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Wireless Communication

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SPECIFICATION

Submodel Template of the
Asset Administration Shell



Submodel Template

IDTA approved

- 100% AAS compliant
- Consistent & interoperable
- Released by the AAS experts

Imprint

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1 General

1.1 About this document

This document is a part of a specification series. Each part specifies the contents of a Submodel template for the Asset Administration Shell (AAS). The AAS is described in [1], [2], [3] and [6]. First exemplary Submodel contents were described in [4], while the actual format of this document was derived from the "Administration Shell in Practice" [5]. The format aims to be very concise, giving only minimal necessary information for applying a Submodel template, while leaving deeper descriptions and specification of concepts, structures and mapping to the respective documents [1-6].

The target groups of the specification are developers and editors of technical documentation and manufacturer information, which are describing assets in smart manufacturing by means of the AAS and therefore need to create a Submodel instance with a hierarchy of Submodel elements. This document especially details on the question, which Submodel elements with which semantic identification shall be used for this purpose.

1.2 Scope of the Submodel

This document is intended to address aspects of wireless communication. The structure of this Submodel is expressed through diagrams and UML tables, clarifying its constituent elements. In addition, potential assets and usage scenarios that can benefit from the adoption of this Submodel are identified. The main objective of this Submodel is to integrate wireless industrial communication in the context of the Industry 4.0 (I4.0) framework. The approach is based on the design of a Submodel that encompasses the parameters associated with an asset with wireless communication characteristics. Such a Submodel model is configured to create a fundamental set of Submodel elements that digitally represent relevant information about the different parts that make up a wireless communication system. This Submodel incorporates parameters relevant to various wireless communication technologies and assets. The underlying idea is that the Submodel has a generic character, allowing its application to different technologies and different types of assets. Therefore, some Submodel parameters may be more or less relevant depending on the technology and asset that will be modelled. In order to make the Submodel more specific, the user has the possibility to expand it by adding additional parameters at the time of AAS implementation. Other Submodels targeting specific communication technologies can be standardized later based on this Submodel. The Submodel focuses on layers 1 and 2 of the ISO-OSI model. The description of aspects from layer 3 upwards are not considered in this document and should be described for other submodels, as they do not depend on the type of technology, be it wireless or wired.

1.2.1 Motivation

I4.0 and smart manufacturing means adapting the production to the needs of customers, without planning every detail of the production system in advance, as for mass production, where you know how many parts you would like to produce. Also, the wireless communication system (WCS) can not be planned and installed for the worst case. If changes are necessary, the WCS and/or its use of the medium should be adapted accordingly. This can only be done when data exchange is possible between the production system and the WCS. In this context, it is necessary to model relevant WCS elements as I4.0 components, which means to develop AAS for them [7].

1.3 Relevant standards for the Submodel template

- ECLASS [8]
- VDI/VDE 2185 Part 1 - Radio-based communication in industrial automation - Requirements and principles [9]
- VDI/VDE 2185 Part 2 - Radio-supported communication in automation technology - coexistence management of radio systems [10]

- VDI/VDE 2185 Part 4 - Radio-supported communication in automation technology - measurement performance evaluation of radio solutions for industrial automation applications [11]
- IEC 62657-2 ED4: Industrial networks - Coexistence of wireless systems - Part 2: Coexistence management [12]

1.4 Use cases, requirements and design decisions

1.4.1 Assets

This Submodel aims to describe aspects of wireless communication of different types of assets. The use cases covered by this Submodel are related to obtaining licences for technologies that require this type of authorization, such as 5G, and also to managing the production system, based on the quality of the radio signal. The assets for which this Submodel is intended to describe are divided into two types: material (tangible) assets and immaterial (intangible) assets. Material assets are components that exist in the physical world, such as 5G routers or base stations. Intangible assets are components that do not exist in the physical world but are relevant to the production process. Intangible assets include not only documents, software or algorithms, but also communication system management systems. Some examples can be found below.

Material Assets:

- **Wireless Industrial Router:** This wireless device forward traffic from the LAN to the wireless network and vice versa. One or more automation devices can be connected to the LAN.
- **Base station:** The base station connects the 5G devices to the core network. It has no function in the application of the production system, however, it is essential to the network operation.
- **Wireless Automation Device:** A device containing at least one wireless module and one application module (see [9]).
- **Wireless Communication System:** A set of associated elements that make wireless communication possible.
- **5G Core Network:** The core network implements several Network functions that establish reliable and secure connectivity to the network end users [13] [14].

Immaterial Assets:

- **Heatmap:** A signal strength heatmap can be formed from the received signal information from different devices in different positions. This is an example of an immaterial asset.
- **Wireless System Manager:** The Wireless System Manager (WSM) is a centralized system that plays a crucial role in optimally managing wireless communication operations. The concept of WSM used here in this work was proposed in [15] that was based on [10].

1.4.2 Use cases

This section shows a list of use cases where a wireless communication Submodel is required. This Submodel will be one part of an AAS that virtually represents an asset. An example of the list is shown how an AAS of a communication device can help to solve problems in the physical domain. This AAS includes the Submodel proposed in this document.

List of relevant use cases:

- **Obtaining a license from the regulator:** Automation and digitization of regulatory and retirement processes. Digital creation and updating of attendance allocations and local certifications.
- **Integration of a new wireless device:** A new wireless device is to be integrated into a communication infrastructure, do some compatibility checks on frequency bands etc.
- **Manufacturer provides a digital version of a wireless sensor to the customer:** The manufacturer of wireless sensors sells the sensor to the customer and together with the sensor, he sends a digital file (passive AAS) with all the sensor information.

- **Replacement of wireless devices:** A defective or outdated equipment/component needs to be replaced. For that a detailed description of its characteristics is necessary.
- **Coexistence management:** Different wireless communication technologies will be implemented at the factory (e.g., Bluetooth, Wi-Fi, IEEE 802.15.4, DECT). It is necessary to organize these communication systems to avoid interference from wireless solutions. The process to ensure coexistence between wireless solutions is called coexistence management process.
- **Co-Working planning:** It is the planning phase for the case of several companies want to use the same wireless communication network in a common industrial park [16].
- **Diagnosis and failure analysis in production systems:** Through data originating from the production system including automation and communication data, diagnosis and fault detection mechanisms can be implemented. For this, it is necessary to have a Submodel that organizes the parameters of the assets in a structured and standardized way.
- **Monitoring of a production system:** An autonomous system monitors production through data from the automation and communication system. The parameters to be monitored are contained in the AAS Submodels that represent the assets.
- **Managing the wireless communication system (WCS) based on production requirements:** An active Digital Twin (DT) of the production system is created and manages the physical counterpart. This DT contains a model description of assets, including wireless communication aspects. The WCS is adapted based on production system, e.g., if a product has priority, then more communication resources are allocated to the machines that produce it [17].
- **Managing the automation system based on local application functions:** An active digital twin of the production system is created and manages the physical counterpart. This DT contains a model description of assets including wireless communication aspects. Local application functions of the automation system are adapted based on other local application functions, e.g., if WCS cannot guarantee more resources for a function that has priority, then the other functions are stopped or slowed down to use less communication resources [15].
- **Managing the automation system based on WCS status:** An active digital twin of the production system is created and manages the physical counterpart. This DT contains a model description of assets, including wireless communication aspects. The production system is adapted based on WCS, e.g., parameters of the controller that controls an Automated Guided Vehicle (AGV) are adapted based on the quality of communication. If the signal is bad, then the AGV chooses another path, or reduces the speed [17].

1.4.3 Details of use case “Managing the automation system based on WCS status”

In our example, an AGV (or several) is (are) part of the production system. This equipment transports materials between different workstations. The AGV has several sensors, such as distance sensors, RFID readers, and cameras, among others and actuators, such as servo motors and robotic arms. The AGV is controlled by a central station that sends instructions to it such as to collect materials from specific stations and deliver them to designated locations within the factory. The communication between this AGV and the central station is carried out by a wireless communication technology (5G, Wi-Fi, etc).

