# D 4.2 PART 2 - INTERFACE SPECIFICATION TRACKSIDE-CLOUD NON-RAILWAY USER

# Executive Summary

This is Part 2 of deliverable 4.2 and provides requirements for the interface between trackside equipment of MMLX, cloud and non-railway users. More specifically, the communication between a SWOC MMLX and a non-railway user via a cloud connection. It also considers cloud facilitated communication with a subset of railway-users for the collection of operational and diagnostic data from connected level crossings even though this is not the focus of the deliverable. It is recommended that the reader first reads the main document of D4.2 [D4.2], that introduces context and main conclusions for this part of the delivery.

In addition, it presents some background and context of the work performed to define the interface together with a discussion relating the implications of the interface on project KPIs presented in [D2.3]. In summary it is expected that using a cloud environment for facilitating trackside to non-railway user communication (e.g. trackside to vehicle communication) is a cost-effective solution compared to, for example, deploying specialized dedicated hardware for the purpose of direct trackside to vehicle communication.

This part maps requirements to layers using the OSI 7-layer model. Requirements from deliverable [D2.2] have been used as top requirements. Those top requirements are referenced with links in this part.

# 1 The cloud

The definition of the term cloud used within the scope of this text is a distributed, scalable infrastructure for the deployment of software services accessible using Internet protocols. It does not dictate a specific operator, technology stack or full set of services provided. Furthermore, using cloud technology does not imply a particular specification for ownership and operational structure. Infrastructure managers have typically been publicly owned whilst cloud services have mostly been provided by market participants from the private sector. However, private ownership has been extended to rail infrastructure and new public actors have become active in the cloud industry.

Consequently, new forms of collaboration between infrastructure managers and cloud service providers are available and not restricted by the solutions introduced here.

# 2 Deployment specific considerations

This deliverable makes use of the terms G1 and G2 to distinguish between two categories of regional lines. Further details on this topic along with architectural considerations are available in [D2.1]. In the case of the track to cloud interface no G1 or G2 specific requirements exist, the interface is intended to be identical for both scenarios.

In addition to dealing with G1 and G2 deployments another common separation of deployment types are *greenfield* and *brownfield* deployments. Greenfield signifying completely new deployments while brownfield is a deployment within existing infrastructure taking currently available trackside equipment and structures into consideration. For the interface presented here no specific adaptations for greenfield vs brownfield scenarios have been deemed as necessary.

# 3 Reuse of Shift2Rail results

The definition of the cloud is further elaborated on, in conjunction with more details on the cloud environment itself, in [D4.4-AS]. For the SWOC MMLX, the communication interface is provided by the SWOC using a wireless or wired connection. This SWOC itself is described in prior work such as [D2.1] and [X2R1-D7.2].

# 4 Requirement structure and process

Figure 1 shows how Part 2relates to others, both part of and outside this delivery. Formal requirement links are denoted by a filled arrow from the part making use of requirements to those defining them. In short summary this draws requirements from deliverable [D2.2] which in turn is based on the system pillar. Requirements presented here are collected in the requirement specification [D4.4-RS] and together with the system pillar used as a basis for the architecture specification [D4.4-AS].

