Requirements Identification for Vehicle-to-Everything and Internet of Vehicles dedicated 5G Slices

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Abstract — **Vehicle-to-Everything (V2X) communications, Internet of Vehicles (IoV) based on V2X and their services have been intensively studied and developed in the last decade. The V2X supports a large range of applications, such as safety oriented, vehicular traffic optimization, autonomous driving, infotainment and auxiliary operations in vehicular area. Various stakeholders/actors are playing roles in such a complex system, e.g., regulators, authorities, service or network providers, operators, manufacturers, tenants and end users. Therefore, to specify and design a specific V2X/IoV system, one should first identify the ecosystem actors and then derive in a structured way the system requirements, while harmonizing needs coming from different entities. The 5G slicing technology is seen as a strong candidate to support V2X communications, in multi-tenant, multi-domain, multi-operator and end-to-end contexts. The 5G slicing allows construction of dedicated slices, to meet particular V2X requirements. Given the large variety of environments and actors involved in a planned V2X system, the identification of the system requirements is a complex process that could benefit from a structured approach. This paper is an extension of the work presented at IARIA Mobility 2020 Conference. It contributes to develop a methodology to perform a top-down systematic identification of requirements for a V2X system supported by 5G dedicated slices. Examples from a recent research project in 5G area are given.**

Keywords — Vehicle-to-Everthing; V2X; Internet of Vehicles (IoV); 5G slicing; Ecosystem; Business model; Stakeholders; Requirements, Software Defined Networking; Network Function Virtualization; Service management.

I. INTRODUCTION

This paper is an extension of a previous paper [1] published in the proceeding of the IARIA Mobility 2020 Conference.

The Vehicle-to-Everything (V2X) communications and services include several types, where X can be: vehicle (V2V), road/infrastructure (V2R/V2I), pedestrian (V2P), vulnerable road user (VRU), network (V2N) - including cellular networks and Internet, sensors (V2S), power grid (V2G) and home (V2H) [1]. The V2X systems can be deployed in single or multi-tenancy, multi-operator and multi-domain contexts. V2X support a large range of services/applications: road safety (warnings, notifications, assistance); road traffic optimization and management; autonomous driving; infotainment. Recently, V2X has been extended to *Internet of Vehicles (IoV)* aiming to create a global network of vehicles – enabled by various *Wireless Access Technologies* (WAT) [1][2].

The V2X/IoV systems are complex, involving several technical and organizational entities, which cooperate in a business *ecosystem V2X-ES (*or, equivalently, business model V2X-*BM).* The participating entities/actors can be organizations/ stakeholders such as technology suppliers, distributors, road authorities, customers/users, municipalities, regulators, vehicle manufacturers *Original Equipment Manufacturers* (OEM), government agencies, etc. The above entities interact with each other, in order to achieve together the general goals of the system. A large variety of use cases and deployments can exist, each one having different functional and performance–related requirements. Apart from general V2X requirements, a specific set should be identified and adapted to the particular V2X-ES selected (including the use cases targeted), and also to some technological solutions and constraints.

Initially, defined as LTE V2X in 3GPP Release 14, C-V2X has been defined as a platform for an evolution track that further enables enhancements in Releases 15, 16, etc. for LTE-Advanced Pro and for the 5G New Radio (NR) [3-5].

Advanced solutions - 5G [6-8] and especially the slicing technology (based on virtualization and softwarization) - can successfully support V2X. 5G can provide dedicated types of services to satisfy various (vertical) customer/tenant demands in a multi-x fashion (the notation –x stands for: tenant, domain, operator and provider) [9-12]. A *Network Slice* (NSL) is a virtual dedicated managed network, isolated from other slices (w.r.t. performance and security), but they share the same infrastructure.

The functional components of a network slice are Physical/Virtual Network Functions (PNFs/VNFs). They are chained in graphs, in order to compose services dedicated to different sets of users. The slices are programmable and expose their capabilities to the users. The actual run-time entities are instantiated slices (NSLIs), whose life cycles are controlled by the management and control entities belonging to the *Management, Orchestration and Control* architectural Plane (MO&C).

The *Network Function Virtualization* (NFV) [13-15] and *Software Defined Networks* (SDN) technologies can cooperate [16] to manage, orchestrate and control the 5G sliced environment. The 3GPP [7][8] has defined three fundamental categories of 5G slices: *Massive machine type communication (mMTC); Ultra reliability low latency communication (URLLC); Enhanced mobile broadband (eMBB).*

Several proposals of V2X systems based on 5G slicing exist, e.g., [17-21]. The V2X dedicated 5G slices can provide the required capabilities for multiple tenants, while working mono or multi-domain infrastructure. However, the basic reference slice types – like eMBB, URLLC and mMTC cannot fully solve the needs of the heterogeneous features of V2X services [20]; additional customization of V2X oriented slice is necessary.

The definition of BMs/ESs, essentially determines the entities, their roles and responsibilities in a system; out of these, one can derive the system requirements and functional architecture. In V2X area, the 5G PPP Automotive Working Group, Business Feasibility Study for 5G V2X Deployment [22]) outlined the BM picture; however, they shows a lack of a complete vision on different stakeholders roles, necessary investments, required rollout conditions, and expected profit from *Connected and Automated Mobility* (CAM) services.

This paper contributes to develop a methodology to perform a top-down and complete identification of requirements for a V2X system supported by 5G dedicated slices. The paper structure is described below. To make the paper more self-contained, the first two sections introduce the elements of the ecosystem/business model. Specifically, Section II offers a summary of ES/BMs in a 5G sliced system, while Section III completes the general ES/BMs and adapt them to 5G V2X environment. Section IV proposes our methodology for systematic requirements identification. Section V details V2X- 5G general requirements. Finally, Section VI develops the requirements identification for a V2X- 5G slice in a structured and top-down way. Section VII summarizes conclusions and future work.

