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Analysis of the BSM Mechanism of Internet of Vehicles

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Abstract

The generation and dissemination of basic safety message (BSM) of Internet of Vehicles (IoV) are key factors affecting the effectiveness and reliability of applications of the IoV and intelligent connected vehicles. Drawing on an analysis of the BSM definitions of IoV, this paper first studies and analyzes several typical communication protocol architecture frameworks, including the Cellular-V2X, the Wireless Access in Vehicular Environments, and the current standards of IoV at home and abroad. Second, this paper discusses the carrier frequency bands and channel divisions of different vehicle network communication protocols. Then, based on the different standard protocols of IoV, the standardized data formats of BSM are introduced. The final section summarizes the current research status of transmission frequency, transmission power parameter setting, and dynamic generation and transmission mechanisms of BSM of IoV used for traffic perceptions.

Keywords: *Intelligent Connected Vehicle, internet of vehicles, cellular-V2X, basic safety message, broadcast mechanism*

I. INTRODUCTION

Basic safety message(BSM) [1] is the vehicle basic state motion information broadcast periodically based on wireless communication technology in the application of Internet of Vehicles (IoV) or intelligent connected vehicle (ICV). Several standards organizations have attempted to define BSM. For example, the Society of Automotive Engineers[2] (SAE) describes the BSM as a kind of message that is frequently broadcast to the surrounding vehicles as required by safety and other applications. BSM is used in a variety of applications to exchange safety data regarding the state of vehicle. The European Telecommunications Standards Institute (ETSI) named this message "Cooperative Awareness Message"[3] (CAM). CAMs are exchanged in a network of intelligent transportation systems (ITS) between ITS stations (ITS-Ss), where the ITS station can be either a vehicle or a road side unit.The goal of exchanging CAMs is to create and maintain collective perception of objectiveITS stations and thus tosupport the application using cooperative data of each objection. The China Society of Automotive Engineers[4] (China-SAE) considers BSM as one of the most widely used messages in the application layers of vehicles for exchanging the state of their safety.

Thanks to the BSM transmissions, vehicles can inform their neighbors of their real-time status. BSM also provides the data source to support the IoV or ICV safety application. Generally, the generation and transmission of BSM are controlled by vehicles at a fixed frequency, and a BSM sent by an originating vehicle can be broadcast to all its neighbors within its direct communication range. With regard to the use of IoV or ICV application for safety reasons, to avoid collisions and other safety risks, vehicles must transmit BSM at a high frequency to ensure that they receive timely and accurate status information from the surrounding vehicles. However, in view of the IoV channel load, the generation and transmission frequencies of BSM must be kept at an appropriately low level to avoid channel congestion. Given the reference consideration of BSM, the generation and transmission mechanisms of BSM must be carefully established to guarantee their alignment with the different communication requirements of IoVor ICV applications.

To solve the above problems, standards organizations in different countries and regions, covering the United States, Europe, and China, have performed a series of standardization work on BSM, employing different IoV architectures. For example, they have formulated the definition of BSM and the communication requirements of the different applications. In 2011, the SAE released the Dedicated Short-Range Communications (DSRC) Message Communication Minimum Performance Requirements Standard J2945.1[5]. This standard specified the usage rules of BSM for vehicle safety applications. In 2016, the SAE also released Standard J2735 for applications utilizing the 5.9GHz DSRC for wireless access in vehicular environments (WAVE) communications systems. This standard specified message and its detailed structure consisting data frames (DFs) and data elements (DEs). In 2014, ETSI released Standard ETSI TS 102 894-2[6], which defined the repository of a set of DEs and DFs, usually used in messages transmitted in ITS applications layer and facilities layer. Accordingly, ETSI released the draft Standard ETSI EN 302 637-2 in 2018, defining the syntax and semantics of CAM and detailed specifications on message handling. In 2017, the China-SAE released the application layer of the vehicle communications system and the application data interaction standard, which is known as T/CSAE 53-2017. They also released the definitions of BSM datasets, DFs, and DEs, Application Programming Interface (API) and Service Provider Interface (SPI) is introduced as well.

