Qualcomm

ITS Stack

80-PE732-64 Rev A

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Objectives

- Discuss protocol stack for different ITS standards
- List the different ITS messages
- Describe ITS stack implementation on Qualcomm C-V2X Development Platform

ITS Stack – Reference Architecture

The ITS stack reference architecture follows the principles of the OSI model for layered communication protocols

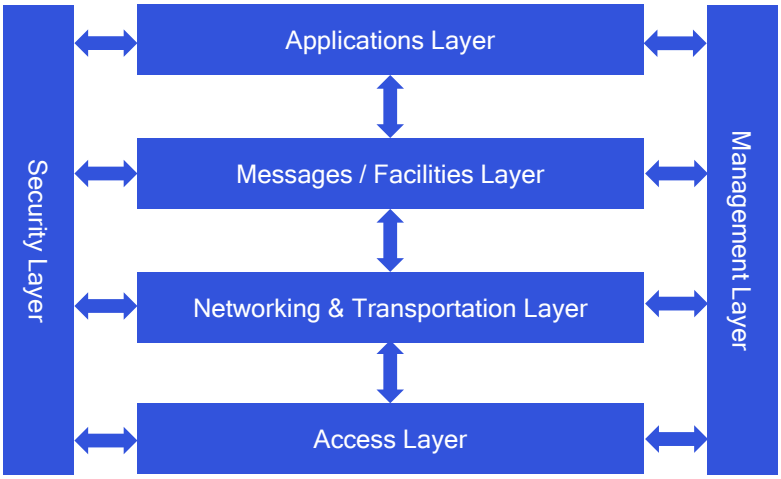
It is extended to include an Applications layer for ITS applications

Access layer ← → OSI layers 1 & 2

Networking & transportation Layer ← → OSI layers 3 & 4

Facilities layer ← → OSI layers 5, 6 & 7

ITS stacks of different ITS standards are quite similar



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ITS access technologies layer covers various communication media and related protocols for the physical and data link layers. The access technologies are not restricted to specific type of media, though most of the access technologies are based on wireless communication.

The access technologies are used for communication inside of an ITS station (among its internal components) and for external communication (for example with other ITS stations). For external communication, some of the ITS access technologies represent complete, non-ITS specific communication systems (such as, GPRS, UMTS, WiMAX) that are regarded as 'logical links' over which ITS data is transparently transported.

The ITS network & transport layer comprises protocols for data delivery among ITS stations and from ITS stations to other network nodes, such as network nodes in the core network (e.g. the Internet). ITS network protocols particularly include the routing of data from source to destination through intermediate nodes and the efficient dissemination of data in geographical areas. ITS transport protocols provide the end-to-end delivery of data and, depending on requirements of ITS facilities and applications, additional services, such as reliable data transfer, flow control and congestion avoidance. A particular protocol in the ITS network & transport layer is the Internet protocol IP version 6 (IPv6). The usage of IPv6 includes the transmission of IPv6 packets over ITS network protocols, dynamic selection of ITS access technologies and handover between them, as well as interoperability issues of IPv6 and IPv4.

The ITS facilities layer provides a collection of functions to support ITS applications. The facilities provide data structures to store, aggregate and maintain data of different type and source (such as from vehicle sensors and from data received by means of communication). As for communication, ITS facilities enable various types of addressing to applications, provide ITS-specific message handling and support establishment and maintenance of communication sessions. An important facility is the management of services, including discovery and download of services as software modules and their management in the ITS station.

The ITS applications layer refers to ITS applications and use cases for road safety, traffic efficiency, infotainment and business.

The two vertical protocol entities are:

- ITS management entity is responsible for configuration of an ITS station, cross-layer information exchange among the different layers and others tasks.
- ITS security entity provides security and privacy services, including secure messages at different layers of the communication stack, management of identities and security credentials, and aspects for secure platforms (firewalls, security gateway, tamper-proof hardware).