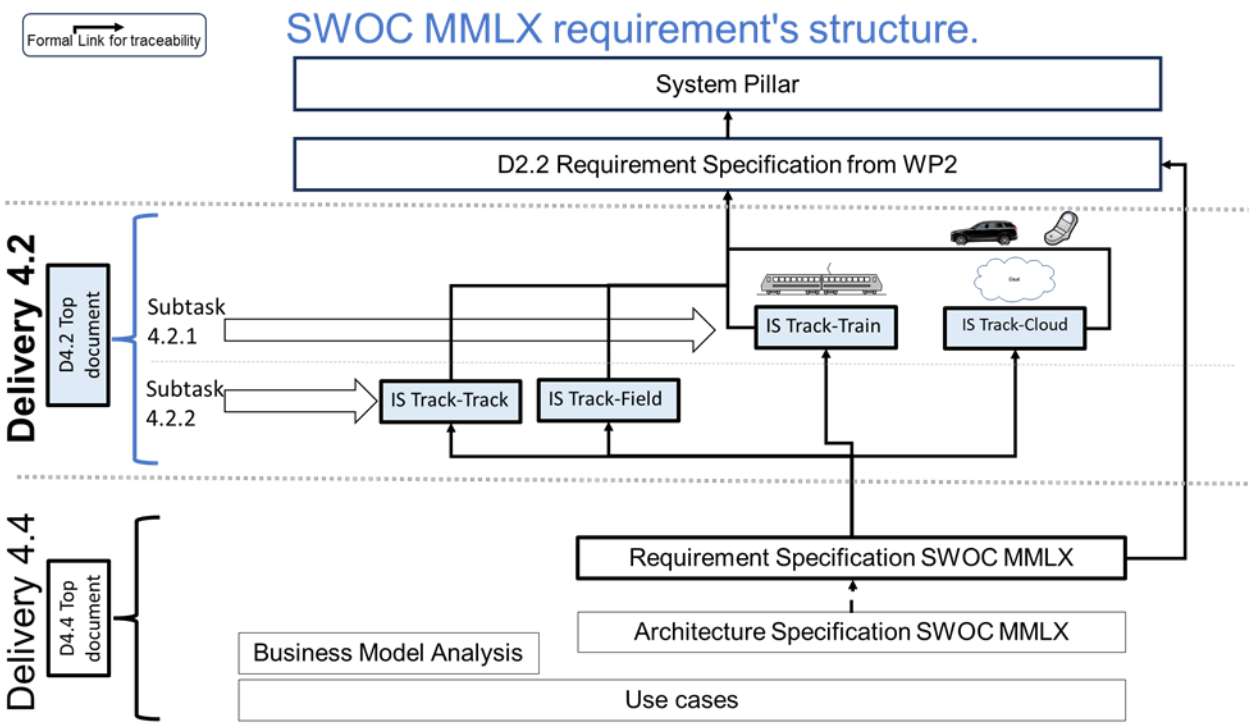


**Figure 1: SWOC MMLX Requirements structure**

As illustrated in Figure 2, establishing the requirements in this part has involved firstly the identification of functions and features resulting in Use Case definitions presented in the use cases document [D4.4-UC]. Based on the use cases requirements were in turn defined, reviewed, consolidated to finally be presented in the requirement documentation.

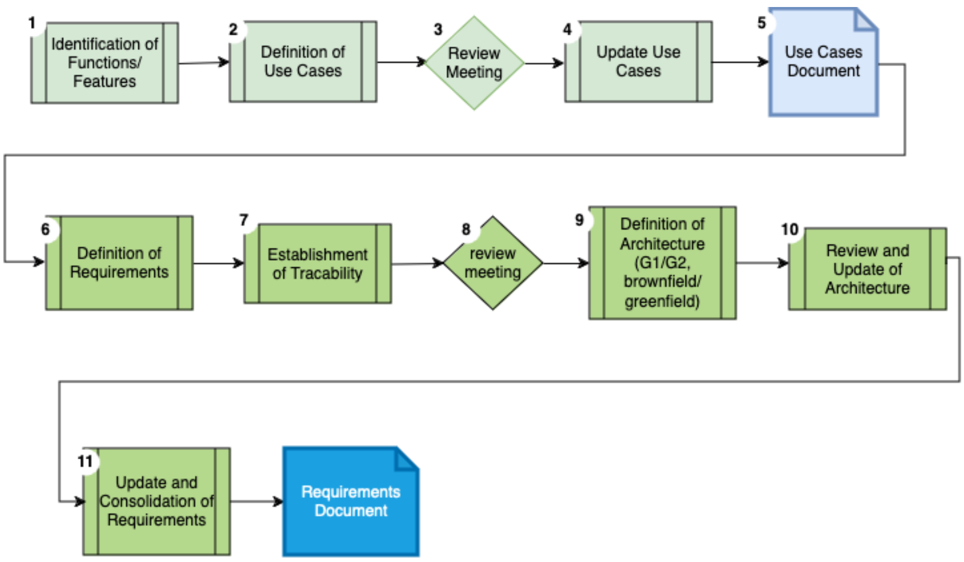


**Figure 2: Requirements process**

# 5 Interface description

The interface can be logically separated into two distinct parts, first the interface between the trackside and the cloud, second the interface between the cloud and the end user. Both parts are similar and share many features but differ for some key aspects. In addition, the cloud environment itself is responsible for exchanging information between connected parties through these interfaces, using a protocol to handle the messaging between the interested parties. The protocol implements a set of rules that govern communication and data exchange. A common protocol type for facilitating such communication is message-based publish/subscribe protocols, one implementation of such a messaging protocol is MQTT [MQTT311].

