Technical Framework Virtual Power Plant

Vol. 2

Version 00.19

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Disclaimer
The content of this document is merely informative and does not represent any formal statement from individuals and/or the Austrian Research Promotion Agency (FFG), the Austrian Climate and Energy Fund, or any official bodies involved. Instead, it is a public document from contributing editors with visionary perspective based on years of experience with interoperability testing and energy system safety. The opinions, if any, expressed in this document do not necessarily represent those of the entire IES project team and/or its funding bodies. Any views expressed are those of the contributing person at the time being and do not commit a common position.

Table of Content

1 About the Document

A **Technical Framework** represents a technical specification, which is integrated into a predefined document structure. Please note that a technical framework does not equal a new standard. It rather describes the normalised use and application of existing standards and practices to avoid interoperability issues. Integration Profiles state constraints/recommendations that define how to apply standards and good practice to realise a specific feature of a Business Function in an important interoperability fashion. The technical framework is embedded in a business domain overview, which is accessible from the project homepage at http://www.iesaustria.at. The concept is based on the IHE technical framework that subdivides a technical framework into two part: volume 1 for an informative and volume 2 for a normative description. This document describes volume 2.

The document structure of the technical framework is as follows:

Volume 1:

- Business Case Overview (informative)
  - Typical use cases
  - Relevant meta-actors
  - Related standards
- Business Functions (informative)
  - Describe the interoperability issues with the IEC 62559 Use Case Methodology
  - Use Case diagrams

Volume 2:

- Integration Profiles (informative and normative)
  - Technical solution for a specific interoperability issue from the Business Function
  - Definition of transactions that are needed
  - Definition of actors that are involved
- Transactions (normative)
  - Specification of actors that shall be implemented
  - Specification of the IT standards and how options/variants shall be used

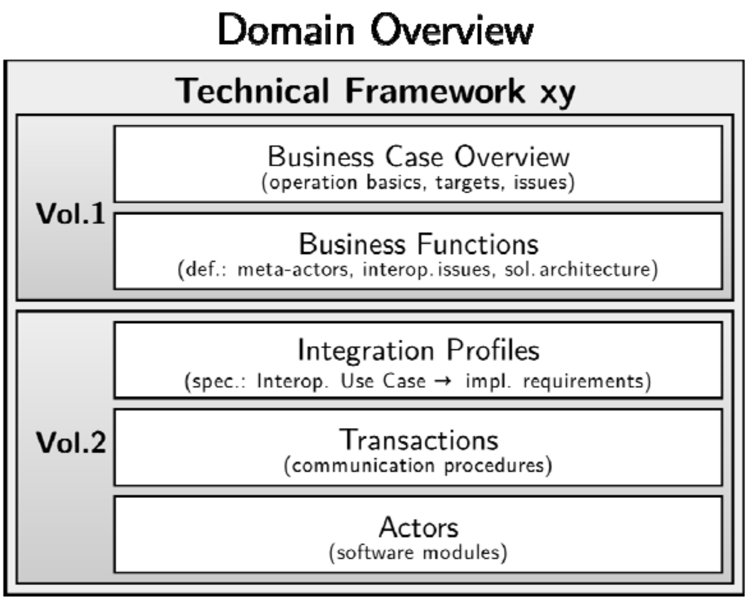

Figure 1: Structure of the Document (IES Technical Framework Template)

2 Definitions

Actor (based on IHE)
is a functional component of a system that executes transactions with other actors as defined in an IHE Integration Profile

Conformance Testing
is a standalone process to ensure that the implementation conforms to specified standards and profiles, i.e. the implementations outputs and response are checked against rules and patterns.

Interoperability Testing
is a process to check whether the system interacts effectively with foreign systems, i.e. when different vendors meet to test their interfaces against each other (e.g. Connectathon).

Interoperability Use Case
is the part of a Business Function that relies on data exchange between different actors according to an Integration Profile (i.e. where interoperability is required).

Meta-Actor
joins functional components (actors) in order to fulfil all the functionalities required for a Business Function (IHE grouping).

Transaction (based on IHE)
is the specification of a set of messages (1..n) exchanged between a pair of actors that realise the Use Case specific information exchange (in one or both directions, in a strict or loose order) as specified by an Integration Profile.

Operational Use Case
is the part of a Business Function that describes an activity not involving any data exchange between actors. This kind of use cases are mentioned in the IES Technical Framework, but not considered in Integration Profiles because per se they do not raise interoperability problems.

3 Integration Profiles

In Volume 2, the integration profiles are described and exemplary implementations are given. The profiles are normative descriptions of the mentioned use cases; therefore, the name of the Use Case and Integration Profile is similar.

3.1 Dependencies among Integration Profiles

The following table defines the dependencies for the Integration Profiles defined in this document. When possible, already defined and used Integration Profiles from IHE are referenced. The IHE Integration Profiles can be found at http://www.ihe.net.

Table 1: Dependencies among Integration Profiles

Integration Profile	Depends on	Dependency Type	Purpose
Send Asset Configurations (SAC)	IHE - Consistent Time[1]	Each SAC Actor shall be grouped with the IHE Time Client Actor	To ensure consistency among timestamps
Send Asset Configurations (SAC)	IHE – Audit Trail and Node Authentication[2]	Each SAC Actor shall be grouped with IHE Secure Node or IHE Secure Application Actor	Required to manage audit trail of exchanged messages, node authentication and transport encryption
Send Planned Schedule (SPS)	IHE - Consistent Time[1]	Each SPS Actor shall be grouped with the IHE Time Client Actor	To ensure consistency among timestamps
Send Planned Schedule (SPS)	IHE – Audit Trail and Node Authentication[2]	Each SPS Actor shall be grouped with IHE Secure Node or IHE Secure Application Actor	Required to manage audit trail of exchanged messages, node authentication and transport encryption
Send Measured Values (SMV)	IHE - Consistent Time[1]	Each SMV Actor shall be grouped with the IHE Time Client Actor	To ensure consistency among timestamps
Send Measured Values (SMV)	IHE – Audit Trail and Node Authentication[2]	Each SMV Actor shall be grouped with IHE Secure Node or IHE Secure Application Actor	Required to manage audit trail of exchanged messages, node authentication and transport encryption

3.2 Integration Profile “Send Asset Configurations”

The profile “Send Asset Configurations” describes the interoperability issue for exchanging asset information and settings from the Distributed Energy Unit Controller (DEUC) to the Distributed Energy Operator (DEUOP) and Virtual Power Plant Operator (VPPOP). The content of the exchanged information depends on the Business Case in Volume 1. The format of the exchanged information and the exchange per se are specified by the used standard series IEC 61850. The different communication relations and the used communication standard lead to the following actors-transactions relations in Figure 2 which are introduced in this Section. The concrete implementation strategy of the transactions is described in Section 4.

[1] The profile Consistent Time (CT) is defined in the latest IHE’s IT Infrastructure (ITI) Technical Framework Vol.1 and Vol.2

[2] The profile Audit Trail and Node Authentication (ATNA) is defined in the latest IHE’s IT Infrastructure (ITI) Technical Framework Vol.1 and Vol.2

3.2.1 Actors/Transactions

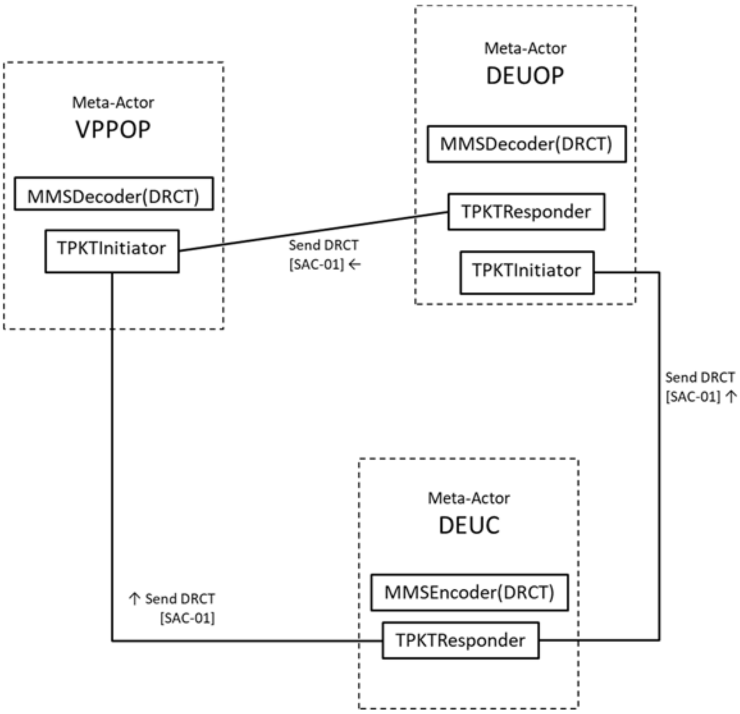

Figure 2: Actors/Transaction Diagram for Send DRCT: The dashed lines represent the grouping of actors into meta-actors.

