RE4DY

MANUFACTURING DATA NETWORKS

RE4DY TOOLKIT

Name of the Tool	**5G User Equipment (UE) Digital Twin [5G UE AAS]**
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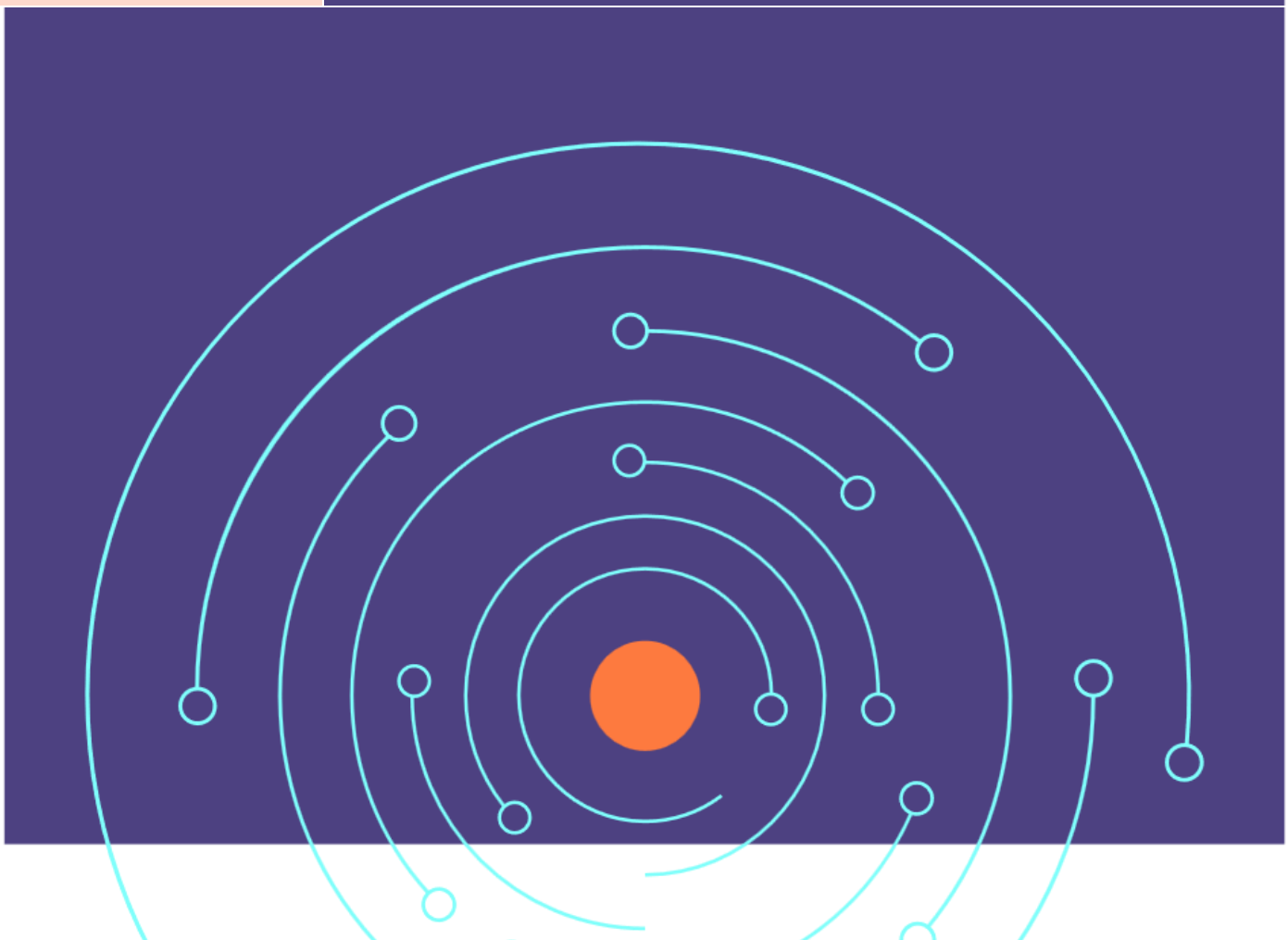

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1. Component Description

This component represents the digital twin or Asset Administration Shell of a 5G User Equipment. An AAS is a digital model or a set of submodels that provides relevant information and features of an asset. AASs describe the technical functionalities exposed by the assets, ensuring interoperability between systems managing manufacturing processes. Asset Administration Shells (AAS) are then standardized digital representations or digital twins of assets and play a crucial role in the management and administration of assets within manufacturing environments.

