Adaptive V2X platform for guaranteed QoS/QoE service based on cloud computing and deep reinforcement learning

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***Abstract*— An industry where technology pushes behind and the market pulls ahead succeeds. In this repect, autonomous driving is a global industry that is rapidly growing in line with the advancement of wireless communication, vision, AI technologies and the smart infrastructure market, including automobiles. In particular, V2X technology is an international communication standard for providing autonomous driving services at the level of mobility 4.0. In this paper, we propose an adaptive V2X service methodology. Autonomous driving is a technology belonging to the MCS field which is directly connected to human life, so we provide enhanced QoS/QoE through proposed method which is guaranteed the real-time based on V2X standard.**

Keywords—Mobility 4.0, autonomous driving, adaptive V2X, cloud computing, real-time streaming, MCS

I. Introduction

Recently, researches for autonomous driving services in the mobility 4.0 stage are being actively conducted, centering on the smart infrastructure construction industry. In addition, the global autonomous vehicle market demand is estimated to be at approximately 6.7 thousand units in 2020 and is anticipated to expand at a CAGR of 63.1% from 2021 to 2030 [1]. This market trend has become an explosive growth engine for IT technology related to the mobility industry. In particular, research for the development and commercialization of autonomous driving technology in in-vehicle and out-vehicle environments is actively being conducted. Autonomous driving is a service that can be realized through the convergence of technologies in various fields such as WAVE, C-V2X standard-based V2X communication, edge cloud, deep learning-based vision and technologies in each field have a close relationship with each other. In particular, since it belongs to the field of Mission critical service (MCS) that is directly connected to human life, high level of safety and reliability is required. Therefore, if the correlation between the technologies is broken or errors occur, it can be a problem that is directly connected to human life [2].

A. Proplem statement

The safety and reliability of autonomous driving can be defined as real-time performance and accuracy in terms of communication and vision. In other words, QoS/QoE is guaranteed by providing accuracy and real-time through object recognition based on deep learning and V2X communication technology. However, the existing V2X provides a high level of real-time and accuracy regardless of the service type. This can be an advantage in terms of safety and reliability of autonomous driving services, but it is inefficient in terms of how to consume IT resources. Although the V2X standard categorizes it into V2I, V2N, and V2P depending on the communication target, it needs to be further subdivided and defined for which the complex traffic environment is considered.

B. Contribution

In this paper, we propose adaptive V2X platform that guarantees enhanced IT resource efficiency (energy, cost) with the same or high level of safety and reliability (QoS/QoE) by analyzing the correlation with communication and vision.

It analyzes all kind of IT resource which is consumed inside/outside vehicle based on V2X standard and deep learning-based object recognition and then estimates the trade-off for real-time and accuracy performance. The task process above is operated in an adjacent edge cloud which provides an offloading method together. Then, IT resources are adaptively managed and distributed according to the service type for energy/cost efficiency and guaranteed QoS/QoE by using a V2X standard-based proposed feedback message.

The rest of this paper is organized as follows. We review the related works and discuss their drawbacks in Section II. The proposed adaptive V2X platform framework for enhancement of QoS/QoE and energy/cost efficiency is presented in Section III. In Section IV, we draw conclusion.

II. Background

A. V2X

The V2X (Vehicle to Everything) communication standard, which corresponds to the Mobility 4.0 stage, literally is a technology that provides connectivity between vehicles and everything, including vehicles. In other words, various technologies are required for autonomous driving services that guarantee reliability and safety. At this time, information through various sensors installed in the vehicle is highly dependent on sensor performance and is limited in that it can be used only within a visible distance. In order to solve this problem, V2X is a standard technology to increase reliability and safety by sharing information on the external environment of the vehicle to recognize a wider area in real time [3].

According to the network type, V2X is largely divided into IEEE 802.11p WAVE based on Wi-Fi/DSRC and 3GPP C-V2X based on cellular network (3G, LTE, 5G). The two technologies are the difference between licensed and non-licensed. The methodology proposed in this paper is applicable to both standard technologies [4].

In this paper, we further categorize the above use-cases by one more step according to the communication target and then adaptively allocate and manage the IT resources (network bandwidth, computational resources etc.) by each service type.

B. Edge cloud computing & Deep learning

Edge cloud is a relatively small-scale intelligent router scattered throughout the network centering on the core cloud, and is also called a cloudlet. In the V2X standard technology, it corresponds to the aforementioned V2N service [5].

Fig. 1 depicts the structure of V2X communication in coverage of core cloud and edge cloud.