C-V2X Reuses Upper Layers Defined by the Automotive Industry

Reuse established service and app layers

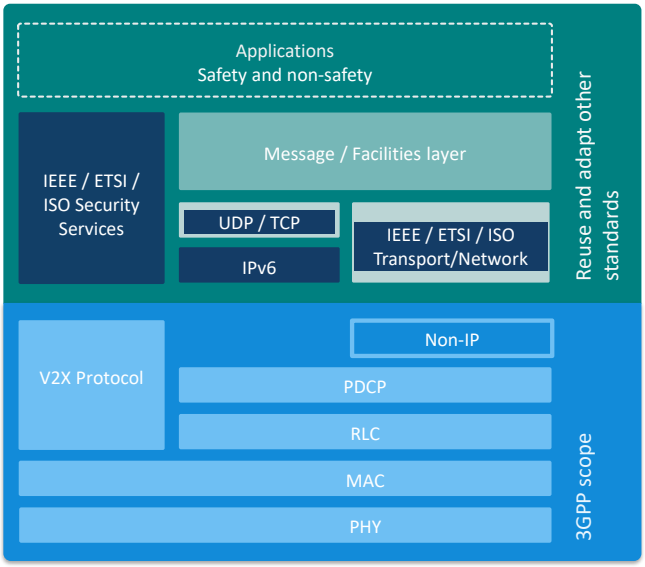
- Already defined by automotive and standards communities, e.g., ETSI, SAE International
- Developing abstraction layer to interface with 3GPP lower layers (in conjunction with 5GAA)