A virtual representation (AAS) of this AGV is developed to monitor and control the AGV. This AAS is composed of Submodels that represent different aspects of this AGV. An example is the Nameplate Submodel, which gives AGV descriptions such as serial number and manufacturer name.

The purpose of this AAS is to ensure that all information about the respective asset (AGV) is concentrated in a virtual entity. With this, it is possible to have status assessment, status control, analysis of status history, negotiation of thresholds and functions.

If the AGV needs maintenance or even if it needs to be replaced, all the necessary data for these procedures is in the AAS, such as the type of sensor used, the size of the screws, among other information. In addition to this static information, dynamic information can also be stored in the AAS. Information, such as time of use, history of failures, among others, can help in the preventive maintenance of the equipment.

Another advantage of the AAS is the assistance of the asset in making decisions as its external environment changes. The AGV will most likely travel through parts of the factory with different conditions that will certainly

influence wireless communication. For example, when the AGV passes behind a wall, most likely the connection may suffer degradation and may cause failures in the process operation. This can be predictable if the AGV always passes through the same place, or it can be unexpected in the case of unforeseen changes in the layout, such as a truck that stops to unload products and is in a position that blocks the line of sight between the AGV and the base station.

In this case, it is necessary to adapt the AGV path (if possible) based on conditions external to the AGV. One way of doing this is to monitor the radio conditions in which the AGV operates and see if any optimizations can be made. A solution may be to divert the AGV to a path where the interference or lack of line of sight is not so significant. In this way, the AGV communication parameters must be included in the digital model. A Submodel must contain the static and dynamic parameters of the AGV communication system. Parameters referring to the quality of signal reception can contribute to the diagnosis of possible failures or even anticipate possible problems and take actions to mitigate them.

Figure 1 shows an AGV (asset) in the physical world and an AAS of this AGV in the virtual world. The passive part of the AAS is made up of Submodels that describe the asset. The Submodel “Comm.” highlighted in blue is an instance of the Submodel proposed in this document (WirelessCommunication).

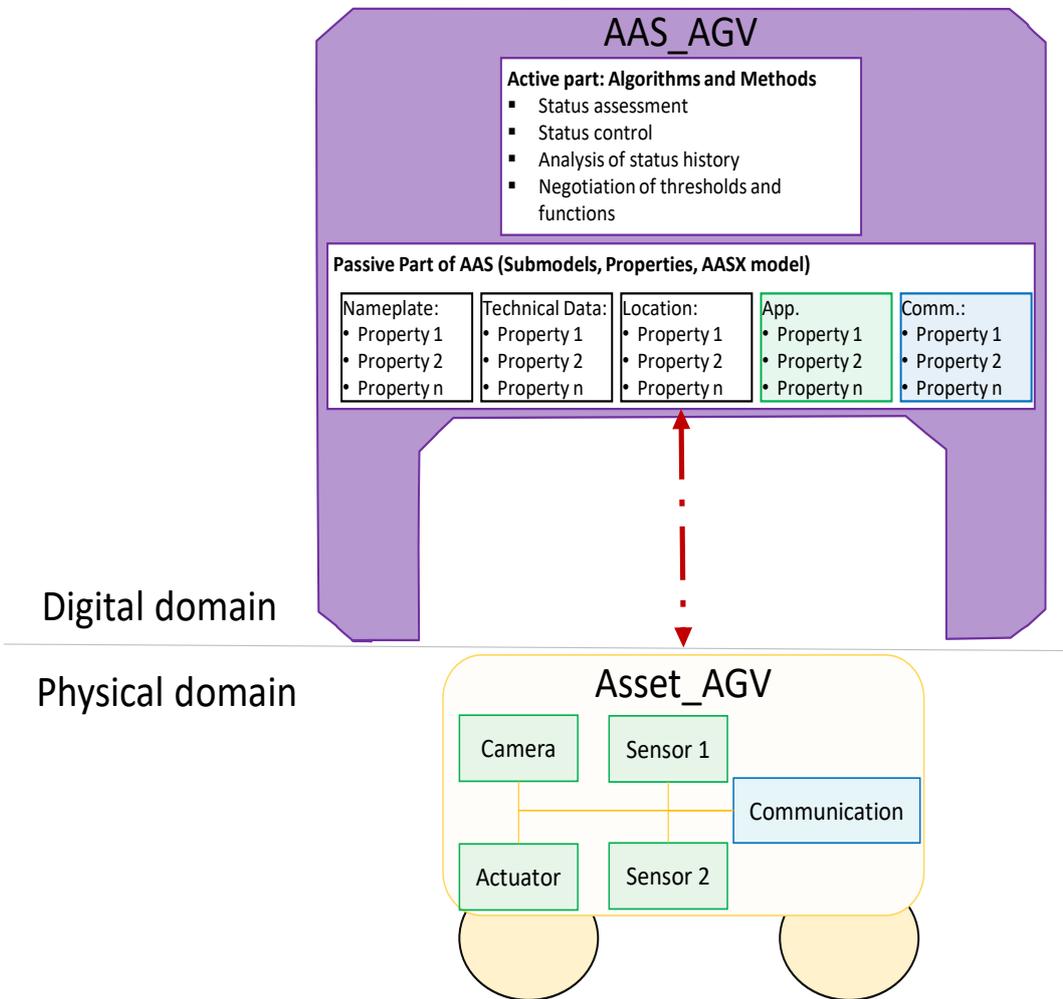


Figure 1: Asset and AAS of an AGV.

Once this AAS contains all relevant information from the AGV, tasks, such as monitoring and fault diagnosis can be performed. In addition, the AGV AAS can communicate with other virtual instances (AAS of other assets) for parameter negotiation, production system management, communication system adaptation, among others. If machine learning algorithms are implemented in the active part of the AAS, the performance of the AGV and the speed of decision making in case of external problems can be improved.

Figure 2 shows a scenario where assets in the physical domain are interconnected with AAS in the digital domain, represented by the purple section. Among these assets, some are material assets, such as AGV (Automated Guided Vehicles) and gNB (5G Base Station), while one material asset called Wireless System Manager (WSM). The primary function of WSM is to oversee the communication system, including a wireless communication submodule that contains essential data related to signal strengths received from various assets like machines and AGVs, as well as the transmission power from different 5G gNBs. It serves as a central hub for efficient wireless communication management, with its foundational concept originating from [10] and [15]. WSM's primary function is resource allocation for local application tasks within a network.

The process begins when the AGV AAS detects a decline in signal quality. At this point, it initiates communication with the AAS WSM to explore possible solutions (e.g., obstacle removal, AGV path alteration, or transmission power enhancement) - marked as Step 1 on the left side of the figure.

Subsequently, the WSM assesses the feasibility of increasing the transmission power and conveys the results to the gNB AAS - represented as step 2 on the right side of the diagram.

