# Design of Integrated LDM Information for Intersection Safety

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***Abstract*—** In autonomous vehicles, many sensors such as camera, LIDAR, and radar are used to accurately identify situations. However, using information from only the on-board sensors can lead to errors in recognizing the environment around the vehicle. Therefore, vehicle communications and Internet of Things infrastructure serve as alternative channels for gathering integrated information. The purpose of this study is to develop a scheme for providing intersection situation and local dynamic map information to a vehicle entering an intersection. Using infrastructure sensor information in conjunction with vehicle communication extends the range of safe driving at intersections.

***Keywords—* *Intersection Safety, V2X, WAVE, LDM***

## I. INTRODUCTION

High-performance sensors such as global position system (GPS), camera, and radar are used in autonomous vehicles to obtain information about vehicle surroundings and traffic conditions. In addition, vehicle to everything (V2X) communication technology are used to obtain information about other vehicles, temporary event information of the road, and precise location information. In this paper, we propose an intersection safety system as a part of the AUTOmated driving Progressed by Internet Of Things (AUTOPILOT) project. The AUTOPILOT project will be employed in conjunction with the Internet of Things (IoT) to enable safer, highly automated.

Intersection safety systems transmit traffic and local dynamic map (LDM) information to vehicles entering an intersection through infrastructure sensors and V2X communications. Moreover, such systems alert a vehicle about approaching pedestrians and dangerous vehicles if the vehicle will turn right or left at an intersection without traffic lights. This helps the vehicle enter the intersection more quickly and safely. For detecting the situation in a given area, it is advantageous for one system to cover the area instead of installing expensive equipment on every vehicle. The infrastructure system collects and transmits information about nearby vehicles and pedestrians through the combined use of radar and camera. It is assumed that this system satisfies the requirements of existing individual sensors, such as coverage and information reliability.

The remainder of this paper is organized as follows. In Section 2, we provide a brief overview of the research related to LDM and intersection safety service. Section 3 describes urban driving scenarios for the vehicle IoT platform as a part of AUTOPILOT project. In addition, a message structure that considers road layout, traffic lights, and vehicles is defined for use in Korea pilot site. Our concluding remarks are given in Section 4.

## II. INTERSECTION SAFETY INFORMATION

### A. *LDM and Intersection Safety Service*

An intersection is a point at which two or more roads meet. In areas with dense vehicle traffic, signal compliance and safety are essential. Especially when individual vehicles broadcast messages independently, frequent collisions of radio waves make it difficult to communicate safety information among vehicles. Therefore, we need an infrastructure system that can generate and manage safety information at intersections.

An intersection generates various types of information. Pedestrian traffic lights and vehicle traffic lights are placed at each intersection, and pedestrian and vehicle movements change all the time. Road conditions and weather indirectly affect the flow of traffic. Local dynamic map is a widely used mechanism for managing map and related data. This information provides a lane-level map that contains static information such as road signs, traffic lights, and dynamic information about pedestrians and traffic flow.

LDM divides all data into layers according to the transmission period and characteristics of information in your location. It has a four-layer model, as shown in Figure 1 [1].

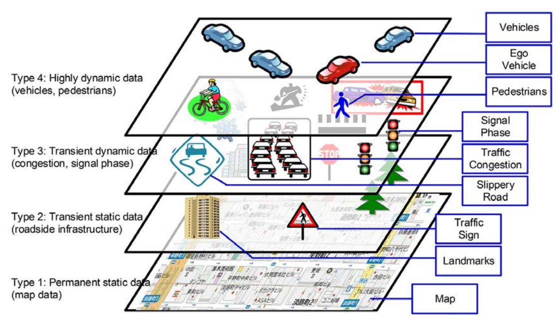


Fig. 1. LDM information [1]

A reference for intersection safety service is the University of California's Advanced Transportation Technology (PATH) program. The Cooperative Intersection Collision Avoidance System (CICAS) project focuses on traffic signal violations at intersections and provides safe driving assistance to avoid collisions in unprotected situations. [2]

