United Kingdom

ZENZIC
SELF-DRIVING REVOLUTION

V2X Architecture

vodafone UTAC A HORIBA COMPANY MIRA commsignia NOKIA

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1 Acknowledgements

The project team led by Commsignia, with support from HORIBA MIRA, Nokia, UTAC Millbrook and Vodafone would like to thank Zenzic for setting up and managing this project as well as the Centre for Connected and Autonomous Vehicles (CCAV) for funding the execution.

2 Abbreviations

3GPP	3rd Generation Partnership Project
4G	Fourth Generation Wireless Broadband
5G	Fifth Generation Wireless Broadband
5GAA	5G Automotive Association
5G-V2X	5G Vehicle-to-Everything
802.11p	IEEE standard for direct communication between road users and with roadside infrastructure
AASHTO	American Association of State Highway and Transportation Officials
ACC	Adaptive Cruise Control
ACEA	European Automobile Manufacturers' Association
ADAS	Advanced Driver-Assistance Systems
AI	Artificial Intelligence
API	Application Programming Interface
AV	Automated Vehicle
BSM	Basic Safety Message
C2C-CC	CAR 2 CAR Communication Consortium
CA	Carrier Aggregation
CACC	Cooperative Adaptive Cruise Control
CAD	Connected Automated Driving
CAM	Cooperative Awareness Message
CAV	Connected and Autonomous Vehicles
CCAM	Cooperative, connected and automated mobility
CCMS	C-ITS Security Credential Management System
C-ITS	Cooperative Intelligent Transport System
CMC	Connected Motorcycle Consortium
CPM	Collective Perception Message
C-V2X	Cellular Vehicle-to-Everything
DATEX II	Data Exchange standard for exchanging traffic information
DENM	Decentralised Environmental Notification Message
DfT	Department for Transport (UK)
DoT	Department of Transportation (US)
DSRC	Dedicated Short Range Communications
E2E	End-to-End
eCall	emergency call
EEI	Energy Efficient Intersection (service)
ERTRAC	European Road Transport Research Advisory Council
eSIM	Embedded SIM
ETSI	European Telecommunications Standards Institute
EV	Electric Vehicle
FCC	US Federal Communications Commission
FCW	Forward Collision Warning

FEA	Fuel Efficiency Advisor
FR1	Frequency range 1 (410 MHz – 7125 MHz [1])
FR2	Frequency range 2 (24250 MHz – 52600 MHz [1])
GBR	Guaranteed Bit Rate
GLOSA	Green Light Optimal Speed Advisory
GNSS	Global Navigation Satellite Service
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IP	Internet Protocol
ISG	Industry Specification Group
ITS	Intelligent Transport Systems
IVS	In-Vehicle Signage
KPI	Key Performance Indicator
LTE	Long Term Evolution
LTE-V2X	3GPP standard for vehicle-to-everything communication
LTE-V2X (PC5)	Interface for direct communication between road users and with roadside infrastructure
LTE-V2X (Uu)	Interface for communication between vehicles and mobile network
MAP	Map Data (message)
MBMS	Multimedia Broadcast Multicast Service
MCM	Manoeuvre Coordination Message
MEC	Multi-Access Edge Computing
MFM	Midlands Future Mobility
MNO	Mobile Network Operator
NCAP	New Car Assessment Programme
NIST	National Institute of Standards and Technology
NSA	non-standalone
OBU	Onboard Unit
OEM	Original Equipment Manufacturer
PSM	Personal Safety Message
PVD	Probe Vehicle Data
QCI	QoS Class Identifier
QoS	Quality of Service
RHW	Road Hazard Warning
RLVW	Red Light Violation Warning
RSU	Roadside Unit
RWW	Road Works Warning
SAE	Society of Automotive Engineers
SDO	Standards Developing Organization
SIM	Subscriber Identity Module
SL	Sidelink
SLA	Service Level Agreement
SPAT	Signal Phase and Time (message)
SRTI	Safety-Related Traffic Information
SVCs	Single Vehicle Collisions
TCU	Telematics control unit
ToD	Tele-operated Driving

