Dynamic eHorizon with Traffic Light Information for Efficient Urban Traffic

Hongjun Pu

Abstract The electronic horizon (eHorizon) is an emerging technology supporting advanced driver assistance systems (ADAS) with respect to fuel efficiency and road safety. Using the static road attributes provided by the eHorizon, new kinds of ADAS applications become possible. Considering the factor that the traffic dynamics, especially in intersection areas, has also a significant impact to the fuel consumption and traffic efficiency, this paper is devoted to the extension of the current products of eHorizon with traffic light information. It introduces a concept for the presentation of the traffic light information in accordance to the ADASIS v2 specification, so that today's subscribers of eHorizon, i.e. the ECUs with ADAS applications, can use the dynamic data with only minimal modification.

Keywords ADAS · eHorizon · Traffic light · Energy efficiency · Traffic efficiency · Road safety

1 Introduction

For diverse reasons, road traffic will remain one of the greatest challenges in the coming years, especially in and around cities. This is because of the globalization of the world economy, the urbanization of developing countries and the re-urbanization of industrial countries due to aging population. Also the individualization of the consume markets, e.g. e-commerce, causes additional traffic related to ware-delivery. All these factors lead to increased road traffic and requirements on intelligent solutions for traffic and energy efficiency.

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The electronic horizon (eHorizon) is an emerging technology that supports advanced driver assistance systems (ADAS) with respect to fuel efficiency and road safety. Current products of eHorizon extract information from a geo-database and provide certain road attributes like intersection, slope, curvature, speed limit and lane information over a well specified CAN-interface.

In this way, nearly all ECUs in the vehicle can get aware of the roads ahead, as if they have an electronic "eye" observing the horizon. Using the data of eHorizon, new kinds of driver assistance functions for energy-efficiency and road safety become possible. For example, a predictive vehicle cruise control of the truck manufacturer Scania using road geometry information can save up-to 3 % fuel consumption compared to a convenient cruise control [1]. In similar ways, the hybrid and electrical vehicles are expected to achieve more energy-efficiency by deploying a driving and charging strategy adaptive to road properties.

Although predictive road information contributes a lot to the optimization of the operations of gear box, fuel supply and braking system, no longitudinal control for urban traffic would be green enough, as long as the traffic dynamics in intersections are not involved. The vehicle motion at intersections, governed by the traffic light, has a significant impact to the total fuel consumption (or energy balance for electrical and hybrid vehicles) of a city route.

Considering the above intersection problem, this paper presents a solution to provide traffic light information in intersection areas by extension of the eHorizon. After a short over view of eHorizon we will discuss the technologies enabling the transmission of traffic light information into the vehicles. Then, as main contribution of the paper, a concept for presenting the traffic light status and phases on the eHorizon will be introduced and discussed. We will illustrate how the dynamic traffic light information can be embedded in the standard structure of eHorizon, so that the subscribers of eHorizon data, i.e. the electronic control units (ECU) with ADAS applications, need only minimal modification in order to use this dynamic information.

2 The eHorizon

The development of eHorizon was initialized by the ADASIS Forum established in 2001 by a group of car manufacturers, in-vehicle system developers and map data companies. Goal of the ADASIS Forum was to develop a standardized interface between digital map and ADAS applications. The first system and interface specification of ADASIS Forum, e.g. ADASIS v1, was worked out within the EU-funded project PReVENT/MAPS&ADAS. The current version, e.g. ADASIS v2 [2], are widely accepted by the automotive industry as de facto standard. Ress et al. published in 2008 a well structured description of ADASIS v2 [3].

2.1 Stubs and Paths

Paths and stubs are the basic elements of eHorizon describing the road segments and the branch-points. As shown in Figs. 1 and 2, a path with a path-ID represents a road link and stubs are defined at the intersections and branching-points on the path. Sub-paths with its own path-ID may start from each stub.

As the name implicates, only road links on the horizon, i.e. ahead of the ego-vehicle and are reachable in reasonable time, are presented as paths of the eHorizon. Further, the paths are one-dimensional, i.e. all road attributes are positioned by their relative distances to the origin of the path.