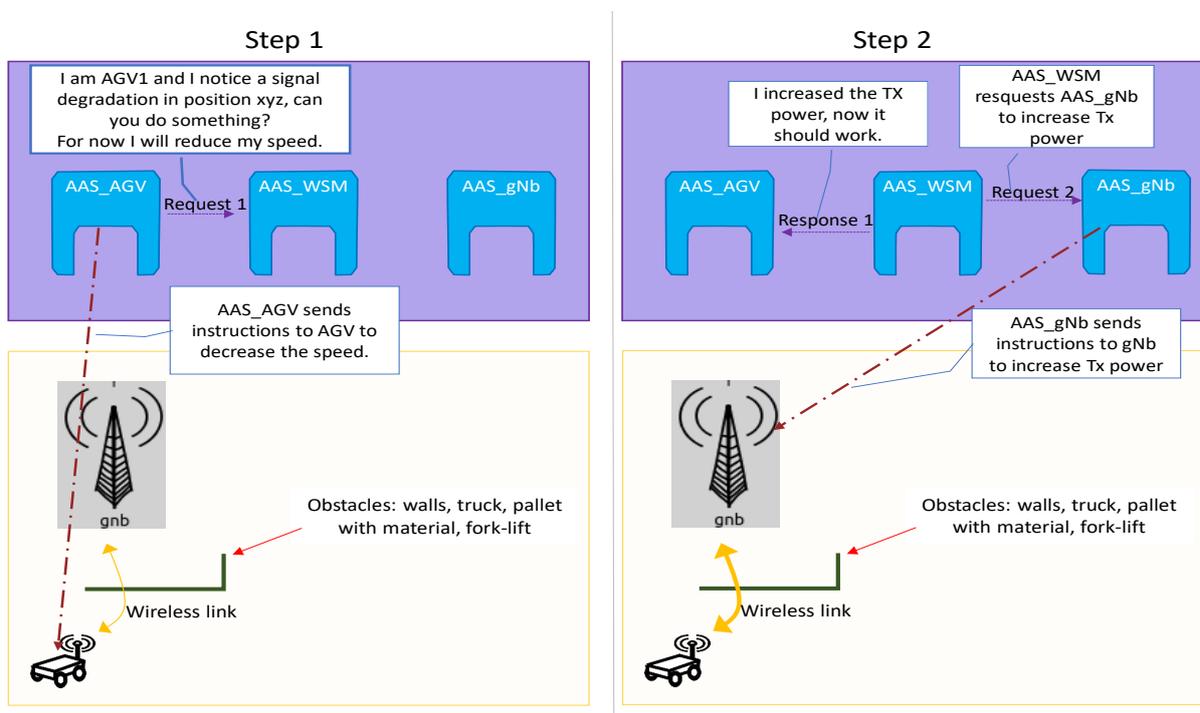


Figure 2: Example of use case for the Submodel with AGV and 5G system.

When wireless communication cannot provide the required QoS due to an obstacle or similar, several actions can be taken:

- The most basic one is, factory or warehouse operator can do something about it (remove obstacle, improve coverage in midterm with changes in the place and additional antennas etc).
- AGV can slow down (if its safety is depending upon wireless communication, such as communication with infrastructure sensors or with other AGVs)
- This information can be used by other AGVs destined to use this path, and if possible, they can use an alternative path
- This information can be used for predictive QoS – question here is, how to learn that the obstacle is removed.
- Another action could be to switch to a different (wireless) communication system, e.g., 5G → Wi-Fi, as fallback.

2 Submodel Wireless Communication

According to this model specification, a Submodel comprises attributes designed to characterize the wireless communication aspects of assets. Not every property or element of the Submodel is obligatory for asset description. For instance, the SMC licence might be essential for assets like a 5G network, but may not be needed for assets like 5G user equipment.

Figure 3 shows the UML-diagram defining the relevant properties which need to be set.

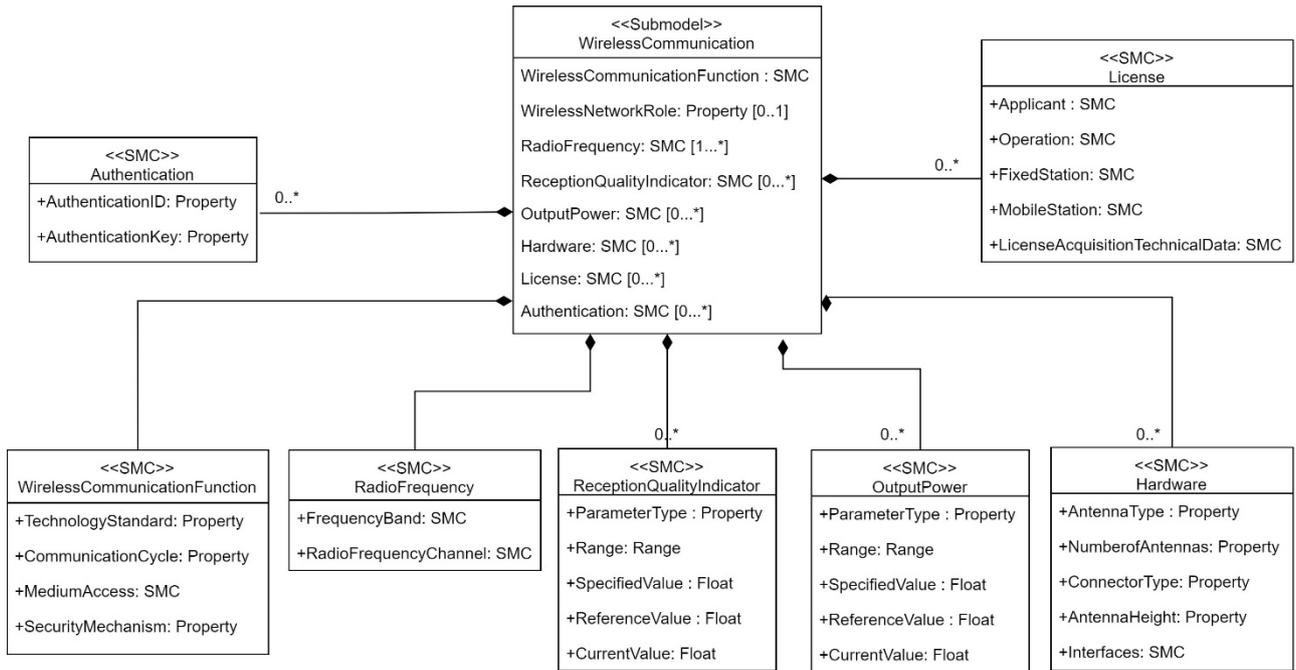


Figure 3: UML-diagram of Submodel WirelessCommunication.

Table 1: Submodel elements for the Submodel WirelessCommunication

idShort:	WirelessCommunication		
Class:	Submodel		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/1/0		
Parent:	--		
Explanation:	Contains the wireless communication aspects of the asset.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[SMC] WirelessCommunicationFunction	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/1/0 Hardware and software implementation of algorithms for wireless communication (VDI/VDE 2185 Part-4, 2019). Describes the parameters of the wireless communication function.	n/a	[1]
[Property] WirelessNetworkRole	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessNetworkRole/1/0 Describes the role of the asset in the network: Access point, end node, repeater. It could also be an immaterial asset as a heatmap, or a wireless communication manager.	[String]	[1...*]
[SMC] RadioFrequency	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/1/0 It describes the characteristics of radio channel as frequency, band and bandwidth.	n/a	[0...1]
[SMC] ReceptionQuality	[IRI] https://admin-shell.io/idta/WirelessCommunication/ReceptionQuality/1/0 Set of parameters that describe the quality of reception. The availability of this parameter depends on the technology and implementations.	n/a	[0...*]
[SMC] OutputPower	[IRI] https://admin-shell.io/idta/WirelessCommunication/OutputPower/1/0 The transmit power is determined by the RF schematic of the wireless module. Depending on the wireless technology, standard, or implementation it is fixed, adjustable in steps or free configurable (VID/VDE 2185 Part4).	n/a	[0...*]
[SMC] License	[IRI] https://admin-shell.io/idta/WirelessCommunication/ License/1/0 The transmit power is determined by the RF schematic of the wireless module. Depending on the wireless technology, standard, or implementation it is fixed, adjustable in steps or free configurable (VID/VDE 2185 Part4).		
[SMC] Hardware	[IRI] https://adminshell.io/idta/WirelessCommunication/Hardware/1/0 A Set of parameters that describe hardware aspects of the asset, such as antenna type, connectors, and interfaces, during different life cycle phases.	n/a	[0...*]

[SMC] Authentication	[IRI] https://adminshell.io/idta/WirelessCommunication/Authentication/1/0 It contains information needed for device authentication. It is required to verify the legitimacy of devices and ensure secure network access.	n/a	[0...*]
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2.1 Submodel elements of SMC “WirelessCommunicationFunction”

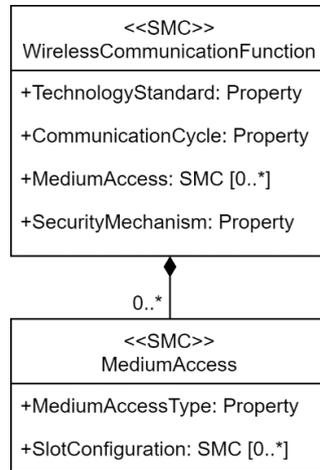


Figure 4: UML-Diagram of the Submodel collection “WirelessCommunicationFunction”.