TR	Technical Report
TSP	Traffic Signal Priority
UE	User Equipment
USIM	Universal Subscriber Identity Module
V2I	Vehicle-to-Infrastructure
V2M	Vehicle-to-Motorcycle
V2N	Vehicle-to-Network
V2P	Vehicle-to-Pedestrian (also includes cyclists)
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VAM	VRU Awareness Message
VMS	Variable Message Sign
VRU	Vulnerable Road User

3 Executive Summary

Within this document the partners of the Zenzic V2X project, consisting of Commsignia, HORIBA MIRA, Nokia, UTAC Millbrook and Vodafone provide a specification for a V2X architecture. It looks at the key factors which the architecture needs to take account of, ranging from the actors and their needs through to the technological components of a V2X system. The document proposes a scalable and flexible architecture which is capable of meeting the current needs, as well as being capable of evolving as the number of V2X applications increases. The architecture has been implemented as part of the V2X Verification and Validation capability deployed at two CAM Testbed UK locations: UTAC Millbrook and HORIBA MIRA.

4 Document Purpose

This document captures a reference architecture for V2X that CAM Testbed UK could adopt as it seeks to provide flexible and extensible facilities for V2X technology and service test and validation.

V2X ("Vehicle to Anything") is a broad term, covering a multitude of concepts, services and technologies for the exchange of real-time messaging between, to and from road vehicles and users. V2X is being addressed by many different industry consortiums, standards bodies, vendors and operators throughout the world. The original concepts for V2X have been standardised in both Europe (via ETSI), in the US (via SAE International) and in China (via SQE China) and implemented by different manufacturers, enabling initial real-world interoperability trials of "day 1" services that address basic safety scenarios. Additionally, there are a number of industry groups such as C-ROADS and 5GAA producing 'implementation' standards, V2X Services and use case definitions. However, both the standards and the real-world deployments have yet to reach the breadth and level of maturity that enables industry confidence regarding which particular services, architectures and technology choices will prevail, when services do start to scale up (both in terms of volumes of users and breadth of use cases supported).

Therefore, there is much ambiguity as to which V2X-enabled services should be prioritised for first at-scale implementation and deployment and how those services should be implemented. This makes it difficult to specify a definitive architecture for CAM Testbed UK to adopt, that will provide CAM Testbed UK with long-lasting, relevant and competitive capabilities in V2X verification and validation as the industry evolves. But demand for facilities that can enable familiarisation, education and testing of initial / early V2X use cases is emerging, hence a reference architecture is needed which can meet short-term needs and evolve in line with industry evolution.

Some clues for what this flexible V2X architecture needs to accommodate can be taken from the European C-ROADS initiative, various US state DOT trials and the outputs of key industry groups including 5GAA, Data for Road Safety (formerly Data Task Force) and the car2car consortium, together with more specific V2X-related provisions that are starting to appear in UNECE regulations and Euro NCAP roadmaps. An analysis of these initiatives is presented in the document "UK national and international V2X capabilities – status and evolution" from WP2 of the Zenzic project "Ensuring the UK's lead in Global V2X Services".

A detailed review of the current status of V2X is available in the report "UK national and international V2X capabilities – status and evolution" also produced as part of the response to Zenzic RFQ: "Ensuring the UK's lead in Global V2X Services" project.

This document provides the following more specific information, as a guide for CAM Testbed UK as it starts and then builds its capabilities in V2X :

1. A definition of the main V2X Services considered in scope of this architecture
2. A definition of the main actors involved in end to end V2X services and their respective needs
3. A V2X Services Architecture (a layered model) which should remain relatively constant as services and technologies evolve
4. A Technical Implementation Architecture and service-specific technical information to guide investment in specific capabilities at specific facilities. This includes an outline of what elements of the architecture are provided by the Commsignia-led Zenzic V2X pilot demonstration project.