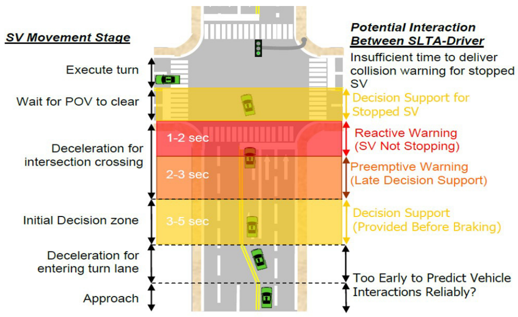


Fig. 2. Illustration of CICAS-SLTA concept [2]

This project works closely with the standards communities. In the application domain, it includes SAE J2735 and the International Organization for Standization (ISO) Working Group. In the radio domain, the CICAS project has contributed to the 802.11p and 1604.2-3 standards of the Institute of Electrical and Electronics Engineers (IEEE). The 802.11p standard defines wireless links with latency less than 100 ms for vehicles operating at speeds up to 200 km/h. [2,4] In recent years, ISO established the "Extension of current specifications for in-vehicle digital map databases" standard in 2016, which can be used to present a lane-level map with static information in compliance with European Telecommunications Standards Institute (ETSI), European Committee for Standardization (CEN), and US Society for Automobile Engineers (SAE) standards. [3]

### B. Intersection Safety Service of AUTOPILOT project

Electronics Telecommunication Research Institute (ETRI) and Metabuild participated in the AUTOPILOT project as Korean organizations. In the present study, we develop an intersection safety information system and service technology based on infrastructure sensors. The Korea demonstration site will be installed at ETRI, DAEJEON. The intersection safety system consists of a roadside intersection safety information (ISI) system and an intersection safety service (ISS) terminal in the vehicle. In addition, Road Side Unit (RSU) and On-board Unit (OBU) are required for V2I communication.

The ISI system provides information about the status and remaining time of traffic lights, location and direction of a moving object, and GPS differential correction. These data can be obtained from IoT devices near the intersection, such as radar sensors, and traffic signal control system. And the safety information system and IoT devices are connected directly or wirelessly. The ISS corresponds to a device such as a navigation terminal or a smartphone mounted in a vehicle, and it executes the intersection safety operation and warning function based on the information provided by the ISI system. The connection between the ISI system and the ISS devices follows the wireless access in vehicular environments (WAVE) standard protocol for vehicle communication. Figure 3 shows the prototype structure of the Korea pilot site.

- LDM data are generated using sensor data
- Sensing devices are radar, traffic signals, and GPS
- Infrastructure safety information is transmitted to OBU via WAVE
- OBU comprises a communication unit, data processing unit, and vehicle controller area network (CAN) Data & GPS
- OBU generates warning outputs

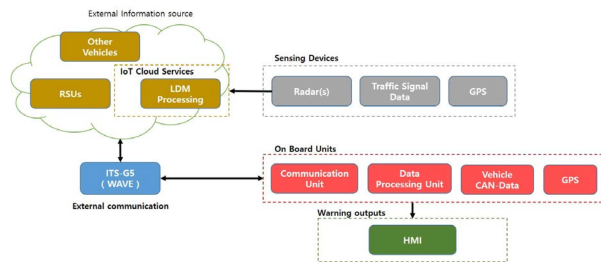


Fig. 3. Prototype architecture of Korea pilot site

## III. DESIGN OF INTERSECTION SAFETY INFORMATION

An urban driving service was implemented at the Korea pilot site. For the urban driving service, we suggest integrated LDM information that combines messages from each of its layers. Messages are not generated at the same time. For example, the map message is created every second, traffic lights status is generated at 200 ms intervals, and vehicle or pedestrian location is delivered at least 10 times per second, i.e. 100 ms interval. In addition, GPS correction information should be included in the specifications to minimize the impact of GPS errors.

Depending on the message cycle, an aggregated message can send, in which no specific information is contained. This message is primarily real-time moving object information, except for other static information. It is updated immediately after collection to improve the accuracy and timeliness. Due to the short interval of time, the ISS system maintains valid data for warning services in emergencies and imminent dangers.

Incoming vehicles receive intersection situation message by means of vehicle to infrastructure (V2I) communication. The infrastructure oversees the integrated intersection safety information. Multiple channels of control channel (CCH) and service channel (SCH) are mapped to dedicated sections of I2V and V2I for reliable data transfer. The vehicle terminal receives the information message generated by the infrastructure during the CCH interval without collisions.

### A. Service Use Case

The use case (Figure 4) is a warning service for crossing possibility and violation. If ego-vehicle enters an intersection with a green signal but stop unavoidably at the intersection, it is a violation because the vehicle interferes with the passage of another vehicle.