2.2 ADAS Attributes

While the paths and stubs present the basic geometry of the road, the useful information for the ADAS applications are provided by the so called ADAS attributes. These are the road classes, scopes, curvatures, speed limits, etc. defined on certain positions and segments of a path.

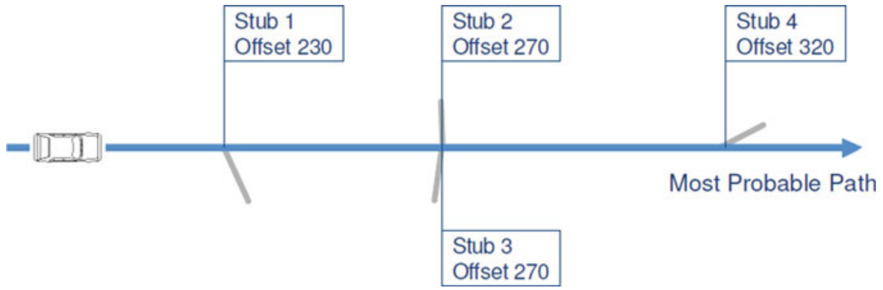

Fig. 1 Stubs of the eHorizon [3]

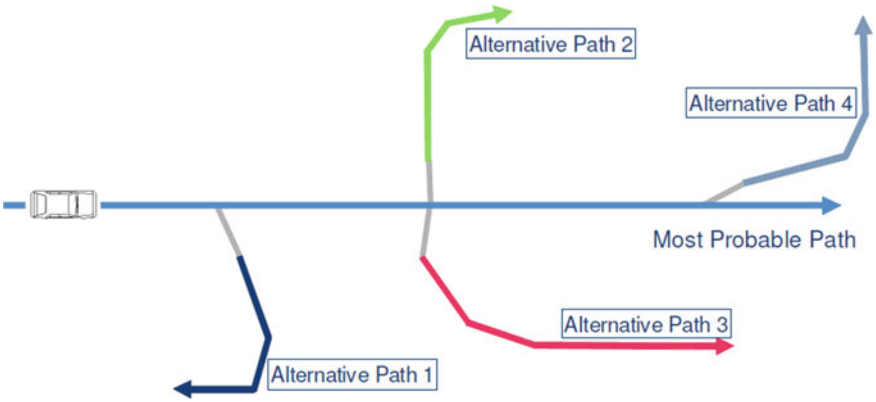

Fig. 2 Sub-paths starting from stubs of the eHorizon [3]

2.3 The Most Probable Path (MPP)

Mainly based on the road classes, possibly also determined by other criteria e.g. navigation guidance, the eHorizon is able to provide a so called most probable path (MPP) indicating the most likely route of the ego-vehicle in near future. The stubs and sub-paths are preferably created along with the MPP. The MPP is continuously checked against the vehicle position and re-created as soon as the ego-vehicle is leaving the current MPP.

2.4 Access to eHorizon via CAN Bus

The ADAIS v2 protocol defines the way to access to the eHorizon via CAN. The choice of CAN was well reasoned from the point of view of the practice, since CAN is the most widely accessible bus system in vehicle.

All eHorizon data are presented in 64-bit CAN frames. Due to the factor that CAN-bus possesses just a limited band-width, the use of CAN messages must be very efficient, e.g. to provide as much as possible information with as less as possible messages.

3 Dynamic Information on eHorizon

Current eHorizon products provide to the ADAS applications static road information extracted from a geo-database. Because of the great significance of dynamic traffic information to the traffic and energy efficiency, there were a serial of publications [4–6] in the past years on the integration of dynamic contents in eHorizon. The presented solutions, however, are of generic nature and did not include concrete ways and steps for the realization.

This paper, in comparison to the previous ones, presents a practical concept to bring traffic light information into the eHorizon in accordance with ADASI v2. Before the solution will be introduced in the following Sect. 4, we firstly discuss in this section the technologies of vehicles communication that make the dynamic traffic light information available in the vehicle.