The digital twin or AAS of a 5G system is integrated by two main components: the digital twin of the 5G UE, which is the endpoint of a 5G link, and the digital twin of the 5G network that encompasses all the nodes and functions within the 5G Radio and Core networks. This component focuses on the 5G UE digital twin.

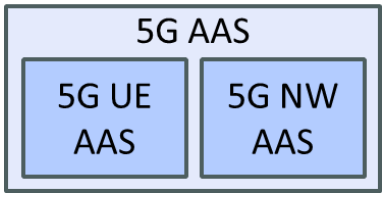


Figure 1 Representation of the main components of a 5G Digital Twin or AAS

2. Input

The 5G UE Digital Twin obtains information from the 5G UE. The information obtained show the current status of the 5G UE and about the different 5G connections established by the UE. In particular, the 5G UE Digital Twin obtains information about technical capabilities of the 5G UE, identification data, network access restrictions, connection status, experienced communication performance, and localization information. The 5G UE Digital Twin uses the interfaces and exposure functions enabled by the 5G systems to make this data available, such as the NEF (Network Exposure Function), and SEAL (Service Enabler Architecture Layer for Verticals) servers.

The 5G UE Digital Twin can also receive input data from other Digital Twins. Specifically, the 5G Network Digital Twin can provide information about the status and operation of the 5G network. Moreover, the Digital Twin of the industrial device to which the UE is related will provide input data about the traffic generated by the industrial application and the status of the device.

3. Output

The 5G UE Digital Twin exposes and simplifies access to 5G UE data, allowing for easier management and utilization of the 5G technology within manufacturing systems. The 5G UE Digital Twin structures and organizes the data obtained from the 5G UE and makes it accessible following and standardized approach that facilitates its seamless integration with the digital twin of manufacturing systems.

4. Information Flow

QoS established for a PDU Session

When a new connection or PDU Session is established by a UE in a 5G network, the UE informs the 5G network about the communication requirements of the traffic generated by the industrial application. Based on these communication requirements, the 5G network decides the QoS parameters associated to the PDU session executing several QoS parameters mapping functions at different nodes of the 5G network. The main purpose of these mapping functions is the conversion of QoS parameters from one format to another. This process is depicted in Figure 2 and described below:

1. The application requirements are communicated and stored in the AF (Application Function) using a session description language (SDI), e.g. Session Description Protocol (SDP) or Media Presentation Description (MPD).
2. The AF maps the application specific information into the appropriate QoS format to be understood by the 5G network.
3. The PCF (Policy Control Function) is in charge of mapping the service information received from the AF into QoS parameters (e.g. Guaranteed Bit Rate, Maximum Bit Rate, Allocation and Retention Priority, etc.) authorized to the UE based on the UE subscription. The PCF combines per direction the individual Authorized QoS parameters per flow.
4. The SMF (Session Management Function) then maps the Authorized QoS parameters received from the PCF to Authorized Access-specific QoS parameters, that is for each QoS flow. The Authorized Access-specific QoS parameters are communicated to the UE.

As shown in Figure 2 the UE has information about the QoS parameters related to each connection established. The 5G UE AAS accesses the information about the established connections and stores the QoS parameters related to each connection. The 5G Network Digital Twin will also model the mapping functions executed at each node of the 5G core network. If this is the case, the 5G UE AAS will interact with the 5G Network Digital Twin to model the QoS mapping process in the digital world.