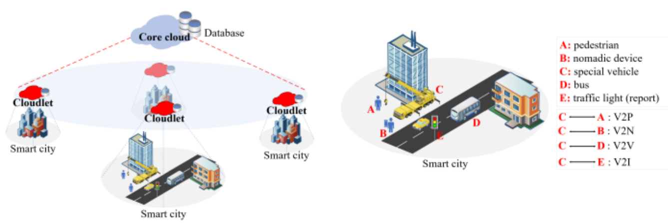

Fig. 1. V2X standard-based service structure in core cloud and edge cloud coverage.

From an out-vehicle perspective, an autonomous vehicle based on V2X communicates with an adjacent edge cloud server, exchanges information, and can recognize and respond to traffic conditions in a wider area in real time. In addition, it is possible to provide drivers various traffic condition which is collected in real-time and long-term traffic flows that are predicted by big data analysis.

From the in-vehicle perspective, it predicts and responds to unexpected situations within the visible distance through object recognition/analysis based on deep learning with data collected by sensors installed inside and outside the vehicle.

In this way, edge cloud and deep learning technologies can be applied to V2X-based autonomous driving services. At this time, the available IT resources owned by the vehicle are limited and fixed. Therefore, the learning model that can be applied to guarantee real-time performance according to the vehicle's hardware specifications is limited, and this may cause a decrease in accuracy performance [6].

In this paper, we provide an offloading method using edge cloud computing to improve accuracy performance and provide real-time performance through a learning model that requires high computational resources.

III. Proposed Architecture

In this paper, we propose an adaptive V2X platform service methodology based on WAVE and C-V2X standards. The proposed methodology classifies services by assigning weights according to the importance of accuracy and real-time, and provides adaptive V2X services depending on each service type in the communication process between each entity during autonomous driving [7].

Fig. 2 shows the proposed framework of the adaptive V2X platform.

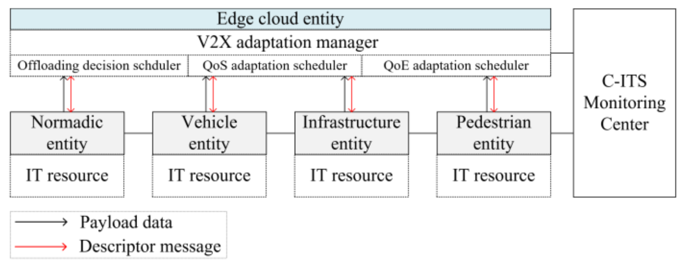

Fig. 2. Framework of the proposed adaptive V2X platform.

As shown in Fig. 2, there is defined as infrastructure including vehicles, nomadic and pedestrian entities. Each entity shares the real-time information through V2X communication. All of these entities are connected to the edge cloud entity and share the necessary information which is formed as V2X adaptation feedback message. The specification of the necessary information is described in the subsection III-A in details. Finally, the C-ITS monitoring center monitors real-time traffic conditions and responds universally according to policies.

Table 1 shows the service types defined according to the importance of real-time performance and accuracy in the V2X environment.

TABLE I. TABLE 1. DEFINITION OF SERVICE TYPE AND USE-CASES IN V2X ENVIRONMENT

Type	Definition	Comment
R1	the case more required accuracy than real-time	- latent-driver analysis - autonomous EV charging-robot
R2	the case more required real-time than accuracy	- AV-stream general monitoring
R3	the case required both real-time and accuracy	- driving-based object recognition (out-vehicle) - driving-based event signaling (in-vehicle) - autonomous driving (in/out-vehicle)
R4	the case non-required both real-time and accuracy	N/A

As shown in Table 1, the V2X adaptation manager in the edge cloud entity allocates IT resources by classifying the importance of real-time and accuracy according to the V2X service type based on the collected necessary information. In addition, it checks the available IT resources of each connected entity in real time and determines whether to offload the modularized process to prevent under/over provisioning.

At this time, resource management and allocation through real-time QoS/QoE adaptation performed by the V2X adaptation manager utilizes an optimization model based on deep reinforcement learning. This is a model suitable for a real-time network environment with characteristics of time-series data, and it derives optimal results in terms of energy/cost. The general formula for this is as follows.

$$Quality = \alpha \cdot (realtime) + \beta \cdot (accuracy) \quad (1)$$

$$\arg\max_{\alpha,\beta} Q = \frac{1}{2}\alpha \log B_{fps}B_{bps} + \beta \frac{C_{task}}{IQA} \quad (2)$$

Then, we describe the necessary information in detail mentioned in the above. The edge cloud entity receives the V2X adaptation feedback message from each entity, classifies the service type based on the parameters in the message, and determines whether to offload. Fig. 3 shows the syntax of the V2X adaptation feedback message defined in this paper.