5 Principles and Scope

- The proposed architecture is intended to support a range of V2X-based services and to support the needs of a range of actors involved in end-to-end V2X services.
- The architecture should be flexible to allow new services to be provided based upon existing V2X standards.
- As far as possible all V2X services, messaging and interfaces should be standards based. Given that the standards are still maturing the architecture should be capable of being updated whilst retaining backwards compatibility to allow phased rollout of new V2X services without interruption.
- The architecture should allow easy access to 3rd parties to provide innovative or localised services.
- The architecture should as far as possible be technology neutral and capable of being able to deliver V2X services via any V2X air interface or via any manufacturer's RSUs.
- The architecture shouldn't be limited to currently defined services but should be extensive to provide new services.
- The architecture should cater for the operation and maintenance of the V2X systems.
- This proposed architecture does not imply that it has been fully implemented by the Zenzic V2X project "Ensuring the UK's lead in Global V2X Services" but aims to provide a framework for the enhancement towards a V2X service operating at the national scale.
- This architecture focusses on the European variant of V2X, however most of the principles should be able to apply to the North American and China variants.

6 V2X Services

The services that can be supported by V2X technologies are still being developed and a number of groups are actively working on creating and standardising V2X use cases. These groups include the C-Roads group and the 5GAA group. The following definition of target services to be supported by the architecture are taken from v1.8.0 of the C-Roads specification "C_Roads_WG2_TF2_Service and Use Case Definitions" :

Service	Use Case
In-Vehicle Signage	
	Dynamic Speed Limit Information (IVS-DSLI)
	Embedded VMS "Free Text" (IVS-EVFT)
	Dynamic Lane Management (IVS-DLM)
	Shock Wave Damping (IVS-SWD)
	Other Signage Information (IVS-OSI)
Hazardous Location Notification	
	Accident Zone (HLN-AZ)
	Traffic Jam Ahead (HLN-TJA)
	Stationary vehicle (HLN-SV)
	Weather Condition Warning (HLN-WCW)
	Temporarily slippery road (HLN-TSR)
	Animal or person on the road (HLN-APR)
	Obstacle on the road (HLN-OR)
	Railway Level Crossing (HLN-RLX)
	Unsecured Blockage of a Road (HLN-UBR)
	Alert Wrong Way Driving (HLN-AWWD)
Road Works Warning	
	Lane Closure (RWW – LC)
	Road Closure (RWW – RC)
	Road Works – Mobile (RWW-RM)
	Winter Maintenance (RWW-WM)
	Road Operator Vehicle in Intervention (RWW-ROVI)
	Road Operator Vehicle Approaching (RWW-ROVA)
Signalized Intersections	
	Signal Phase and Timing Information (SI-SPTI)
	Green Light Optimal Speed Advisory (SI-GLOSA)
	Imminent Signal Violation Warning (SI-ISVW)
	Traffic Light Prioritization (SI-TLP)
	Emergency Vehicle Priority (SI-EVP)
Probe Vehicle Data	
	Vehicle Data Collection (PVD-VDC)
	Event Data Collection (PVD-EDC)

In addition to the above services, which are primarily Vehicle to Infrastructure (V2I) and Infrastructure to Vehicle (I2V) based, there are a range of services that can be implemented through direct, ad-hoc, V2X-standards compliant messaging Vehicle to Vehicles (V2V) that are in proximity to each other. These V2V use cases are not defined here, since they do not require the support of any network or infrastructure components to operate and can therefore be fully developed and validated without requiring V2X-specific capabilities within CAM Testbed UK. However, the ability for an infrastructure operator / provider to observe and harvest information from these direct V2V communications is catered for through the Probe Vehicle Data (PVD) service.

The V2X Architecture would enable CAM Testbed UK to offer the ability for interoperability testing between different OEM vehicles, with the results captured through PVD.

Additionally, the architecture allows for additional V2V testing services to be added such as hybrid physical and simulation V2V scenarios, where a mix of physical vehicles or soft vehicles exist alongside simulated vehicles generated by the V2X testbed infrastructure.