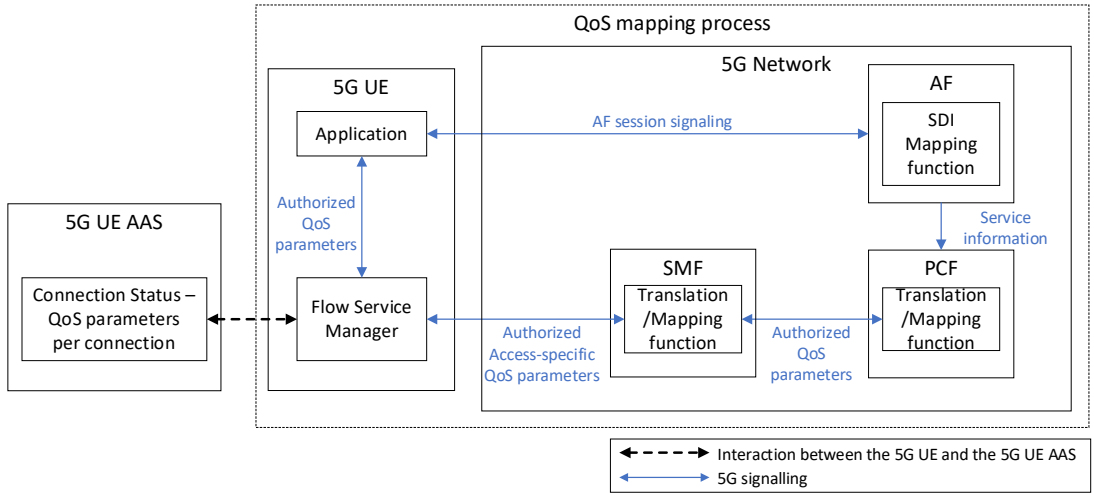


Figure 2 Information exchange between the 5G UE and the 5G UE Digital Twin or AAS

PDU session modification

After a PDU is established, the UE can request a PDU session modification to, for example, request the modification of the QoS parameters related to the PDU session (see Figure X). To this end, the UE sends a 'PDU session modification request' message to the SMF containing the requested QoS parameters. If the request is accepted, it will be granted only if the network can support the petition. The SMF will then send a 'PDU session modification command' message to the UE, containing the Authorized QoS parameters.

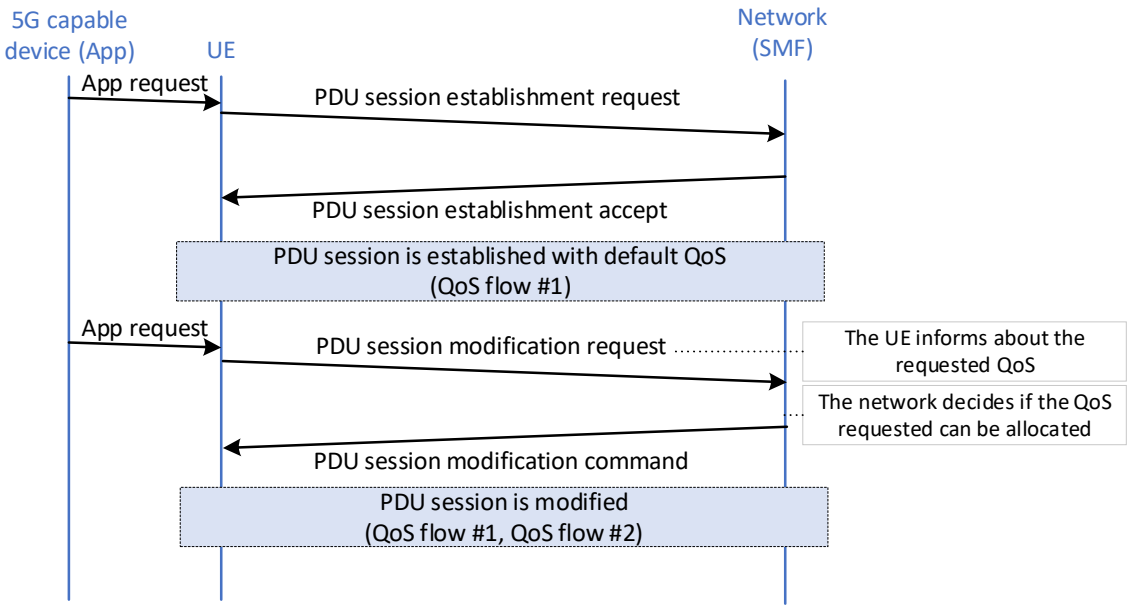


Figure 3 PDU session modification procedure

This PDU session modification procedure can also be modelled in the digital twin of the 5G network. Before to take an action, it could be interesting to know if the network will be capable to support the new requested QoS. In this case, the digital twin of the 5G capable device will interact

with the 5G UE Digital Twin. Upon receiving the request, the 5G UE Digital Twin will process the request and will send a PDU session modification request to the 5G Network Digital Twin which model all the session and QoS management functions. The 5G Network Digital Twin will evaluate the request and will decide if the QoS requested can be allocated. The 5G Network Digital Twin will inform the 5G UE Digital Twin about their decision. By modelling this procedure in the digital world, it is possible to evaluate the results and consequences of the request before taking an action in the physical word.