II. 5G SLICING ECOSYSTEM

This section will shortly present a few relevant ES/BMs proposed for 5G sliced systems, which will be further extended for V2X environment in Section III.

The work [10] (A. Galis), introduces a basic ES/BM for 5G slicing, including several actors:

Infrastructure Provider (InP) - owns and manages the physical infrastructure (network/cloud/data centre). It could lease its infrastructure (as it is) to a slice provider, or it can itself construct slices (the BM is flexible) and then can lease the infrastructure in network slicing fashion.

Network Slice Provider (NSLP) - is typically a telecommunication service provider (owner or tenant of the infrastructures from which network slices are constructed). The NSLP can construct multi-tenant, multi-domain slices, on top of infrastructures offered by one or several InPs.

Slice Tenant (SLT) - is a generic user of a specific slice, including network/cloud/data centers, which can host customized services. A SLT can request from a *Network Slice Provider* (NSLP) to create a new slice instance dedicated to support some SLT specific services or subscribe to a convenient existing one. The SLT can also lease virtual resources from one or more NSLPs in the form of a virtual network, where the tenant can realize, manage and then provide *Network Services* (NS) (composed of *Network Functions (NFs))* to its individual end users. A single tenant may define and run one or several slices in its domain.

End User (EU): consumes (part of) the services supplied by the slice tenant, without offering them to other business actors.

The above model is operational only, i.e., it does not detail all external entities, which may influence the system architecture and functionalities, e.g., Standards Developing Organizations (SDOs), policy makers, etc. The above BM is its recursive (see Ordonez et al., [11]); a tenant can at its turn offer parts of its sliced resources to other tenants, and so on.

The 5G-PPP Architecture Working Group [7] introduces a BM in which the main entities are: *Service Customer (SC), Service Provider (SP)* and *Network Operator (NOP).* The SP role is actually an umbrella, comprising three possible sub-roles, depending on the service offered to the SC: *Communication SP, Digital SP* and *Network Slice as a Service (NSLaaS) Provider*. The SPs must design, build and operate high-level services, using aggregated network services. The NOP orchestrates resources, potentially offered by multiple *virtualized infrastructure providers* (VISP) and uses aggregated virtualized infrastructure services to design, build, and operate network services that are offered to SPs. Another actor could be *Data Center SP (DCSP),* which designs, builds, operates and offers data center services. A DCSP differs from a VISP by offering "raw" resources (i.e., host servers) in rather centralized locations and simple services for consumption of these raw resources. In practice, a single organization can play one or more roles of the above list.

Other similar models have been proposed [23-27], some of them being more refined than the basic previous one. Several recent Public Private Partnership (PPP) Phase I/II research projects have as objectives 5G technologies [10]. Some of them extended the list of role definitions, to allow various possible customer-provider relationships between verticals, operators, and other stakeholders.

III. 5G V2X ECOSYSTEM

This section provides an extended example of ES/BM for 5G V2X. It is forecasted that advanced CAM services (e.g., high-definition (HD) maps support, highway chauffeur, tele-operated driving, platooning, fully autonomous driving, extended sensors, etc.) will be enabled through next-generation 5G V2X defined in 3GPP Release 16 specifications [4-5][24].

The 5G PPP Automotive Working Group [22] has defined a general 5G V2X-ES, capturing operational features and business relationships. One can distinguish among *operational* BM including: *5G industry* (network operators, network and devices vendors), *automotive industry*, *road infrastructure operators, users* and *external* entities such as *Standards Developing Organizations* (SDOs), and *policy makers - the latter providing input requirements for the operational BM* (Figure 1).

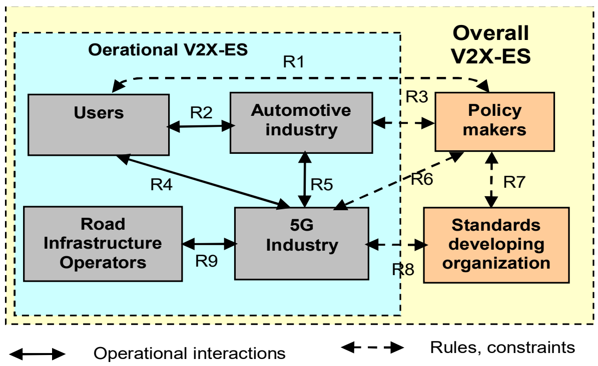

Figure 1. The main stakeholders and interactions in 5G V2X-ES (adapted from [22])

5G industry - includes any business entity developing or using/providing 5G-related services, e.g., *Mobile Network Operators (MNOs), Telecom vendors, Cloud providers*, device providers, software developers, etc.

Automotive Industry (AutoIn) - includes car *Original Equipment Manufacturer (OEMs)* (e.g., car/component manufacturers), Tier 1 suppliers, CAM SPs HD map providers and other automotive-specific technology providers. This category brings the automotive expertise and services (including mobility services) to customers (business and consumers).

Road Infrastructure Operators (RIO are national or regional entities performing deployment, operation, and maintenance of physical road infrastructure. They may also manage road traffic operations, own or operate the toll system, etc. *Users can be* drivers, vehicle owners, passengers or pedestrians.

The *external* entities are providing significant inputs to the operational V2X-ES actors, strongly influencing the requirements to be met by the overall system.