The abovementioned BSM standards vary according to the policies of each country/region and its adopted communications technologies. Drawing on the typical communication protocol stacks of IoV, this paper first discusses the underlying framework of current standards of different IoV architectures. Then, this paper explains the spectrum distributions and channel designations of IoV laid out by different research organizations in different countries/regions. Subsequently, based on the definition of BSM, this paper compares the detailed BSM data structures with different standards documents. Next, it analyzes two important transmission parameters (i.e., packet rate and power) which are involved in BSM originating from both network layer and access layer. Finally, the current research status of transmission mechanisms of BSM for traffic perceptions, especially the transmission frequency and the transmission power parameter setting, is analyzed and elucidated. This paper intends to develop a basic understanding of BSM to support future research on the generation and propagation mechanisms of BSM for traffic perceptions.

II. TYPICAL IOV PROTOCOL STACKS

DSRC Based on 802.11p

WAVE in the United States

In 1999, the Federal Communications Commission (FCC) announced to allocate licensed spectrum in the 5.9GHz band, the bandwidth of which is 75 MHz, for both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications in scenarios where objects move in a highspeed. In July 2010, the Institute of Electrical and Electronics Engineers (IEEE) released Standard 802.11p[7], which is modified according to IEEE 802.11 (Wi-Fi) standard andis utilized in physical (PHY) and medium access control (MAC) layers. Subsequently, the IEEE 1609 Working Group published a suite of standards, including IEEE 1609.2, IEEE 1609.3, and IEEE 1609.4[8], defining the communication protocols above the MAC layer and thus building the DSRC/WAVE protocol stacks [9]. The WAVE protocol stack is illustrated in figure (Figure 1).

ITS-G5 in Europe

In 2010, ETSI released the European profile of standards for the PHY and MAC layers of ITS operating inthe 5GHz frequency band using IEEE 802.11 as the base [10]. This profile of standards specified the functionality protocols and parameters as ITS-G5 and laid out the different communication requirements for each vehicular application. In September 2010, ETSI specified the architecture of communications in ITS [11], also known as ITSC (Intelligent Transportation Systems Communications), which supported a variety of existing and new access technologies and ITS applications. In 2014, ETSI defined the DEs and DFs used as component ofmessages transmitted in facilities layer and application layer of ITS, such as CAM. The protocol stacks of ITS-G5 are appeared in the accompanying figure (Figure 2).

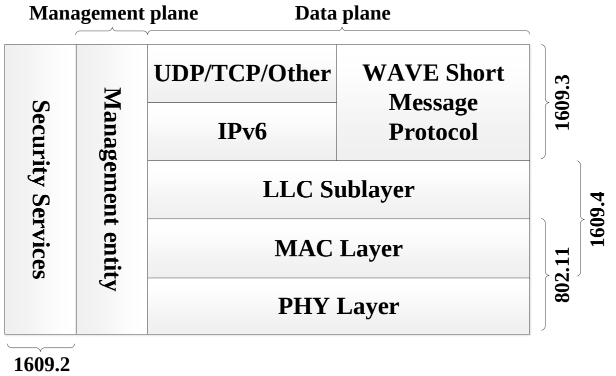

Fig 1: WAVE structure

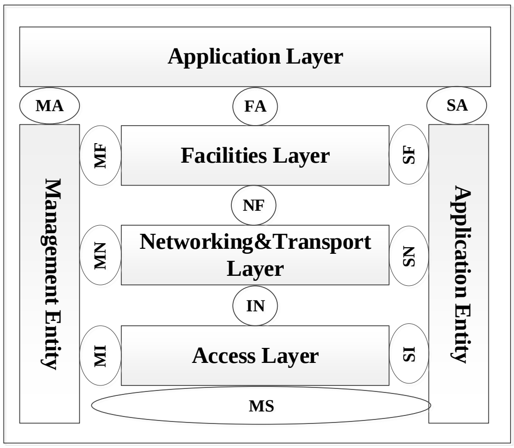

Fig 2: ITS-G5 protocol stacks

DSRC in Japan

DSRC in Japan originates from the United States. In 1997, the Association of Radio Industries and Businesses (ARIB) released DSRC standard framework oriented toward transport information and control systems [12]. The ARIB construct the communication structure with three layers, which includes Layer 1, 2, and 7 originate from the Open System Interconnection/Reference Model (OSI/RM). The functions in Layers 3–6, defined in the OSI/RM, are all accomplished in Layer 7. Moreover, the standards published in 2001 specified the parameters of the wireless air interface between different devices in DSRC system.