Table 2: Transactions for Send Asset Configurations

Actors	Transaction	Optionality	Section
TPKTInitiator	Send DRCT [SAC-01]	R	3.2.1.1.1
TPKTResponder	Send DRCT [SAC-01]	R	3.2.1.1.2

3.2.1.1 Actor Descriptions and Actor Profile Requirements

See the definition of the actors in Section 3 of Volume 1.

3.2.1.1.1 TPKTInitiator

A TS-user (initiator) indicates that it wants to establish a connection to another actor – the TPKT responder.

3.2.1.1.2 TPKTResponder

A TS-user (responder) indicates that it will honour the request from the initiator. The responder answers with a message.

3.2.1.2 Transactions

3.2.1.2.1 Send DRCT

The LN DRCT defines the control characteristics and capabilities of one DER unit or aggregations of one type of DEU device with a single DEUC as controller. The transaction “Send DRCT” describes the transmission from the DEUC to the DEUOP or VPPOP as well as from DEUOP to VPPOP. The transaction follows after a trigger from the VPPOP or DEUOP to get settings from the DEUC; therefore, the TPKTInitiator of the VPPOP and DEUOP pulls the data from the TPKTResponder of the DEUC. The data representing the LN is stored in a SCD file, before the transmission of the Byte-block via a TLS 1.2 encrypted virtual TPKT circuit over TCP/IP takes place.

3.2.2 Actor Options

Options that may be selected for each actor in this profile are listed in Table 3. Afterwards, the options are described and dependencies between options are specified.

Table 3: Actor Options for Send Asset Configurations

Actor	Option	Vol. & Section
VPPOP	Market participant	Vol.2, 3.2.2.1
	Plant Operator	Vol.2, 3.2.2.2
DEUOP	Station Operator	Vol.2, 3.2.2.2
DEUC	DEU Controller	Vol.2, 3.2.2.4
DEU	Producer	Vol.2, 3.2.2.5
	Consumer	Vol.2, 3.2.2.6

3.2.2.1 Market participant

The VPPOP can act as a market participant on the energy market, e.g. using the CIM standard series (IEC 62325) to negotiate and sell schedules. The respective VPP is called commercial VPP (cVPP)[3].

3.2.2.2 Plant Operator

The VPPOP manages many small assets, integrated into one large virtual asset. Every traditional plant operator is bound to the contracted grid access limits bought from the DSO. In addition, plant operators may contribute to ancillary services that help the DSO to balance the network. In case of a VPP, the DSO can ask the VPPOP to adjust the schedules in a grid friendly manner. Based on the agreed measures, the VPPOP can adapt schedules and send adjusted schedules to the DEUOPs and DEUCs that are connected to the DSO's grid to execute the new schedule. A VPP that maximises its revenue on this basis is called technical VPP (tVPP)[3].

3.2.2.3 Station Operator

Alike every Prosumer can a DEUOP act as a local plant operator and offer ancillary services to its DSO, independent of its integration in a VPP. As already mentioned, ancillary services are a more general Business Function not only available to VPPs, and has to be defined independent of the VPP Use Case.

3.2.2.4 DEU Controller

The DEU Controller (DEUC) provides the interface between the DEU hardware and the user. In case the DEU is integrated in a VPP, the DEUC communicates with the VPPOP or DEUOP and translates the messages received into control signals that make the hardware perform as intended by the messages sent from the VPPOP or DEUOP.

3.2.2.5 Producer

DER and storages occur as energy producer inserting an unknown schedule if not managed. Managed by a DEUC the behaviour can be controlled such that they intend to fulfil a planned schedule.

3.2.2.6 Consumer

Loads and storages occur as energy consumer causing an unknown load schedule. Managed by a DEUC the behaviour can be controlled such that they intend to fulfil a planned schedule.

3.2.3 Integration Profile Process Flow

The transmission of asset configurations from the DEUC to the VPPOP as plant operator follows a sequence of single transactions between the DEUC, DEUOP and VPPOP as described above (see Figure 3). The detailed process flow is shown in Figure 8 and the detailed description of the transactions, their data objects and common data classes can be found in Section 4.

[3] SyC Smart Energy: IEC 63097/TR/Ed1: Smart Grid Roadmap, p. 121, 2016.

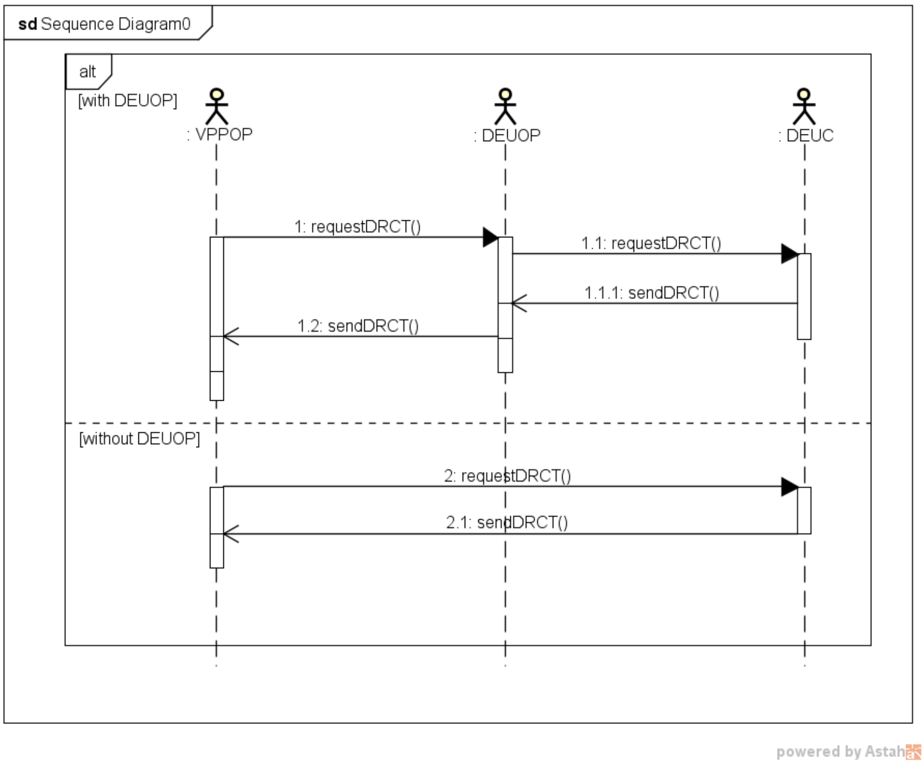

Figure 3: Sequence Diagram for "Send DRCT"

3.2.4 Implementation Strategies

3.2.4.1 IEC 61850 Basics

The IEC 61850 Ed. 2.0 standard series describes a concept how intelligent electronic devices (IDE) from the power grid domain can be represented as logical devices that are constructed by logical nodes to communicate with each other. The logical nodes depict the data structure of the IEDs and show which data can be exchanged between them under specific conditions. The functional decomposition helps to understand logical relationships between IEDs and how specific functions work.

The 61850 standard series define the information model used for communicating information between instances of logical devices (LDs) and/or logical nodes (LNs). The model uses a strict hierarchy as shown in Figure 4. A logical device can be composed out of one or more logical nodes, where each logical node represents a certain information element with dedicated functionalities. The LN itself is based on data objects that can be used in different LNs. The common data classes are the bases of the data objects and group common attributes. The bases of this hierarchy are the standard data types.