The set of SDO is large: 3rd Generation Partnership Project (3GPP), European Tele-communications Standards Institute (ETSI), Internet Engineering Task Force (IETF), Internet Research Task Force (IRTF), Institute of Electrical and Electronics Engineers (IEEE) and 5G-related alliances such as Next Generation Mobile Networks (NGMN), Industrial Internet Consortium (IIC), 5G Automotive Association (5GAA) and Automotive Edge Computing Consortium (AECC). For safety-related 5G applications (e.g., *Advanced Driver Assistance Systems* - ADAS and autonomous driving), pertinent standards developing organizations such as International Organization for Standardization (ISO) may be also relevant players.

Policy Makers (PM) are the highest authorities that regulate the relationships within the V2X-ES. They are international or national government authorities or organizations defining the legal framework and policies, such as road and transport authorities or telecom regulators. The ITU as well as national spectrum regulators belong to this category.

The detailed description of the interactions between the stakeholders is given in [23]. They will influence the system requirements addressed to different functional blocks. The interactions are shortly described below.

The policy makers and SDOs provide sets of rules to the operational entities and get feedback from the latter. The interactions are: *R1 (Users - PMs)*, *R3 (PMs - AutoIn), R6 (PMs - 5G Industry), R8 (SDO - 5G Industry)*. The *R7 (PMs -SDO)* represents cooperation between SDOs and policy makers in order to harmonize their specifications. The interactions inside the V2X-ES operational part are: *R2 (Users – AutoIn, R4 (Users - 5G Industry), R5 (AutoIn - 5G Industry), R9 (5G Industry - RIO)*.

Usually, the 5G network providers will own and operate most or parts of the network infrastructure. However, RIOs may participate in the deployment of 5G V2X and provide or facilitate licenses or other infrastructure requirements that are under their responsibility (PMs are also involved here). The 5G Industry shall offer communication services to the RIO based on commercial agreements.

The 5G part can be split into Radio Access Network (RAN) infrastructure provider and cloud infrastructure provider (central data centers providing virtual resources, such as computing, storage, and networking). In practice, the roles of 5G network providers can be taken by the Mobile Network Operators (MNOs), but is possible that RIOs deploys or operate (parts of) the 5G V2X network, directly providing the necessary coverage for CAM services to the users. The model in Figure 1 is general; potentially, any actor (e.g., a road operator) could invest in network deployment.

Another similar V2X-ES/BM is adopted in the research projects 5GCAR [25][26].

Actually, the variety of involved (directly or indirectly) actors and also generating requirements for a V2X-ES/BM, is still larger than that described in Figure 1. Actors providing key services for the automotive sector can be split in two major categories:

- service providers of enabling platforms, which manage the data and allow services to be built on top of the data;
- connectivity providers, which construct and manage connectivity facilities over cellular networks. Inside each category several types of actors can be included.

A non-exhaustive list of actors comprises: *Connectivity Players* (MNOs, Transport Services Providers, (TSPs), ICT Solution & Cloud Platform Providers, Intelligent Transportation System (ITS)); *Automotive OEMs* (Cars, Trucks); *Suppliers* (Tier 1 & 2 (System Integrators), Wireless Module Vendors, Chipset Vendors, Software/Solutions, Middleware, Over the Top Services Providers (OTT), Connectivity/ Bluetooth, Databases, etc.); *Application platforms* (Software - based, Fleet/ Commercial, Autonomous Driving, Smartphone Platforms); *Business Users* (Public Transport, Company Fleets, Freight, Car Rental, Taxi Fleets, Delivery systems, Emergency Response systems); *Consumers* (End user consumers, Families, Small Office Home Office (SoHo); *Application types* (Mobility as a Service, Maps & Navigation Telematics / Tracking, Communications Safety & Maintenance, Media & Entertainment, Productivity). More than these, *additional stakeholders* can play specific roles: Insurance, Dealers, Auto Repair, Regulatory Bodies, Local Authorities (Government, Law Enforcement, Smart City, Road Operators), Location-based commerce players, Security infrastructure and services providers.

The above large picture clearly shows that the process of collecting and aggregating system requirements for a V2X system is really a challenging one and a methodology for this would be useful.

IV. Requirements Identification Methodology

This section will outline a methodology to structure the process of system requirements identification with example of a use case - V2X system 5G-sliced based. This will be shortly named "SYSTEM".

A. The Business Model Impact on Requirements

The V2X-ES/BM (Section III) will be considered and particularly the operational part of the BM. The target is to identify the system requirements for a V2X-5G sliced system. The factors outside the operational BM itself will be called "external". The influence of them can be captured by some *Assumptions, Dependencies and Constraints (ADC).*

The ADCs are expressed as *initial - general* (*predefined) statements* derived from both the environment in which the SYSTEM will work and from its main objectives. They can also represent *predefined restrictions* obtained from SYSTEM scope. So, the ADCs also establish the limits of the SYSTEM related to services offered, technologies used and the scope and its relationship with its environment.

The *assumptions* are factors considered to be true during the SYSTEM life cycle. If changed, they may affect negatively the system outcomes. They include, but are not limited to, End-User characteristics, technology used, resource availability, and funding availability. Some external *dependencies* may exist, that can affect the system requirements specification (SRS). They are outside of the system scope of control and must remain true for the SYSTEM life, to succeed. (e.g., an application relies on a different application, outside the SYSTEM, to get specific data).

