

# Study of CAN-to-3GPP LTE gateway architecture for automotive safety in V2I environment

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**Abstract**— To realize the V2I communication technology based on 3GPP LTE infrastructure, the gateway is required to connected 3GPP network to in-vehicle communication system. The gateway must be suitable for the legacy vehicle E/E systems and functional safety requirements.

In this paper, I describe the architecture of CAN-to-3GPP LTE gateway to fit those requirements. CAN is the general purpose communication system in the automobile domain to connect and control vehicle E/E systems.

**Keywords**— V2X, V2I, 3GPP LTE, CAN, AUTOSAR, ISO26262

## I. INTRODUCTION

Recently, it has been increased the interest of smart car to decrease the possibility of accidents by providing traffic safety services.

Smart car is a human-friendly vehicle that provides high-safety functions and facilities combining electronics and IT technology with legacy automobiles technique to recognize the safety-related status from internal or external car area. [1]

To realize the smart car, there are lots of embedded systems in the vehicle that can provide safety for drivers and pedestrians. Vehicles are also connected each other to sharing valuable information, that is called V2X communication technology. V2X communication technology connect vehicles to interact with each other (V2V), the roadside infrastructure (V2I) via wireless communications.

Standardization of V2X is underway actively in the various organization and it is noteworthy that 3GPP starts to standard V2V communication by applying mobile communication technology. I think that it can contribute robust infrastructure to traffic safety services because 3GPP mobile communication technologies provide high reliable and trusted network system.

Traffic safety system in the vehicle can receive external information from the 3GPP infrastructure that is very useful to control safety system timely. These technique can be applied in driverless car.

We must notice that the gateway is required to connected 3GPP network to in-vehicle communication system. The gateway must be suitable for the legacy automobile E/E systems and functional safety requirements.

In this paper, I describe the architecture of CAN-to-3GPP LTE gateway to fit those requirements. CAN is the general purpose communication system in the automobile domain to connect and control vehicle E/E systems.

## II. RELATED WORK

### A. AUTOSAR overview

AUTOSAR (AUTomotive Open System Architecture) is the industrial standard for developing automotive embedded software. AUTOSAR is a partnership of automotive manufacturers and suppliers working together to develop and establish an open industry standard for automotive E/E architectures. AUTOSAR aims to improve complexity management of integrated E/E architectures through increased reuse and exchangeability of SW modules between OEMs and suppliers. Moreover AUTOSAR intends to improve flexibility for product modification, upgrade and update, reliability of E/E system, and to enable detection of errors in early design phase.

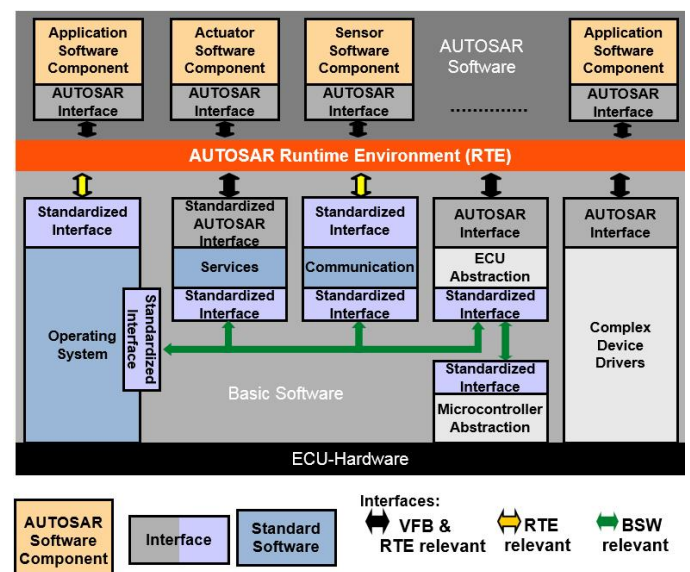


Figure 1. AUTOSAR Software Architecture [2]

Fig 1 shows the AUTOSAR software architecture that distinguishes four basic layer, application, RTE (RunTime Environment), BSW (Basic SoftWare) and microcontroller. The RTE provides the infrastructure services that enable communication to occur between AUTOSAR software-components as well as acting as the means by which

AUTOSAR software-components access basic software modules including the OS and communication services. [2] The BSWs are divided into functional groups that are System, Memory, Diagnostic and Communication Services. These services are used in automotive system commonly.