5. Internal Architecture

The information and functions within the 5G UE Digital Twin are organized in different submodels. Submodels are technically isolated from each other. Each submodel comprises submodel elements, which serve as the components suitable for describing and distinguishing assets. These submodel elements can be properties, operations, and collections, enabling a hierarchical structure for asset differentiation.

The defined 5G UE Digital Twin relies on a comprehensive understanding of 5G networks, their operation, and functions, and 3GPP standards. In addition, the definition of the 5G UE Digital Twin or AAS is done based on the specifications defined by Plattform Industrie 4.0 for the definition of AASs, and the indications provided by 5G-ACIA. Figure 4 shows the defined 5G UE Digital Twin and the different submodels at which the information is organized. The submodels included in the 5G UE Digital Twin are next presented. Some of these submodels are default submodels that all AASs need to include based on the specifications of Plattform Industrie 4.0. Other submodels have been defined to include the relevant information, data, and functions of a 5G UE.

Figure 4 Submodels of the 5G UE Digital Twin or AAS

Standardized or default submodels.

- Nameplate submodel provides identifying information about an asset, such as the manufacturer's name, model type, and serial number.

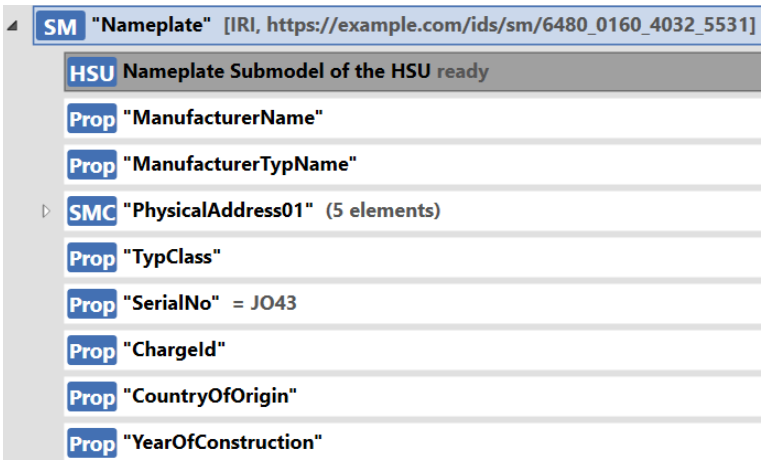


Figure 5 Nameplate submodel of a 5G UE Digital Twin or AAS

- Identification submodel is utilized for property recognition. It comprises elements such as the manufacturer's name, supplier's name, asset ID, manufacturing date, device revision, software revision, hardware revision, etc. Despite some overlapping elements with the Nameplate submodel, these serve different functions in varied scenarios.

Figure 6 Identification submodel of a 5G UE Digital Twin or AAS

- Documentation submodel organizes and categorizes pertinent documents, making it easier to locate them. This encompasses items like data sheets, maintenance manuals, and user guides.

Figure 7 Documentation submodel of a 5G UE Digital Twin or AAS

- Service submodel contains support and maintenance information. It offers contact details for necessary support. Elements within this submodel may include supplier name, contact info role, email, or phone number.