The *constraints* are factors to be obeyed by the SYSTEM; they can impose rules, can limit the system scope and functionality, etc. Here, one can include (but not limited) regulatory policies, e.g., coming from SDOs and policy makers (see Section III, V2X-ES/BM). Also, one may have limitations related to infrastructure, technologies, resources and licensing. Constraints are imposed on the solution by circumstance, force, or compulsion. They limit the options available to the system design by imposing immovable boundaries and limits.

The *ADCs* may be expressed at two levels: *Business (High) level* – resulted from business or regulation considerations; *Technical (Low)/ level* – usually derived from the former (expressed as technical sets or can be directly expressed in technical form.

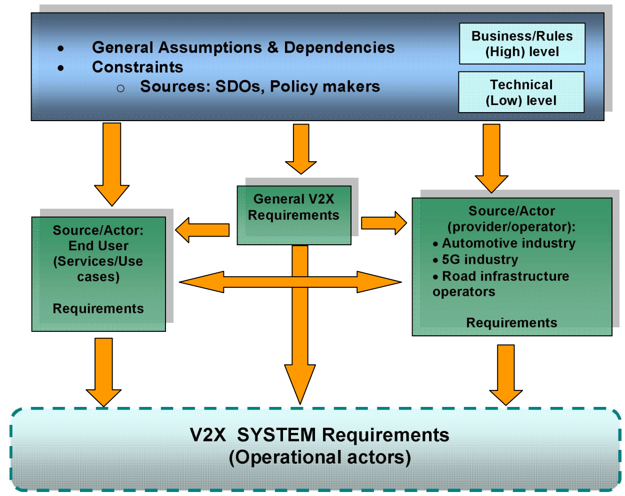

Figure 2. Requirements identification methodology for a V2X system

The *ADCs scope* is *global* to a multi-domain environment if they are related to the SYSTEM as a whole. However, the ADCs can also be applied recursively to subsystems. There can be a mapping *1-to-1* or *1-to-many* between an ADC statement and a requirement in the sense that a given ADC can induce a single system requirement or several ones.

The Figure 2 shows the relationships between entities. The general ADCs can influence directly the *General, User* and *Provider Requirements.* The *End-User Requirements* and *Provider Requirements* specify refinements of the assumptions from their point of view and introduce additional specific requirements, which will be finally mapped on system requirements. Two generic sources/actors issuing requirements are defined: *End-User (usage scenarios)* – defining requirements to be met by the SYSTEM in order to satisfy the high-level services scenarios and user needs; *Provider/Operator* – defining requirements to be met by the SYSTEM to satisfy the provider/operator needs (can be specific to the development, exploitation and maintenance).

A bi-directional interaction arrow between *End-User (usage scenarios)* and *Provider/Operator* may exist because: a. Some *End-User* needs will influence the *Provider/Operator* choices if wanting to satisfy the user needs; b. Some *Provider/Operator* business or technical decisions may affect or limit the range of requirements asked from the system by the *End-User*.

B. Requirements Taxonomy

In a simplified view, two generic actors/business entities are generating requirements: *customer* and *provider*. The customer asks services from a *provider* and therefore this induces some requirements on provider side. In a V2X system one can consider as generic customers the entities providing applications and services to real end users. The providers could be *5G industry* (network operators, network and devices vendors), *automotive industry*, *road infrastructure operators, etc.* They may also impose a set of requirements upon the system, which is managed by it as a consequence of: some ADCs that have been already generally defined and/or some own business and technical considerations.

The requirements categories can be: *Functional* - related to the correctness, which the functions of the system should fulfil; *Non-functional* – related to flexibility, reliability, availability, scalability, security, traffic capacity, performance metrics, etc. Note that, generally, depending on the system role, some non-functional requirements can be included in the functional category (e.g., security).

One can distinguish two levels of expressing requirements: *Business/Rules (high) level* – they are resulted from business considerations or regulations; *Technical (low) level* - usually translated from the former in a set of technical ones, or can be directly expressed in technical form.

The requirements may have one of the three scopes: *Global* to a multi-domain environment, i.e., referring to a larger environment than SYSTEM scope. Such requirements will characterise the environment in which the SYSTEM will act. They are actually needed and should be fulfilled in order that SYSTEM can smoothly cooperate in end-to-end environment with other systems. Actually, these global requirements are expressed as general ADCs or derived from them; *Local* to "SYSTEM" (Local_SYSTEM); *Local* to a *subsystem* of the SYSTEM (*Local_subsystem*).

One can define as a *class*, a "dimension" or a "point of view" on a given requirement. Therefore, the same particular requirement may belong to several classes. We may have:

Specific function class - defining the specific requirements of a functionality or subsystem. On the vertical architectural vision, it is not strictly related/ limited to a given architectural layer.

Architectural class - related to one or more architectural layers set seen as a whole.

The degree in which some requirements have to be met are: *Mandatory: must be met* (during system validation the decision on their fulfillment is *yes* or *no*); *Trade-offs:* they are more or less quantitatively met; note that mandatory requirements could be seen in some cases as lowest limits of the trade-offs requirements.

V. 5G V2X General Requirements

This section will shortly present the general 5G V2X requirements, which are coming from SDOs, Policy makers, V2X application scenarios (serving the users) and 5G industry actors. Then, for different use cases, specific refined requirements should be derived.

Support of the CV2X requirements has been introduced for Long Term Evolution (LTE) in 3GPP Release 14, 15 [3], and then, with regards to 5G, Release 16 has been completed in 2019 [4-5][24].

The document 3GPP TS 22.186 V16.2.0 (2019-06) "Enhancement of 3GPP support for extended *eV2X* scenarios", Stage 1 (Rel.16) [4] specifies the general requirements for eV2X based on 5G. The generic SYSTEM considered in the Section IV will be here a 3GPP System.