I adapt AUTOSAR architecture to design CAN-to-LTE gateway because AUTOSAR is the most notable platform in the vehicle industry recently. AUTOSAR based CAN-to-LTE gateway is able to interwork with non-AUTOSAR based ECUs as well as AUTOSAR based ECUs in the vehicle.

### B. V2I

V2X is the all over communication technology to connect vehicles on the road. Connected vehicles interact with each other (V2V), the roadside infrastructure (V2I) via wireless communications.

V2I communications for safety is the wireless exchange of critical safety and operational information between vehicles and roadside infrastructure, intended primarily to avoid or mitigate vehicle crashes but also to enable a wide range of other safety. V2I communications apply to all vehicle types and all roads, and transform infrastructure equipment into smart infrastructure through the incorporation of algorithms that use data exchanged between vehicles and infrastructure elements to perform calculations that recognize high-risk situations in advance, resulting in driver alerts and warnings through specific countermeasures. Infrastructures are the legacy communication network, Wi-Fi, 2G/3G cellular network, GPS, etc.

Recently, 3GPP starts to V2V/V2I study based on LTE technology. So we study the architecture for data exchange between 3GPP LTE and Safety system in the vehicle and describe that in the next chapter.

## III. ARCHITECTURE OF AUTOSAR BASED CAN-TO-LTE GATEWAY

### A. NETWORK Architecture

Fig 2 is the network architecture for providing V2I services based on the LTE infrastructure. Control center are in the legacy Internet and eNB is in the LTE infrastructure. There are lots of ECUs for traffic safety system and CAN-to-LTE gateway to bridge between two heterogeneous communication systems in the vehicle.

The control center in the Internet collects safety-related information, for instance car accidents, traffic jam, bad weather by using LTE devices, CCTVs, GPS in the respective regions. If traffic incidents are happened in the specific area, control center trigger CBC (Cell Broadcast Center) to broadcast the information that is need to start the safety system. CAN-to-LTE gateway translates the information from LTE infrastructure to in-vehicle systems and analysis data to decide which system to start up. CAN-to-LTE gateway sends the applicable ECUs the signal to run. ECUs receiving the signal from gateway start up for intentional purpose.

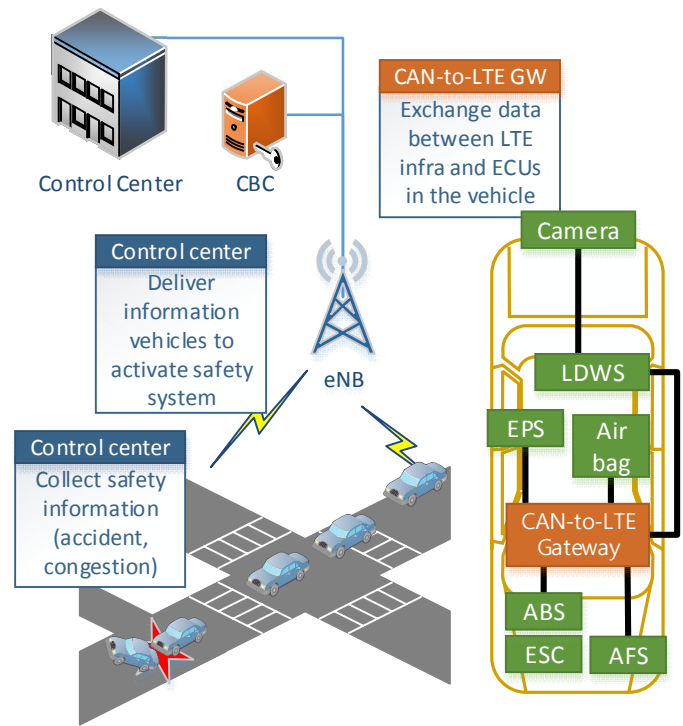


Figure 2. Network architecture of V2I services

Fig 3 shows the simple flow control for V2I services.

