On Systematic Identification of Requirements for Vehicle-to-Everything 5G Slices

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Contents

1. Introduction

- **Vehicle-to-Everything (V2X) and its extension- Internet of Vehicles (IoV)**
  - V2X and IoV - intensively studied and developed in the last decade
  - The V2X : 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
  - **To specify and design a specific V2X system**, one should
    - first **identify the ecosystem actors, their interactions** and then
    - **derive in a structured way the *system requirements***, while harmonizing needs coming from different entities
- **5G slicing technology** - strong candidate to support V2X, in multi-tenant, multi-domain, multi-operator and end-to-end contexts
  - 5G slicing allows construction of **dedicated virtual network 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
- **Objective of this work**
  - **Contribution to develop a methodology to perform a top-down systematic identification of requirements for a V2X system supported by 5G dedicated slices**

1. Introduction

- **Types of V2X communications**
  - **vehicle-to-**
    - vehicle (V2V), road/infrastructure (V2R/V2I)
    - pedestrian (V2P) - direct communication
    - vulnerable road user (VRU)
    - network (V2N) - including cellular networks and Internet
    - sensors (V2S), power grid (V2G), home (V2H)
- **V2X use cases and services/applications**
  - active road safety applications (including autonomous driving); warnings, notifications, assistance; traffic efficiency and management applications; infotainment applications
- **IoV extends the V2X services** to novel target domains
  - e.g.: enhanced traffic management, automobile production, repair and vehicle insurance, road infrastructure construction and repair, logistics and transportation, etc.
- **5G and its slicing technology** - powerful candidate to serve V2X needs
  - high **capacity, speed, flexibility** and **large range of customizable services**
  - 5G can provide specific types of services to satisfy various customer/tenant demands in a **multi-x** fashion (the notation –x stands for: **tenant, domain, operator** and **provider**)
  - The **3GPP** [7]: three major categories of 5G slices: ***Massive machine type communication (mMTC); Ultra reliability low latency communication (URLLC); Enhanced mobile broadband (eMBB)***

1. Introduction

- ***5G Network Slice* (NSL)**
  - A managed logical group of subsets of resources, organized as virtual dedicated networks, isolated from each other (w.r.t. performance and security), but sharing the same infrastructure
  - NSLs functionalities -implemented by **Physical/Virtual network functions** (PNFs/VNFs), chained in graphs, in order to compose services dedicated to different sets of users
  - ***Network Function Virtualization* (NFV)** and ***Software Defined Networks* (SDN)** can cooperate to manage, orchestrate and control the 5G sliced environment, in a flexible and programmable way
- **V2X BM-ES - new actors are involved**, besides traditional Internet and network/ service providers or operators
  - road authorities, municipalities, regulators and vehicle manufacturers *Original Equipment Manufacturers* (OEM)
- The 5G sliced systems development needs to initially define the BMs
  - **BM-ES:** defines **roles and responsibilities** of the entities, **interactions** and precedes **the system requirements and architecture definition**
- **V2X- BMs - still open research topic**
  - *5G PPP Automotive Working Group,* Business Feasibility Study for 5G V2X Deployment : “there is still some lack of insights into the required rollout conditions, roles of different stakeholders, investments, business models and expected profit from *Connected and Automated Mobility* (CAM) services”