V2X Services are agnostic of geographical location and of V2X radio technology although some services may be better suited to specific radio technologies.

7 V2X Actors and their needs

The proposed CAM Testbed UK V2X architecture is defined for use by the following target actors. The CAM Testbed UK V2X architecture should help these actors to familiarise themselves with how V2X services operate, the impact they can have, what is involved in the implementation and operation and give them a means to trial elements of, or complete end-to-end implementations of new services before wider adoption on live roads.

7.1 Road Authorities

- Local and regional road operators
- Central Government / sovereign transport authorities

Road Authorities are responsible for the safe, efficient and environmentally compliant orchestration of traffic on public road infrastructure. Road Operators will require the ability to configure and control information that is sent to road users over V2X, derived from both manual and automated data sources. They also require the ability to gather actionable insights that support their objectives in operating road networks.

7.2 Transport Service Operators

- Emergency (blue light) Service Operators
- Public transport (Bus / MaaS) operators
- Fleet / Car hire operators
- Micromobility service providers

Transport Service Operators operate fleets of vehicles on road networks which provide a mobility service for end users. V2X services can provide geospatially targeted real-time information to improve the efficiency and safety of vehicles and can provide data and insights to support new or improved services.

7.3 Traffic Systems & Infrastructure Technology Providers

- ITS equipment vendors
- Road Infrastructure Data Providers

Traffic systems and infrastructure technology providers offer equipment that is installed at the roadside, to control, monitor and/or communicate with vehicles and road users. Such equipment will need to integrate with V2X services, to enable the co-ordination of traditional roadside equipment (such as traffic lights, traffic sensors and dynamic road signs) with information being exchanged with vehicles and road users via V2X-enabled services.

7.4 V2X Service and Technology Providers

- V2X technology providers (RSUs, OBUs)
- Mobile Network Operators
- V2X Data Providers

V2X Service and Technology providers provide (and sometimes also operate) equipment that is responsible for the creation and transmission of standard-compliant V2X messages between vehicles and infrastructure elements. Their products and services include the components necessary for V2X message construction, routing, wireless transmission, reception and subsequent processing, together with O&M capabilities. This includes both short-range solutions based on DSRC (G5) or C-V2X (PC5) and cellular-based solutions based on 4G/5G.

7.5 Vehicle Manufacturers and their Tier 1 / Tier 2 suppliers

- Cars
- Motorbikes
- Mobility Scooters
- Light commercial vehicles & heavy freight
- Micro Mobility vehicles (bikes, e-bikes, scooters)

Manufacturers (and their subsystem/component suppliers) who sell road vehicles that are equipped with the capability to send and receive V2X messages.

7.6 Travellers (End Users)

- Drivers / passengers
- Pedestrians and cyclists
- Other road users

Owners/drivers/passengers of V2X-enabled vehicles.

8 V2X Services Architecture

Figure 1 provides a generic layered model, showing how the different actors interact with each other to realise V2X services. The six interfaces defined in Figure 1 provide a useful reference point and standard definition for how the specific Actors interwork and are expanded further below.