Cellular-V2X

The rapid advances in cellular mobile communications technology toward vehicle-to-everything (V2X) offer many benefits, such as reliable access to vast information, less time delay to safety-related applications, and massive mobile terminal connections. Since 2015, several standards supporting V2X communications, including Long-Term Evolution-V2X (LTE-V2X) and 5G-V2X, have been employed by the 3rd Generation Partnership Project (3GPP). In March 2017, following the standardization completion of PC5-based V2V and LTE Uu-based V2X, the 3GPP RAN (Radio Access Network) froze the V2X standardization work of 3GPP LTE Rel-14[13] and accomplished the design of physical layer of the wireless access network to meet the basic service requirement of LTE-V2X applications.

Currently, the 3GPP LTE Rel-14 is aiming to meet the application requirements of assistant driving. As for the autonomous driving application requirements in the future, the 3GPP has been promoting a series of standardization works on 5G-V2X since 2016. In Rel-15 [14], as part of the 5G/NR (5G New Radio) evolution, the 3GPP has identified several advanced V2X use cases to be targeted by the 5G technology. These cases consider solutions that can be applied to sub-6GHz and mmW unlicensed bands. This work, to be completed in 2018, has designed new sidelink channel models and specified multiple scenarios and standalone NR operations in the unlicensed spectrum. In the same year, the 3GPP launched the "V2X based on 5G New Radio (Rel-16)," developed by MIMO (multipleinput, multipleoutput) enhancements to increase efficiency in mmWave bands [15]; it also aimed to fix and enhance NR and enable new services on NR. In addition, Rel-16 enhanced the 5G-V2X application use case according to the NR Uu interface and specified PHY layer structure, broadcast mechanism, and synchronization of the NR sidelink. It is important to note that using LTE, Rel-16 also expanded V2X beyond what is currently available and provided the technical solution of air interface service quality management.

In China, with the large-scale deployment of 4G/5G cellular communication networks, organizations, such as China Communications Standards Association (CCSA), China Intelligent Transportation System (C-ITS), and China-SAE,performed a series of work to build the standard LTE-V end-to-end system. In 2017, the China-SAE published the application layer specifications and data exchange standards in the Cooperative Intelligent Transportation System (C-ITS). The standards specified the vehicular communications framework with six layers, namely, system application, application layer, transmit layer, network layer, MAC layer, and PHY layer, referring to the OSI/RM presented by the International Organization for Standardization (IOS). Furthermore, the standards specified different Service Provider Interfaces (SPI) for compatibility with a variety of communication modes and devices using either DSRC or 3GPP LTE-V2X. The compatibility categories of communications technology in data interaction standards are illustrated in figure (Figure 3).

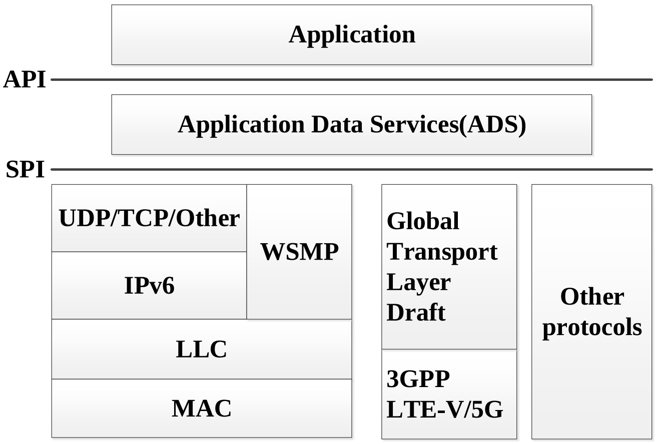

Fig 3: China-SAE compatibility categories of communications technology

In July 2019, the European Union (EU) formally issued a statement rejecting the proposal presented by the European Commission for the use of DSRC as future IoV communications technology. In 2020, the latest approved ETSI standards EN use C-V2X as access layer technology for ITS terminals. Moreover, the updated ETSI standards can support the access layer protocols based on C-V2X technology. The above standards and specifications have now formed the ETSI ITS Release 1 specifications set. They are also used as a foundation for other related industries for developing C-V2X ITS solutions and terminals in the future.

Another point worth noting is that in December 2019, the FCC passed the proposal to redistribute the 5.9GHz spectrum, with the 20MHz band being dedicated to C-V2X.

