horizon Reconstructor suitable for the particular purpose.

To achieve greater flexibility and scalability a general protocol for transferring Electronic Horizon data can be designed. In this case the Head Unit needs to only implement one Horizon Provider Module. Further, the Horizon Reconstructors on the ECUs may also share the same code base as they will receive and reconstruct using the same protocol and Electronic Horizon (Figure 10).

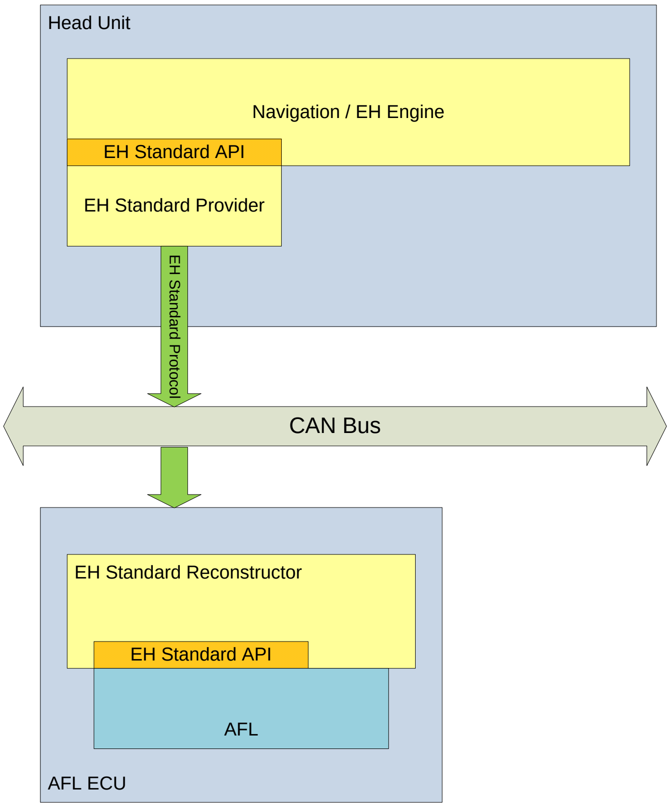

Figure 10 AFL on ECU, standard EH protocol and API

Besides the use of an EH standard API to access the Electronic Horizon at the Head Unit the same API can also be exposed by EH Reconstructor at the ECU.

Having a Standard Electronic Horizon Protocol, Provider and API offers the greatest flexibility and scalability of the ADAS architecture. Not only can additional ADAS ECUs be added to the system without increasing the complexity of the HU but also ADAS functions can be integrated on the HU itself. Moreover the location of the ADAS functionality – HU or ECU—is transparent for the software module and can be chosen relatively late in the development phase (Figure 11).

Use of a Standard EH protocol offers another advantage of easy exchange of the providers of the Electronic Horizon. Instead of the Head Unit an Electronic Horizon ECU, such as MPE, can be integrated into the vehicle (Figure 12).