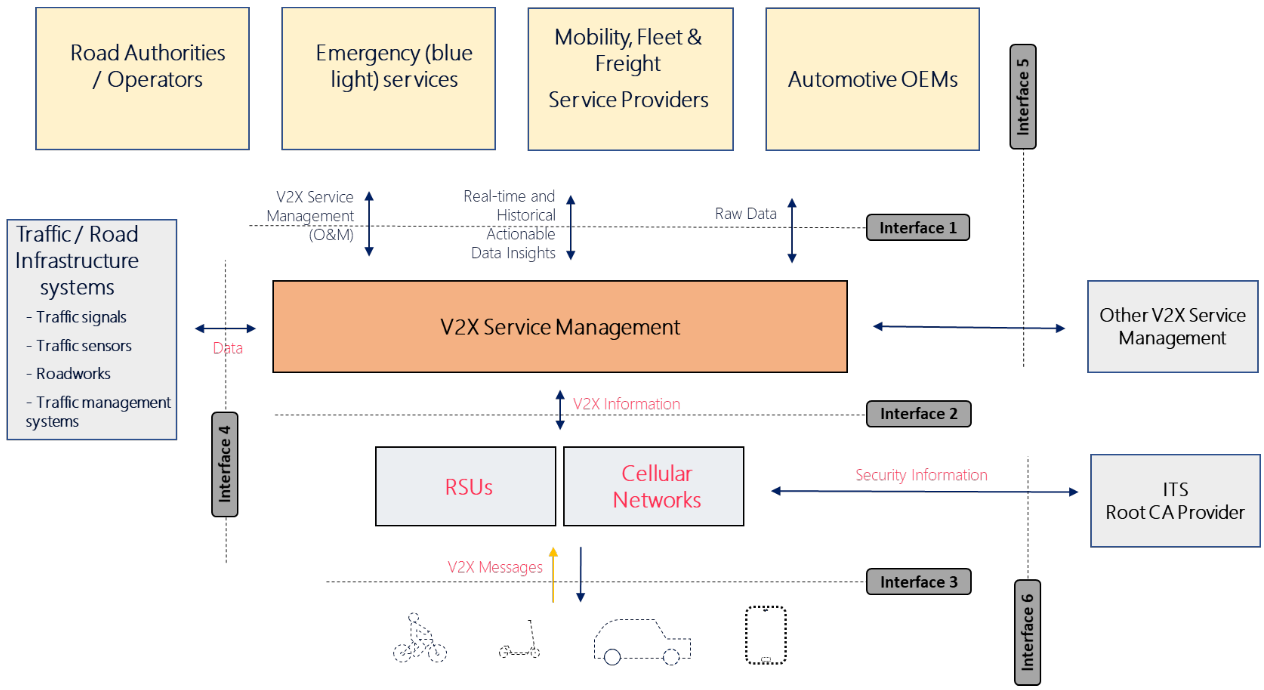

Figure 1: V2X Services Architecture

8.1 Users Interface (Interface 1)

Provides the access point for all of the V2X actors, except Travelers (End Users) to interact with the V2X Services.

This interface uses:-

- The ability to operationally manage the V2X system and estate of RSUs
  - Reconfigure RSUs or update Software versions
  - Detect failing RSU hardware
  - RSU coverage planning
- Access to real time actionable data Insights. Examples of this may be
  - Real time vehicle populations by road section, junction etc.
  - Real time own vehicle positions such as Ambulance fleets, taxis, recover vehicles
  - Real time current road speeds
  - Real time current journey times
  - Real time detected road incidents (stopped vehicle, wrong way driving, crash, traffic jam)

- The ability to define and enable traveller messaging in real time e.g.:
    - Inform travellers of disruptions, traffic jams, accidents, road works, closed lanes, broken down vehicles, animals in the road. Etc.
- The ability to see raw V2X data
    - Limited to testing facilities

Functionality would only be enabled for trusted and authorised actors as appropriate.

There are no standards for this interface.

8.2 RSU Interface (Interface 2)

Provides the interface between the V2X Service Management and RSUs and the equivalent MNO functionality.

The interface provides the operational (data) interface for sending and receiving V2X messages along with the ability to manage, monitor and maintenance RSUs.

Currently there are no European standardised interfaces.

There are a number of North American standards, in development, from NEMA, USDOT, NTCIP for the management of RSUs although they do not plan to cover operational data interface.

This interface is RSU and MNO specific.

8.3 Terminal Equipment Interface (Interface 3)

This interface is the interface between vehicles (V2V) and Infrastructure and Vehicles (I2V and V2V) which is standardised by ETSI/SAE/ISO, covering radio standards and communication protocols.

Note there are variations in both the radio technologies and the higher layers protocols (V2X messages) between Europe, North America and Asia.

The standards for the interface to vehicles over the cellular networks is still in progress, although this interface follows the higher layer (V2X messages) standards of I2V and V2I but uses a variation of the lower layer protocol for transmission of messages.