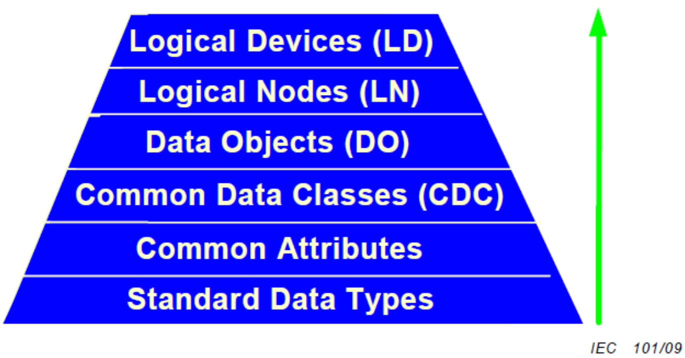

Figure 4: Information model hierarchy (Source: [1])

The principle structure of the data model is organized as follows: The IED is represented by a logical device (LD), which includes various logical nodes (LN) for implementing different functions. The LNs include various data objects, which describe the data flow and information model. The hierarchical structure is illustrated in Figure 5.

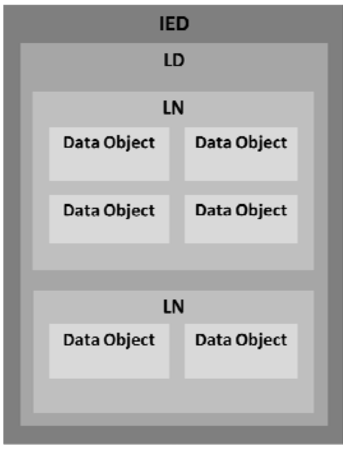

Figure 5: Data Structure in IEC 61850

The outermost component is the IED; it describes any device incorporating one or more processors with the capability of receiving or sending data from or to external sources, such as controllers or operating systems for VPPs and DEUs. The IED is represented by a LD which contains various LN to describe its functionality. LDs are not clearly defined by the IEC 61850 standard series because manufacturers shall be free to classify their devices with their own functions that are mapped to the LN data structure. The data structure is defined by data objects from specified common data classes and data attributes as mentioned above. The data attributes in the data objects can have different function types with different triggering options. These types are defined in IEC 61850-7-2 and have to be considered in the description of the transactions.

In this Technical Framework, the IEDs are VPPOP, DEUOP and DEUC. The 61850-7-420 standard mentions the following LD for these IEDs: VPPOP is depicted as DER plant operations, DEUOP is shown as DER Plant Controller and the DEUC is a controller of one or more DEUs without a concrete data structure. The part IEC 61850-7-2 and 61850-7-42 of the standard series describe all functions of the LNs for these three LDs. Each LD contains the LNs LLN0 and LPHD to provide physical information about the IED; these are shown in Table 4.

Table 4: LLN0 and LPHD content for VPPOP, DEUOP and DEUC

Logical Node	Data Object	Data Attribute	Common data class	Functional Constraint	Description
LLN0	Beh	EnumType	ENS	STs	The current status of the logical device. Its behaviour can be: on, on-blocked, test, test/blocked, or off.
LPHD	PhyNam	vendor	DPL	DC	Vendor Name of the physical device.
	PhyNam	cdcName	DPL	EX	Name of the physical device. Details are written in IEC 61850-7-1.
		cdcNs	DPL	EX	Name space of the physical device. Details are written in IEC 61850-7-1.
	PhyHealth	EnumType	ENS	ST	The current health status of the device. Its status can be: Ok, Warning, or Alarm.
	Proxy	stVal	SPS	ST	Indicates if the LN is a proxy, i.e. stVal is only a Boolean.
		q	SPS	ST	Quality of the proxy
		t	SPS	ST	TimeStamp of the proxy

Figure 6 shows a typical grouping of LNs to LDs. Please note that this graph makes no claims of being complete nor specifying a normative architecture and is therefore an informative example. It can be derived from the figure that the LD DER Unit Controller consists of the LNs DRCT, DRCS, DRCC, FSEQ, and MMXU. These logical nodes are normatively named according to IEC 61850-7-420 where a detailed specification on the contained data objects can be found. Partially, these logical nodes are used in the transactions of this Technical Framework.

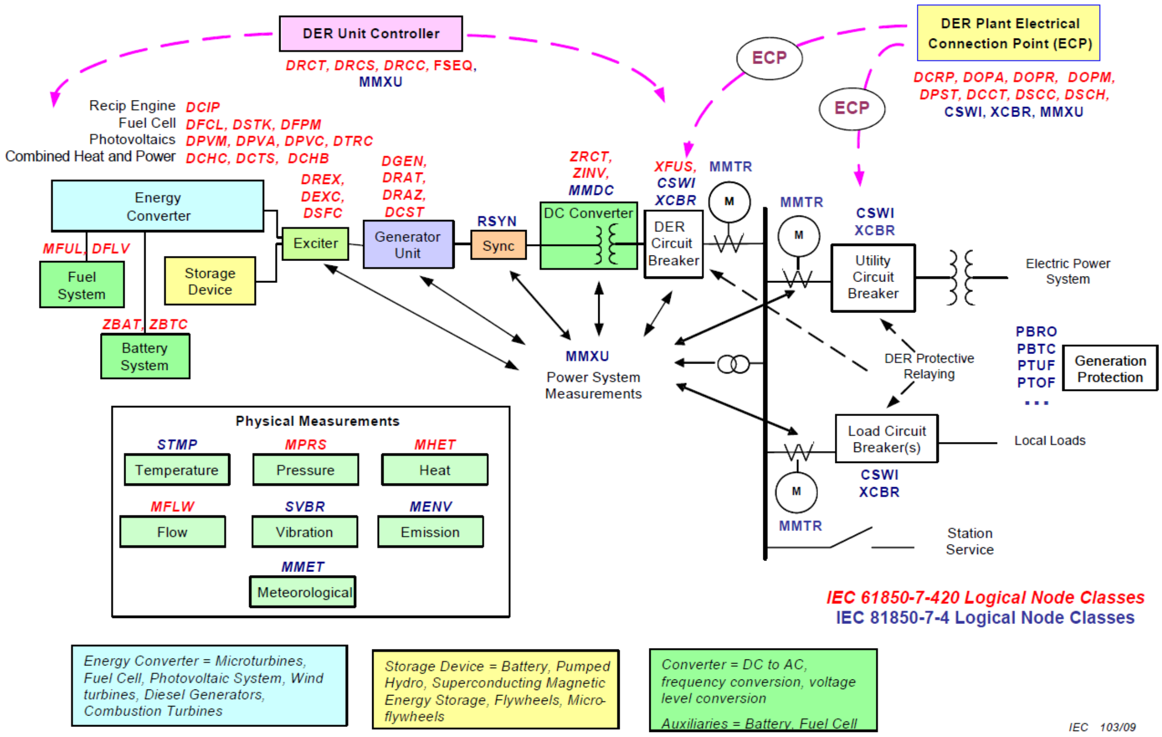

Figure 6: Conceptual organisation of DER logical devices and logical nodes (Source: [1])

The IEC 61850-7-3 gives an overview on the common attribute types and the common data objects which are linked in the LN description of the 61850-4-720 part. The common data classes specify status information, measured information, control information, status settings, and analogue settings. With these data, a well-structured data exchange between substations, power plant and control centres, and DEUCs can be described. Thus, the parts IEC 61850-7-2, IEC 61850-7-420, and IEC 61850-7-3 are essential for implementing the communication mechanisms between devices from the power grid domain, especially the asset setting, schedule exchange, and measurement values.

After modelling the data structure with the LNs and the data flow, these information can be represented by an XML file - the Substation Configuration Language (SCL) that is explained in the IEC 61850-6 part. The SCL supports the standardized design of IEDs functionalities because the XML files can be exchanged easily between projects and different tools that can handle the SCL simpler than diagrams of LDs and their LNs. So, the SCL files can be used as common basis for IED functionalities (ICD files); however it should be always possible to extend the ICD files for implementing further functionalities with an IED (project-specific files - IID), i.e. mandatory parts or common functionalities cannot be removed from the SCL file (based on the ICD or IID file) to enable interoperability with other IEDs that use the SCL file. Next to the content of the LNs, the SCL file handles the data flow and describes the communication path by describing the IP address of connected IEDs. So, the type of the SCL file is a SCD (Substation Configuration Description) file. The SCD file is used to describe a complete substation detail. It contains substation, communication, IED and data type template sections.