Table 2: Submodel elements of SMC “WirelessCommunicationFunction”.

idShort:	WirelessCommunicationFunction		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/1/0		
Parent:	WirelessCommunication		
Explanation:	Hardware and software implementation of algorithms for wireless communication (VDI/VDE 2185 Part-4, 2019). Describes the parameters of the wireless communication function.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[Property] TechnologyStandard	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/TechnologyStandard/1/0 It includes the name of the technology and the release/version.	[string] 5G NR Rel.15 802.11ac	[0...1]
[Property] CommunicationCycle	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/CommunicationCycle/1/0 It describes the cycle with which the communication stack executes requests from the application and the wireless medium in ms.	[integer]	[0...*]
[SMC] MediumAccess	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/MediumAccess/1/0	n/a	[0...*]

	The media access control ensures, for example, that a communication request is served as long as the medium is free (CSMA) or it allocates the request to well-defined time slots (TDMA).		
[Property] SecurityMechanism	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/SecurityMechanism/1/0 It specifies how the security objectives of the application are met by the implemented security mechanisms.	[string]	[0...*]

2.1.1 Submodel elements of SMC “MediumAccess”

Table 3: Submodel elements of SMC “MediumAccess”.

idShort:	MediumAccess		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/MediumAccess/1/0		
Parent:	WirelessCommunicationFunction		
Explanation:	The media access control ensures, for example, that a communication request is served as long as the medium is free (CSMA) or it allocates the request to well-defined time slots (TDMA).		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[Property] MediumAccessType	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/MediumAccess/MediumAccessType/1/0 It describes which technique is used for accessing the radio medium. It can be, for example, CSMA or TDMA. Furthermore, it highly depends on the Technology.	[string]	[1]
[SMC] SlotConfiguration	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/MediumAccess/SlotConfiguration/1/0 Depending on the medium access type, the slot configuration can be described as number of slots for downlink, uplink and shared slots.	n/a	[0...1]

2.1.2 Submodel elements of SMC “SlotConfiguration”

Table 4: Submodel elements of SMC “SlotConfiguration”.

idShort:	SlotConfiguration		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/MediumAccess/SlotConfiguration/1/0		
Parent:	MediumAccess		
Explanation:	Depending on the medium access type, the slot configuration can be described as the number of slots for downlink, uplink and shared slots.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[Property] NumberOfDownlinkSlots	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/MediumAccess/SlotConfiguration/NumberOfDownlinkSlots/1/0 Number of timeslots reserved for downlink communication.	[integer]	[1]
[Property] NumberOfUplinkSlots	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/MediumAccess/SlotConfiguration/NumberOfUplinkSlots /1/0 Number of timeslots reserved for uplink communication.	[integer]	[1]
[Property] NumberOfSharedSlots	[IRI] https://admin-shell.io/idta/WirelessCommunication/WirelessCommunicationFunction/MediumAccess/SlotConfiguration/NumberOfSharedSlots/1/0 Number of timeslots that are reserved for downlink and uplink communication.	[integer]	[1]

2.2 Submodel elements of SMC “RadioFrequency”

In this specific SMC, the overall frequency range that encompasses all the channels is represented by the "FrequencyBand" SMC, whereas the individual bandwidth of each channel is denoted by the "RadioFrequencyChannel".

A frequency band refers to a range of contiguous frequencies within the electromagnetic spectrum. Frequency bands are often designated by their lower and upper limits. For example, the “2.4 GHz band” refers to the frequency range from 2.4 GHz to 2.4835 GHz. Different frequency bands are allocated to various services and technologies to avoid interference. A radio frequency channel, on the other hand, is a specific frequency or range of frequencies within a frequency band used for a specific communication link. In wireless communication systems, the available frequency band is typically divided into individual channels, and each channel is assigned a specific frequency. These channels allow multiple communication links to coexist without interfering with each other. For example, in Wi-Fi networks, the 2.4 GHz band includes multiple channels (e.g., channel 1, channel 6, channel 11) and devices can communicate on different channels to reduce interference.

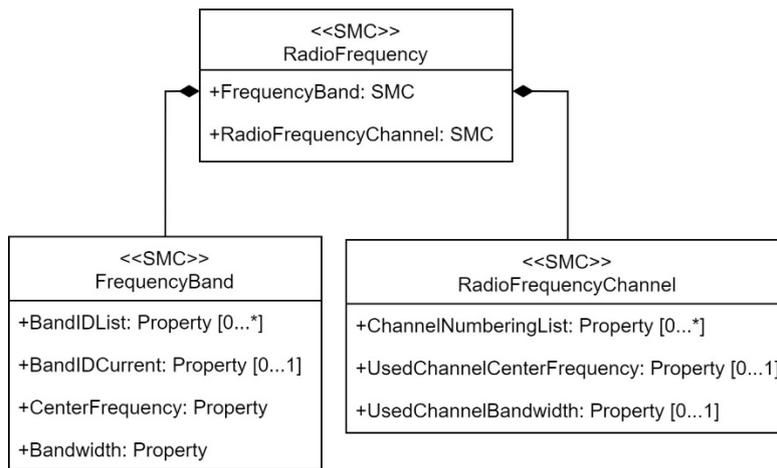


Figure 5: UML-diagram of Radio Frequency Submodel collection.

Table 5: Submodel elements of SMC “RadioFrequency”.

idShort:	RadioFrequency		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/1/0		
Parent:	WirelessCommunication		
Explanation:	Part of the frequency band that is characterized by a lower cut-off frequency and an upper cut-off frequency, or by centre frequency and bandwidth.@en		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[SMC] FrequencyBand	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/FrequencyBand/1/0 Contains information related to the frequency band used by the asset. It refers to a range of frequencies within the electromagnetic spectrum, which includes all frequencies of electromagnetic radiation. Different technologies and applications often use specific frequency bands for communication.	n/a	[1]
[SMC] RadioFrequencyChannel	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/RadioFrequencyChannel/1/0 Refers to a specific channel of frequencies used for wireless communication. Radio communication technologies divide the spectrum into channels.	n/a	[1]

2.2.1 Submodel elements of SMC “FrequencyBand”

Table 6: Submodel elements of SMC “FrequencyBand”.

idShort:	FrequencyBand		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/FrequencyBand/1/0		
Parent:	RadioFrequency		
Explanation:	Contains information related to the frequency band used by the asset. It refers to a range of frequencies within the electromagnetic spectrum, which includes all frequencies of electromagnetic radiation. Different technologies and applications often use specific frequency bands for communication.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[Property] BandIDList	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/FrequencyBand/BandIDList/1/0 List of bands that can be configured on the asset.	[string] [n78, n43]	[0...*]
[Property] BandIDCurrent	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/FrequencyBand/BandIDCurrent/1/0 ID of the current configured band.	[string] [n78]	[0...1]
[Property] CenterFrequency	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/FrequencyBand/CenterFrequency/1/0 Center frequency in MHz of the current configured band.	[float] 3700.0	[1]
[Property] Bandwidth	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/FrequencyBand/Bandwidth/1/0 Bandwidth in MHz of current configured band. Bandwidth is the difference between upper cut-off frequency and lower cut-off frequency. The bandwidth is the range of frequencies occupied by a modulated carrier signal.	[float] 100.0	[1]