Many such protocols use a topic as a label to categorise and specify what content is in a stream of data. The topic can convey very detailed information on what data is communicated. The topic can also be used to group data with a common denominator. In the case of a cloud connected MMLX a topic is used to represent all messages related to a specific level crossing. Furthermore, topics themselves can be refined into levels allowing functionally related messages generated by a level crossing to be gathered in a dedicated topic below the main one. For example, the main topic representing a level crossing could have sub-topics for events related to different parts of the infrastructure such as the open / closed state or the obstacle detector. This separation of events into topics makes it easier for consumers to filter messages based on their application needs.

Communication is facilitated by a broker consisting of a server (or multiple servers) acting as a hub for connected clients. The broker keeps track of connected clients and related message topics. Clients can receive messages on subscribed topics or publish messages to selected topics. Broker functionality, both for data collection and publishing of messages to connected users, can be implemented in the cloud environment as described in the D4.4 Architecture Specification MMLX [D4.4-AS]. Note that the cloud solution is not used to convey any safety-critical information.

The flow of messages related to the MMLX, is illustrated by the arrows in Figure 3. The MMLX (to the left) publishes events to the broker and connected subscribers (on the right) receive events based on their subscription preferences. The message flow is, as illustrated, strictly unidirectional. However future analysis may consider bidirectional data flow allowing the LX/train to receive information about possible non-railway events. The MMLX is the only actor that may publish messages and may not subscribe to messages from the broker. Respectively, users may only subscribe to messages and not publish.

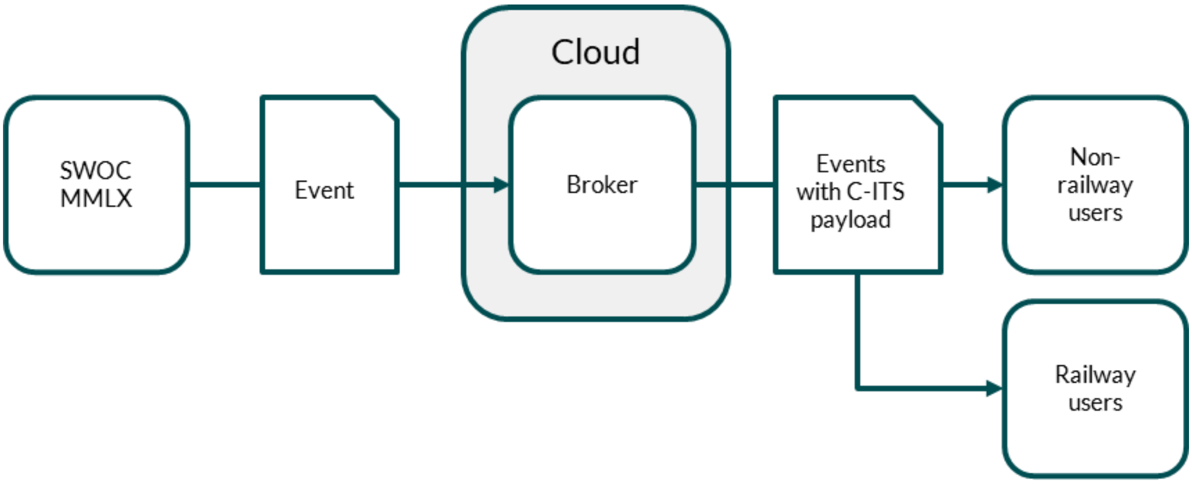


**Figure 3: Cloud system overview in a typical use case with a connected LX and railway and non-railway users interacting with the SWOC MMLX.**

In the above example, payload conversion to the C-ITS (Cooperative Intelligent Transport Systems) format would typically be managed by the cloud environment. However, this is not the only available solution and therefore is not defined as mandatory. It is possible that, following a previous implementation, messages from the MMLX are already compliant with the appropriate C-ITS standard.

Furthermore, different implementations should be allowed to convert from other message formats, based on system requirements or the needs of other end users (e.g., non-railway users). Processes for converting payloads from non-C-ITS to C-ITS format may already be available and it could be redundant, complex or labour-intensive to implement new ones specifically for the cloud solution.

## 5.1 Track to cloud

The communication channel between the MMLX and the cloud shall only be used as a way of sending information from the MMLX to the cloud and by extension to cloud users. It shall not be used to remotely control or in other ways communicate with the MMLX.