Global Standards of V2X Technologies

The above analysis of current IoV communication protocols suggests two main categories of IoV communication protocols: (1) DSRC dominated by the IEEE using 802.11p as a core technology and (2) C-V2X based on LTE-V and future 5G NR developed by the 3GPP. At present, governments and standardization organizations of different countries and regions have also formulated a standard communications system of vehicular network using IEEE 802.11p and LTE-V. As presented intable (Table 1), thus far, both IEEE 802.11p and C-V2X technologies have completed technical research and standardization.

As a mainstream of the communications technology of IoV, DSRC has attracted considerable attention and has been developed extensively. However, DSRC relies on a large number of infrastructure deployments, which dramatically increases the construction and operating costs. At the same time, the DSRC physical layer has inherent defects of asynchronous communications, which directly influence the timeliness of safety applications in IoV and ICV, with the evolution path for the improvement or resolution of this problem remaining unclear. In addition, DSRC can hardly meet the requirements of robustness and reliability due to the diversity and complexity of massive applications in IoV and ICV. Considering the extensive coverage and stable communication quality of mobile communications technology, as well as its clear evolution path, the use of cellular communications technology in support of IoV applications to complete data interactions is increasingly gaining popularity. As a result, more and more countries/regions and standards organizations have accepted C-V2X, releasing a series of standards on a global scale.

Table 1. Major V2X technologies

Region	**Technology**	**Standard**
United States	802.11p	IEEE 802.11-2012,IEEE1609.2-.4, SAE J2735, SAE J2945/x series
Europe	802.11p	ITS-G5, ETSI ITS series
Japan	802.11p	ARIB STD-109
China	Cellular LTE	T/CSAE 53-2017
Global	Cellular LTE	3GPP TS 22.185, TS 23.285 (for V2X and LTE), TS 36 series (for wireless access)
Global	Cellular 5G	3GPP TS 22.186, TS 23.501 (for network structure), 3GPP 38 series (for wireless access)

Although relevant standardization works and experiments have been conducted with a degree of success, the accomplishment of the comprehensive application of IoV and ICV, based on 5G-V2X, continues to be time-consuming. Recently, LTE-V2X has focused on the basic V2X services, with NR-V2X acting as a supplementary.

III. ALLOCATION OF FREQUENCY AND CHANNEL

Frequency Allocation

During the development of electronic toll collection (ETC), the United States, Japan, and Europe allocated the working frequency bands for IoV communications. In the United States, the spectrum allocated by FCC is in 5.850-5.925 GHz in the 5.9GHz band. The spectrum allocated in 5.855–5.925 MHz was divided into seven channels with same bandwidth, which is 10MHz,and was used by different IoV services. In addition, the left 5MHz spectrum allocated in 5.850–5.855 MHz was reserved as a guard band at the low end.

In the late 1990s, Japan allocated 5.770–5.850 MHz to DSRC in the applications of ETC and Vehicle Information and Communication System (VICS). In 2012, the ARIB released the 700MHz band and employed the 755.5–764.5MHz band for road safety applications in ITS.

Considering the different requirements of different applications, ETSI established the specifications of radio spectrum resources for the 5GHz band in ITS. The frequency ranges and related regulatory requirements demanded thatITS-G5A (5.875–5.905 GHz) is dedicated used for ITS road safety applications, ITS-G5B (5.855–5.875 GHz) used for ITS road non-safety applications, and ITS-G5C (5.470–5.725 GHz) for applications using other communications technologies, such as Broadband Radio Access Networks (BRAN) and wireless local area network (WLAN). Moreover, ETSI has reserved the 5.905–5.925 GHz to meet the requirements of future ITS applications.

In 2013, the Ministry of Industry and Information Technology of China announced the adjustment of 5.725–5.850MHz band frequencies for use in the broadband wireless access system; wireless communication for ITS, including ETC; point-to-point or point-to-multipoint spread spectrum communications system; and general micropower (short-range) radio transmitting equipment. In 2018, the Ministry of Industry and Information Technology of China issued the regulation on the use of 5.905–5.925 MHz for IoV direct communication, which specified 5.9 GHz as the working frequency band for IoV direct communication, based on LTE or C-V2X communications technology[16]. The frequency allocation of different countries is presented in figure (Figure 4).