3.1 Traffic Light Information via ITS-G5 (C2X)

Via C2X communication (ITS-G5/IEEE802.11p), the traffic light control unit can directly send a message named “Signal Phase and Timing” (SPAT) to the vehicles in a range of some hundreds of meters.

Usually, a SPAT message is dedicated for a traffic light governing certain road lanes in an intersection and contains information of the status and the next changes of this traffic light. The geometric information of the intersection, e.g. ingresses, egresses and lanes are described by another C2X message called "INTERSECTION". Each SPAT message has to be related to an INTERSECTION message. And an INTERSECTION message may be referenced by many SPAT messages.

Since the standardization of the C2X messages "INTERSECTION" and "SPAT" is still ongoing, the exact contents of the messages are subjected to further changes. However, the basic information depicted in the following Fig. 3 can be expected from a SPAT message.

3.2 *Traffic Light Information as TPEG-TSI*

Traffic light information can also be presented in a dedicated TPEG-message, e.g. Traffic Signal Information (TSI). Like other TPEG-messages, the TSI may be transmitted via different channels, e.g. Internet, DAB, etc.

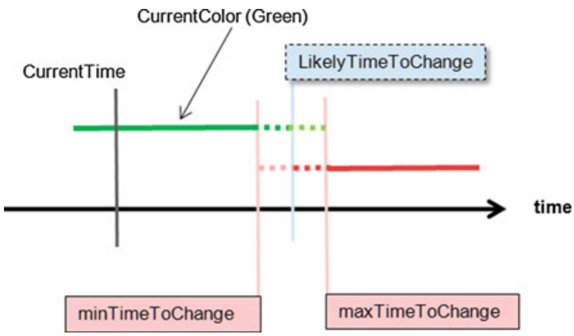

Fig. 3 Traffic light information involved in a C2X SPAT message

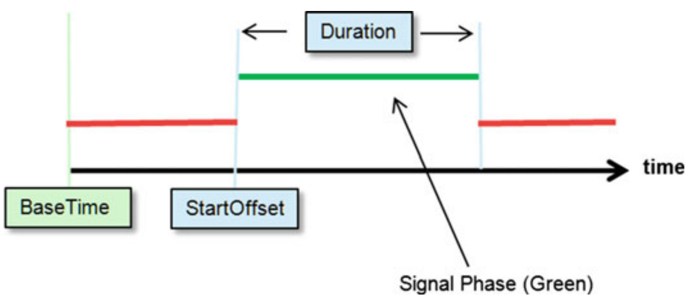

Fig. 4 Traffic light phase information of fixed time control

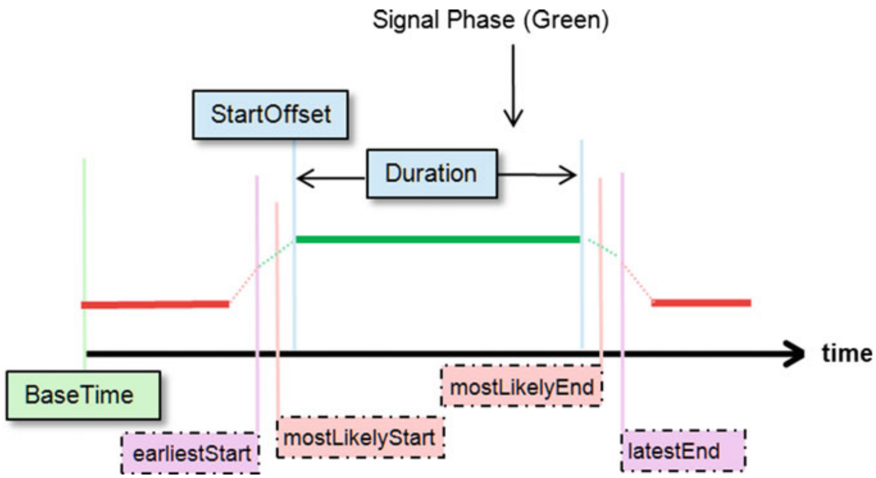

Fig. 5 Traffic light phase information in case of dynamic time control

Because of the almost unlimited range of transmission over Internet and DAB Broadcasting, a TPEG-TSI message about an intersection may be received by vehicles far from this intersection.