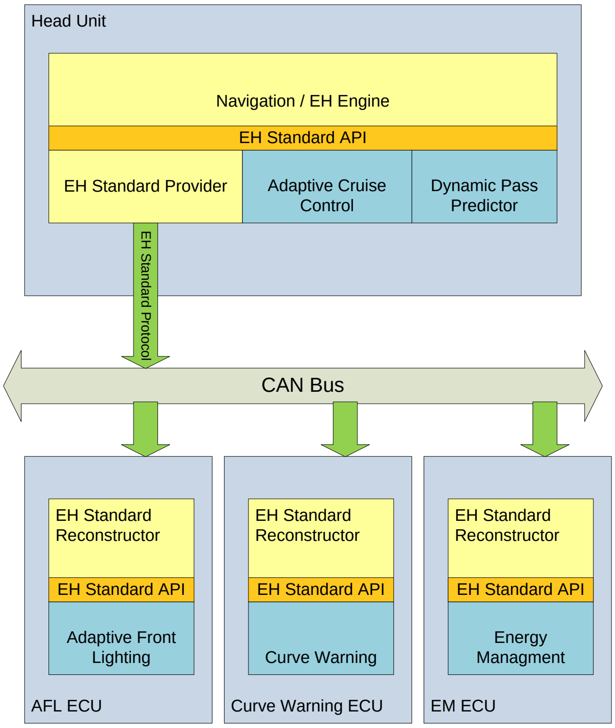

Figure 11 Multiple ADAS with HU

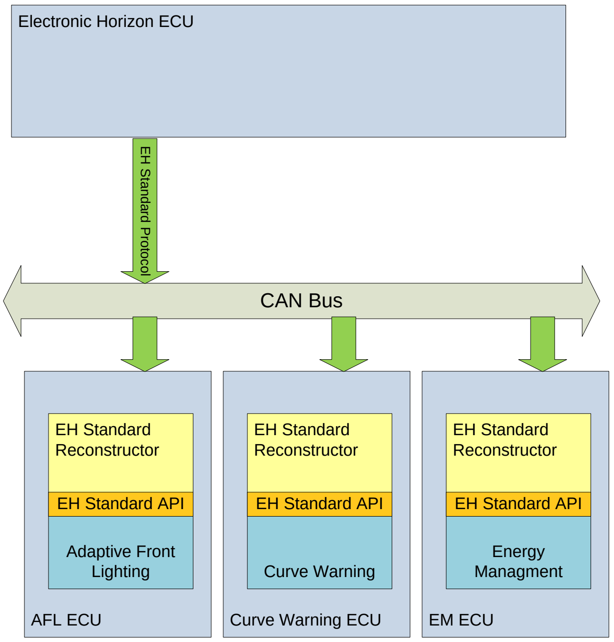

Figure 12 Multiple ADAS with EH ECU

VI. ADASIS v2

Need for standardization of Electronic Horizon API and protocol was recognized early on in the industry. The ADASIS Forum [4] was started in 2001 and today it numbers more than 30 members. Importantly, all major cars manufactures and system suppliers are active in the Forum.

ADASIS Forum initiated EU-funded MAPS & ADAS project that defined the ADASIS v1 specification [5][6].

In April 2010 the ADASIS v2 Protocol and API specification was released [7]. In addition to specifying the protocol and API that is used to realize the architecture depicted in Figure 11 an Implementation Task Force realized a reference ADASIS v2 Horizon Reconstructor, developed in MISRA-C. This code, a result of the cooperation between Daimler, Ford, Opel, Volvo, Bosch, Continental, Navteq and TeleAtlas, is available free of charge to the ADASIS Forum members and can be used as basis for commercial implementations. While ADASIS v2 Protocol targets CAN bus, it can be easily adapted to MOST, FlexRay or TCP/IP.

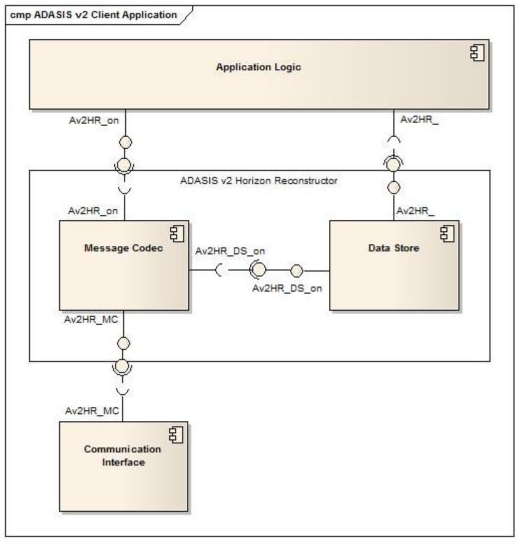

Figure 13 ADASIS v2 Horizon Reconstructor

For prototyping and pre-development several frameworks supporting ADASIS v2 are now available. For instance the NAVTEQ ADAS Research Platform version 2010.1 [8] includes both ADASIS v2 Horizon Provider plug-ins as well as the ADASIS v2 Reference Reconstructor library.

VII. CONCLUSIONS

Standardized architecture of the ADAS offers multiple advantages over function-specific approaches. Introduction of the ADASIS v2 Protocol and API standard, as well as the availability of the ADASIS v2 Reference Reconstructor greatly simplifies development and deployment of the ADAS in the car.

REFERENCES

[1] http://de.wikipedia.org/wiki/Abstandsregeltempomat.
[2] Jan Loewenau et al., *"Dynamic Pass Prediction — A New Driver Assistance System for Superior and Safe Overtaking"*, Advanced Microsystems for Automotive Applications: Springer, 2006.
[3] Mezger K, (2005) editor, "*ADASIS Functional Architecture*". D2, MAPS & ADAS Consortium and ADASIS Forum
[4] http://www.ertico.com/adasisforum/
[5] Otto H.U, et al (2005), "*Data Requirements*" D1, MAPS & ADAS Consortium and ADASIS Forum, Brussels
[6] Angenvoort J, et al (2005), "*Draft Specifications*", Deliverable D3, MAPS & ADAS Consortium and ADASIS Forum, Brussels
[7] Durekovic S, et al (2010), "*ADASIS v2 Specification*", Deliverable 2.2, ADASIS Forum, Brussels
[8] Durekovic S, et al (2010), "*ADASRP User's Manual*", NAVTEQ