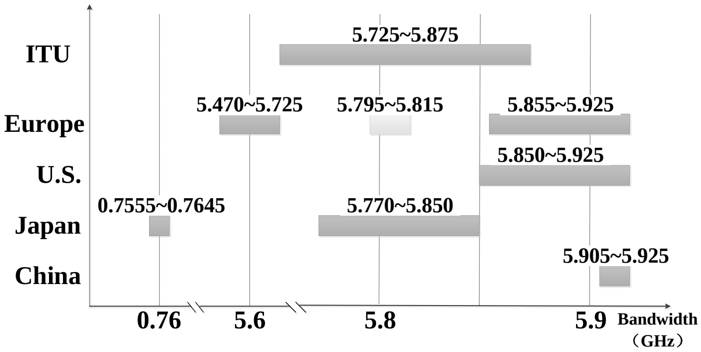

Fig 4: Global spectrum allocations for DSRC and V2X

It is important to note that on December 12, 2019, the FCC announced the redistribution of the 75MHz radio spectrum resources, which was originally allocated to DSRC—the lowest 45 MHz (5.850–5.895 GHz) allocated for the use of unauthorized technologies and the general public. The upper 30 MHz (5.895–5.925 GHz) was reserved for transport and vehicle safety applications. Notably, 20 MHz (5.905–5.925 GHz) was classified as a dedicated band for cellular-based communications technology (i.e., C-V2X).

Channel Allocation

The spectrum allocated in 5.855–5.925 MHz in the United States is divided into seven 10MHz channels, which comprise one control channel (CCH), two service channels (SCHs) used for safety-related applications, and four SCHs used for non-safety-related applications. Among these seven channels, CCH is specifically used to transmit service announcements and control messages. Contrarily, SCH is mainly used for exchanging information related to the ITS application. As illustrated in figure (Figure 5), the channels numbered 174 and 176 can be combined to the SCH numbered 175 with a 20MHz bandwidth. However, the channel numbered 181 is combined in the same way with the channels numbered 180 and 182. Considering its WSMP packet format, BSM can be transmitted through both CCH and SCH without registration.

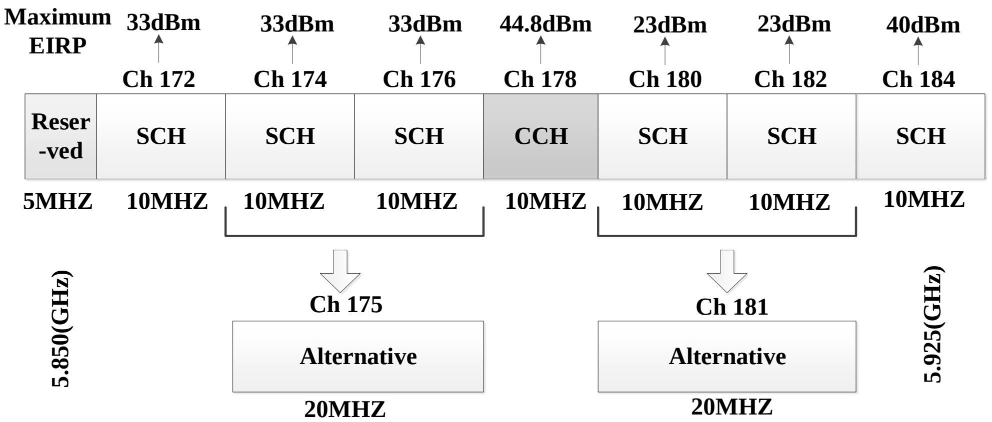

Fig 5: Channel allocation and number in the United States

ETSI also divided the channel into two categories: (1) the physical channel allocated to ITS-G5 control channel (G5CC) and (2) four fixed channels and one variable physical channel named as ITS-G5 service channel (G5SC). Table (Table 2)presents the specifications of channel allocation. Moreover, when using the above six channels to transmit messages, three rules must be followed. First, the G5CC is dedicated used for applications related to road safety and traffic efficiency, ITS announcements of services operating within the range of the G5SC1 to G5SC5 is allowed as well. Second, the G5SC1 and G5SC2 must be used for applications to improve ITS road safety and traffic efficiency. Finally, the G5SC3, G5SC4, and G5SC5 can be used for other ITS applications.