TPEG-TSI provides more comprehensive information of traffic light compared to SPAT as illustrated in Figs. 4 and 5.

4 Presentation of Traffic Light Information on eHorizon via ADASIS v2

4.1 The Basic Idea

The solution presented in this section is based on a patent application submitted by Continental Automotive GmbH to the Deutsches Patent- und Markenamt on October 15, 2014 [7]. In our concept, we suppose that traffic light information of an intersection ahead of the ego-vehicle is available in 2 different ways,

(a) Only the actual state, e.g. red, green and amber as well as the rest duration of the current state are known. This is the case when the traffic light information is transmitted directly over short range communication, e.g. as C2X SPAT. Due to the short distance between the vehicle and the traffic light, the actual signal state and its rest duration are mostly interested.

(b) The complete signal phases, i.e. the duration of the green, amber and red phases are known. This is the case when the traffic light information is transmitted via TPEG-TSI. In this case, the vehicle can receive traffic light information of an intersection which is far from the ego position.

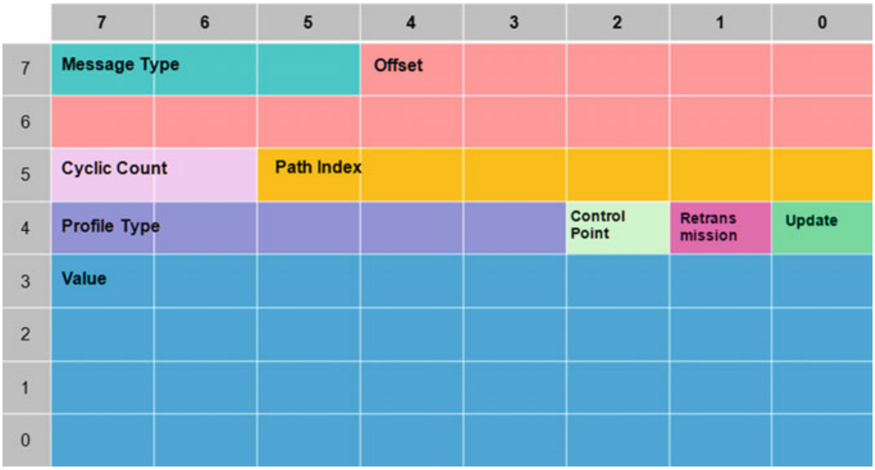

Fig. 6 Layout of the eHorizon message "PROFILE-LONG" [2]

The basic idea of the dynamic extension of eHorizon is to present the traffic light information on the eHorizon paths using ADAIS v2 interfaces.

We choose the PROFILE-LONG message [2] as container for the traffic light information, since it has the greatest payload (32 bit) among all eHorizon messages. The PROFILE-LONG message has the CAN-layout depicted in Fig. 6.

4.2 Construction of New eHorizon Message for Traffic Light Information

The eHorizon provides the road geometry as paths (sub-paths) and stubs. Using the road geometry data, the transmitted intersection and, particularly, stop lines can be resolved along with the eHorizon as following.

(a) Each stop line, for which traffic light information is available, will be matched to the corresponding stub on the eHorizon
(b) The stop lines on the MPP are referred as relevant stop lines
(c) For each relevant stop line, eHorizon-messages will be created for the traffic light timing information.

4.2.1 The eHorizon-Message for the Case that Only the Actual Signal Status and the Switching Time Are Known

In this case, e.g. C2X.message "Signal Phase and Timing" (SPAT), the signal status, the most likely as well as the earliest and the latest time for the next switch are known. The eHorizon-Message can then be defined as following Table 1.