2. 5G Slicing Ecosystem

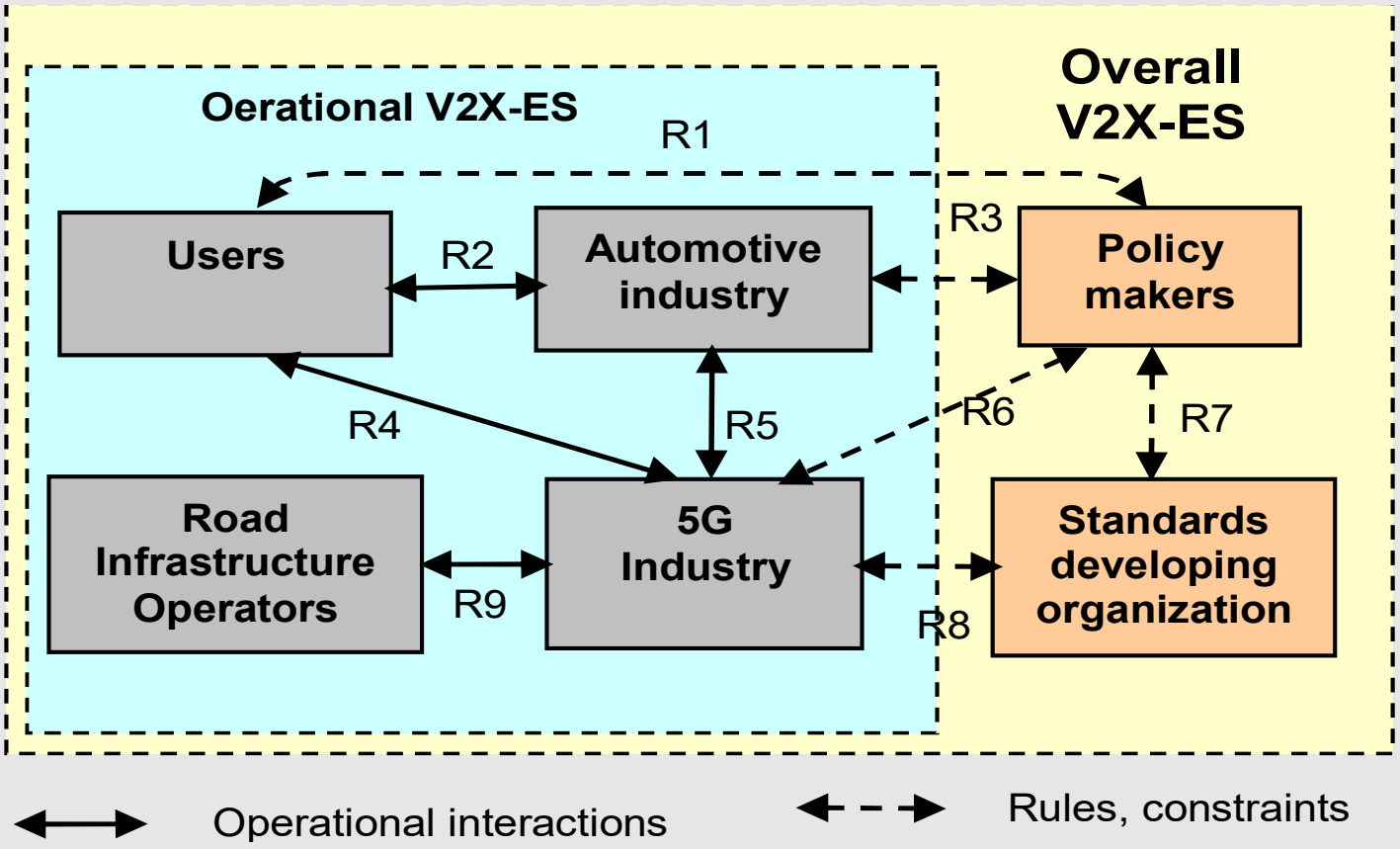
- **Example** *(ref [10])*
- ***End User* (EU):** consumes (part of) the services supplied by the slice tenant; it does not provide services to other business actors
- ***Slice Tenant (SLT)*:** generic user of a specific slice, including network/cloud/data centers, which can host customized services
- A SLT can
  - request from a ***Network Slice Provider*** **(NSLP)** to create a new **slice instance** dedicated to support some SLT specific services
  - **lease** virtual resources from NSLPs in the form of a virtual network, where the tenant can realize, manage and then provide ***Network Services*** **(NS)** to its individual end users.
    - A NS is a composition of ***Network Functions (NFs),*** defined in terms of the individual NFs and the mechanism used to connect them. A single tenant may define and run one or several slices in its domain
- ***Network Slice Provider (NSLP)*:** typically a telecom Service Provider (owner or tenant of the infrastructures)
  - It can construct multi-tenant, multi-domain slices, on top of infrastructures offered by one or several InPs
- ***Infrastructure Provider (InP)*:** owns and manages the PHY 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 lease the infrastructure in network slicing fashion
- Other similar models are proposed (see Refs [7], [23-26] in the paper)