The service requirements to enhance 3GPP support for V2X are grouped in six areas: General aspects (interworking, communication-related requirements valid for all V2X scenarios); Vehicles platooning; Advanced driving; Extended sensors; Remote driving; Vehicle quality of service support. In a slicing solution one can design a specific slice to serve a given scenario/use case, e.g., platooning, advanced driving, extended sensors, etc., or a more complex slice could offer several services. Of course, the system requirements will strongly depend on such a choice.

As an example, advanced driving enables semi-automated or fully automated driving. Longer inter-vehicle distance is assumed. Each vehicle and/or Roadside Unit (RSU) should share data obtained from its local sensors with vehicles in proximity, thus allowing vehicles to coordinate their trajectories or manoeuvres. In addition, each vehicle should share its driving intention with vehicles in proximity. The benefits of this use case group are safer travelling, collision avoidance, and improved traffic efficiency.

A relevant aspect of eV2X applications is the *Level of Automation (LoA)*, which reflects the functional aspects of the technology and affects the system performance requirements. In accordance with the levels from SAE Int'l. Std. J3016", US Homeland Security Digital Library, "Self-Driving Cars: Levels of Automation", March 2017, the LoA are: 0 – No Automation, 1 – Driver Assistance, 2 – Partial Automation, 3 – Conditional Automation, 4 – High Automation, 5 – Full Automation. A general 3GPP system should be able to be customized for all levels of automation.

The document 3GPP [4] defines general requirements for a 3GPP system supporting V2X, to be met by any particular V2X system, irrespective if slicing technology is used or not. Considering the taxonomy developed in Section IV, these requirements are applied for the overall system and belong to the architectural class, i.e., they can affect several layers of the functional layered architecture. Given the importance of security, confidentiality and reliability capabilities in V2X systems, those specific requirements have been included in the functional categories. Note: when "User Equipment" (UE) appears in a requirement text, actually it means "UE supporting V2X applications".

A. Functional 5G-V2X requirements-3GPP

The 3GPP system shall support

- a defined communication range for a message transmitted by a UE;
- the message transfer for group management operations as requested by the application layer;
- message transfer among a group of UEs;
- message transfer between two UEs belonging to the same group of UEs;
- confidentiality and integrity of message transfer among a group of UEs;
- relative lateral position accuracy of 0.1 m between UEs;
- high connection density for congested traffic;
- control the UL and DL reliability of transport of V2X

communications, depending on the requirement of V2X application;

- message transfer of type UE-UE and UE-[UE-type RSU] (UEs could be or not subscribers of the same PLMN);
- discovery and communication between UEs supporting the same V2X application;
- the operators to select which 3GPP RAT to use for a V2X application;
- a UE to obtain network access via another UE supporting V2X application;
- a UE to discover another UE supporting V2X application that can offer access to the network;
- switching between direct 3GPP connection and indirect 3GPP connection via a UE;
- confidentiality and integrity of message transfer between a UE and network, when the UE is using an indirect 3GPP connection;
- a UEs to use *New Radio (NR)* direct communication when the UEs are not served by a RAN using NR;
- UEs to use *E-Universal Terrestrial Radio Access* (E-UTRA) for direct communication when the UEs are not served by a RAN using E-UTRA;
- an RSU to be able to communicate with up to 200 UEs;
- confidentiality and integrity of message transfer between a UE and a V2X application server;
- provision of addressing information (e.g., IP address) of V2X application server(s) to the UEs;
- the UE to use multiple 3GPP RATs (i.e., NR & E-UTRA) simultaneously for direct communication.

B. Non-functional 5G-V2X requirements

The 3GPP system shall

- optimize the communication between UEs belonging to the same group and in proximity;
- support efficient coordination of radio resources used (spectrum utilization and reliability);
- minimize the impact to E-UTRA(N) by UE supporting only New Radio (NR) based V2X communication;
- minimize the impact to NR by UE supporting only E-UTRA based V2X communication;
- in case the UEs are subscribers to different PLMNs, there shall be no service degradation of the message transfer.

C. Other 5G V2X General Requirements

Apart from requirements defined in Subsection A, still more general requirements can be identified, for 5G V2X systems and also specific ones, in order to support V2V, V2I, V2N, V2P, V2S, V2H scenarios in multi-domain, multi-operator/provider, multi-tenant contexts.

Let us consider for instance, the Mobile Network Operator (MNO) as a principal actor belonging to the 5G Industry category, in a general 5G-V2X-ES/BM environment. Usually, the MNO owns and manages the physical and logical (virtualized) infrastructure, to support the above services. Specific sets of requirements can be identified for 5G dedicated slices, provided by MNO, for V2V, V2I, V2N, etc. However, more general aspects are still open issues in V2X area.

For critical vehicle functions and improved safety, connectivity is demanded from MNO but also for the delivery of audio, video, social media access and location-based services, among others, in daily driving. However, there is still lack of flexibility for vehicle owners to choose the MNO to serve their vehicles. Currently, the connected service packages integrated in vehicles are limited to a single designated provider. From a business perspective it is a future requirement that vehicle owners may select their MNO, as they do for their smart phones today. So, interoperability of vehicles among available cellular networks will ensure redundancy for critical safety features and will result in better value and service for consumers. Such a multi-MNO model is proposed in the work [28][29] as an extended business model including several MNOs, while sharing the same infrastructure. Also, some other entities are defined in the BM, e.g., location-based services providers, cloud providers, intermediate bodies, etc.