Table 2. Channel allocation and number in Europe

Channel Type	Center Frequency	Channel Number	Channel Spacing	TX Power Limit
G5CC	5900MHz	180	10MHz	33 dBm EIRP
G5SC2	5890MHz	178	10MHz	23 dBm EIRP
G5SC1	5880MHz	176	10MHz	33 dBm EIRP
G5SC3	5870MHz	174	10MHz	23 dBm EIRP
G5SC4	5860MHz	173	10MHz	0 dBm EIRP
G5SC5	5470-5725MHz		Several	30 dBm EIRP (DFS master)
				23 dBm EIRP (DFS slave)

IV. BSM STRUCTURE AND MECHANISM

BSM Data Structure

The SAE data structure

According to the SAE J2735, the precise structure of a DSRC message comprises the DF and DE. The DF of BSM contains BSM Part 1 and Part 2. Part 1 data must be included in each BSM, whereas Part 2 data are optional or included as per specific applications. Contrarily, the DE of BSM contains core data written in Part 1. Meanwhile, a BSM without Part 2 content is still a valid message. The structure of BSM is illustrated in figure (Figure 6).

As an important message type in the SAE J2735, the DEs written in BSM Part 1 include not only the location or other critical state information of vehicle but also the state information of the operating system, supporting the safety application between vehicles. The DEs in BSM Part 1 are presented in figure (Figure 6). Because BSM is extremely sensitive to bandwidth consumption, particularly BSM Part 1, the components of BSM Part 1 are not individually encoded by Distinguished Encoding Rules (DER). Except for this, considering that the message identification (ID) is parsed independently, it must be separately DER-encoded. BSM Part 1 data consume 39 bytes.

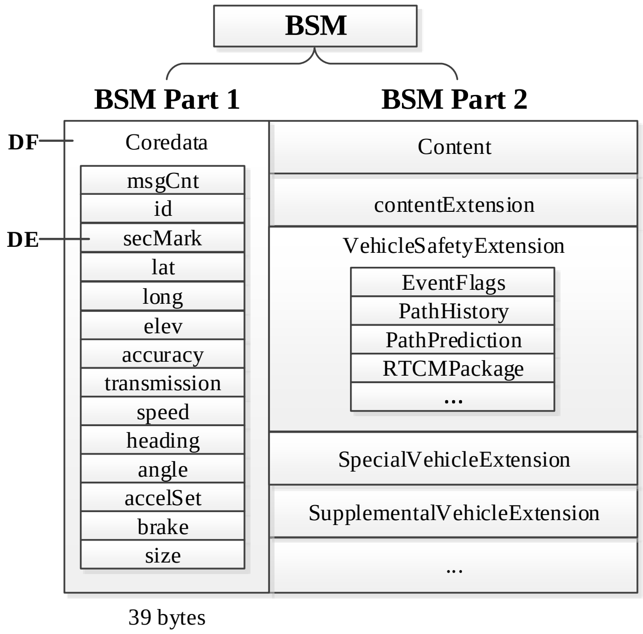

Fig 6: BSM data structure

Compared with BSM Part 1, the data in Part 2 are more flexible. For instance, some data types in Part 2 have a lower frequency than those in the overall BSM. At the same time, Part 2 data can easily fit newly defined information (e.g., originate from newlydesigned sensors) and latest applications. Furthermore, they support customized messages to support company-specific features. In BSM Part 2, there are four DEs which are most often used: (1) EventFlags denoting the trigger of an event, (2) PathHistory reporting the trajectory history of vehicles, (3) PathPrediction predicting the vehicle trajectory, and (4) RTCMPackage conveying Global Positioning System (GPS) correction data in the RTCM style. The above DEs are collected in a BSM Part 2 DF and it is known as *VehicleSafetyExtension*.

ETSI data structure

Referring to the ETSI EN 302 637, a CAM should consist of one common ITS PDU header and at least two containers, where the ITS PDU header containing the protocol version, message type, and ITS-S ID of the originating ITS-S. If the ITS-Ss is a vehicle, CAM originate by it must comprise four kinds of containers: (1) basic container containing basic information related to the originating ITS-S, (2) high-frequency container (HF container) containing information of the originating ITS-S which is changed frequently, (3) low-frequency container (LF container) containing information that is static or not often changed, and (4) one or more special containers is related to the specific role information of the originating ITS-S. The structure of CAM is illustrated in figure (Figure7).