8.4 ITS systems Interface (Interface 4)

This interface is to connect V2X services with other ITS systems.

This enables the integration of V2X either as a source of data to ITS systems or existing systems as a source of dynamic data for V2X. Examples of the type of system that may be connected would be

- Traffic light controllers (for Signal Phase and Timing) and the V2X Signalised Intersection service
- Roadwork systems which contain up to date information of roadworks
- Traffic sensor systems that detect traffic jams
- Traffic Management Systems so that V2X can provide additional information to Traffic Management Centres.
- Weather service providers.
- Mapping Services providers

The interface is partially standardised by legacy systems and data standards such as DATEXII although in practice each vendor's interfaces are different, if an external interface is provided at all, and my vary with the age of the installed systems.

8.5 Inter V2X Services Interface (Interface 5)

This interface provides a mechanism for federating V2X services between different service providers.

Typically this would be done to allow seamless borders between services i.e. at country borders, however it would also be appropriate for close regional services to be connected and also if regional and national services overlapped.

The interface is standardised by C-Road in the document 'C-ITS IP Based Interface Profile' with 2 interfaces defined Basic Interface and Improved Interface. The C-Roads interface is based upon the Inter Core IF2 Interface.

8.6 PKI Security Interface (Interface 6)

This interface provides access to an ITS PKI certificate provider, providing, validating and updating PKI certificates for trusted V2X providers.

The PKI and ITS trust interfaces are standardised by ETSI for Europe and IEEE for North America.

9 V2X Technical Implementation Architecture

This section looks at the technical aspects of the Services Architecture in more detail. It looks at what has been implemented for the Zenzic "Ensuring the UK's lead in Global V2X Services" project and what remains for future implementation.

9.1 V2X Radio Technology

There are 3 different V2X radio technologies, 2 short range technologies and 1 longer range technology.

Short Range Technologies

- DSRC–V2X. Dedicated Short Range Communication - V2X, based upon the 802.11p radio interface and standardised by ETSI for Europe as ETSI-G5
- C-V2X. Cellular V2X – is a short range radio interface based upon cellular radio interfaces and standardised by ETSI as PC5. There are 2 versions of this interface: Rel 14 based upon the LTE(4G) standard and Rel 16 based upon the NR(5G) standard. Note this does not involve the Mobile cellular network, nor does it require a SIM card.

Both of these technologies require the installation of Road Side Units (RSU) to communicate with vehicles. These RSUs have an effective radio range in the region of up to 500 meters.

Longer Range Technologies

- C-V2X Cellular V2X - this uses the existing Mobile Network its Uu interface. This does require a physical or eSIM card.

This technology does not require any additional hardware to be installed at the road side.

For the purpose of a services architecture, both G5 and PC5 short range radio standards have the same characteristics and will be referred to as RSU-V2X. To avoid confusion with the C-V2X terminology the version of V2X that uses the existing mobile network will be referred to as MNO-V2X.

9.2 Effect of V2X Radio Technology on the Services Architecture

The differences between short range RSU-V2X and the cellular MNO-V2X are:

- RSU-V2X enables very low latency direct Vehicle to Vehicle (V2V) communication but requires the roll out of a network of Road Side Units (RSU) for communication between Vehicle and Infrastructure or vehicle and Network (V2I, I2V, V2N, N2V)
- NMO – V2X does not allow direct V2V communication with vehicle to vehicle communication going via the network V2N2V at the cost of increased latency. MNO-V2X uses the existing mobile networks and does not require the rollout of any additional radio infrastructure.

The difference in latency for V2V communication will impact the ability to implement some services use cases, particularly those involving the need for the car and not the driver to respond quickly.

With the use of edge based computing in the mobile network this additional latency can be reduced and may be sufficiently low for many use cases.

Since the rollout and maintenance of RSUs is expensive it is unlikely to see near 100% coverage of the road network. Thus it is likely that services enabling vehicles to 'see around the corner' will be possible with both RSU-V2X and MNO-V2X but only MNO-V2X will enable reliable services allowing vehicles to 'see over the horizon'. It also follows that that RSU-V2X specific services will be highly localised.