3. 5G V2X Ecosystem

- **5G PPP Automotive Working Group, "Business Feasibility Study for 5G V2X Deployment",** [22]
- ***Operational entities***
  - ***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
  - ***Road Infrastructure Operators (RIO) –*** national/ regional entities: 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
- ***External entities*** provide inputs to the operational V2X-ES actors, strongly influencing the requirements to be met by the overall system.
  - **SDO examples** : 3GPP), ETSI, IETF, IRTF, IEEE) NGMN, Industrial Internet Consortium (IIC), 5G Automotive Association (5GAA) and Automotive Edge Computing Consortium (AECC), etc.
  - ***Policy Makers (PM)*** authorities regulating the relationships within the V2X-ES.
    - Int'l 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

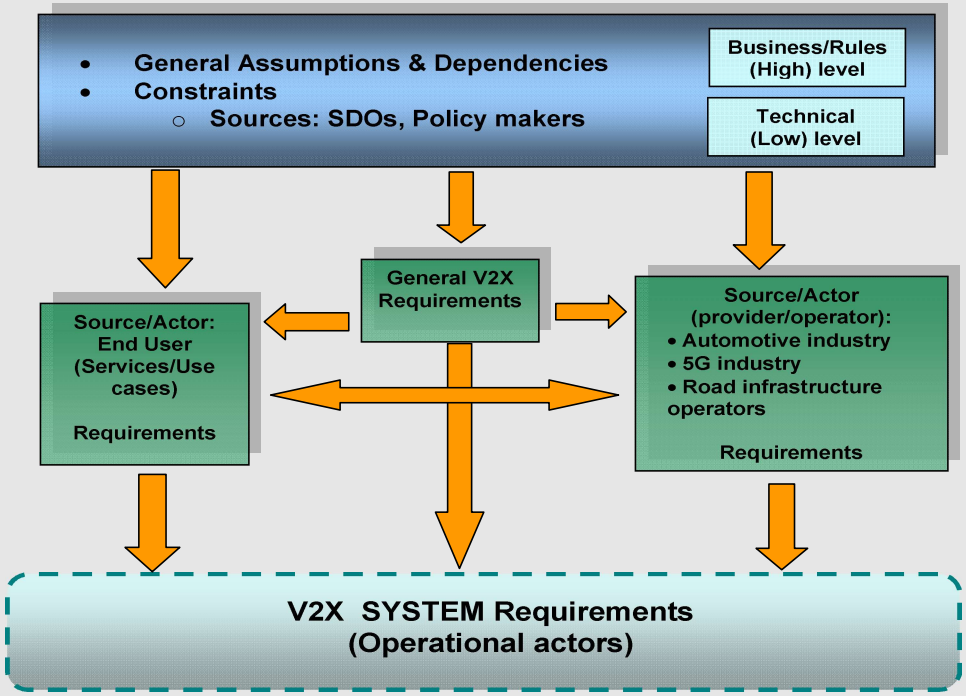
3. 5G V2X Ecosystem

- **5G PPP Automotive Working Group, "Business Feasibility Study for 5G V2X Deployment"**, [22]



4. Requirements Identification Methodology

- The V2X-ES/BM will be considered and particularly the **operational part of the BM.**
- **Target: to identify the system requirements for a V2X-5G sliced system**
  - The factors outside the operational BM are “external”. Their influence can be captured by ***Assumptions, Dependencies and Constraints (ADC)*** (*See the paper for details*)
  - The *ADCs scope* is *global* to a multi-domain environment if they are related to the SYSTEM as a whole, but 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 a requirement



4. Requirements Identification Methodology

- The general ADCs can influence directly the ***General, User*** and ***Provider Requirements***
- ***Requirements Taxonomy***
  - Two generic actors generating requirements: ***customer*** and ***provider (in V2X)***
    - generic **customers**- the entities providing applications and services to real end users
    - **providers** could be *5G industry* (network operators, network and devices vendors), *automotive industry*, *road infrastructure operators, etc.*
  - **Requirements categories**
    - *Functional* - related to the correctness which the system should fulfil
    - *Non-functional* – related to flexibility, reliability, availability, scalability, security, traffic capacity, performance metrics, etc.
  - **Levels of expressing requirements**
    - *Business/Rules (high) level* –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
  - **Requirements scopes**
    - ***Global*** to a multi-domain environment, i.e. referring to a larger environment than SYSTEM scope, characterising the environment in which the SYSTEM will act. They are expressed generally as ADCs or derived from them
    - ***Local*** to "**SYSTEM**" (Local_SYSTEM)
    - ***Local* to a *subsystem*** of the SYSTEM (*Local_subsystem*)

4. Requirements Identification Methodology

- ***Requirements Taxonomy (cont'd)***

- ***Class*****:** a "dimension" or a "point of view" on a given requirement.
  - 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.