Syntax	Value	No. of bits	Mnemonic
V2X_adaptation_feedback_message () {			
message_id		8	uimsbf
version		8	uimsbf
length		32	uimsbf
extension {			
reserved	"11 1111"	6	bslbf
}			
if (message_id == "0x00") {			
service_type_index		8	uimsbf
}			
else if (message_id == "0x01") {			
offloading_decision_flag		8	uimsbf
}			
QoS_adaptation_parameter_info {	N1		
for (i=0; i<N1; i++) {			
current_available_bitrate		32	float
maximum_bitrate		32	float
minimum_bitrate		32	float
current_average_bitrate		32	float
current_latency		16	double
packet_loss_rate		32	uimsbf
BER		32	uimsbf
reserved	"11 1111"	6	bslbf
}			
}			
QoE_adaptaion_parameter_info {	N2		
for (i=0; i<N2; i++) {			
IT_resource_capacity		32	uimsbf
modulized_process_complexity		32	uimsbf
full_reference_IQA_index		8	uimsbf
no_reference_IQA_index		8	uimsbf
peak_signal_to_noise_ratio		32	uimsbf
reserved	"11 1111"	6	bslbf
}			
}			
}			

Fig. 3. Syntax of V2X adaptation feedback message.

As shown in Fig. 3, the V2X adaptation feedback message is composed of real-time or non-real-time parameter information, and the information is transmitted and received in the form of a descriptor message in Fig. 2.

Fig. 4 shows the meaning and information of each parameter in Fig. 3. In this paper, the proposed adaptive V2X service is provided through the service types in Table 1 and the V2X adaptation feedback messages in Fig. 3 and 4. For example, since the analysis of potential drivers corresponding to R1 (refer to Table 1) is accuracy more important than real-time, it is possible to efficiently manage resources by limiting the allocation of IT resources and making reservations for other services. In addition, the previously reserved network bandwidth is consumed as needed in the real-time monitoring service corresponding to R2 (refer to Table 1). In other words, the adaptive V2X platform provides efficient resource management as well as QoS/QoE is guaranteed.

message_id − indicates the V2X adaptation feedback message ID. The length of this field is 8 bits.
version − indicates the version of V2X adaptation feedback message whether this message is current or not. The length of this field is 8 bits.
length − indicates the length of V2X adaptation feedback message. The length of this field is 32 bits. If the value is 0, the messasge is no used.
reserved − this is reserved-field.
service_type_index − indicates the index of service type. The length of this field is 8 bits. The service type is defined as R1, R2, R3 and R4 according to importance of QoS and QoE.
offloading_decision_flag − indicates the flag of offloading decision. The length of this field is 8 bits. Intelligent router entity could decide whether the module(s) offloads or not by depending on real-time information of the QoE_adaptation_parameter_info and the QoS_adaptation_parameter_info.
current_available_bitrate − indicates the current available bitrate in real-time. The length of this field is 32 bits.
maximum_bitrate − indicates the maximum bitrate in real-time. The length of this field is 32 bits.
minimum_bitrate − indicates the minimum bitrate in real-time. The length of this field is 32 bits.
current_average_bitrate − indicates the current average bitrate in real-time. The length of this field is 32 bits. The range for measurement of average value is variable.
current_latency − indicates the current latency in real-time. The length of this field is 16 bits.
packet_loss_rate − indicates the packet loss rate in real-time. The length of this field is 32 bits.
BER − indicates the bit error rate in real-time. The length of this field is 32 bits.
reserved − this is reserved field.
IT_resource_capacity − indicates the capacity of IT resource in real-time. The length of this field is 32 bits. The capacity of IT resource contains information of CPU, GPU, memory, storage and so on.
modulized_process_complexity − indicates the complexity of modulized process. The length of this field is 32 bits. The unit of complexity could be a number of clocks at CPU or second based on NTP (Network Time Protocol).
full_reference_IQA_index − indicates the index of full-reference (FR) image quality assessment. The length of this field 8 bits. The FR-IQA method could be various assessment metrics such as SSIM, EPSNR, MSE etc., expect for PSNR.
no_reference_IQA_index − indicates the index of no-reference (NR) image quality assessment. The length of this field is 8 bits. The NR-IQA method could be MOS (Mean Of Score) metric.
peak_signal_to_noise_ratio − indicates the peak signal to noise ration (PSNR). The length of this field is 32 bits. This field is temporary and could be changed to reserved field by being integrated to full_reference_IQA_index.
reserved − this is reserved-field.

Fig. 4. Semantics of v2x adaptation feedback message.

IV. Conclusion

In this paper, we categorized the service type more detail according to the real-time and the accuracy and then we provide the adaptive V2X platform which could guarantee the QoS/QoE efficiently based on the proposed framework which defines the service type, V2X adaptation feedback message and V2X adaptation manager. This methodology will cover more V2X entities compared to conventional platform by managing the available IT resources and also for commercialization of this proposal, we need to study for the handover issues when switching between the edge cloud servers.

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