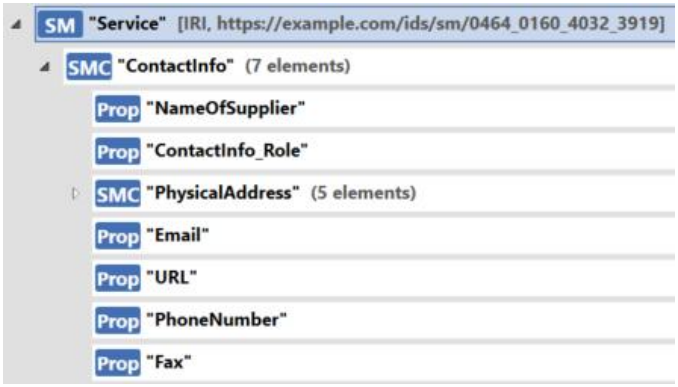


Figure 8 Service submodel of a 5G UE Digital Twin or AAS

- TechnicalData submodel aims to provide interoperable technical data that describes the asset of the respective Asset Administration Shell. The “TechnicalData” submodel has been extended to include specific technical characteristics of a 5G UE, such as the operating bands, channel bandwidth, duplex mode, and technical characteristics of the transmitter and receiver.

Figure 9 TechnicalData submodel of a 5G UE Digital Twin or AASI

5G UE related submodels

- SIMCard submodel includes all the information related to the SIM (Subscriber Identity Module) card used by the UE. The SIMCard submodel contains the IMSI (International Mobile Subscriber Identity), ICCID (Integrated Circuit Card ID), PIN (Personal Identification Number). The submodel also includes the Service Provider Name (SPN) that identifies the name of the mobile operator providing the service, and the Authentication Key that is a unique value for each SIM card that authenticates the UE in the network.

Figure 10 SIMCard submodel of a 5G UE Digital Twin or AAS

- UE_5G_Identification submodel contains data that is used to uniquely identify a UE within the 5G network such as the Permanent Equipment Identifier, UE identity GPSI, the certificate of authentication and the certificate status.

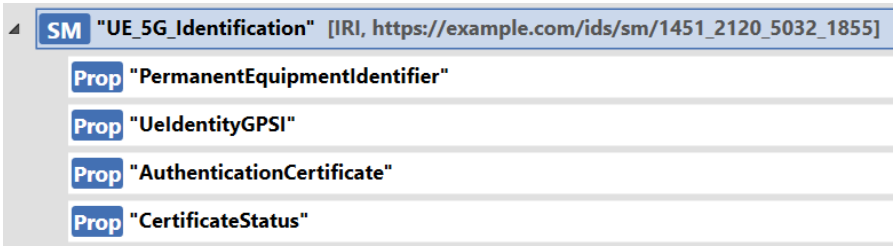


Figure 11 UE_5G_Identification submodel of a 5G UE Digital Twin or AAS

- NetworkAccessRestrictions submodel includes physical and logical access restrictions to the network. It contains a list of cells and slices to which the UE can access.

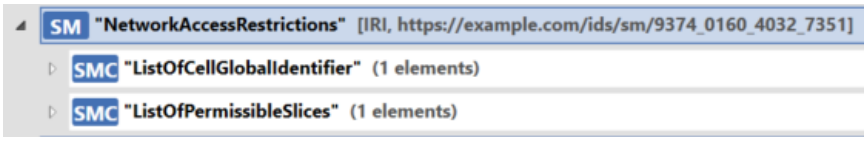


Figure 12 NetworkAccessRestrictions submodel of a 5G UE Digital Twin or AAS

- UeAttachAndConnectionStatus submodel contains information about the connection status of the UE and a list of the connections or Protocol Data Unit (PDU) sessions established with the UE (acting as a source or destination of the communication). For each PDU session, the submodel stores the information about the QoS parameters that need to be supported, and the Radio Resource Management (RRM) parameters that are used to meet the established QoS.