The MMLX connects to the cloud service through the message broker protocol. Each MMLX publishes information on a specified set of topics related to the specific MMLX and types of events. The types of events to be published is configurable by the infrastructure manager.

## 5.2 Cloud to users

Users subscribe to messages from the cloud environment. In addition, infrastructure managers may choose to provide Application Programming Interface (API)-based access to allow for on-demand querying of data.

The cloud service must be able to provide information linking the message broker topics to a physical position, such as coordinates and other information available for the connected level crossing. This enables the software running on the non-railway user's device to use positioning data available on the device to subscribe to events from a level crossing in the user's vicinity or along a specified route.

The cloud service shall provide infrastructure managers facilities for regulating access to collected data for both railway and non-railway users. When connected to the cloud service, the device asks for a list of available topics. A topic consists of information related to a MMLX device. The non-railway device subscribes to the relevant topic using its own position and the information provided by the cloud service. A non-railway device can be connected to several topics at the same time.

The cloud function should be able to handle both public and private messages. Examples of public messages are those related to the public MMLX status i.e. if the level crossing is closed for road vehicle passage. Example of private messages are log messages from the MMLX. Both public and private messages can be handled by the message broker using access control.

The cloud service is responsible to offer a mapping between physical position and related message broker topic, i.e. MMLX. The non railway user is responsible to figure out which topic (physical location) to subscribe to. This minimises the number of messages received by the non-railway user.

Message brokers can be setup in tiers to make a clear distinction between public and private messaging. It is up to infrastructure managers to offer aggregated or calculated information flows on top of the message broker function. Example of such functions are long term storage of messages and subsequent analysis, i.e. predictive maintenance. It is up to the cloud infrastructure managers to handle message broker load balancing, backup, service redundancy etc.

# 6 General and Miscellaneous requirements

In following sections, requirements are sorted according to the most relevant OSI layer. Requirements that do not fit the OSI 7-layer model, or that span multiple layers, were mapped to general/miscellaneous requirements.

Table 1 lists the general and miscellaneous requirements of track-to-cloud and non-railway-users communication which do not specifically fit in one single layer of the OSI 7-layer model.

**Table 1: General and or Miscellaneous Requirements**

| ID | Statement | Rationale | Source |
|---|---|---|---|
| TCG 1. | No safety critical information shall be transmitted over the cloud infrastructure. | The communication is conducted using infrastructure unsuited for the transmission of safety-critical information. | |

# 7 PHYSICAL LAYER

The cloud shall be interconnected to the SWOC MMLX via a wireless or wired communication channel. Wireless communication may be conducted over cellular networks or using other wireless communication technology that fulfils the requirements given in Table 2.

**Table 2: Requirements for the Physical layer.**

| ID | Statement | Rationale | Source |
|---|---|---|---|
| FRCM 20.1. | The communication system should possess the capability to integrate and utilize public, private, and/or hybrid solutions infrastructure while concurrently supporting multiple and different wireless interfaces towards various wireless transport networks offering required QoS. | Supports OPEX reduction by providing flexibility in choosing cost-effective solutions. | [D2.2, FRCM 20] |
| NFRCM 1. | The communication system shall be scalable covering minimal regional systems up to | Supports OPEX reduction by facilitating cost-effective expansion. | [D2.2] |

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|---|---|---|---|
| | full equipped regional MMLX (Multi Modal LX). | | |
| NFRCM 8. | When possible and economically advantageous, the communication system physical layer (layer 1) shall be based on a wireless communication link. | Aligns with both OPEX and CAPEX considerations as it can potentially reduce infrastructure costs, streamline deployment, and contribute to long-term operational efficiency, resulting in cost-effective and scalable communication system. | [D2.2] |
| NFRCM 9. | The wireless communication system shall, when possible, use open standards. | OPEX reduction by fostering interoperability, minimizing vendor lock-in, and ensuring cost-effective adaptability to evolving technologies. | [D2.2] |
| NFRCM 10. | The wireless communication system shall comply with either IEEE, 3GPP, ITU, ISO terrestrial and non-terrestrial radio standards. | Aligning with OPEX and CAPEX reduction by promoting a standardized and cost-effective approach to wireless communication technology. | [D2.2] |
| NFRCM 15. | The wireless communication system design shall be conceived for minimising power consumption of the overall system. | To decrease OPEX by reducing energy costs, enhancing operational efficiency, and ensuring long-term sustainability in a cost-effective manner. | [D2.2] |
| ORCM 14. | The communication system shall use wireless communication networks based on Mobile Network Operators (MNOs) or private infrastructures instead of cabling networks infrastructures. If costs and safety and security requirements are met. | Main goal of the wireless communication system is to reduce cost compare with current wired systems. Wireless networks minimize infrastructure costs, simplifies deployment, and ensures long-term operational efficiency through a potentially more flexible and cost-effective communication solution. | [D2.2] |

# 8 LINK LAYER

The cloud and the SWOC MMLX shall use a standard wired or wireless Internet connection that is suitable for the communication needs for the SWOC MMLX. The link layer shall follow the requirements listed in Table 3.