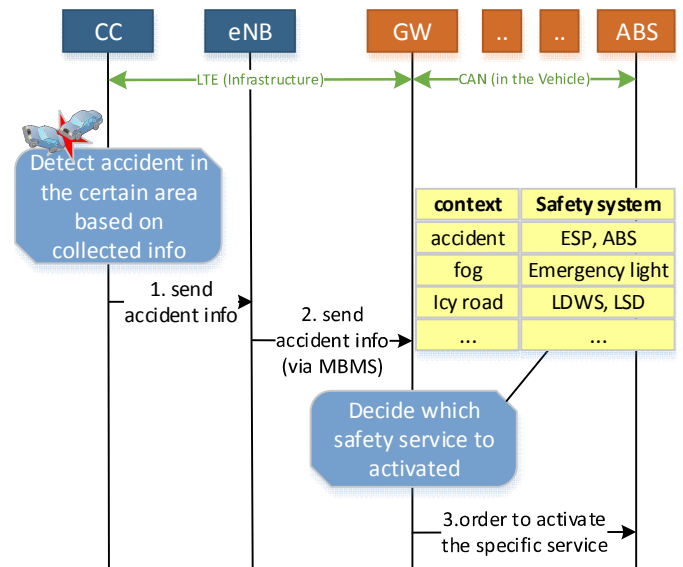


Figure 3. Simple flow of the service

### B. Gateway Architecture

Fig 3 describe the internal architecture of CAN-to-LTE architecture.

The gateway consists of two separate MCU in the same board because AUTOSAR software runs above the AUTOSAR OS system that is optimized to the vehicle E/E

systems. So one MCU (MCU1) is to load the LTE module and application to translate LTE data to in-vehicle system event and the other (MCU0) is to run the AUTOSAR platform and application to trigger appropriate safety systems.

Information received from control center is delivered to application through the LTE protocols in the MCU1. Application above LTE protocol exchange information from LTE infrastructure to in-vehicle systems and send data to MCU 2 via IPC, for instance SPI (Serial Peripheral Interface) or UART (Universal asynchronous receiver/transmitter) etc.

If UART is used for IPC, it must be implemented to Complex Device Driver module that can be interact with AUTOSAR RTE to provide AUTOSAR interface. The Complex Device Drivers will be used to implement drivers for hardware which is not supported by AUTOSAR. [3]

In case of SPI, it can be communicated via ECU Abstraction module provided by AUTOSAR platform because AUTOSAR supports SPI communication.

Event from IPC is delivered to AUTOSAR application via appropriated I/O interface and RTE.

AUTOSAR application is the control station of the in-vehicle ECUs, in case the event is coming from external vehicle, especially LTE infrastructure. AUTOSAR application analyses the event and decide which safety system to run.

AUTOSAR application send the event signal to ECUs that perform the safety system and ECU is trigger by that signal.