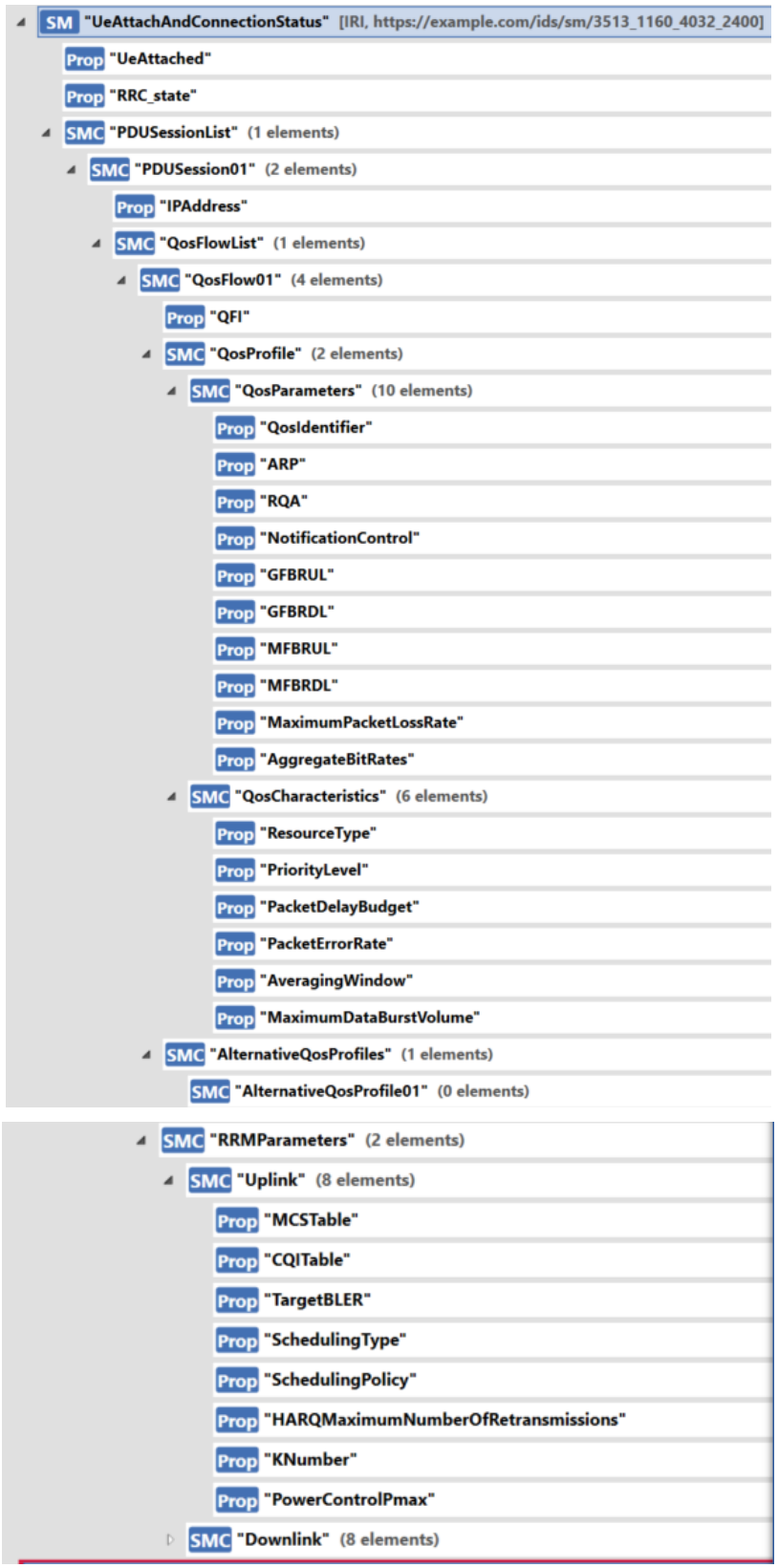
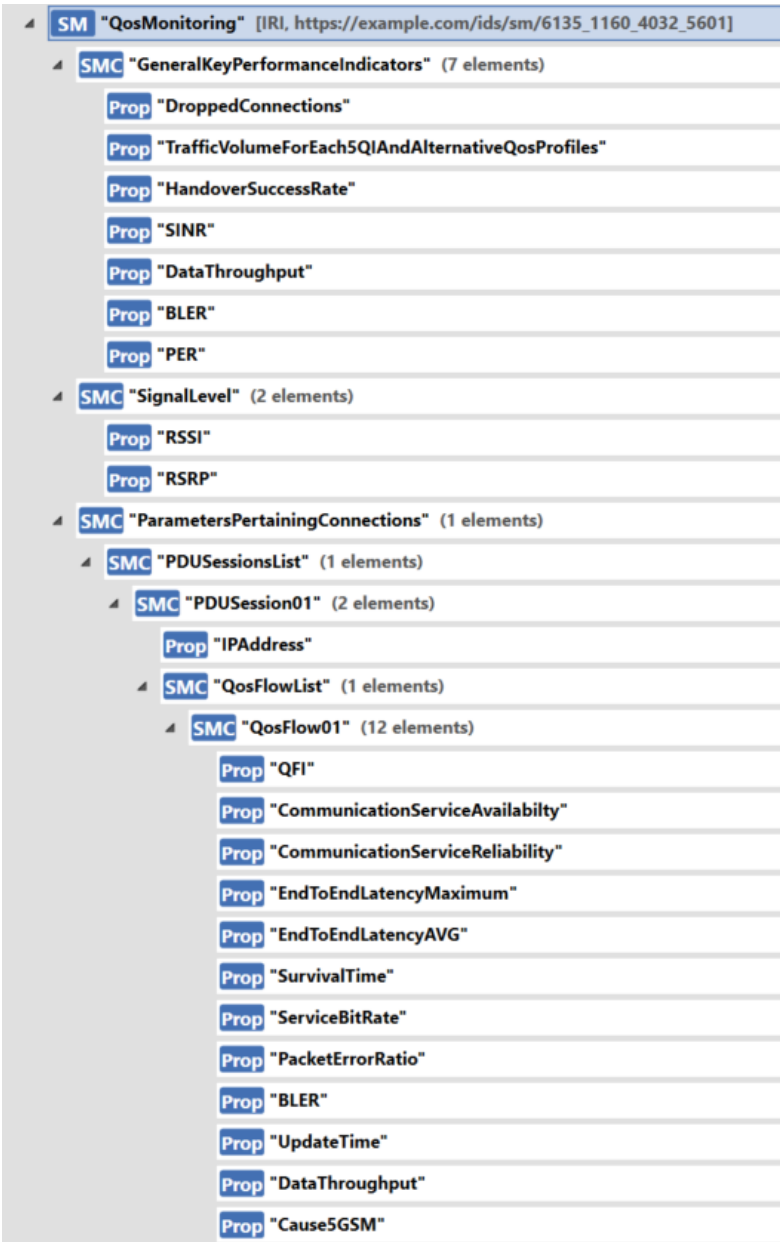