The data flow can be determined by the functional constraints. In IEC 61850-7-3, an explanation of the functional constraints for the data attributes is given. In IEC 61850-8-1, an order for the data attributes is recommended. So, the order is not mandatory; however, it specifies a logical sequence. Furthermore, the IEC 61850-8-1 describes the mapping of the LNs and data objects according to Manufacturing Message Specification (MMS) to enable data exchange over an ISO/IEC 8802-3 Local Area Network (LAN) between all kinds of IEDs.

Notes:

- LLN0: The Logical Node Zero is used to address common issues of logical devices. For instance, it includes information about the LD's health and current operation mode.
- LPHD: The Logical Node Physical Device is used to present common issues of physical devices alike location, inventory ID and maintenance interval.
- FSCH: The LN FSCH defines a schedule.
- MMXU: The LN MMXU defines measurement values for calculations of currents, voltages, powers and impedances.
- DRCT: The LN of the DER controller defines the control characteristics and capabilities of one DER unit or aggregation of one type of DER.

3.2.4.2 Structure of the SCD file

As mentioned above, the data structure visualized with the LNs is mapped in a SCD file. The SCD file has the following structure:

- Header: with schema information about the file
- Substation section: describes the functional structure and its relation to primary devices
- Communication section: describes the connection between the IED access points to the respective subnetwork and includes also properties of the access points
- IED section: contains a description of the supported communication services, the access points and the IEDs, LD, LN, and their attributes
- Data type template section: contains a declaration of all types used in the SCD file, LN type, DO types, attributes and enumerations.

How the SCD looks like can be viewed in Section 4.1.4.1.2.

3.2.4.3 Further information

The complete documentation of the Business Function and the information collection about the IEC 61850 can be found at the project website; also further information about the implementation process are provided. These information can be found at: https://mahara-mr.technikum-wien.at/group/integrating-the-energy-systems/usecases.

The test procedure is not part of the Technical Framework. For the IES project, an own Gazelle test platform was set up. Gazelle helps to manage the test cases and to check whether the transactions implemented by vendors work. Further information about the test procedure can be found at: http://iesaustria.at.

3.2.5 Communication Requirements

The message type within the Integration Profile "Send Asset Configurations" is a Low speed message (Type 3, cf. IEC 61850-5). The message contains complex messages that may require being time-tagged. The message type should be used for slow speed auto-control functions, transmission of event records, or reading or changing set-points. In doing this, the transmission shall be less than 500 ms with TCP/IP. Thus, time-tagged asset configurations may belong to this type because the transmission is not time-critical to establish a VPP which can participate on the Energy Exchange the previous day.
To utilize better timing GOOSE packs control information directly into Ethernet frames, skipping the TCP/IP layers. This is a different, better method that can be used within the reach of a LAN.

3.2.6 Security Considerations

The data exchange has to be done with symmetric encryption (IEC 62351 – TLS 1.2), i.e. both actors (alias communication partners) exchange a secret key which is used to encrypt and decrypt the information for a single transaction. Therefore, the connection establishment is needed to generate the key on both side of the communication partners (e.g. VHPready proposes the Diffie-Hellmann-Algorithm). After the key exchange, the messages have to be encrypted before being transferred.
Further security considerations:

- Authentication of the communication partners
- Protecting the message integrity
- Preventing Replay-Attacks
- Logging the message exchange and errors

These security considerations are addressed by the IHE Audit Trail and Node Authentication (ATNA) Profile. All SPS Actors shall be either grouped with a Secure Node or a Secure Application Actor as defined by IHE. Furthermore all SPS Actors shall be grouped with a Time Client Actor as defined in IHE Consistent Time (CT) profile.

The IHE ATNA profile describes a structure for logging transactions between actors. This is mandatory to get an interoperable logging semantic (cf. Section 4.1.5).

3.3 Integration Profile “Send Planned Schedule” (SPS)

The profile “Send Planned Schedule” describes the interoperability issue for exchanging control information among the central Virtual Power Plant Operator (VPPOP), local Distributed Energy Unit Operators (DEUOPs) and the different Distributed Energy Unit Controllers (DEUCs) executing the contribution of the different Distributed Energy Units (DEUs) to the Virtual Power Plant (VPP). The content of the exchanged information depends on the Business Function, see the descriptions in Volume 1. The format of the exchanged information and the exchange per se are specified by the used standard series IEC 61850. The different communication relations and the used communication standard lead to the following actors-transactions relations in Figure 7 which are introduced in this Section. The concrete implementation strategy of the transactions is described in Section 4.

3.3.1 Actors/Transactions

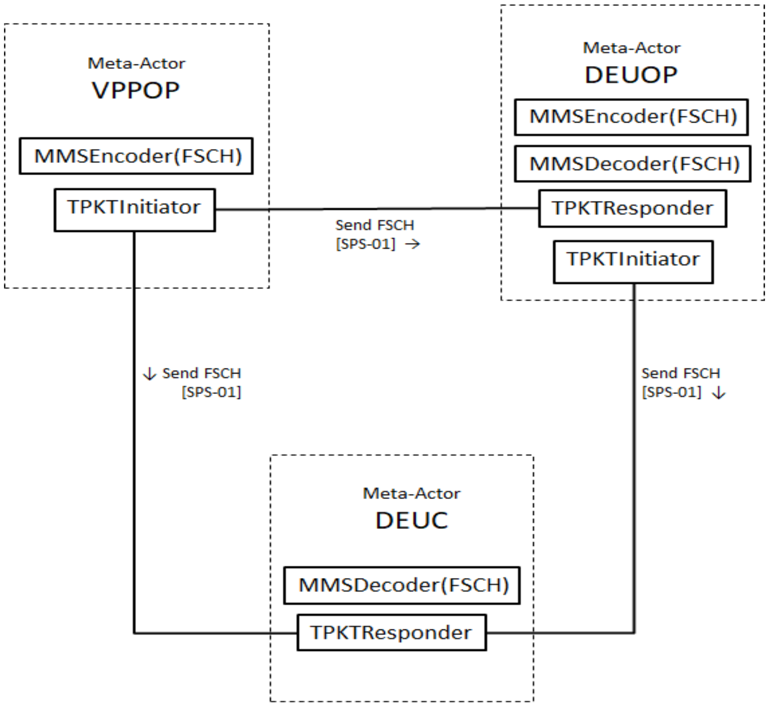

Figure 7: Actors/Transaction Diagram for Send FSCH: The dashed lines represent the grouping of actors into meta-actors.

Table 5: Transactions for Send Planned Schedule

Actors	Transaction	Optionality	Section
TPKTInitiator	Send FSCH [SPS-01]	R	4.1
TPKTResponder	Send FSCH [SPS-01]	R	4.1

Hint: The DSCH was removed by the IEC 61850-7-4 (2016) and is fully replaced by the FSCH. Therefore, no transactions and profiles for the DSCH are created.

3.3.1.1 Actor Descriptions and Actor Profile Requirements

See the definition of actors in Section 3 of Volume 1 and in Section 3.2.1.1.

3.3.1.2 Transactions

3.3.1.2.1 Send FSCH

The FSCH, functional schedule, is a Logical Node (LN) defined in IEC 61850 that is provided by the actor initiating the functional schedule exchange, e.g. by the VPPOP. The data representing the LN is mapped to the SCD structure. Transmission of the Byte-block via a TLS 1.2 encrypted virtual TPKT circuit over TCP/IP to the responding actor (e.g. the DEUOP transaction responder) is established and performed by the transaction initiator. Finally, the responding actor transfers the values back in the LN structure.

3.3.2 Actor Options

See the definition of the actor options in Section 3.2.2.

3.3.3 Integration Profile Process Flow

The transmission of the planned schedule between the VPPOP or DEUOP and the DEUCs follows a sequence of single transactions between the VPPOP, DEUOP and DEUC as described above. The process flow is shown in Figure 8. The detailed description of the transactions, their data objects and common data classes can be found in Section 4.