2.2.2 Submodel elements of SMC “RadioFrequencyChannel”

Table 7: Submodel elements of SMC “RadioFrequencyChannel”.

idShort:	RadioFrequencyChannel		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/RadioFrequencyChannel/1/0		
Parent:	RadioFrequency		
Explanation:	It refers to a specific frequency or range of frequencies within the frequency band that is allocated for a particular communication purpose. Multiple channels can exist within a frequency band, enabling multiple communication links to operate simultaneously without interference.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[Property] ChannelNumbering	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/RadioFrequencyChannel/ChannelNumbering/1/0 Most wireless technologies assign numbers to the specified radio channels. This parameter lists the specified numbers. It may be used for some technologies (e.g., Bluetooth). Blacklisting can be considered.	[integer] 14	[0...*]
[Property] UsedChannelCentreFrequency	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/RadioFrequencyChannel/UsedChannelCentreFrequency/1/0 Centre frequency is the geometric mean of lower cut-off frequency and upper cut-off frequency of a radio channel. This parameter assigns the centre frequencies to the radio channels. It serves to specify the utilized frequency, crucial for systems like Wi-Fi. However, in instances of channel-hopping technologies like BLE, IOLW, and WirelessHART, where channels dynamically change, it's recommended to leave this property empty.	[float]	[0..1]
[Property] UsedChannelBandwidth	[IRI] https://admin-shell.io/idta/WirelessCommunication/RadioFrequency/RadioFrequencyChannel/UsedChannelBandwidth/1/0 Bandwidth is the difference between upper cut-off frequency and lower cut-off frequency. The bandwidth is the range of frequencies occupied by a modulated carrier signal. The data rate of reliable communication is directly proportional to the bandwidth of the signal used for the communication.	[integer]	[0...1]

2.3 Submodel elements of SMC “ReceptionQualityIndicator”

Different parameters are utilized in various wireless technologies to assess the quality and intensity of the received signal. The Submodel does not define a specific parameter, but rather provides a framework that can be used for various parameters indicating the intensity or quality of the signal, regardless of the communication technology used. Additionally, some examples of how to use this SMC for different technologies are provided in the annex.

In this SMC, the life cycle phases are considered. The specified value refers to the value established during the design phase, serving as the minimum threshold for the application to operate in alignment with the proposed objectives. The reference value represents the measurement taken during the commissioning phase. It's the value detected by the wireless device at its installation location. The current value is the last value recorded by the asset during its operation. It can be used to detect anomalies or alterations within the wireless channel, and it can also be archived for subsequent analysis or predicting potential failures.

Table 8: Submodel elements of SMC “ReceptionQualityIndicator”.

idShort:	ReceptionQualityIndicator		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/ReceptionQualityIndicator/1/0		
Parent:	WirelessCommunication		
Explanation:	<p>A set of parameters that describe the quality of reception during different life cycle phases.</p> <p>The availability of these parameters depends on the implementation. It may be that not all parameters described in this section are provided/used by the manufacturer.</p>		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[property] ParameterType	<p>[IRI] https://admin-shell.io/idta/WirelessCommunication/ReceptionQualityIndicator/ParameterType/1/0</p> <p>It is a string that describes the parameter type depending on the technology.</p>	<p>[string]</p> <p>For 5G: SS-RSRP or RSRQ</p> <p>For bluetooth RSSI or SINR</p>	[1]
[range] Range	<p>[IRI] https://admin-shell.io/idta/WirelessCommunication/ReceptionQualityIndicator/Range/1/0</p> <p>The range delimits the limits that define the extent of acceptable values or conditions for the parameter. In the context of a reception quality indicator, one of the thresholds can typically be defined by the reception sensitivity parameter of some wireless modules.</p>	<p>[float,float]</p> <p>0 to -125 dBm</p>	[1]
[property] SpecifiedValue	<p>[IRI] https://admin-shell.io/idta/WirelessCommunication/ReceptionQualityIndicator/SpecifiedValue/1/0</p> <p>It is the value specified during the design phase.</p>	<p>[float]</p> <p>-85 dBm</p>	[0...1]
[property] ReferenceValue	<p>[IRI] https://admin-shell.io/idta/WirelessCommunication/ReceptionQualityIndicator/ReferenceValue/1/0</p> <p>It is the value configured in the commissioning phase.</p>	<p>[float]</p> <p>-85 dBm</p>	[0...1]

[property]CurrentValue	[IRI] https://admin-shell.io/idta/WirelessCommunication/ReceptionQualityIndicator/CurrentValue/1/0 It is the last received signal strength value stored by the communication module.	[float] -85 dBm	[0...1]
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2.4 Submodel elements of SMC “OutputPower”

This SMC uses the same structure as ReceptionQualityIndicator. Here, different parameters can be considered. Examples are:

- TPO, which is the raw output power of the transmitter.
- ERP accounts for antenna gain, but does not consider transmission line losses.
- EIRP takes into account both antenna gains and losses on the transmission line, providing a more accurate representation of the actual radiated power.

The specified value refers to the value established at the design stage, typically as an estimate of transmission power to ensure coverage in the specified area without causing disturbance to neighbors. The reference value represents the value during the commissioning phase. It may differ from the specified value as it may be necessary to adjust the access point's transmit power up or down. The current value is the value currently configured on the asset during its operation. This value may vary if management techniques are used to increase or decrease transmission power during operation.

Table 9: Submodel elements of SMC “OutputPower”.

idShort:	OutputPower		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/ReceptionQuality/OutputPower/1/0		
Parent:	WirelessCommunication		
Explanation:	<p>A set of parameters that describe the Output power during the lifecycle phase. The transmit power is determined by the RF schematic of the wireless module. Depending on the wireless technology, standard or implementation it is fixed, adjustable in steps or free configurable. (VID/VDE 2185 Part4)</p> <p>The availability of this parameter depends on the implementations. It may be that not all parameters described in this section are provided/used by the manufacturer.</p>		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	Example	
[property] ParameterType	[IRI] https://admin-shell.io/idta/WirelessCommunication/OutputPower/ParameterType/1/0 It is a string that describes the parameter type depending on the technology.	[string] EIRP	[1]
[range] Range	[IRI] https://admin-shell.io/idta/WirelessCommunication/OutputPower/Range/1/0 The range delimits the limits that define the extent of acceptable values or conditions for the parameter. In the context of output power, it is typically defined by the maximum transmit power of the transceiver.	[float, float] 0 to -125 dBm	[1]
[property] SpecifiedValue	[IRI] https://admin-shell.io/idta/WirelessCommunication/OutputPower/SpecifiedValue/1/0 It is the value specified during the design phase. (float)	[float] -85 dBm	[0...1]

[property] ReferenceValue	[IRI] https://admin-shell.io/idta/WirelessCommunication/OutputPower/ReferenceValue/1/0 It is the value configured in the commissioning phase.	[float] -85 dBm	[0...1]
[property] CurrentValue	[IRI] https://admin-shell.io/idta/WirelessCommunication/OutputPower/CurrentValue/1/0 It is the current value of the parameter.	[float] -85 dBm	[0...1]

2.5 Submodel elements of SMC “Hardware”

In this section, hardware aspects of wireless communication assets are considered, specifically highlighting antenna properties. Understanding characteristics such as gain, bias, and bandwidth is crucial to optimizing the performance and connectivity of assets in I4.0. This information can provide valuable insights to engineers during the design phase.