Reuse existing security and transport layers

- Defined by ISO, ETSI, and IEEE 1609 family

Continuous enhancements to the radio/lower layers

- Supports the ever-evolving V2X use cases



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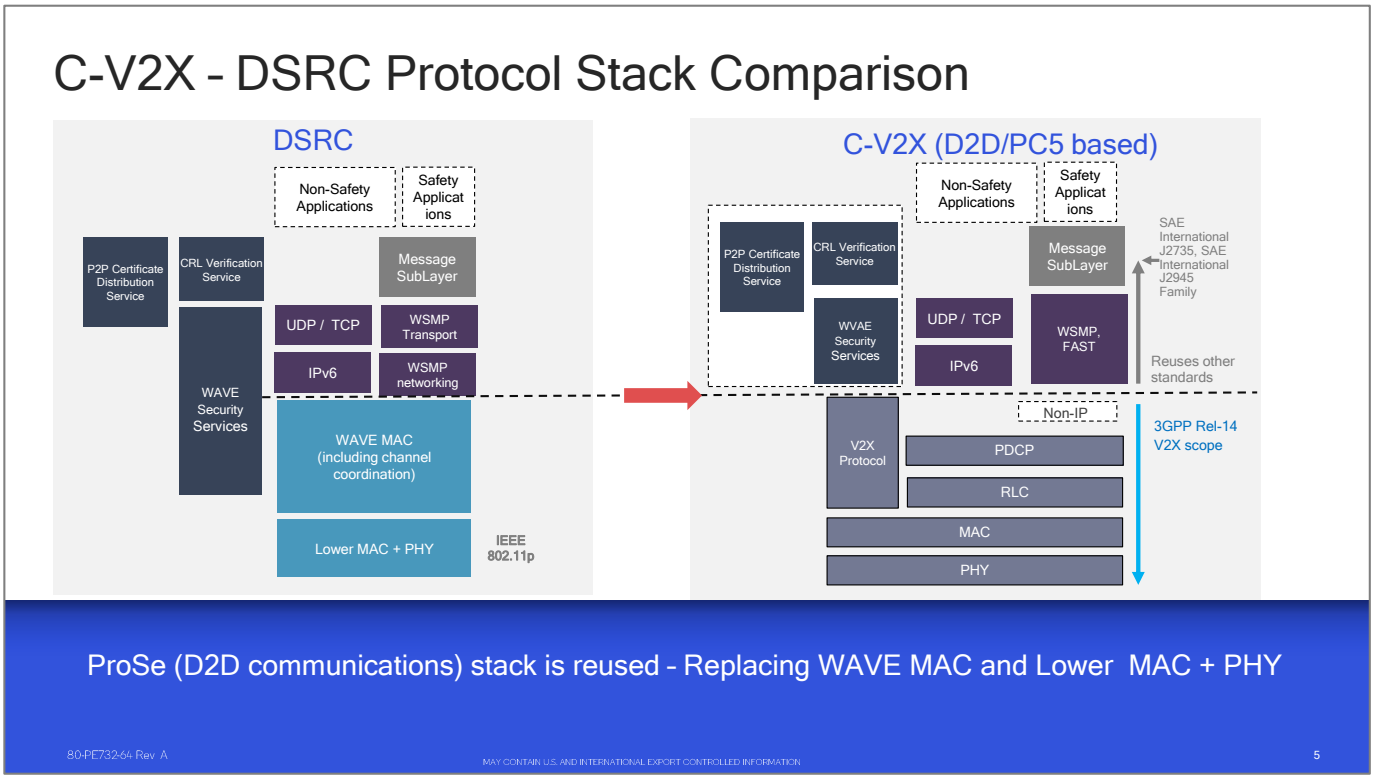
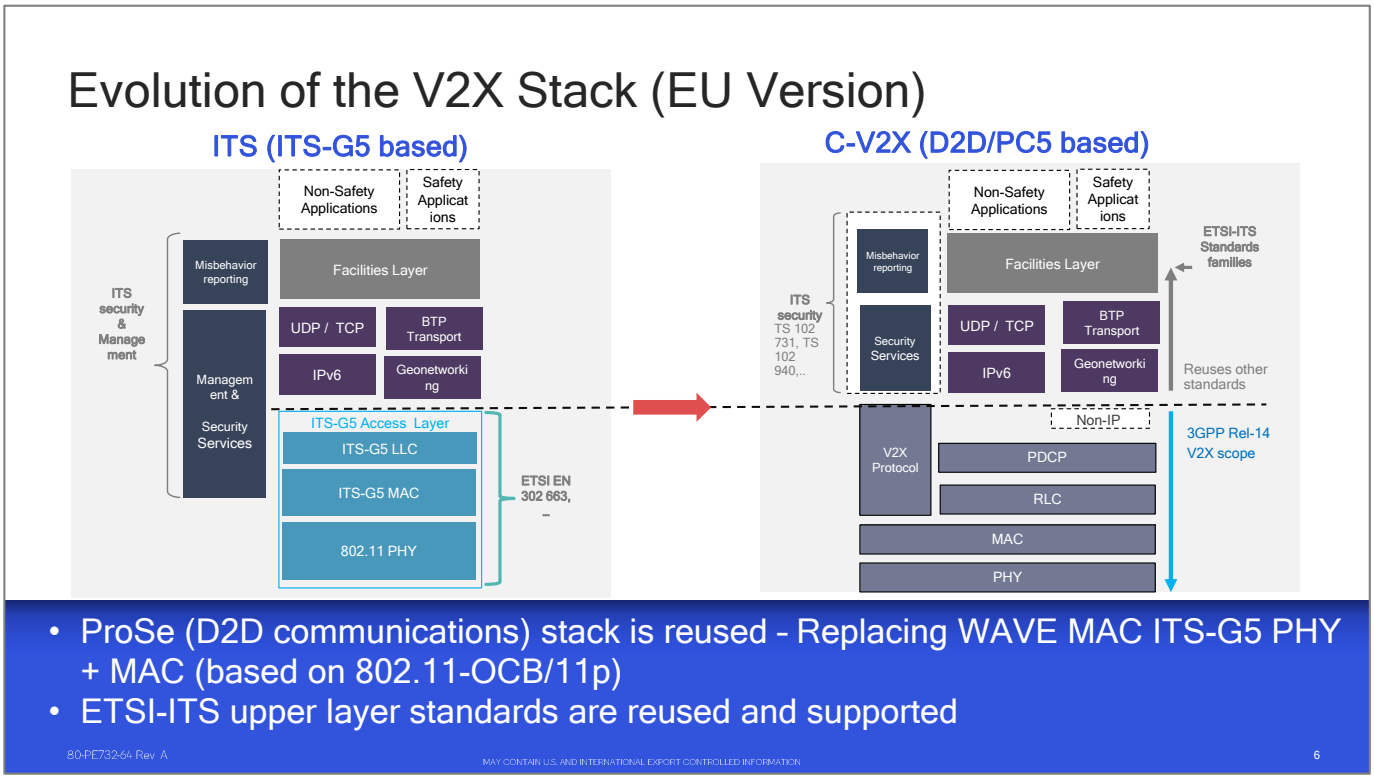
The automotive industry, through SAE International, ETSI, and IEEE, have done considerable work in defining the Applications, the message/facilities later, security services and the Transport/networking layers. C-V2X leverages all of the existing standards in these layers, and just replaces the PHY and the MAC (commonly called the Access layers) from 3GPP to provide the end to end solution.