**Table 3: Requirements for the Link Layer**

| ID | Statement | Rationale | Source |
|---|---|---|---|
| FRCM 13.1 | The communication system should allow the establishment of per-traffic class priority policies. | Aligning with OPEX and CAPEX considerations, the system optimizes efficiency, reduces latency, and ensures resource efficiency through tailored priority management for diverse traffic classes, fostering a cost-effective and responsive communication infrastructure. | [D2.2, FRCM 13] |

# 9 NETWORK LAYER

The network layer shall follow the requirements listed in Table 4.

**Table 4: Requirements for the Network Layer**

| ID | Statement | Rationale | Source |
|---|---|---|---|
| FRCM 15.1. | The network layer shall support the IPv4 protocol, defined in IETF/RFC791, as its means for packet sending. Support of IPv6 for future applications is recommendable and by IETF RFC 2460 standard. | IPv4 and IPv6 are widely used for packet transmission. | [D2.2, FRCM 15] |

# 10 TRANSPORT LAYER

The transport layer shall follow the requirements listed in Table 5.

**Table 5: Requirements for the Transport Layer**

| ID | Statement | Rationale | Source |
|---|---|---|---|
| FRCM 3. | The communication system shall be designed for supporting TCP/UDP protocols in the Transport layer. | Aligning with OPEX and CAPEX, supporting TCP/UDP protocols enhances operational flexibility, reduces disruptions, and ensures cost-effective communication through widely used, standardized protocols. | [D2.2] |

# 11 SESSION/PRESENTATION/APPLICATION LAYER

To better conform to the TCP/IP structure of the communication, a simplified notation of the OSI-model is used. Hence, session/presentation/application layer is merged into one section. Typical messages sent from the SWOC MMLX to Cloud can be status information related to the connected Functional Modules or data generated by the connected Functional Modules.The session/presentation/application layer shall follow the requirements listed in Table 7. If not stated otherwise, use cases refer to [D4.4-UC].

**Table 6: Requirements for the Session/Presentation/Application Layer**

| ID | Statement | Rationale | Source |
|---|---|---|---|
| NFRCM 5.1. | Access control mechanisms shall be present to prevent unauthorized use of the cloud services. | | [D2.2, NFRCM 33.] |
| NFRCM 5.2. | Data collected from the MMLX for maintenance and diagnostic purposes shall not be available to non-railway users. | | [D2.2, NFRCM 33.] |
| NFRCM 5.3. | Software services should be deployed using a load balanced or clustered solution for scalability or take other technical measures to ensure a high availability. | | [D2.2, NFRCM 32.] |
| NFRCM 5.4. | APIs and message brokers intended for non-railway users shall be deployed as separate services from those intended for use by railway users. | Separation provides benefits from a resilience and security perspective | [D2.2, FRCM 18.] |
| SRCM 5.3. | The cloud shall provide facilities for long- and short-term storage of collected data. | | [D2.2, ORCM 10.] |
| FRCM 5.1. | The cloud shall provide means for users to request data regarding the state of one or several line crossings through an API. | | UC_WP4_4.4_001 [D2.2, FRCM 5] |
| FRCM 5.2. | The cloud shall provide facilities for users to subscribe to messages. | | UC_WP4_4.4._001 [D2.2, FRCM 21. ] |