Table 10: Submodel elements of SMC “Hardware”.

idShort:	Hardware		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/Hardware/1/0		
Parent:	WirelessCommunication		
Explanation:	A set of parameters that describe hardware aspects of the asset, such as antenna type, connectors and interfaces, during different life cycle phases.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[property] AntennaType	[IRI] https://admin-shell.io/idta/WirelessCommunication/Hardware/AntennaType/1/0 It describes the antenna used for the wireless asset. (Monopole antenna, directional antenna, dipole antenna, special antenna). It also defines the antenna connector.	[string]	[0...*]
[property] NumberOfAntenas	[IRI] https://admin-shell.io/idta/WirelessCommunication/Hardware/NumberOfAntennas/1/0 It defines how many antennas the asset has.	[int]	[0...*]
[property] ConnectorType	[IRI] https://admin-shell.io/idta/WirelessCommunication/Hardware/ConnectorType/1/0 Connector type of the antenna.	[float]	[0...*]
[property] AntennaHeight	[IRI] https://admin-shell.io/idta/WirelessCommunication/Hardware/AntennaHeight/1/0 Height of the antenna.	[float]	[0...*]
[Property] Interfaces	[IRI] https://admin-shell.io/idta/WirelessCommunication/Hardware/Interface/1/0 It describes the interfaces that the asset has: Ethernet, USB, Wireless, Digital IO, etc..	n/a	[0...*]

2.6 Submodel elements of SMC “Authentication”

To represent the parameter used for device authentication in a generic way across various wireless industrial communication networks, the property called "Authentication Identifier" is used. This term encompasses the different parameters such as APN (5G), Master ID (Bluetooth), SSID (Wi-Fi), or any other specific identifier used by a particular wireless network for device authentication. By using this generic term, it can refer to a common concept without being tied to a specific network or technology. The "Authentication Identifier" is a generic term used in the context of wireless industrial communication networks to refer to a specific parameter or piece of information required for the authentication of devices wishing to join a network. This parameter plays a crucial role in verifying the legitimacy of devices and ensuring secure access to the network. While the exact nature of the Authentication Identifier may vary from one wireless technology to another, it serves as a unique or predefined piece of data that must be presented by a device during the authentication process.

Some technologies also use "Authentication Keys" as cryptographic codes or credentials used alongside the Authentication Identifier. These keys add an extra layer of security to the authentication process. While the Authentication Identifier serves as a unique identifier, the Authentication Keys are secret codes or data that only authorized devices possess.

Table 11: Submodel elements of SMC “Authentication”.

idShort:	Authentication		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/Authentication/1/0		
Parent:	WirelessCommunication		
Explanation:	It contains information needed for device authentication. It is required to verify the legitimacy of devices and ensure secure network access.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[property] AuthenticationIdentifier	[IRI] https://admin-shell.io/idta/WirelessCommunication/Authentication/AuthenticationIdentifier/1/0 It is a parameter for device authentication in networks. It varies across wireless technologies, serving as a unique data piece presented during authentication, such as 5G's "Access Point Name," Bluetooth's "Master ID," and Wi-Fi's "SSID."	[String]	[0...1]
[property] AuthenticationKey	[IRI] https://admin-shell.io/idta/WirelessCommunication/Authentication/AuthenticationKey/1/0 Cryptographic codes or credentials used alongside the Authentication Identifier.	[String]	[0...1]

2.7 Submodel elements of SMC “License”

This section comprises parameters related to licensing, which are utilized by the regulatory authority when applying for a license. It's worth noting that certain parameters found within this SMC may also appear in other SMCs, resulting in duplication.

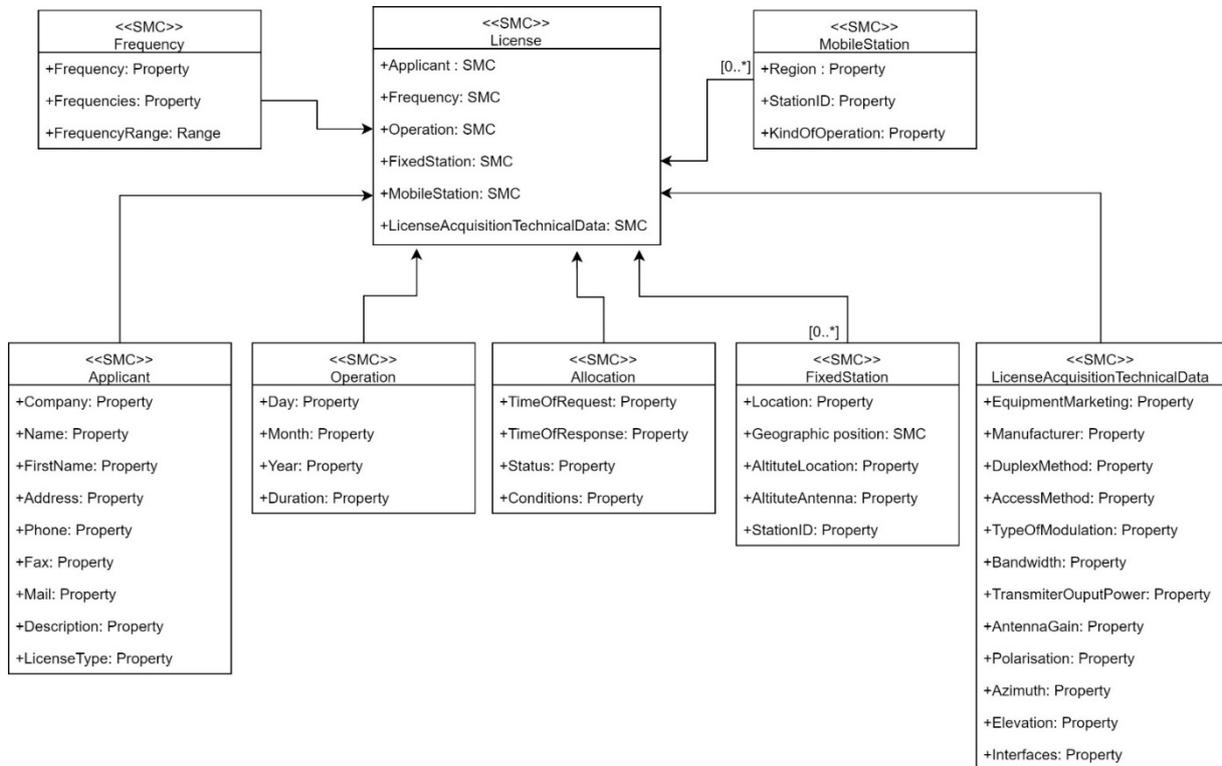


Figure 6: UML-Diagram of the Submodel collection “License”.