The mobile system should provide "predictive QoS", i.e., inform the vehicle of connectivity quality changes to be provided in the future so that the vehicle could decide to switch from autonomous driving mode to manual driving mode (factors: weather conditions, road situation, network availability at the vehicle position/location, etc.).

D. General requirements for applications

The large range of V2X applications generates a lot of requirements. Here we only give some examples of general requirements [31]. We denote with VAE, a *V2X Application Enabler.* Considering the taxonomy of the Section IV the requirements below belong to the architectural class and are focused mainly on the functional application layer.

- The VAE client and the VAE server shall support
  - one or more V2X applications;
  - obtaining information of the available V2X services (e.g., identified by V2X service ID) from the V2X application;
  - obtaining information of the associated geographical area from the V2X application;
- The VAE client shall be able to communicate to multiple VAE servers
- The VAE capabilities should be offered as APIs to the V2X applications;
- the VAE capabilities shall enable V2X UEs to obtain
  - the address of available V2X application servers associated with served geographical area information;
  - the information of available V2X services (e.g., identified by V2X service ID).

Specific requirements are defined for V2X group communication, V2X dynamic groups, File distribution capability, V2X application message distribution, Service continuity.

TABLE I. PERFORMANCE REQUIREMENTS FOR ADVANCED DRIVING (simplified, adapted from [4])

Note 1: The reliability required for all scenarios is higher than 99.9%
Note 2: All UEs are supposed to support V2X applications.

Communication scenario description		Payload (Bytes)	Tx rate (Message/Sec)	Max E2E latency (ms)	Data rate (Mbps)	Min required Communication range (meters) (NOTE 4)
Scenario	Automation Degree					
Cooperative collision avoidance between UEs		2000 (NOTE 5)	100 (NOTE 5)	10	10 (NOTE 1)	
Information sharing for automated driving between UEs	Lower	6500 (NOTE 1)	10	100		700
	Higher			100	53 (NOTE 1)	360
Information sharing for automated driving between UE and RSU	Lower	6000 (NOTE 1)	10	100		700
	Higher			100	50 (NOTE 1)	360
Emergency trajectory alignment between UEs		2000 (NOTE 5)		3	30	500
Intersection safety information between an RSU and UEs		UL: 450	UL: 50		UL: 0. 25 DL: 50 (NOTE 2)	
Cooperative lane change between UEs	Lower	300-400		25		
	Higher	12000		10		
Video sharing between a UE and a V2X application server					UL: 10	

NOTE 1: This includes both cooperative maneuvers and perception data exchanged using two separate messages within the same period of time (e.g., required latency 100ms).
NOTE 2: This value is referring to a maximum number of 200 UEs. The value of 50 Mbps DL is applicable to broadcast or is the maximum aggregated bitrate of all the UEs for unicast.
NOTE 3: Sufficient reliability should be provided even for cells having no values in this table
NOTE 4: This is obtained considering UE speed of 130km/h. Vehicles may move in different directions.
NOTE 5: These values are based on calculations for cooperative maneuvers only.

E. Example of 5G V2X Requirements for Specific Scenarios : Advanced Driving

Specific scenarios have different requirements; therefore, a slicing approach is attractive. As an example, the TABLE I shows the performance requirements for a 5G-V2X system, dedicated to advanced driving adapted from [4]. The requirements are coming from the use cases scenarios. Their level is *Technical (low),* specifying quantitative ranges for different parameters. Their scope is system-wide, i.e., addressed to the system as a whole. However, after defining the system architecture and subsystems, these requirements should be mapped on those specific subsystems mainly involved to contribute to achieving the required ranges.

Similar examples of technical requirements are identified in [4] for other scenarios like Vehicles platooning, Extended sensors, Remote driving and Vehicle quality of service support.

VI. 5G V2X Slicing Requirements

The slicing solution to realize 5G V2X systems should of course take into account the general requirements issued by different participating actors in the 5G V2X ES/BM. However, it has been shown (C. Campolo, [20]) that V2X services require complex features, which do not map exactly on the basic reference slice types: eMBB, URLLC and mMTC. Therefore, dedicated V2X slicing solutions have been proposed [17][20][30]. This paper space does not allow to detail and structure all the aspects of 5G V2X slices requirements in the manner presented in Section IV. So, an outline of more relevant challenges will be presented here.

Traffic safety and efficiency oriented slices (use cases - V2V, V2P, V2I) should be able to: transport and process periodic and event-driven messages (carrying position and kinematics information of vehicle); allow vehicles to broadcast messages to surrounding environment; assure low latency and high reliability requirements.

Autonomous driving oriented slices (use cases - V2V, V2I, V2N) should: enable ultra low-latency V2V RAT connection mode; support additional RAN/Core Network (CN) functions (e.g., for network-controlled resource allocation over the interface PC5 - in eNBs); support mobility, authentication, authorization and subscription management (in Mobility Management Entity – MME and Home Subscribers System – HSS); support low-latency and reliable video/data exchange needs by the V2X Application servers (AS), deployed at the network edge.

Tele-operated driving slices should: assure ultra-low latency and highly-reliable E2E connectivity between the controlled vehicle and the remote operator (typically hosted outside the CN; data flows passes through a Packet Gateway P-GW); identify the special circumstances in which such services should be activated.

Vehicular Internet and Infotainment slices should be able to use multiple RATs to get a high throughput; the contents can be located in the remote/edge cloud (e.g., server co-located in eNodeBs via *Multi-Access Edge Computing technology* - MEC); multiple MME instances may be required depending on the users mobility degree.