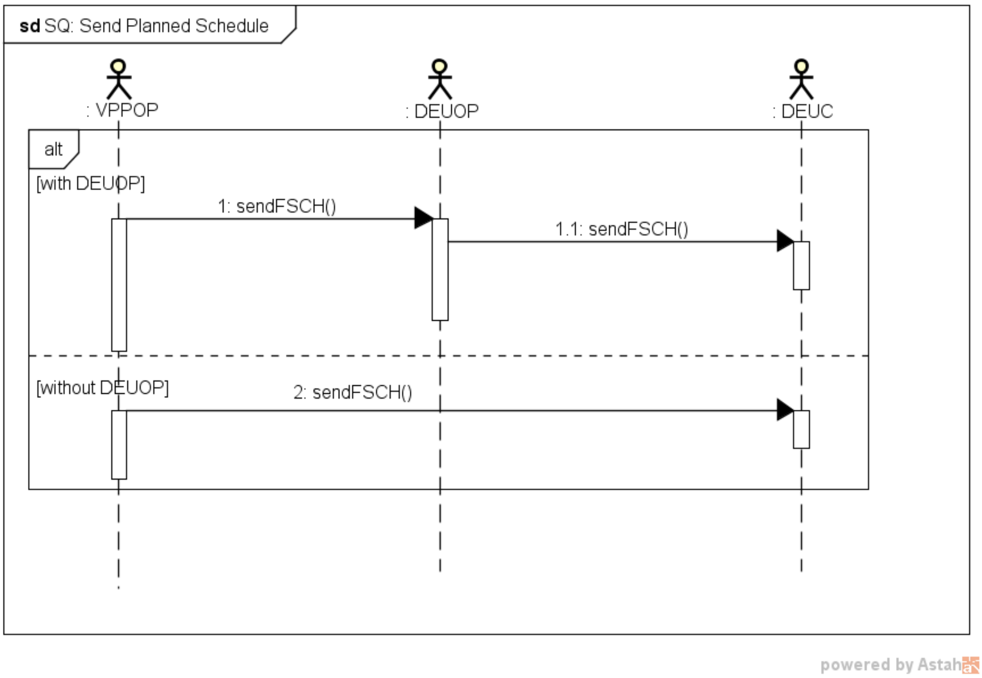

Figure 8: Sequence Diagram for "Send Planned Schedule"

3.3.4 Implementation Strategies

The same implementation strategies as in Section 3.2.4 apply. Additional details for the schedule exchange are described below.

3.3.4.1 State diagram for the schedule

For sending a schedule, the IEC 61850 has defined the LN *functional schedule (FSCH).* The FSCH can be in different states as shown in Figure 9. The schedule can be in the states: “not ready”, “validated”, “ready” or “running”. The state is set by the data objects VldReq, EnaReq, EdtReq, and DsaReq. The schedule can be edited in the state “not ready”, i.e. if a schedule is in state “validated”, the state has to be changed with the data attribute EdtReq; otherwise, the schedule has to be disabled before it can be edited. Before, the schedule can be activated, it has to be validated and set to the state “ready”. The activation of the schedule only depends on an external trigger or the time stamp that was set in the schedule.

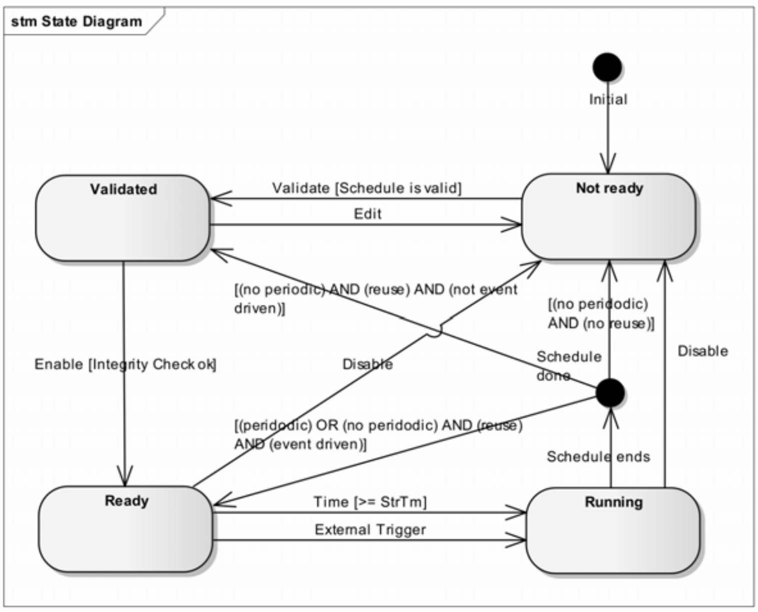

Figure 9: FSCH State Machine

3.3.5 Communication Requirements

The message type within the Integration Profile “Send Planned Schedule” is a Low speed message (Type 3, cf. IEC 61850-5). The message contains complex messages that may require being time-tagged. The message type should be used for slow speed auto-control functions, transmission of event records, or reading or changing set-points. In doing this, the transmission shall be less than 500 ms with TCP/IP. Thus, time-tagged schedules may belong to this type because the transmission is not time-critical for schedules which were negotiated on the Energy Exchange the previous day.
To utilize better timing GOOSE packs control information directly into Ethernet frames, skipping the TCP/IP layers. This is a different, better method that can be used within the reach of a LAN. A better implementation of the same information exchange, perfectly applicable for DEUOP – DEUC transactions.

3.3.6 Security Considerations

See Section 3.2.6 Security Considerations.

3.4 Integration Profile “Send Measured Values by the DEUC”

The profile “Send Measured Values by the DEUC” describes the interoperability issue for the data exchange of measured values of the power grid status from the DEUC to the VPPOP, DEUOP and DSO. In this case, the VPPOP, DEUOP and DSO pull the data from the DEUC to get live data from the unit. The content of the exchanged information depends on the Business Function, see the descriptions provided in Volume 1 of the IES Technical Framework. The format of the exchanged information and the exchange per se are specified by the used standard series IEC 61850. The different communication relations and the used communication standard lead to the following actors-transactions relations in Figure 10. The concrete implementation strategy of the transactions is described in Section 4.

3.4.1 Actors/Transactions

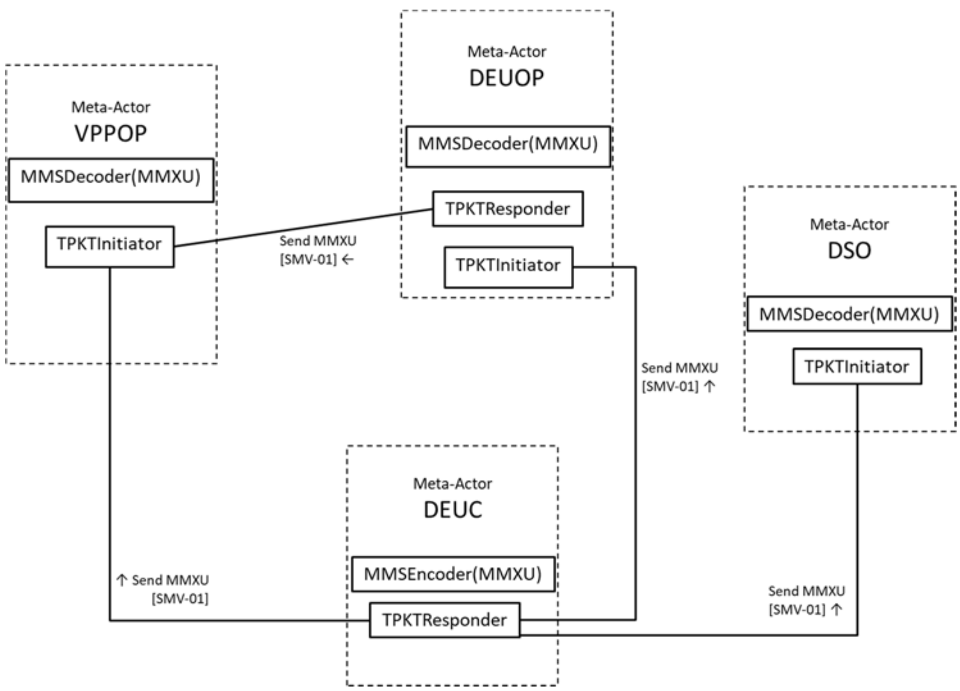

Figure 10: Actor/Transaction Diagram for Send MMXU: The dashed lines represent the grouping of actors into meta-actors

Table 6: Transactions for Send Measured Values

Actors	Transaction	Optionality	Section
TPKTInitiator	Send MMXU [SMV-01]	R	4.2
TPKTResponder	Send MMXU [SMV-01]	R	4.2

3.4.1.1 Actor Descriptions and Actor Profile Requirements

See the definition of actors in Section 3 of Volume 1 and in Section 3.2.1.1.