Figure 13 UeAttachAndConnectionStatus submodel of a 5G UE Digital Twin or AAS

- QosMonitoring submodel contains data about the performance experienced by the UE. In particular, it shows key performance indicators (KPIs) that provide information about the general performance experienced by the UE, and also KPIs related to the particular performance achieved in each connection or PDU session established by the UE. This submodel also contains a list of the connectivity-related events to which the UE is subscribed in the 5G network. Some examples of the events to which the UE can subscribe are: Maximum latency exceeded, minimum service bit rate not achieved, communication service availability fell below the requested value, connectivity lost/ re-established. The model also shows and saves the registered events as a result of the subscriptions.



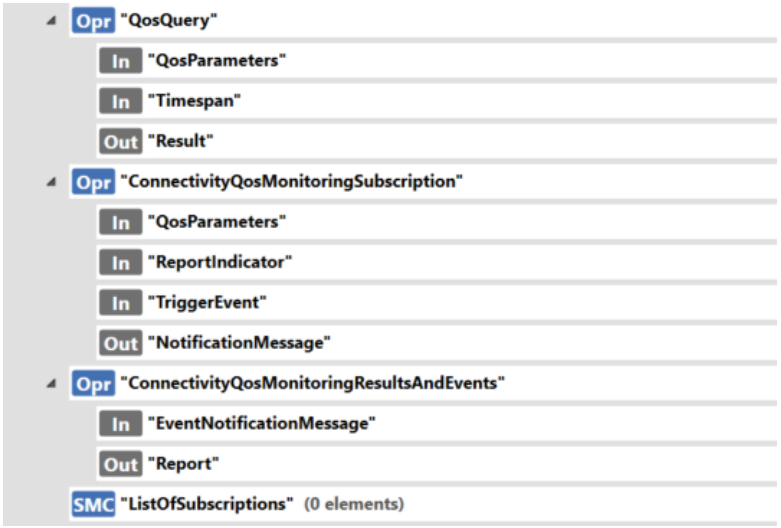


Figure 14 QosMonitoring submodel of a 5G UE Digital Twin or AAS

- LocalizationReport submodel includes a list of localization events to which the UE is subscribe in the 5G network, as for example. In addition, this submodel provides information about localization events to which the UE is subscribed.