Vehicle management and remote diagnostics slices should support the exchange of low-frequency small amounts of data between vehicles and remote servers outside the core network; the architectural Data Plane and Control Plane should handle multiple interactions.

The general approach of V2X 5G slicing involve multi-tenant, multi-domain multi-operator and E2E capabilities. E2E V2X slices need dynamic composition of different slice instances in the RAN and in the CN segments; e.g., some functions in CN can be shared by several specific slices (authentication/ authorization), while each slice in RAN domain could be differently customized.

3GPP proposed for slices creation a multi-dimensional slice descriptor. It contains among others: *Tenant ID* (e.g., the car manufacturer, the road authority), *Slice Type* (e.g., vehicular infotainment, remote diagnostic), but also some additional specific parameters like: position/kinematics parameters.

A vehicle can be a multi-slice device, able to simultaneously attach to multiple slices.

Multi-tenancy and multi-operator capabilities raise several new requirements given that different providers can offer different services mapped onto different slices, over the infrastructure owned by different network operators. Optimal Resource allocation between domain-scoped slices composing a general E2E slice generates a rich set of functional and security performance requirements.

VII. EXAMPLE OF A 5G V2X SLICED SYSTEM

This section will present a 5G system oriented towards IoV/V2X services and maritime applications, "A Massive MIMO Enabled IoT Platform with Networking Slicing for Beyond 5G IoV/V2X and Maritime Services" - SOLID-B5G [31] (https://solid-b5g.upb.ro/). (see Figure 3). Requirements identification (after defining the target use cases) is an important activity, supporting further the architecture definition and then the system design.

The objectives of the SOLID-B5G project are the following:

- O1: To develop ultra-low latency massive MIMO based concurrent transmission mechanisms for data collection in massive IoT;
- O2: To develop advanced B5G slicing methods, algorithms, and protocols with a focus on Orchestration Management and Control (OMC) of resources and dedicated services for IoV/V2X and maritime services;
- O3: To develop decentralized decision-making mechanisms by introducing data processing capacity and intelligence to the edge (based on Multi-access (Mobile) Edge Computing (MEC) and machine learning (ML)-to-the-edge);
- O4: To implement a proof-of-concept *standalone* B5G testbed to demonstrate the orchestration of RAN and CN based on 5G network slicing and MEC procedures. Two main categories of use cases, i.e., IoV/V2X and satellite based maritime low-latency will be considerd.

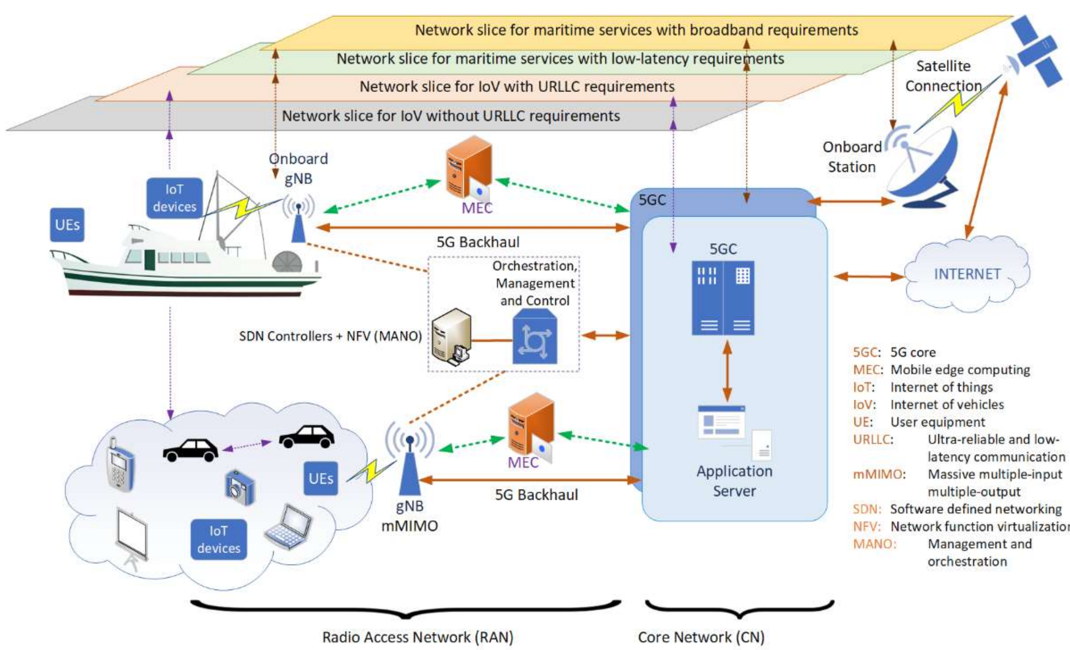

Figure 3. SOLID-B5G system architecture - high level view

One goal of the the SOLID-B5G project is develop a study and contributions in the domain of V2X/IoV systems based on 5G slicing solutions. The basic three types of 3GPP-defined slices, i.e., ultra- reliable low-latency communications (URLLC), enhanced mobile broadband (eMBB) and massive machine type communications (mMTC), will be investigated.

5G URLLC-type slices are appropriate to support e.g., *automated driving, road safety* and *traffic efficiency* services, etc., given that many such V2X use cases and associated scenarios can be considered as latency sensitive applications. The cars can be fully connected and can react to complex road situations by cooperating with each other. The information is disseminated among vehicles reliably within short time duration. On top of an URLLC slice, vehicles can perform V2V or V2I communications. The typical UCs supported are automated overtake, cooperative collision avoidance and highdensity platooning, which require an end-to-end latency of 5–10ms and a BLER down to 10^{-5} [32].