Comparison of the DSRC and C-V2X implementation allows for reusing the upper layers from DSRC products and replacing lower layers compliant with 3GPP spec for a C-V2X solution.



The same approach is taken for EU version of the WAVE stack. Replacing the Access layer based on ITS-G5 with 3GPP based C-V2X stack.

802.11 and IEEE 1609.X Specs

Quick Overview

Based on 802.11 PHY

- Contention based transmission (CSMA/CA)
- Limits Capacity

Uses part of 802.11 MAC and LLC

- Uses MAC Data Frame structure of a MAC-PDU
- dot11OCBActivated == true,
  - See IEEE 1609.4-2016 Section 41, 802.11-2016 Section 11.21
- Specific LLC code to identify DSRC traffic
  - 0x88DC for WSMP, 0x86DD for IPv6, IEEE 1609.3-2016 Section 5.2.3

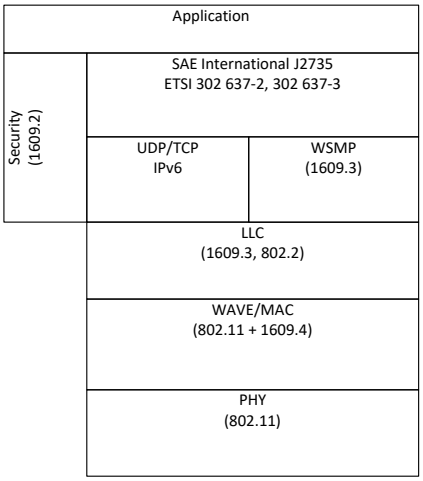
Uses IEEE 1609.4, 1609.3 upper MAC

- IEEE 1609.3 specifies WAVE message formats
- IEEE 1609.12 lists all assigned PSIDs
- IEEE 1609.2 specifies security procedures

SAE International J2735

ETSI 302 637-2 (CAM), Co-operative Awareness Messages

ETSI 302 637-3 (DENM), Decentralized Environment Notification msgs.



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This slide lists all the specifications that have been developed and implemented for providing functionality at each layer.

WAVE stands for Wireless Access in Vehicular Environment and comprises the WSMP (Wireless services messaging protocol) based on IEEE 1609.3 standard, the SAE International J2735 (Society of Automotive engineers J2735 for message dictionary), the Security based on IEEE 1609.2.

The corresponding ETSI spec versions are also listed for comparison.

Common ITS Messages

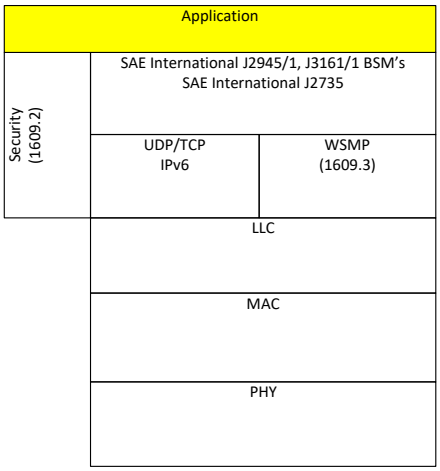
SAE International Message	ETSI ITS Message
Basic Safety Message (BSM)	Co-operative Awareness Message (CAM) / Decentralized Environment Notification Message (DENM)
Emergency Vehicle Alert (EVA)	DENM
Signal Phase & Timing (SPaT / MAP)	Same
Traveller Information Message (TIM)	DENM
Curve Speed Warning (CSW - special TIM)	n/a

SAE International and ETSI have different names for certain ITS messages, though their function may be the same. For example, safety messages in SAE International are called BSMs, whereas in ETSI they are referred as CAM or DENM.