Table 12: Submodel elements of SMC “License”.

idShort:	License		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/1/0		
Parent:	WirelessCommunication		
Explanation:	It contains parameters related to licensing, which are utilized by the regulatory authority when applying for a licence. Certain parameters found within this SMC may also appear in other SMCs, resulting in duplication.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[SMC] Applicant	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Applicant/1/0 A set of parameters that include the information about the license holder as well as the contact person.	n/a	[1]
[SMC] Frequency	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Frequency/1/0 This list contains information about the used frequency or frequency ranges. Only one of the three fields must be filled in.	n/a	[1]
[SMC] Operation	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Operation/1/0 This list contains information on the period of use of the frequency ranges applied for.	n/a	[1]
[SMC] FixedStation	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/FixedStation/1/0 This list contains the geographical information of the fixed stations. Information must include both the postal and geographic address, as well as the height of the antennas.	n/a	[0...*]
[SMC] MobileStation	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/MobileStation/1/0 This list contains the information about the mobile station (used geographical area, number of mobile stations, and kind of operation).	n/a	[0...*]
[SMC] LicenseAcquisitionTechnicalData	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/TechnicalData/1/0 This list contains the technical parameters of the network.	n/a	[1]
[SMC] Allocation	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Allocation/1/0 Information about the time and status of application.	n/a	[1]

2.7.1 Submodel elements of SMC “Applicant”

Table 13: Submodel elements of SMC “Applicant”.

idShort:	Applicant		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Applicant/1/0		
Parent:	License		
Explanation:	A set of parameters that include the information about the license holder as well as the contact person.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[property] CompanyName	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/CompanyName/1/0 Official name of the applying/responsible company.	[string]	[1]
[property] ContactSurname	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/ContactSurname/1/0 Name of the responsible person	[string]	[1]
[property] ContactFirstName	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/ContactFirstName/1/0 First name of the responsible person.	[string]	[1]
[property] Address	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Address/1/0 Official company address	[string]	[1]
[property] Phone	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Phone/1/0 Phone number	[string]	[1]
[property] Fax	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Fax/1/0 Fax number (optional parameter)	[string]	[1]
[property] Mail	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Mail/1/0 Contact mail address (optional parameter)	[string]	[1]
[property] Description	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Description/1/0 Description of the intended use (Aproximately one page).	[string]	[1]
[property] LicenseType	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/LicenseType/1/0 Type of license: Trial operation, normal operation.	[string]	[1]

2.7.2 Submodel elements of SMC “Frequency”

Table 14: Submodel elements of SMC “Frequency”.

idShort:	Frequency		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Frequency/1/0		
Parent:	License		
Explanation:	This list contains information about the used frequency or frequency ranges. Only one of the three fields must be filled in. Only one of the three fields must be filled in.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[property] Frequency	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Frequency/1/0 Frequency for operation in the radio spectrum, subject to license application.	[float]	[1]
[property] Frequencies	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Frequencies/1/0 List of frequencies for operation in the radio spectrum, subject to license application.	[float]	[1]
[range] FrequencyRange	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/FrequencyRange/1/0 List with “start frequency” and “stop frequency” for operation in the radio spectrum, subject to license application.	[float]	[1]

2.7.3 Submodel elements of SMC “Operation”

Table 15: Submodel elements of SMC “Operation”.

idShort:	Operation		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Operation/1/0		
Parent:	License		
Explanation:	This list contains information on the period of use of the frequency ranges applied for.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	idShort	Description@en
[property] Day	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Operation/Day/1/0 Begin of operation Day.	[string]	[1]
[property] Month	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Operation/Month/1/0 Begin of operation Month.	[string]	[1]
[property] Year	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Operation/Year/1/0 Begin of operation Year.	[string]	[1]
[property] Duration	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Operation/Duration/1/0 Duration of operation in Days.	[string]	[1]

2.7.4 Submodel elements of SMC “FixedStation”

Table 16: Submodel elements of SMC “FixedStation”.

idShort:	FixedStation		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/License//1/0		
Parent:	License		
Explanation:	It contains the geographical information of the fixed station. Information must include both the postal and geographic address, as well as the height of the antennas.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[property] Location	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/FixedStation/Location/1/0 Address of the location.	[string]	[1]
[SMC] GeographicPosition	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/FixedStation/GeographicPosition/1/0 Geographic Position in East and North Degree, Minute and Second.	[string]	[1]
[property] AltitudeLocation	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/FixedStation/AltitudeLocation/1/0 Altitude above sea level.	[string]	[1]
[property] AltitudeAntenna	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/FixedStation/AltitudeAntenna/1/0 Altitude above earth's surface.	[string]	[1]
[property] StationID	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/FixedStation/StationID/1/0 Identification number of fixed stations.	[string]	[1]

2.7.5 Submodel elements of SMC “Allocation”

Table 17: Submodel elements of SMC “Allocation”.

idShort:	FixedStation		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Allocation/1/0		
Parent:	License		
Explanation:	Information about the time and status of application.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[property] TimeofRequest	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Allocation/TimeofRequest/1/0 Date of application submission.	[string]	[1]
[property] TimeOfResponse	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Allocation/TimeOfResponse/1/0 Date of response from regulatory authority.	[string]	[1]
[property] Status	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/Allocation/Status/1/0 Response from the regulatory authority. Application approved/Application approved subject to compliance with conditions/Application rejected	[string]	[1]
[SMC] Conditions	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/FixedStation/AltitudeAntenna/1/0 Conditions so that the license application is accepted. e.g., restriction of transmission power, alignment of the antenna	[string]	[1]

2.7.6 Submodel elements of SMC “MobileStation”

Table 18: Submodel elements of SMC “MobileStation”.

idShort:	MobileStation		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/MobileStation/1/0		
Parent:	License		
Explanation:	This list contains the information about the mobile station (used geographical area, number of mobile stations and kind of operation).		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[property] Region	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/MobileStation/Region/1/0 Region in which the mobile should be used. Specification of the coverage area. If possible, a description using a Google Maps image with the BS and coverage area shown as a circle or polygon.	[string]	[1]
[property] StationID	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/MobileStation/StationID/1/0 Id of the mobile station.	[string]	[1]
[property] KindOfOperation	[IRI] https://admin-shell.io/idta/WirelessCommunication/License/MobileStation/KindOfOperation/1/0 One way or two-way communication.	[string]	[1]

2.7.7 Submodel elements of SMC “LicenseAcquisitionTechnicalData”

Table 19: Submodel elements of SMC “LicenseAcquisitionTechnicalData”.

idShort:	LicenseAcquisitionTechnicalData		
Class:	SubmodelElementCollection		
semanticId:	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/1/0		
Parent:	Licence		
Explanation:	This list contains the technical parameters of the network.		
[SME type]	semanticId = [idType]value	[valueType]	card.
idShort	Description@en	example	
[property] EquipmentMarketing	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/EquipmentMarketing/1/0 Name or code of the equipment. This parameter is optional for a “Trial License”.	[string]	[1]
[property] Manufacturer	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/Manufacturer/1/0 Manufacturer of the equipment. This parameter is optional for a “Trial License”.	[string]	[1]
[property] DuplexMethod	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/DuplexMethod/1/0 Duplex mode (FDD or TDD).	[string] FDD, TDD	[1]
[property] AccessMethod	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/AccessMethod/1/0 Access mode, e.g., FDMA	[string]	[1]
[property] TypeOfModulation	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/TypeOfModulation/1/0 Type of modulation, e.g., FM	[string]	[1]
[property] Bandwidth	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/Bandwidth/1/0 Used bandwidth in MHz.	[string]	[1]
[property] TransmitterOutputPower	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/TransmitterOutputPower/1/0 Transmitter output power in dBm, e.g., 10dBm	[string]	[1]
[property] AntennaGain	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/AntennaGain/1/0 Antenna gain in dBi respectively antenna pattern	[string]	[1]

[property] Polarisation	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/Polarisation/1/0 Polarisation of the antenna, e.g., horizontal, vertical, ...	[string]	[1]
[property] Azimuth	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/Azimuth/1/0 Azimut of the antenna.	[string]	[1]
[property] Elevation	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/Elevation/1/0 Elevation of the antenna.	[string]	[1]
[property] Interfaces	[IRI] https://admin-shell.io/idta/WirelessCommunication/LicenseAcquisitionTechnicalData/Interfaces/1/0 Connection between radio system and other telecommunication systems, e.g., private or public network. This parameter is optional for a "Trial License".	[string]	[1]

Annex A. Examples of use of SMC “Reception Quality”

Examples of how to use the Reception Quality Indicator in various technologies are provided. By following these examples, users will be able to model the reception quality of assets using different technologies.