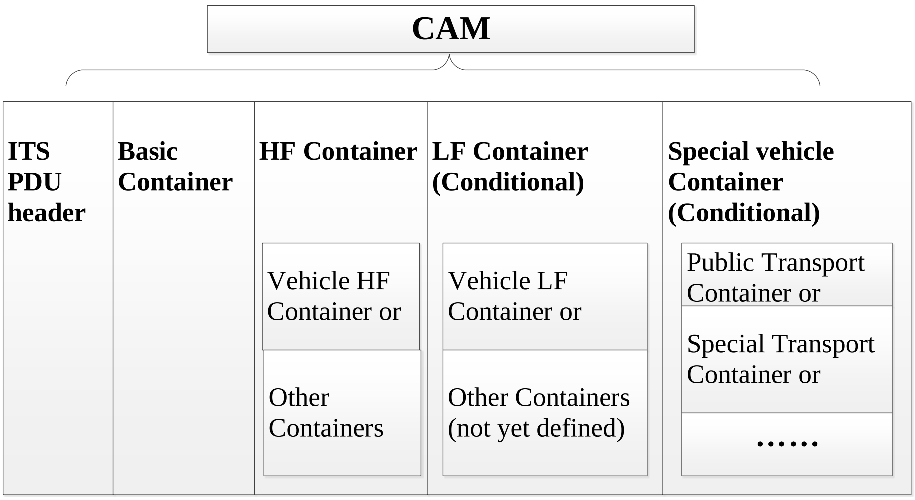

Fig 7: CAM data structure

Similarly, for a CAM, the ITS PDU header and the containers all act as the basic DF, with the content written in each DF varying according to different requirements. It is also worth noting that the ITS PDU header, basic container, and HF container must all be included in the CAM in which the LF container and special containers are optional.

Data structure in China-SAE

The normalized data structure of BSM presented by the China-SAE also follows the logical design of BSM in the SAE in the sequence of message set, DF, and DE. In addition, as a basic message set, the BSM definition in the China-SAE is adjusted to the content of BSM Part 1 in the SAE, according to China's context. In brief, the changes in BSM in the China-SAE mainly encompass four aspects. First, the length of vehicle ID information is extended to fit the number of electronic vehicle ID information. The second aspect concerns a combination of DE, combining DEs *lat* and *long*, describing the area information of the three-dimensional location information DE *pos* on the one hand and DEs *elev*and *accuracy*, which describe the accuracy of the area information, on the other, combined into the single DE *accuracy*. The third aspect relates to the change of DE *angle*, which describes the optional angle of the steering wheel. The last aspect concerns the addition of three DEs: the *VehicleClass* describing the vehicle type information, the optional DE *motionCfd* giving the motion confidence set, and the extended DE *safeExt.*

BSM Transmission Mechanism

The research on the BSM mechanism has mainly focused on transmission frequency and power. Currently, different standards organizations recommend different parameter ranges.

BSM transmission frequency

BSM transmission frequency is a key factor affecting the channel load and application performance. In fact, the logical design of BSM is based on the WAVE Short Message Protocol (WSMP) [17]. With regard to the IEEE 1609.3, the use of transmission mechanisms, such as the Transmission Control Protocol (TCP) with more robustness when using the WSMP packet to transmit BSM, is not recommended. In other words, the BSM transmission mechanism is decided by upper application, which directly renders it more flexible and diversified. For safety-related applications, especially for DF *VehicleSafetyExtension* in BSM Part 2, a 10Hz BSM is considered necessary in the SAE J2935. Moreover, the transmission rate of DF in BSM Part 1 must be kept at a high level to ensure data timeliness.

In terms of ETSI, the cooperative awareness basic service provider manages the transmission frequency of CAM based on the different roles played by ITS-S. For the scenario where the ITS-S is a vehicle, the minimum generation interval of CAM, named *T_GenCamMin*, must not less than100ms, whereas the maximum generation interval *T_GenCamMax* must be superior to 1,000ms. In other words, the corresponding generation rate of BSM is from 1 to 10 Hz. For the scenario where ITS-S is a roadside unit, the generation interval of BSM *T_GenCamMin* must be superior to 1,000ms to guarantee thatat least one BSM is received if vehicle is within the communication range of the RSU ITS-S. In light of the above BSM rules, the cooperative awareness basic service provider generates BSM also has to consider the ITS-S dynamic status and thetransmit condition. To maintain several consecutive BSMs, the conditions for generating BSM must be checked periodically at every *T_CheckCamGen*, where *T_CheckCamGen* is equal to*T_GenCmMin*or less than it.