3.4.1.2 Transactions

3.4.1.2.1 Send MMXU

The TPKTInitiator of the VPPOP, DEUOP or DSO requests the measured values from the DEUC. The measurement values are grouped by the DEUC in the LN MMXU defined in IEC 61850. The LN MMXU is used for summarizing calculations of currents, voltages, powers and impedances in a three-phase system. For providing measurement values, the DEUC gathers the data and sends these to the DEUOP, VPPOP and DSO after a request. Before, the TPKTInitiator has created a secure connection. The data are transformed in a SCD file and transmitted as message via the secure connection. The message is received by the TPKTResponder of the VPPOP, DEUOP or DSO.

3.4.2 Actor Options

Table 7: Actor Options for Provide Measured Values

Actor	Option	Vol. & Section
VPPOP	Market participant	Vol.2, 3.2.2.1
	Plant Operator	Vol.2, 3.2.2.2
DEUOP	Station Operator	Vol.2, 3.2.2.2
DEUC	DEU Controller	Vol.2, 3.2.2.4
DEU	Producer	Vol.2, 3.2.2.5
	Consumer	Vol.2, 3.2.2.6
DEU	Producer	Vol.2, 3.2.2.5
DSO	Grid Operator	Vol. 2, 3.4.2.1
	Balance Power Controller	Vol. 2, 3.4.2.2

3.4.2.1 Grid Operator

The DSO is responsible for the operation and expansion of the electric power grid that can be used by the energy producer and consumer to transport electricity from the generator to the customer.

3.4.2.2 Balance Power Controller

The DSO has to check the current status of the electric power grid at each time. Therefore, measured values from DEUC are used as well as own measurements and key performance indicators.

3.4.3 Integration Profile Process Flow

The transmission of measured values can be separated in the following two steps “requestMeasuredValues” and “sendMeasuredValues”. The detailed message transmission is summarized in the transaction “Send MMXU” (cf. Section 4.3). Both steps are executed between the DEUC and the DEUOP, VPPOP or DSO. The messages of the transaction are always the same independent of the involved actors. The detailed description of the transaction, their data objects and common data classes can be found in Section 4.

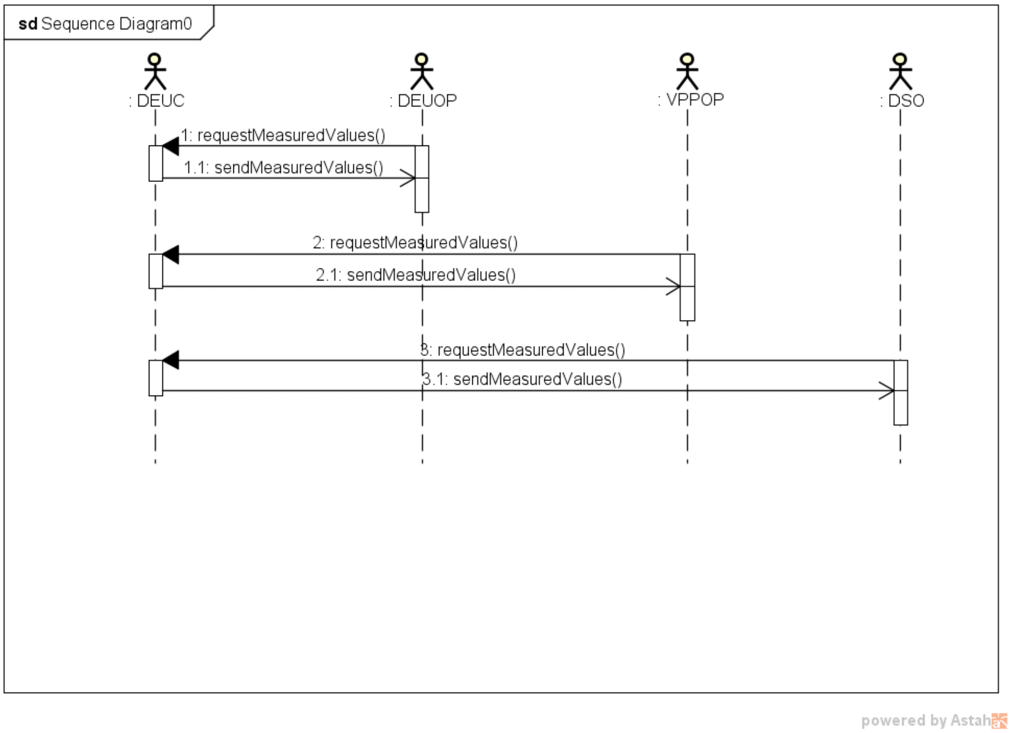

Figure 11: Sequence Diagram for "Provide Measured Values"

3.4.4 Implementing Strategies

The structure of the LN is the same as described above in Section 3.2.4.

3.4.5 Communication Requirements

The message type within this Integration Profile shall be a medium speed message (Type 2, cf. IEC 61850-5). This type should be used to transmit measured values. It is important that messages are time-tagged by the sender and the receiver shall react after an internal time delay. The total transmission time shall be less than 100 ms via TCP/IP.

3.4.6 Security Considerations

See Section 3.2.6 Security Considerations.

4 Transactions

The transactions describe a concrete implementation of the interoperability issue described in the Business Function in Volume 1 of the Technical Framework which were specified through the integration profiles in Section 3. The interoperability issues are described in each transaction as brief interoperability use cases which demonstrate the challenge and the actors involved of the transaction.

4.1 Transaction: “Send FSCH”

4.1.1 Scope

After the participation on the energy market and the coordination with the DSO according to the planned schedules, the VPPOP creates functional schedules for its DEUs and sends them to the DEUOPs or directly to the DEUCs. The DEUOPs manage different DEUs and is responsible to execute the schedules in the operative mode. The interoperability issue is the direct schedule exchange between VPPOP and DEUOP, VPPOP and DEUC, or DEUOP and DEUC via a secure connection. Before, the transaction of the schedule can be executed, the VPPOP has to create the SCD file which will be transferred to the DEUOP or DEUC.

Hint: The DSCH was removed by the IEC 61850-7-4 (2016) and is fully replaced by the FSCH. Therefore, no transactions and profiles for the DSCH are created.

4.1.2 Actor Roles

Table 8: Actor Roles for Send FSCH

Role	Description	Actor
Transaction Initiator	The transaction initiator starts and sends the values of the SCD file to a receiving actor's transaction responder actor via TCP/IP. If specified, the transaction initiator uses the IHE ATNA profile to establish a secured connection before the data transmission actually starts, if it is not already in place.	The following actors may play the role of transaction initiator: VPPOP, DEUOP
Transaction Responder	The transaction responder receives the values of the SCD file. In case a secure connection is required, it cooperates with the transaction initiator in establishing security.	The following actors may play the role of transaction responder: DEUOP, DEUC

4.1.3 Referenced Standards

- IEC 61850-7-420 (logical nodes)
- IEC 61850-7-2 (data objects, services)
- IEC 61850-5 (protocol requirements)

4.1.4 Interaction Diagrams

The interactions are depicted as sequence diagram. For the transaction "Send FSCH", the sequence diagram includes the interoperability use cases *set the schedule state* (as precondition) and *write functional schedule* according to IEC 61850.