There are several possible types of OBUs catering for the need of different users or vehicles, such as vehicles and their drivers, pedestrians, cyclists, mobility scooters etc. These OBUs can be deployed with or without a Human Machine Interface (HMI) or may be through a mobile handset application.

OBU differences could affect V2X Services they can provide, however this should not affect the V2X Services Architecture which should cater for all types of OBU and radio interfaces.

There are also impacts on the effectiveness of certain V2X services based upon the penetration rate of OBUs, the details of which are outside the scope of this paper.

9.3 Separation of services (data separation)

With MNO-V2X it is possible to separate travellers (end users) into groups and provide tailored services to those groups, which remain private to these groups. Similarly, the raw data sent by those users and any insights derived from these end users could remain private to the end users.

Where data separation is not needed, the specific end user group of 'public' is used, which is accessible to all users.

The Separation of Services can be used to allow targeting of services these may include the provision of V2X test services on public roads, or for specific user groups such a public transport, haulage companies or for testing purposes.

9.4 Users Interface (Interface 1)

There are several different functions provided by the user interface, with all functionality being accessed via a graphical user interface either web browser or via standard openly available applications.

9.4.1 Management of RSU estate.

Provide the operators of RSUs the ability to:

- Remotely configure / re-configure their RSU
- Update software / firmware versions
- Monitor the health statistics of the RSU for example V2X traffic loading, CPU, temperature, memory etc. along with any alarms the device generates.
- Add or remove RSUs from service

The interface must take care to allow only authorised users to access this functionality and to control which users have access to specific RSUs, in the scenario where RSUs are owned and operated by different entities.

Each manufacturer's RSU provides a different O&M functionality and a different technical interface, requiring each RSU model to be separately integrated. This project supports the management of Commsignia RSUs.

The O&M of the C-V2X radio infrastructure is taken care of by the Mobile Network Operator (MNO) with a reliable, highly available, fault tolerant delivery system that is already operating at scale.

9.4.2 Define and Enable Traveller Messaging in Real Time

This interface provides road or fleet operators the ability to directly message travellers in addition to any automatically generated messaging. This could include IVS, RWW or HLN Services.

The interface must take care to allow only authorised users to access this functionality and to control which users have access to specific user groups and geographic locations.

In this project, the interface is implemented with the messages being created by Commsignia Central from information supplied by the 2 test tracks operators. The test track operators will group the messages to create test scenarios. The test track operators are able to dynamically chose which test scenario is active at any particular time and to which user group the messages are directed via a graphical user interface.

9.4.3 Access to V2X data

This interface provides users with access to V2X data.

The interface must take care to allow only authorised users to access specific sets of data. As part of the process for granting access to specific data the principles of data privacy and it's associated legislation (e.g. GDPR) has to be considered, in particular the access to raw V2X data where it may be possible to derive personal information by combining raw CAM data with other readily accessible data.

V2X data is organised and stored in datasets by

- Data direction - Received from vehicles or transmitted to vehicles
- Data type – V2X Message Type CAM, DENM, IVIM etc. or by derived insights such as Vehicle Generated Data (VGD)
- Message route in the case of received data (Cellular or RSU)
- Date and Time
- User group

Access to the historic archive of the datasets is via the Secure File Transfer Protocol (SFTP), with user groups being given their own username and SSH key. There are many freely available SFTP clients that can be used to access the dataset such as WinSCP for MS windows.

9.5 RSU Interface (Interface 2)

This interface provides the method for sending and receiving V2X messages via RSU or Cellular and also for the monitoring and management of the RSU.

There are no standards for this interface and each RSU type will be different. Therefore the architecture needs to be able to handle multiple different protocols and formats. For example, the V2X message PDUs may be need to be encoded in UPER, XER or JER formats and there may need to be an additional Geo Networking information.

The interface also needs to be able to handle the retransmission of the messages if the RSU or Cellular interface does not.