Thus far, China’s relevant IoV standards organization has not specified the underlying communications technology of BSM. Considering the function defined by BSM, to exchange safety status data between vehicles, for example, this article refers to the data collection rate introduced in the group standard, which is known as the T/CASE 100, released by the China-SAE in 2018. Generally, the T/CASE 100 specified the data collection period and the general principles of coding rules. Moreover, it divided data collection into the periodic collection and event-triggered collection. The periodic collection is further divided into the high-frequency collection, with a maximum collection period of no more than 1s, and the low-frequency collection, with a minimum collection period of no less than 15s. The event-triggered collection does not specify the event type.

BSM equivalent isotropic radiated power (EIRP)

According to Section 3, both the SAE and ETSI employ the control channel to transmit BSM. In other words, BSM is used to transmit the service statement information of ITS application. As presented in figure (Figure 5) and table (Table 2), EIRP in the control channel is equal to or higher than EIRP in other channels. This situation is due to the fact that data in the statement message need to be transmitted with high accuracy within a large scale. The EIRP values are 44.8 dBm in the SAE standard and 33 dBm in ETSI standard. In China, according to the regulations document of technical requirements for direct communication radio equipment for IoV, the EIRP value of onboard or portable radio equipment working within 5.905–5.925 MHz must be 26 dBm, with the radio equipment on roadside being limited to 29 dBm.

Research on the BSM mechanism

Several problems must be addressed when designing the BSM structure and transmitting mechanism. First, the standardization of the BSM transmitting mechanism is strongly dependent on the standard safety application. However, the standardization of safety applications is not yet complete. Moreover, the transformation scheme aiding message-transmitting parameters to suit the various performance levels of safety applications have not been developed. Second, the optimal message-transmitting mechanism is probablyapplied in different communication channel, while different communication channel is of different physical characteristics and changed rapidly.

Current studies Ref.[18-21], which are focused on the BSM transmitting mechanism, mainly discuss at application layers. Ref. [18] designed an adaptive scheme to dynamically adjust the BSM transmission parameters according to different application requirements and real-time channel loads. To improve network performance, Ref.[19] proposed a transmitting mechanism that can adjust the transmission frequency and power by sharing the maximum tolerance time and channel load information in message packets that are periodically transmitted. By designing the distributed density estimation algorithm and the distributed power control algorithm, Ref.[20] proposed a power adaptive adjustment scheme of BSM based on local vehicle density. The BSM transmitting mechanism applied in a scenario where multiple applications run simultaneously is presented in Ref.[21]. By designing a Message Dispatcher, the proposed BSM transmitting mechanism helps vehicle avoid sending duplicated BSMs. For instance, when different applications need to transmit the same DEs with different transmission frequencies, the Message Dispatcher would generate message packets at the lowest rate to meet all the application requirements.

Among the proposed documents of the BSM transmitting mechanisms, the scenarios in Ref.[18-20] only relate to single applications. Thus, they do not suit the complex application scenarios in real IoV and ICV systems. The mechanism in Ref.[21] ignores the different requirements for communication range and transmission power of different applications of IoV and ICV. Moreover, recent research on BSM transmitting mechanisms has hardly paid attention to V2I and V2P. Therefore, analyzing and improvingof BSM transmitting mechanisms are necessary to accomplish numerous requirements of applications, especially those related to road safety, traffic efficiency, and entertainment service. At the same time, it is important to test the performance of various BSM transmitting mechanisms with different traffic parameters, such as density and velocity, to make them suitable for real traffic systems.

V. CONCLUSION

Rapid advances in mobile communications technology have accelerated the evolution of IoV. To discuss the research on the BSM mechanism, this paper first systematically analyzed and synthesized current BSM mechanisms. Then, drawing on different IoV architectures presented by different standards organizations, the BSM mechanism was discussed comprehensively from the physical layer to the wireless access layer and application layer. A sound BSM mechanism not only improves the accuracy of the IoV safety application but also helps the system maintain scalability of the network. Hence, future research on BSM mechanisms is advised to concentrate on the balance between the application requirement and network performance. In addition, in light of the complexity and diversity of IoV application scenarios, research on the BSM mechanism of multiple scenarios and applications is recommended.

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