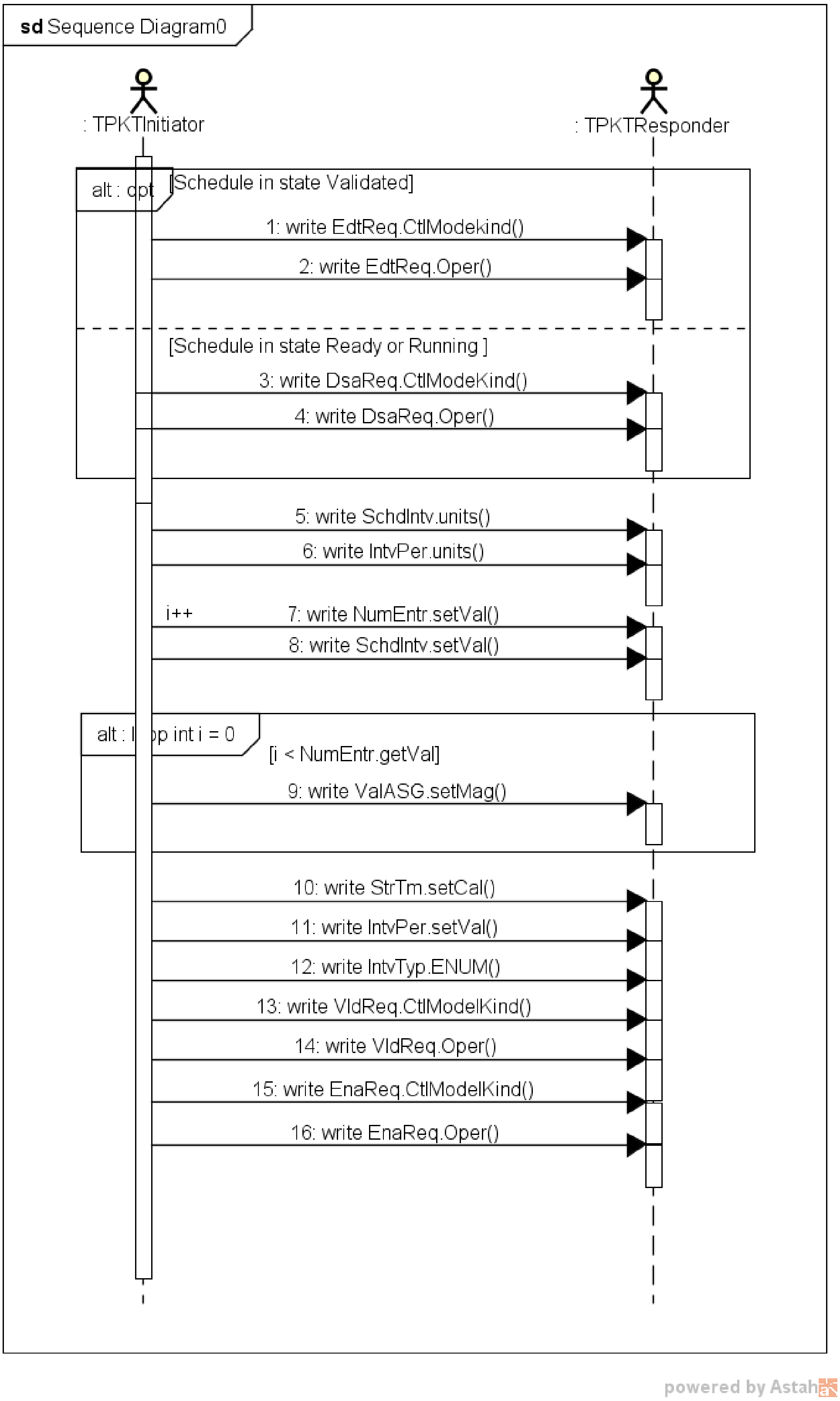

Figure 12: Data flow for Send FSCH

4.1.4.1 Create the message

4.1.4.1.1 Trigger Events

The VPPOP triggers the transmission of the schedule including the FSCH LN to the respective DEUOP or DEUC; otherwise, the DEUOP triggers the transmission to the DEUC. Therefore, the LD has to be in the status *on* and the health state *Ok*. Additionally, the schedule state of the LD has to be *not ready* (cf. Section 3.3.4) for changing the schedule values in the next step (cf. Section 4.1.4.1.2).

Table 9: Data objects for behavior mode

Logical Device	**Logical Node**	**Data Object**	**Common data class**	**Data Attribute**	**Functional Constraint**	**Description**
VPPOP / DEUOP / DEUC	LLN0	Beh	ENS	EnumType	ST	The current status of the logical device. Its behaviour can be: on, on-blocked, test, test/blocked, or off.

The content of the SCD file for the behaviour mode includes:

```
<LNodeType lnClass="LLN0" id="LLN0">
        <DO desc="Name plate" name="NamPlt" type="LPL"/>
        <DO desc="Behaviour" name="Beh" type="ENS_BehaviourModeKind"/>
        <DO desc="Health" name="Health" type="ENS_HealthKind"/>
        <DO desc="Mode" name="Mod" type="ENC_BehaviourModeKind"/>
</LNodeType>
<DOType cdc="ENS" id="ENS_BehaviourModeKind">
        <DA name="stVal" bType="Enum" type="BehaviourModeKind" dchg="true" dupd="true" fc="ST"/>
        <DA name="q" bType="Quality" qchg="true" fc="ST"/>
        <DA name="t" bType="Timestamp" fc="ST"/>
</DOType>
<DOType cdc="ENS" id="ENS_HealthKind">
        <DA name="stVal" bType="Enum" type="HealthKind" dchg="true" dupd="true" fc="ST"/>
        <DA name="q" bType="Quality" qchg="true" fc="ST"/>
        <DA name="t" bType="Timestamp" fc="ST"/>
</DOType>
<DOType cdc="ENC" id="ENC_BehaviourModeKind">
        <DA name="stVal" bType="Enum" type="BehaviourModeKind" dchg="true" fc="ST"/>
        <DA name="q" bType="Quality" qchg="true" fc="ST"/>
        <DA name="t" bType="Timestamp" fc="ST"/>
        <DA name="ctlModel" bType="Enum" type="CtlModelKind" dchg="true" fc="CF"/>
</DOType>
<EnumType id="BehaviourModeKind">
        <EnumVal ord="1">on</EnumVal>
        <EnumVal ord="2">blocked</EnumVal>
        <EnumVal ord="3">test</EnumVal>
        <EnumVal ord="4">test/blocked</EnumVal>
        <EnumVal ord="5">off</EnumVal>
</EnumType>
<EnumType id="HealthKind">
        <EnumVal ord="1">Ok</EnumVal>
        <EnumVal ord="2">Warning</EnumVal>
        <EnumVal ord="3">Alarm</EnumVal>
</EnumType>
<EnumType id="CtlModelKind">
        <EnumVal ord="0">status-only</EnumVal>
        <EnumVal ord="1">direct-with-normal-security</EnumVal>
        <EnumVal ord="2">sbo-with-normal-security</EnumVal>
        <EnumVal ord="3">direct-with-enhanced-security</EnumVal>
        <EnumVal ord="4">sbo-with-enhanced-security</EnumVal>
</EnumType>
```

Table 10: FSCH state data objects

Logical Device	**Logical Node**	**Data Object**	**Common data class**	**Data Attribute**	**Functional Constraint**	**Description**
VPPOP / DEUOP / DEUC	FSCH	VldReq	SPC	ctlModel	CF	Specifies the control model for validate transition request, possible values are: status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security
		EnaReq	SPC	ctlModel	CF	Specifies the control model for enable transition request,

						possible values are: status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security
		EdtReq	SPC	ctlModel	CF	Specifies the control model for edit transition request, possible values are: status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security
		DsaReq	SPC	ctlModel	CF	Specifies the control model for disable transition request, possible values are: status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security

The content of the SCD file to set the state of the schedule includes:

```
<LNodeType lnClass="FSCH" id="FSCH" desc="Schedule">
		<DO name="VldReq" type="SPC"/>
		<DO name="EnaReq" type="SPC"/>
		<DO name="EdtReq" type="SPC"/>
		<DO name="DsaReq" type="SPC"/>
</LNodeTyoe>
<DOType cdc="TSG" id="SPC">
		<DA name="ctlModel" bType="Enum" type="CtlModelKind" fc="CF" dchg="true"/>
</DOType>
<EnumType id="CtlModelKind">
		<EnumVal ord="0">status-only</EnumVal>
		<EnumVal ord="1">direct-with-normal-security</EnumVal>
		<EnumVal ord="2">sbo-with-normal-security</EnumVal>
		<EnumVal ord="3">direct-with-enhanced-security</EnumVal>
		<EnumVal ord="4">sbo-with-enhanced-security</EnumVal>
</EnumType>
```

4.1.4.1.2 Message Semantics

If the preconditions in the triggering event are fulfilled, the schedule can be edited by changing the following data objects of the LN FSCH. The values of the SCD file from the LN are transmitted.

The schedule needs the following data objects from the FSCH (IEC 61850-7-420):

Table 11: FSCH Data Objects

Logical Device	Logical Node	Data Object	Common data class	Data Attribute	Functional Constraint	Description
VPPOP / DEUOP / DEUC	FSCH	SchdSt	INS	stVal	ST	State of this schedule
				Q	ST	Quality of schedule state
				T	ST	Timestamp of schedule state
		NumEntr	ING	setVal	SP	The number of schedule entries that are valid out of the instantiated ValASG. It shall be > 0.