The others are also listed for comparison.

SAE International J2735 Messages: Examples

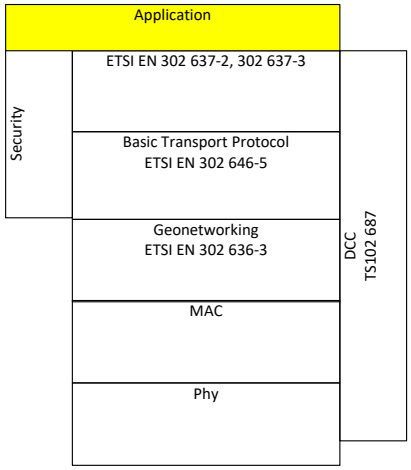
Scenario	Relevant SAE International Message
FCW (Forward Collision Warning)	BSM
EEBL (electronic Emergency Brake Light)	BSM
Emergency Vehicle	BSM – part II (Special Vehicle)
Weather Warning	TIM
In-Vehicle Signage	TIM
Road Work	RSA, TIM
VRU / PSM (Pedestrian Safety)	PSM
Green Speed	BSM, RSA, PSM, MAP
IMA (Intersection Movement Assist)	BSM, RSA, PSM, MAP, TIM
BSW/LCW (Blind Spot Warning, Lane Change Warning)	BSM
LTA (Left Turn Assist)	BSM



Various warnings and informational messages can be realized using the available SAE International messages as explained earlier. The table above lists some of the example scenarios that can be realized by utilizing one or more of the BSMs, TIMs, MAP, etc.

ETSI CAM/DENM Messages: Examples

Scenario	Relevant ETSI Message
LCRW *(Forward Collision)	CAM: Basic + HF
LCRW (EEBL)	CAM: Basic + HF + LF
Emergency Vehicle	CAM: Basic + HF + Special
Weather Warning	DENM
In-Vehicle Signage	DENM: Basic +HF(RSU)
Road Work	DENM, seeTS103.301 and TS19321
GLOSA (green light optimal speed advisory)	SPAT + Map
ICRW (Intersection Collision)	CAM: Basic +HF +LF
BSW/LCW (Blind Spot Warning, Lane Change Warning)	CAM: Basic + HF + LF
LTA (Left Turn Assist)	CAM: Basic + HF + LF