The SpecifiedValue, plays a fundamental role in the design phase of a communication system. This value is carefully defined and established to ensure that the system meets application requirements effectively and smoothly. On the other hand, the ReferenceValue is a reference measurement that is often used to compare with the current value. This comparison is essential for making critical decisions and preventing possible system failures. The CurrentValue is the actual measurement obtained by the communication module at a specific moment, reflecting the actual operating conditions. These three elements represent the life cycle aspects of the asset and work together to ensure the performance and reliability of the communication system in various application contexts.

1. 5G

In the context of 5G technology, several parameters play a crucial role in evaluating connection quality. Among these parameters, the RSRP (Received Signal Reference Power) stands out, which measures the power of the received reference signal; SINR (Signal-to-Interference-plus-Noise Ratio), which quantifies the relationship between the desired signal and interference together with noise; and RSRQ (Reference Signal Received Quality), which evaluates the quality of the received reference signal, taking into account the amount of interference present. These parameters play a key role in optimizing 5G connectivity, enabling network operators and engineers to monitor and tune network performance to deliver a more efficient and reliable user experience in diverse 5G environments.

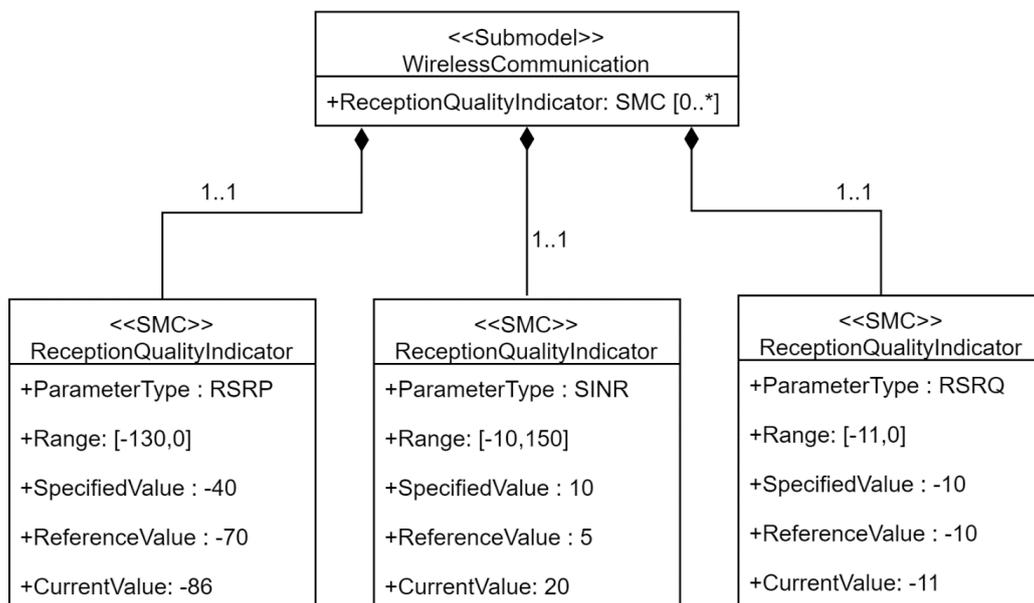


Figure 7: Example of use of the Submodel ReceptionQuality for 5G.

2. Bluetooth and IO-Link Wireless

In the context of Bluetooth and IO-Link Wireless technologies, some essential parameters for evaluating connection quality include RSSI (Received Signal Strength Indicator), which measures the strength of the received signal, and Link Quality, which evaluates the overall quality of the connection. RSSI provides information about signal strength, while Link Quality considers several factors, such as the stability and reliability of the connection. These parameters are fundamental for optimizing connectivity in devices and systems that use Bluetooth and IO-Link Wireless, allowing users to monitor and adjust network performance to ensure more effective and robust communication in different application scenarios.

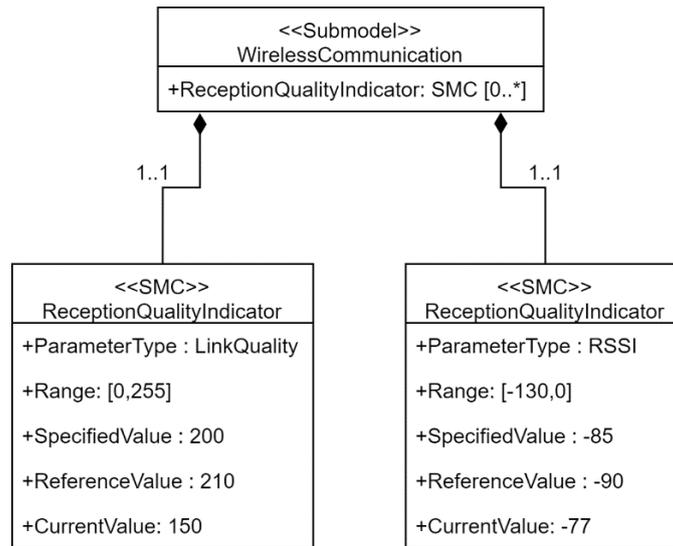


Figure 8: Example of use of the Submodel ReceptionQuality for Bluetooth and IO-Link Wireless.

3. WirelessHART

Within the context of WirelessHART technology, one of the essential parameters for evaluating connection quality is the Received Signal Level (RSL), according to IEC 62591. This parameter measures the strength of the received signal and plays a crucial role in determining the robustness and effectiveness of communication in WirelessHART systems. By monitoring RSL, operators and engineers can adjust network configuration and take steps to ensure stable and reliable connectivity in industrial and automation environments where WirelessHART is widely used.

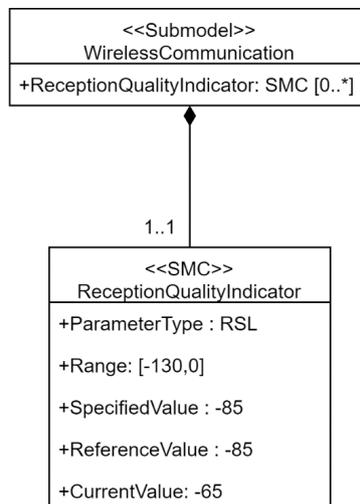


Figure 9: Example of use of the Submodel ReceptionQuality for WirelessHART.

Annex B. Explanations on used table formats

1. General

The used tables in this document try to outline information as concise as possible. They do not convey all information on Submodels and SubmodelElements. For this purpose, the definitive definitions are given by a separate file in form of an AASX file of the Submodel template and its elements.

2. Tables on Submodels and SubmodelElements

For clarity and brevity, a set of rules is used for the tables for describing Submodels and SubmodelElements.

- The tables follow in principle the same conventions as in [5].
- The table heads abbreviate 'cardinality' with 'card'.
- The tables often place two informations in different rows of the same table cell. In this case, the first information is marked out by sharp brackets [] from the second information. A special case are the semanticIds, which are marked out by the format: (type)(local)[idType]value.
- The types of SubmodelElements are abbreviated:

SME type	SubmodelElement type
Property	Property
MLP	MultiLanguageProperty
Range	Range
File	File
Blob	Blob
Ref	ReferenceElement
Rel	RelationshipElement
SMC	SubmodelElementCollection

- If an idShort ends with '{00}', this indicates a suffix of the respective length (here: 2) of decimal digits, in order to make the idShort unique. A different idShort might be chosen, as long as it is unique in the parent's context.
- The Keys of semanticId in the main section feature only idType and value, such as: [IRI]https://admin-shell.io/vdi/2770/1/0/DocumentId/Id. The attributes "type" and "local" (typically "ConceptDescription" and "(local)" or "GlobalReference" and "(no-local)") need to be set accordingly; see [6].
- If a table does not contain a column with "parent" heading, all represented attributes share the same parent. This parent is denoted in the head of the table.
- Multi-language strings are represented by the text value, followed by '@'-character and the ISO 639 language code: example@EN.
- The [valueType] is only given for properties.

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