This project has implemented interfaces to Cohda RSUs and Vodafone STEP V2X functionality for IVIM and DENM messages.

9.6 Terminal Equipment Interface (Interface 3)

This interface provides the interface to the travellers (end users) via their OBU or V2X handset.

The interface is standardised across almost all aspects from the radio layer through to protocol, message content and PKI message signing.

The MNO interface to the travellers is not currently part of any standards. It uses the same V2X message standards over a secure MQTT point to point data connection. The interface spec and Software Development Kits for Android and iOS are available upon request.

This project supports CAM, DENM & IVIM messages to with the following standards

ISO TS 14906:2018/Amd 1:2020
ISO TS 14906:2018/Amd 1:2020
ISO TS 19091:2018
ISO TS 19091:2018
ISO TS 19091:2018
ETSI TS 103 301 V1.3.1 (2020-02)
ETSI TS 103 301 V1.3.1 (2020-02)
ISO TS 19321:2020
ETSI TS 102 894-2 - V1.3.1 (2018-08)
ETSI EN 302 637-2 V1.4.1 (2019-01)
ETSI EN 302 637-3 V1.3.1 (2019-04)
ISO_TS_14823
ISO TS 14816:2005/AMD 1:2019
ISO TS 17419:2018
ISO TS 24534-3:2015

The PKI signing of messages is supported if the RSUs used support PKI signing and are configured to sign messages. PKI signing is currently not supported on the MNO interface.

9.7 ITS systems Interface (Interface 4)

This interface provides access to external systems that my either provide data that can be used to create V2X content or use data from the V2X Services.

This project has not implemented any connections using this interface.

9.8 Inter V2X Services Interface (Interface 5)

This interface allows V2X Services to be interconnected for the exchange of messages.

This project has not implemented this interface.

9.9 PKI Security Interface (Interface 6)

This interface is for ITS stations to enrol, authorise and validate security certificates. The interface is standardised by ETSI for Europe and by IEEE for North America.

The interface is implemented and enabled on an individual RSU basis. The Cohda RSUs used in this project support this interface. This interface has not implemented for Vodafone STEP.

The choice of Root CA provider or cypher algorithm is outside the scope of this document.

10 V2X Services Cyber Security

Cyber security must be considered as part of any system architecture. This should include not only the technical architecture but also the processes and procedures of the operating entities.

It is beyond the scope of this document to examine cyber security principles, as this project implements appropriate security controls in line with the following guidance.

10.1.1 Technical Security

The technical design of the V2X system complies with best practice cyber security principles such as those provided by the National Cyber Security Centre https://www.ncsc.gov.uk/.

10.1.2 Operational Security

The operators of V2X systems comply with good operational security principles and have in place effective processes and procedures for: applying good security principles, for monitoring compliance to the standards and for regular review and improvement of the procedures.

10.1.3 Interconnection between systems

All interconnection between systems are, as a minimum, encrypted and all data passing between systems is encrypted in transit.

10.1.4 Data Security

V2X systems can produce a large amount of data and whilst the V2X standards have been written to ensure that the data produced does not directly identify individuals, it is recognised that it might be possible to derive Personally Identifiable Information (PII) when large volumes of data is analysed and combined with readily available external data.

The availability of data to organisations will be limited to processed data, where the processing removes the ability to identify PII (usually this will be some form of aggregation).

If there is a need to make raw V2X data available then suitable Data Processing Agreements will be established.

Raw data will be stored and protected on the basis that it contains non sensitive PII in accordance with GDPR regulations.

11 Test Services

The V2X services architecture must provide services to CAM test bed UK for Off and On Road Test facilities to enable the various actors identified in this paper to be able to test existing services and try out new services before they are rolled out.

The V2X services architecture must provide a logical route for testing of services in their development from simulation to live deployment. Different manufacturers need to be able to test their components as part of a complete systems and where appropriate the interoperability of components from different manufacturers.

The Services Architecture needs to provide access to data and logs from appropriate points in the system to allow testers to verify and validate their components.

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