Table 1 The eHorizon message for signal status and switching time

Tag	Bit	Content and format
Head		
Message Type	3	
Profile Type	5	=16
Cyclic Count	2	
Path Index	6	ID of the path, on which the stop line is
Offset	13	Position of the stop line as offset to the origin of the path
Value		
Current Color	3	0–7 for green, red, amber, amber-blinker, red + green arrow right, red + green arrow left, dark green and not available
MinTimeToChange	10	The earliest time of next switch; Resolution 0.1 s; Range 0–1021; 1022 for all greater values; 1023 for not available
IntervalTimeToChange	5	Max. time to change after MinTimeToChange; Resolution 0.1 s; Range 0–29; 30 for all greater values; 31 for not available
LikelyTimeToChange	5	Likely time to change after MinTimeToChange; Resolution 0.1 s; Range 0–29; 30 for all greater values; 31 for not available
Confidence	4	Probability of LikelyTimeToChange; Range 0–15; The value 15 means 100 %
GreenWaveSpeed	5	Reference speed for remaining in green wave; Optional; Range 0–30 m/s (0–108 km/h); 31 for not available

4.2.2 The eHorizon-Messages for the Case that the Signal Phase Is Known

In case of a fixed time control, the traffic light phase data like start of the phase, duration of the phase and the duration of a cycle, etc. are available.

In case of a dynamic time control, the traffic light phase data are available, but subjected to sudden changes. They can only be estimated within a band. According to the estimation confidences, additional values are provided as earliest start, most likely start, most likely end and latest end.

The key issue of the presentation of traffic light phase with eHorizon messages is the time factor which was so far not treated by the ADASIS v2 protocol. According to Fig. 6, the maximal effective payload of a PROFILE-LONG message is 32 bit and this is not sufficient for a standard time object. On the other hand, the traffic light phase must be attached with an unambiguous time indicator because of the non-synchronized message transmission in CAN.

To solve this conflict, we propose to attach one absolute time within a day (24 h) to the eHorizon-message and all other time variables are presented relatively to the absolute time.

Using the above traffic light data, 2 eHorizon-Messages are defined. The first message is for the traffic light phase without dynamic adaptation, i.e. in fact fixed time control.

The duration of the amber phase depends on the speed-limit and lasts usually a few seconds. In this paper, the amber phase is not explicitly treated and we define the non-green phase covering the red and amber phase, as shown in Table 2.

The second message will be created only, when the signal phase is not fixed time controlled (Table 3).

Table 2 The 1st eHorizon message for traffic light without dynamic adaption

Tag	Bit	Content and format
Head		
Message Type	3	
Profile Type	5	=17
Cyclic Count	2	
Path Index	6	ID of the path, on which the stop line is
Offset	13	Position of the stop line as offset to the origin of the path
Value		
ControlStatus	1	0 = fixed time; 1 = Dynamic time
NextStartGreen	17	Start of the next green phase within a day (24 h); Resolution 1 s
GreenPhase	7	Range 0–125 s; Duration of the green phase; 126 for values ≥126; 127 for not available
NoGreenPhase	7	0–125 s; Duration of the non-green phase; 126 for values ≥126; 127 for not available

Table 3 The 2nd eHorizon message for the case of dynamic time control

Tag	Bit	Content and format
Head		
Message Type	3	
Profile Type	5	=18
Cyclic Count	2	
Path Index	6	ID of the path, on which the stop line is
Offset	13	Position of the stop line as offset to the origin of the path
Value		
SignalDirection	4	Bit string
MostLikelyStart	7	Most likely start as delta before NextStartGreen; Resolution 0.1 s
MostLikelyEnd	7	Most likely end as delta after NextStartGreen + GreenPhase; Resolution 0.1 s
EarliestStart	7	Earliest start as delta before NextStartGreen; Resolution 0.1 s
LatestEnd	7	Latest end as delta after NextStartGreen + GreenPhase; Resolution 0.1 s

4.2.3 Multiple Messages in Sequence

According to the specifications, it is possible to present successive changes of traffic information for each stop line in just one SPAT or TPEG-TSI message. In this case, multiple eHorizon messages as described in Sects. 4.2.1 and 4.2.2 will be consequently created.

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