The urban driving use case is about offering an intersection safety service based on LDM. First, the road radar detects traffic jams. It distinguishes the dangerous end of a queue from a slow-moving vehicle. Next, traffic information is combined with traffic signal information. Then, the RSU generates cognitive information in a timely manner and the OBU displays a warning on the user's device. While the traffic light is green, the OBU is necessary to constantly check for the end of congestion. Finally, the OBU determines whether ego-vehicle can enter the lane in the driving direction.

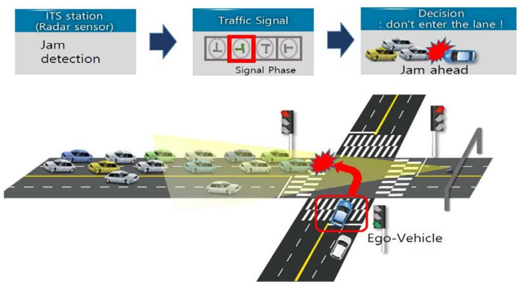


Fig. 4. Use case of intersection safety service

This system closely connects the roadside system with vehicles, which helps vehicles at an intersection can share information and avoid critical situations.

### B. Message Structure and Requirement

All information is generated on a lane basis. Integrated intersection safety message is based on the SAE J2735 Basic Safety Message (BSM), Signal Phase and Timing (SPaT), and National Marine Electronics Association (NMEA) message specifications. Abstract Syntax Notation One (ASN.1) specification of intersection safety message appears in Figure 5. Figure 5 shows that the integrated LDM consists of intersection, detected vehicles, detected pedestrians, traffic signal, and NMEA correction information.

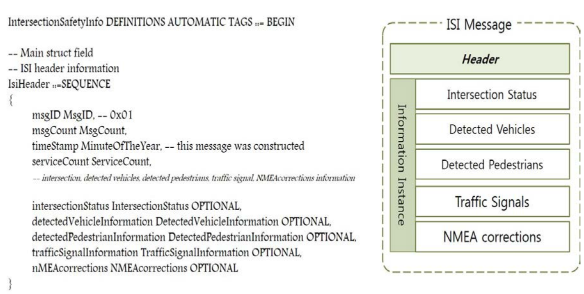


Fig. 5. Structure of Intersection Safety Information (ISI)

The OBU local database assumes that there is a map for the path. The intersection information includes detailed intersection state, hazard information, and temporary road information. The ISI system can collect "detectedVehicleInformation" by road radar and V2I messages, and collect "detectedPedestrianInformation" by the road radar and camera. On the other hand, the CICAS project defines a new message called "MSG_VehicleDigest" for encapsulating and delivering information about the speed and location of vehicles (including bicycle or pedestrian). [2,5]

We select two-time metrics, time to collision (TTC) and post-penetration time (PET), which represent a safety guideline for the intersection safety service the following Figure 6. In VISSIM (simulation software developed by PTV) results, it was found that intersection safety information reduced traffic delays for all lanes and increased TTC and PET.

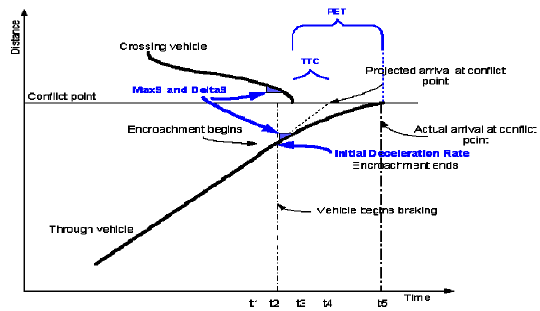


Fig. 6. Aassessment metrics for intersection safety

## IV. Conclusion

In this study, we proposed a method to transmit LDM intersection information when a vehicle enters an intersection. We defined the structure of the integrated message and used an urban driving use case to demonstrate the proposed system. The system will be tested in an actual intersection at the Korean pilot site in the future.

## Acknowledgment


This research was funded by the government (Ministry of Trade, Industry and Energy) in 2017 with the support of the Korea Institute of Industrial Technology Development and the European Union's Horizon 2020 research and innovation program. (N0002453, Development of intersection safety information system and service technology for autonomous driving, Grant Agreement No. 731993).


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