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| FRCM 5.3. | Users shall be able to specify which MMLX or geographical region they wish to receive messages from. | The user requests a list of MMLX based on users location,<br>but the user's location is not disclosed to the cloud.<br>The user is free to subscribe to a subset of the list.<br>This gives the user some anonymity. | ]<br>UC_WP4_4.4._001[D2.2, FRCM 14] |
| FRCM 5.4. | The cloud shall provide facilities for users to unsubscribe from messages. | | UC_WP4_4.4._001[D2.2, FRCM 21. ] |
| NFRCM 5.5. | The cloud may distribute notifications using text messaging protocols. | For users unwilling or unable to install an app on their device. | UC_WP4_4.4._001[D2.2, ORCM 11.] |
| FRCM 5.5. | The cloud shall relay messages based on state changes occurring in a connected MMLX (e.g. opening, closing, obstacle detected etc.) relevant to subscribing non-railway users. | | UC_WP4_4.4._001<br>[D2.2, FRCM 24. ] |
| FRCM 5.6. | Messages distributed by the cloud shall always contain a unique identifier of the MMLX | | UC_WP4_4.4._001<br>[D2.2, FRCM 4] |
| FRCM 5.7. | Messages distributed by the cloud shall always contain the geographical location of the MMLX | | UC_WP4_4.4._001[D2.2, FRCM 4] |
| FRCM 5.8. | The cloud shall provide means for railway users to request data collected from connected level crossings through an API. | | UC_WP4_4.4._001[D2.2, FRCM 5] |
| NFRCM 5.6. | The cloud should provide railway users with direct read access to the long- and short-term data storage. | | UC_WP4_4.1.1_302<br>[D2.2, ORCM 10.] |
| FRCM 5.9. | The cloud shall provide facilities for railway-users to subscribe to messages. | | UC_WP4_4.1.1_304<br>[D2.2, FRCM 21. ] |

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|---|---|---|---|
| FRCM 5.10. | Users shall be able to specify which MMLX or geographical region they wish to receive messages from. | | UC_WP4_4.1.1_304 [D2.2, FRCM 11] |
| FRCM 5.11. | Users shall be able to specify types of messages they wish to receive (e.g. state transitions, logs). | | UC_WP4_4.1.1_304 [D2.2, FRCM 4] |
| FRCM 5.12. | The cloud shall provide facilities for railway-users to unsubscribe from messages. | | UC_WP4_4.1.1_304 [D2.2, FRCM 21. ] |
| FRCM 5.13. | The cloud shall relay messages based on events occurring in a connected MMLX to subscribing railway users. | | UC_WP4_4.1.1_304 [D2.2, FRCM 4] |
| FRCM 5.14. | The SWOC MMLX shall provide the option for infrastructure managers to configure which state changes should be reported. | | UC_WP4_4.4._001 [D2.2, FRCM 4] |
| NFRCM 4. | The wireless communication system shall not compromise the current level of safety and security. | Aligns with OPEX reduction by maintaining established safety standards and reducing the risk of potential incidents. Considering the use of MNO public and /or SAT networks, the implementation of safety and cybersecurity measures is mandatory. | [D2.2] |
| ORCM 1. | The wireless communication system shall be able to prioritize at least three distinct operational modes: Control (in normal operation), Monitoring, and Maintenance. | Supports OPEX reduction by ensuring efficient resource allocation based on specific operational needs. | [D2.2] |
| SRCM 5.4. | In the current version of this deliverable the message format should follow the ETSI TS 102 894-2 standard in version v2.1.1 (2022-11). | To clarify, the message from MMLX to cloud preserves the ETSI standard message. | [D2.2, FRCM 4], UC_WP4_4.4_008 |

## 12 References


| DOC-ID | Title | Version |
|---|---|---|
| [D2.2] | Regional lines operational and functional requirements FP6-WP02-D-MER-001-01 | M06 |
| [D2.3] | First release of KPI achievement | M14 |
| [ETSI TS 102 894] | Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary; Release 2 | V2.2.1 (2023-10) |
| [802.11] | IEEE Standard for Information Technology--Telecommunication and Information Exchange between Systems - Local and Metropolitan Area Networks--Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications | |
| [D4.2] | D4.2 Requirements Specification Communication Report_V5.0 | M24 |
| [D4.4-RS] | D4.4 Requirements Specification SWOC MMLX_v4.2 | M24 |
| [D4.4-AS] | D4.4 Architecture Specification SWOC MMLX_v4.2 | M24 |
| [D4.4-UC] | D4.4_Use_Cases_T4.2&T4.4_v4.2 | M24 |
| [X2R1-D7.2] | Railway requirements and Standards application conditions<br>Available at<br>https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2RAIL-1 | 1.0, May 2018 |
| [D2.1] | Regional lines architecture specification FP6-WP02-D-MER-001-01 | 1.0, M06 |
| [MQTT311] | MQTT Version 3.1.1, OASIS Standard. Available at http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/os/mqtt-v3.1.1-os.html | 3.1.1 |