URLLC is supported by 5G New Radio (NR), as specified in 3GPP Release 15 and Release 16. Typical requirements are ~ 1 ms for latency, end-to-end security, small data packet loss of 10^{-5} and high reliability ~ 99.999%. [33]. The URLLC is useful when events occur and warning, alarm, etc. are necessary to be triggered, with very small delay and high reliability. Usually, the URLLC transmissions are aperiodic and are supported by appropriate scheduling (grant-based, grant-free/configured grant scheduling) to guarantee high reliability and efficient resource usage. The requirements for such sporadic communication still ask for predictability of available resources, diversity using multiple frequencies or spatial resources in addition to random access.

UCs like *platooning, remote driving, advanced driving,* and *extended sensors* require low latency ~ 1 ms and reliability of up to 99.999%. Open research issues in V2X supported by URLLC are related to resource allocation, energy savings, etc. Given the specific needs of V2X/IoV and also IoT for maritime systems the project will also apply decentralized solutions like Multi-access Edge Computing (MEC), in a sliced environment. Therefore, an important challenge is MEC-URLLC integration, to improve latency, throughput and computation -intensive processing. Additional system requirements appear in this solution.

eMBB- type slices are supported by 5G new radio (NR) and to increase the data rate in data-driven UCs that require high data rates across the coverage area, and to ensure reliability with a packet error rate in the range of 10^{-3}. The services that can be supported by eMBB are virtual reality, augmented reality and direct video transmission in UltraHD or 360 degrees while respecting the latency and reliability requirements; such services can be also useful in IoV/V2X domain [33]. The advanced V2X use cases need high data rate requirements. eMBB with 10 Gbps for uplink and 20 Gbps for downlink channel are important solutions for various multimedia services (e.g., in-car video conferences/games, HD map downloading). eMBB Slices can serve vehicles on the highway with heterogeneous traffic requirements. Slices for autonomous driving safety messages and infotainment and video streaming can also be constructed. eMBB are important for V2X applications, e.g., when high data rates requirements exist for the extended sensors group or sharing high-precision video as in the case of remote driving. eMBB even has non-safety applications such as infotainment and multimedia services.

mMTC-type slices are appropriate for sporadic and data is transmitted randomly, but for a high number of connected machines/objects. The geographical area is wider and the objectives are low-power, low-cost, low complexity, and low transmission rate communications with a packet error rate of 10^{-1} [34]. The number of active devices using radio resources is variable, so it is necessary to have random access to resources. Narrowband IoT (NB-IoT) and enhanced MTC(eMTC) are specfied by 3GPP to support long and medium range IoT applications respectively and can meet 5G mMTC needs. With mMTC slices, vehicles can sense and learn environmental changes from built-in sensors deployed in cars or within infrastructure. mMTC is also important within a dense connected environment to support non-delay-sensitive V2X applications (e.g., dynamic ride sharing, software update) or even to provide more data for safety-related applications [33].

Generally, two types of dedicated slices URLLC and non-URLLC will be considered in the project, for two categories of applications:

Safety and traffic efficiency slice- for V2V and vehicle-to-pedestrian (V2P). Such slices will transport and process *event-driven* and *periodic* messages containing position and kinematics parameters and support applications such as: forward collision warning; cooperative adaptive cruise control that allows a group of vehicles in proximity to share the same path (a.k.a. platooning); vulnerable road users (VRU) safety to alert a vehicle of the presence of a VRU;

Autonomous driving slice – having more powerful characteristics than those for safety applications, the reason being higher speed, more complex environment- including geographical and road-related aspects, cooperative needs, etc. Such slices can offer ultra-low-latency V2V communications via RAT connection mode and additional RAN/CN functions.

VIII. CONCLUSIONS AND FUTURE WORK

This paper had as objective to develop a systematic procedure for V2X system requirements collection and apply it on examples of implementation solutions based on a

5G sliced infrastructure. First, the paper introduced the ecosytems/ business models (ES/BM), given that the system requirements are issued by the participating actors.

It has been shown that business models/ecosystems for 5G V2X systems are considerably richer than those for basic 5G slicing. The reason consists in large set of V2X applications and variety of commercial services offered.

A general methodology is proposed to structure the process of system requirements identification. Considering the above, examples of V2X system requirements have been exposed.

Several steps should be followed to identify the system requirements. First, the V2X set of high level of services (seen from the end user perspectives) to be implemented should be defined among the rich possible ones. Then, the identification of the set of involved actors and a first assignment of their roles (especially from business/services point of view) is the next step. Here, some actors would provide only indirect actions (Policy Makers, SDOs, local regulators, etc.). Other actors will participate at operational phases (MNOs, OEMs, Service providers - e.g., OTT, Infrastructure providers, etc.) at run-time.

Some general characteristics of the overall system should be defined such as multi-domain, multi-tenant, multi-operator characteristics. Definition of interactions between the actors will complete the high-level description of the 5G V2X BM/ecosystem. The regulations, standards, etc., to be enforced have to be identified; they will define but also limit the system capabilities and scope.

The following steps will refine the BM and go to the requirement identification, where inputs coming from all actors involved in ES/BM should be considered.

To refine the requirements for a 5G V2X slicing solution, it is necessary to select technologies for RAN, core and transport part of the network) should be selected. Then, the system architecture (general and layered - functional) has to be defined, allowing further technical refinement of the system design.

An example is given of a system based on 5G slicing in a research project SOLID-B5G, aiming V2X/IoV and maritime applications.

Future work can go further to consider more deeply depending on use cases targeted, and the multi-x aspects, system capabilities.

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