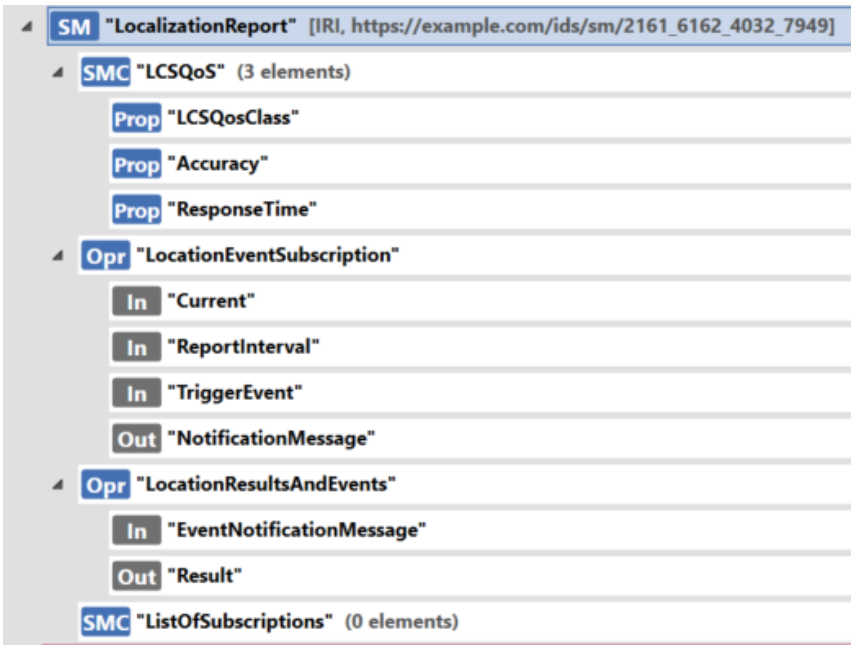


Figure 15 LocalizationReport submodel of a 5G UE Digital Twin or AAS

6. API

The 5G UE Digital Twin is one of the two components that integrate a 5G Digital Twin. The second component is the 5G Network Digital Twin that digital models all the components and functions of the 5G Radio and Core networks. In this context, the 5G Digital Twin closely interacts with the 5G Network AAS to form a robust digital twin of a 5G network.

On the other hand, the 5G UE Digital Twin will closely interact with the digital twin of the industrial 5G-enabled device where the 5G UE is integrated. The digital twin of the industrial 5G-enabled device will provide information about the traffic generated by the industrial application and the status of the device. The 5G UE Digital Twin could provide information about the status of the communications to the 5G-enabled device digital twin in order to take any preventive action.

The interfaces necessary to interact with other digital twins or AASs (with the Digital Twin of the 5G network part and the Digital Twin of industrial devices) are being currently designed. Following the specifications of Platform Industry 4.0, the interfaces are being implemented using OPC-UA following a Client-Server communication approach.

7. Implementation Technology

The 5G UE Digital Twin or AAS has been developed following the specifications provided by Platform Industry 4.0 for the development of AASs. The first version of the developed 5G UE Digital Twin or AAS focuses on the design of a passive Digital Twin or AAS that only contains documents and static information. To this end, the 5G UE Digital Twin or AAS has been implemented using the AASX Package Explorer software. This software is developed by Platform Industry 4.0 and employs a graphical interface for creating, editing, and viewing AAS in adherence to the standardized specifications of Platform Industry 4.0. It primarily focuses on creating passive AAS with the correct structure in a static manner.

We are currently working on providing dynamism to the 5G UE Digital Twin and achieving an active AAS that can exchange information with others AAS. To this end, we are using Python-based programming tools (in particular, PyI40AAS and basyx-python-sdk libraries) to add active functionalities to the 5G UE AAS.

8. Comments

This component provides the general description of a 5G UE Digital Twin or AAS and describes the different submodels and how the data should be organized to make it accessible to other digital twins or applications. It is important to highlight that the 5G UE Digital Twin or AAS needs to be specifically configured based on the requirements of the current deployment scenario.