- **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
    - See also IETF degrees for requirements**: "must", "should", "may"**

5. 5G V2X General Requirements

- 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 become 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 **V2X slicing solution** one can design a specific slice to serve
  - a given scenario/use case, e.g., platooning, advanced driving, etc.
  - or a more complex slice could offer several services
  - the system requirements will strongly depend on such a choice
- A relevant aspect of eV2X applications is the ***Level of Automation (LoA)***
  - it reflects the functional aspects of the technology and affects the system performance requirements.
  - LoA -levels from SAE Int'l. Std. J3016", US Homeland Security Digital Library, "Self-Driving Cars: Levels of Automation", March 2017:
  - **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

5. 5G V2X General Requirements

- ***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, among a group of UEs; between two UEs belonging to the same group
▪ confidentiality and integrity of message transfer among a group of UEs
▪ high connection density for congested traffic
▪ control the UL and DL reliability of transport of V2X communications
▪ message transfer of type UE-UE and UE-[UE-type RSU]
▪ 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; - 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 messages nin the network and application server
▪ a UEs to use *New Radio (NR)* and *E-Universal Terrestrial Radio Access* (E-UTRA)
▪ an RSU to be able to communicate with up to 200 UEs
▪ the UE to use multiple 3GPP RATs (i.e. NR & E-UTRA) simultaneously for direct communication.

5. 5G V2X General Requirements

- ***Non-Functional 5G-V2X requirements-3GPP***
- **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
- ***Other 5G V2X General Requirements***
  - 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**
  - **Example:**
    - Mobile Network Operator (MNO) as a principal actor belonging to the 5G Industry category
    - Usually, the MNO owns and manages the physical and logical (virtualized) infrastructure
    - Specific sets of requirements can be identified for 5G dedicated slices, provided by MNO, for V2V, V2I, V2N, etc.

5. 5G V2X General Requirements

- ***General requirements for applications***
- We denote with VAE, a *V2X Application Enabler.*
- The requirements below belong to the architectural class
- The VAE client and the VAE server shall support
  - one or more V2X applications;
  - obtaining info of the available V2X services from the V2X application
  - obtaining info 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
  - shall enable V2X UEs to obtain
    - the address of available V2X AS associated with served geographical area information
    - the information of available V2X services

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

5. 5G V2X General Requirements

- **Example: performance requirements for advanced driving**

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.

6. 5G V2X Slicing Requirements

- It has been shown ([20]) that **V2X services complex features do not map** exactly on the basic 3GPP reference slice types**: eMBB, URLLC and mMTC.**
  - **Dedicated V2X slicing solutions should be designed**

- **Examples** of some relevant challenges
  - ***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

6. 5G V2X Slicing Requirements

- **Examples** of some relevant challenges (cont'd)
  - ***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
  - ***Tele-operated driving*** slices should:
    - 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 Mobility Management Entities (MME) instances may be required depending on the users mobility degree

6. 5G V2X Slicing Requirements

- 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, etc.
- 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

7. Conclusions and Future Work

- **Paper objective**
  - to develop a systematic procedure for V2X system requirements collection
  - apply it on examples of implementation solutions based on a 5G sliced infrastructure
- **First:** introducing the ecosytems/ business models (ES/BM), given that the system requirements are issued by the participating actors
  - The 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

- **Steps should be followed to identify the system requirements**
  - **Definition of the V2X set of high level of services** (seen from the end user perspectives) to be implemented, among the rich possible ones
  - **Identification of the set of involved actors** and a first assignment of their roles (especially from business/services point of view)
    - 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.

7. Conclusions and Future Work

- **Steps should be followed to identify the system requirements (cont'd)**
  - Definition of general characteristics 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
- The **system architecture (general and layered - functional) can now to be defined,** allowing further technical refinement of the system design
- **Future work** can go further to **consider more deeply depending on use cases targeted, and the multi-x aspects**, system capabilities.

Thanks!
Questions?

References – selective list

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