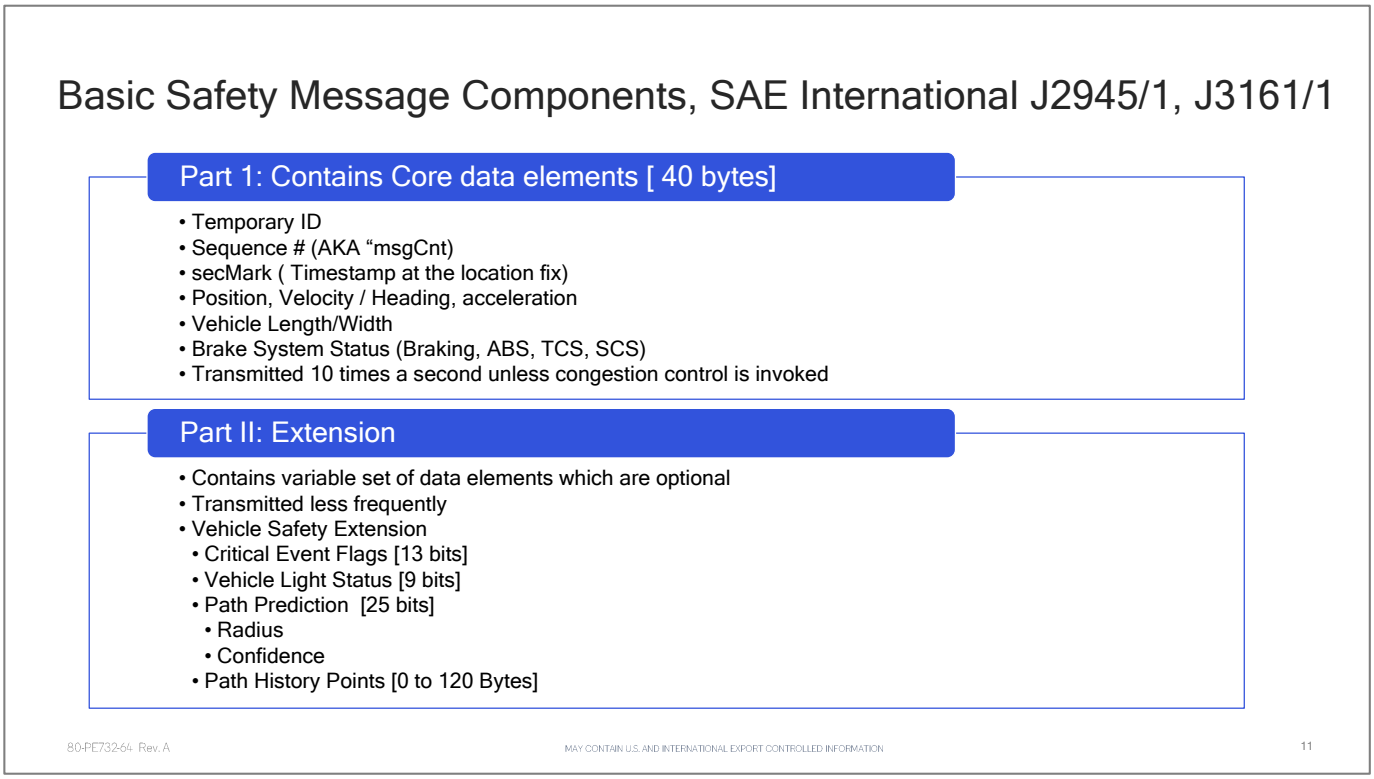


*LCRW = Longitudinal Collision Risk Warning

HF - High Frequency

LF - Low Frequency

Various warnings and informational messages can be realized using the available ETSI messages as explained earlier. The table above lists some of the example scenarios that can be realized by utilizing one or more of the CAM, DENM, SPAT, MAP, etc.



BSM comprises 2 parts, each containing different data elements and extension fields.

BSM is technically extensible via optional fields and regional extensions. However J2945/1 has, for the time-being, “locked down” the content.
Part 1 is sent once every 100 ms whereas Part 2 is sent less frequently.

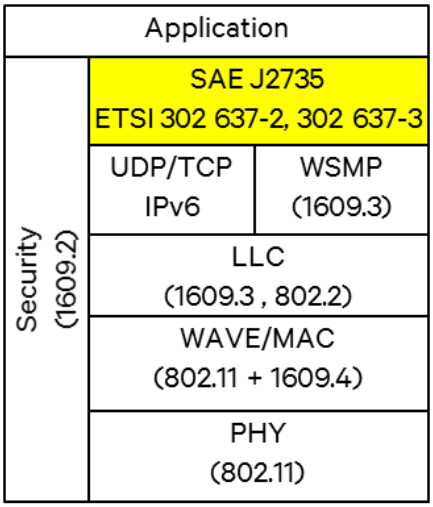
Global ITS-AID/PSID Assigned Maps to 3GPP L2

ETSI

- CAM = 0p24 , 0x24
- DENM = 0p25 , 0x25

SAE International J2735 (specifies in SAE International J2945/0)

- BSM - V2V safety and awareness = 0p20, 0x20
- BSM – Tracked vehicle safety and awareness = 0p21, 0x21
  - Tracked vehicles are railroad trains, light trucks, etc.
- PSM/VRU – Vulnerable road users safety = 0p27, 0x27
- RTCM – Diff. correction, uncompressed = 0p80-00, 0x80
- RTCM – Diff. corrections, compressed = 0p80-01, 0x81
- SPAT, MAP – Intersection safety and awareness = 0p80-02, 0x82
- TIM – Traveler info and roadside signage = 0p80-03, 0x83
- PDM, PVD – mobile probe exchange = 0p80-04, 0x84
- EVA – Emergency and erratic vehicle = 0p80-05, 0x85