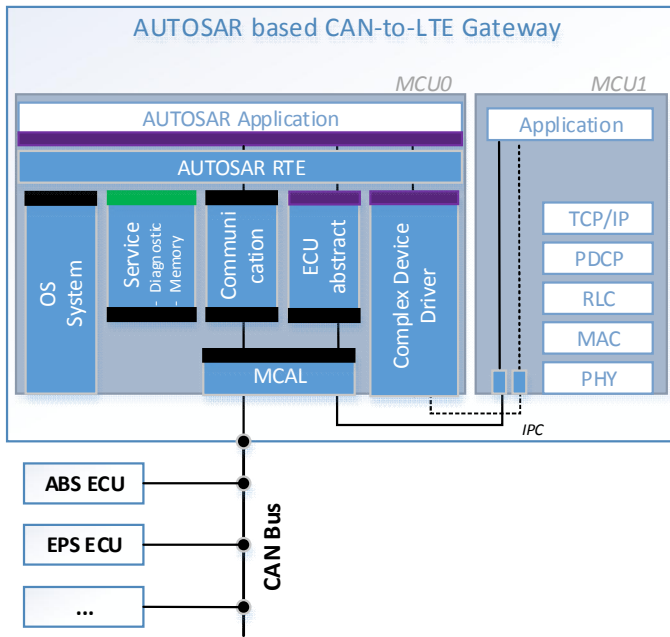


Figure 4. CAN-to-LTE Gateway architecture

### C. Application Example

There can be many different types of V2I applications based on the LTE infrastructure.

Gerhard P. Fettweis who suggests the Tactile Internet says that it is able to applicable to traffic safety. For example,

Tactile Internet technology makes all the cars in the specific area to start their safety system, ABS (Antilock Braking System) or VDC (Vehicle Dynamic Control) / EPS (Electronic Stability Program) when the unpredictable events are happened to avoid to spread that situations. [4]

Our architecture can realize those services for example as follows;

- 1) Central controlled Warning system
- 2) Central controlled LDWS
- 3) Central controlled AEB
- 4) Central controlled Anti-theft system

If the accident happened in the front area where the eyesight is not good, infrastructure send the information to the vehicles. That information can include the accident information – distance, lane, and speed in that area. According to the information, gateway trigger the safety system in vehicle. First, gateway start up the central controlled warning system. It can be voice alarm for driver or emergency light. It can be noticed which system is start up soon or just call a drivers attention to the accident. Second, the vehicle approached the crash area, the gateway can start to run ABS or VDC and so on.

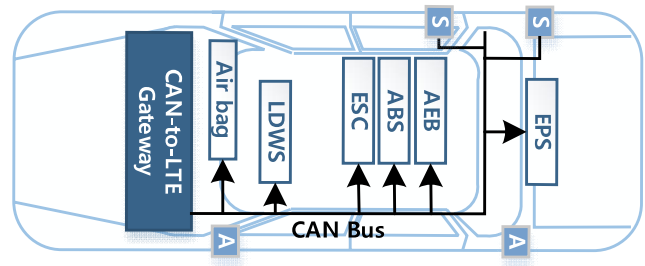


Figure 5. Example of the ECU deployment in the vehicle

## IV. CONCLUSIONS

Recently, the functional safety of the in-vehicle system becomes a hot issue in the automobile industry because of increasing the E/E systems in geometric progression.

To control the in-vehicle safety system for the drivers and the pedestrians is included in the functional-safety category, so it is needed to be the reliable and stable system. ISO 26262 is the Functional Safety standard that intended to be applied to safety-related systems that include one or more electrical and/or electronic (E/E) systems. The prominent automotive OEM in the world is preparing the system to accommodate the ISO 26262 standard.

AUTOSAR provides the most suitable standard to compliance the SW development methodology proposed by ISO 26262. Because it provides model-based design techniques that can verify the SW in the design step and the architecture for reuse of reliable SW. So the AUTOSAR is the optimal solution to build the gateway to interwork between in-vehicle systems and infrastructure just like LTE.

But we have to take into the proper measurement for the reliability of information of infrastructure. If the control

information comes from the 3rd attacker by Spoofing, it should make very risky situation.

Traditionally, the automotive technology must be prudential to adapt the new systems because the automobile is connected to human safety directly. Although IT technology including V2X is very convenient and innovative, it may have fateful consequence because of error or wrong operation, etc.

If we can apply the new technology to car domain properly, it result in creating additional value for the legacy infra-related industry as well as the automobile's. So we have to study the mechanism to run the system more reliably

In this paper, I describe the first step that is the LTE-to-CAN gateway architecture and its application instance.

#### ACKNOWLEDGMENT

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) [R0101-15-244, Development of 5G Mobile Communication Technologies for Hyper-connected smart services]

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