PS-ID - Provider Service Identifier

ITS-AID - Intelligent Transportations Systems Application Identifier

Message Encoding

Message type Identified by PSID or ITS Application ID (ISO ETSI) Standard specifies encoding of each application ID

UPER[1] most compact, and preferred, standardized CAM/BSM

Security headers use another encoding DER

SAE International J2735 Data Dictionary is ASN.1 available from SAE International

ETSI version in ETSI TS 102 894

Note 1. Unaligned packed encoding rules (UPER)

SAE International J2945/1 – Excellent easy to read standard, covers most of what any ITS stack needs to do the following:

- Security profile
- Message content
- Distributed application level congestion control

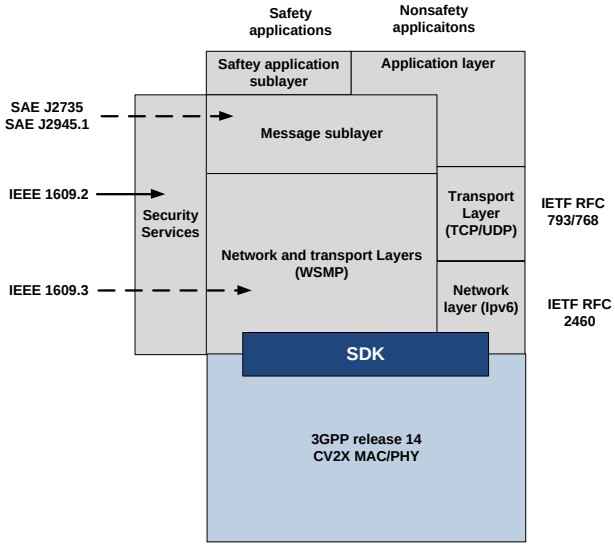
	Digest BSM 0 PH	Digest with 5 PH (91%)	Digest + Max PH	Full Cert BSM, 0 PH	Full Cert BSM, 5 PH (91%)	Full Cert BSM, 15 PH Pts.	Full Cert ABS MAX PH
PH Points	0	5	15	0	5	15	23
Seccurity Type	digest	digest	digest	full cert	full cert	full cert	full cert
Transport header (WSMP/GN)	4	4	4	5	5	5	5
Core Payload Bytes	39	39	39	39	39	39	39
Part II Content header Bytes	1.3	1.3	1.3	1.3	1.3	1.3	1.3
safety extension events Bytes	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Path Prediction Bytes	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Lights status Bytes	1.3	1.3	1.3	1.3	1.3	1.3	1.3
PH Header + Anchor	0.0	2.6	2.6	0.0	2.6	2.6	2.6
Total unsecured BSM+WSMP Payload	50.5	53.1	53.1	51.5	54.1	54.1	54.1
1609.2 Secuty overhead	93	93	93	192	192	192	192
ITS Family ID	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Path History Bytes	0	40	120	0	40	120	184
3GPP PC5 headers	17	17	17	17	17	17	17
Grand Total	162	205	285	262	305	385	449

Qualcomm C-V2X Development Platform - ITS Stack and Applications

A third-party ITS stack and ITS Application is hosted on the applications processor top of the Platform SDK

Supports both SAE International /WAVE and ETSI versions of the ITS stack

In a specific deployment either the SAE International or ETSI ITS stack is used.



SAE International Application and WAVE ITS (upper layer) on 3GPP PHY/MAC

Qualcomm has an externally available Development Platform which has been used extensively for the trials worldwide. It uses the ITS stack from a 3rd party to run on an Application processor. An SDK layer is provided to interface with the C-V2X Radio. The C-V2X MAC/Phy software stack is Qualcomm's deliverable providing the 3GPP based PC5 stack.

Key Takeaways

- ITS protocol stack across different ITS standards are very similar
- C-V2X leverages the upper layers of established ITS standards
- Key ITS messages include
  - For SAE International: BSM, EVA, SPaT, MAP & TIM
  - For ETSI: CAM, DENM, SPaT & MAP
- C-V2X technology can be realized on Qualcomm Development Platforms using either SAE International or ETSI messages
- Qualcomm Development Platform SDK facilitates:
  - Implementation of different vendor ITS stacks as well as
  - Development of different SAE International and ETSI applications