		SchdIntv	ING	setVal	SP	The schedule interval duration
				units	CF	Eg.: sec, min, h, d
		ValASG	ASG	setMag	SP	The ASG scheduled values (current value output as MV (FC: Measured Value))
		StrTm	TSG	setCal	SP	Start time of the schedule in calendar time
		IntvPer	ING	setVal	SP	Interval period
				units	CF	Eg.: sec, min, h, d
		IntvTyp	ENG	ENUM	SP	Interval type

Notes:

FSCH: Functional schedule
ING: Integer status setting
ASG: Analogue setting
TSG: Time setting group
SP: setting point
EX: extended

Based on the LNs, a SCD file is generated with the IEC 61850 Substation Configuration Tool (SCT) by the H+S Hard- & Software Technologie GmbH & Co. KG. The SCD file shall content at least the following structure:


```xml
<?xml version="1.0" encoding="UTF-8"?>
<SCL xmlns="http://www.iec.ch/61850/2003/SCL" xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" version="2007" revision="B">
	<Header id="" version="1" revision="1" toolID="Notepad++">
		<History>
			<Hitem version="0" revision="1" when="2017-09-25 11:45:55" who="Schicklgruber" what="Initial creation of model" why="Initial version"/>
		</History>
	</Header>
	<Substation name="SUBSTATION">
		<VoltageLevel name="VOLTAGELEVEL">
			<Bay name="BAY"/>
		</VoltageLevel>
	</Substation>
	<Communication>
		<SubNetwork name="NETWORK" type="8-MMS">
			<BitRate unit="b/s" multiplier="M">100</BitRate>
			<ConnectedAP iedName="OPENMUCIED" apName="AP1">
				<Address>
					<P type="IP">10.0.0.1</P>
					<P type="IP-SUBNET">255.0.0.0</P>
					<P type="IP-GATEWAY">0.0.0.0</P>
				</Address>
			</ConnectedAP>
		</SubNetwork>
	</Communication>
	<IED name="OPENMUCIED">
		<Services>
			<DynAssociation max="5"/>
			<GetDirectory/>
			<GetDataObjectDefinition/>
			<DataObjectDirectory/>
			<GetDataSetValue/>
			<DataSetDirectory/>
			<ConfDataSet max="20" maxAttributes="250" modify="true"/>
			<DynDataSet max="20" maxAttributes="250"/>
			<ReadWrite/>
			<ConfReportControl bufConf="true" bufMode="both" max="15"/>
			<GetCBValues/>
			<ReportSettings bufTime="Dyn" cbName="Conf" datSet="Dyn" intgPd="Dyn" optFields="Dyn" owner="true" resvTms="true" rptID="Dyn" trgOps="Dyn"/>
			<GSESettings appID="Conf" cbName="Conf" datSet="Conf"/>
			<GOOSE max="50"/>
			<ConfLNs fixLnInst="false" fixPrefix="false"/>
			<TimeSyncProt c37_238="true" other="false" sntp="true"/>
		</Services>
		<AccessPoint name="AP1">
```

```xml
                <Server>
                    <Authentication/>
                    <LDevice inst="LD1">
                        <LN0 lnType="LLN0" lnClass="LLN0" inst=""/>
                        <LN lnClass="LPHD" inst="1" lnType="LPHD"/>
                        <LN prefix="Normal_" lnClass="FSCH" inst="1" lnType="FSCH"/>
                    </LDevice>
                </Server>
            </AccessPoint>
        </IED>
        <DataTypeTemplates>

            <LNodeType lnClass="FSCH" id="FSCH" desc="Schedule">
                <DO name="SchdSt" type="ENS_ScheduleStateKind"/>
                <DO name="NumEntr" type="ING"/>
                <DO name="SchdIntv" type="ING"/>
                <DO name="ValASG" type="ASG"/>
                <DO name="StrTm" type="TSG"/>
                <DO name ="IntvPer” type =”ING”/>
                <DO name =”IntvTyp” type =”ENG”/>
            </LNodeType>
            <DOType cdc="ING" id="ING">
                <DA name="setVal" bType="INT32" dchg="true" fc="SP"/>
                <DA name="units" bType="Unit" dchg="true" fc="CF"/>
            </DOType>
            <DOType cdc="ENG" id="ENG">
                <DA name="setVal" bType="Enum" type="CalcIntervalKind" dchg="true" fc="SP"/>
            </DOType>
            <DOType cdc="ASG" id="ASG">
                <DA name="setMag" bType="Struct" type="AnalogueValue" dchg="true" fc="SP"/>
            </DOType>
            <DOType cdc="TSG" id="TSG">
                <DA name="setCal" bType="Struct" type="CalendarTime" fc="SP" dchg="true"/>
            </DOType>

            <EnumType id="ScheduleStateKind">
                <EnumVal ord="1">Not ready</EnumVal>
                <EnumVal ord="2">Validated</EnumVal>
                <EnumVal ord="3">Ready</EnumVal>
                <EnumVal ord="4">Running</EnumVal>
            </EnumType>
            <EnumType id="CalcIntervalKind">
                <EnumVal ord="1">MS</EnumVal>
                <EnumVal ord="2">PER_CYCLE</EnumVal>
                <EnumVal ord="3">CYCLE</EnumVal>
                <EnumVal ord="4">DAY</EnumVal>
                <EnumVal ord="4">WEEK</EnumVal>
                <EnumVal ord="4">MONTH</EnumVal>
                <EnumVal ord="4">YEAR</EnumVal>
                <EnumVal ord="4">EXTERNAL</EnumVal>
            </EnumType>

            <DAType id="AnalogueValue">
                <BDA name="f" bType="FLOAT32"/>
            </DAType>
            <DAType id="CalendarTime">
                <BDA name="occ" bType="INT16U"/>
                <BDA name="occType" bType="Enum" type="OccurrenceKind"/>
                <BDA name="occPer" bType="Enum" type="PeriodKind"/>
                <BDA name="weekDay" bType="Enum" type="WeekdayKind"/>
                <BDA name="month" bType="Enum" type="MonthKind"/>
                <BDA name="day" bType="INT8U"/>
                <BDA name="hr" bType="INT8U"/>
                <BDA name="mn" bType="INT8U"/>
            </DAType>
        </DataTypeTemplates>
</SCL>
```

4.1.4.1.3 Expected Actions

The FSCH LN is transferred to the SCD structure for the TPKTInitiator.

4.1.4.2 Establish Secure Connection

Before data is exchanged between actors, a secure connection has to be established. Therefore, the already existing IHE Audit Trail and Node Authentication (ATNA) profile shall be used. The profile can be downloaded from IHE: http://wiki.ihe.net/index.php/Audit_Trail_and_Node_Authentication. Further information in Section 0.

The secure connection remains for more than one transaction to get an efficient use of encrypting a connection between two actors.

4.1.4.3 Transmit Message

The TPKTResponder writes the values of its SCD file to the SCD file of the TPKTInitiator via a secure TCP/IP connection.

4.1.4.4 Validate LN FSCH

The transaction initiator of the VPPOP or DEUOP received an SCD file containing the functional schedule.

4.1.4.4.1 Trigger Events

The transaction responder of the DEUOP received a message containing a schedule from the VPPOP.

4.1.4.4.2 Message Semantics

The SCD file described in Section 4.1.4.1.2 was transmitted and the same LN structure like in Table 11 shall result.

4.1.4.4.3 Expected Actions

The TPKTInitiator got the LN FSCH data.

4.1.5 Security Considerations

For a secure transmission, a connection via TLS 2 (Transport Layer Security 2) is mandatory (cf. 3.4.6). Aspects for authentication/authorization and logging as described the IHE ATNA Profile shall also be considered for this transaction: http://wiki.ihe.net/index.php/Audit_Trail_and_Node_Authentication. The logging should contain parameters of the transmitter, receiver, time-stamp, and status of the transmission (successful or failing). Additional, reasons for the incorrect message transmission can be defined. A concrete schema for the logging still has to be defined – work in progress.

4.2 Transaction: "Send DRCT"

4.2.1 Scope

Before a VPP can interact at the electric energy market and power system, the VPPOP has to group DEUs to a VPP together. For the VPPOP as a plant operator, it is important to know the settings of each single DEU to organize schedules and the general participation at the electric energy market as well as the power grid to supply or consume energy. At this point, the interoperability issue is the data exchange from the DEUC to the DEUOP and VPPOP to share their settings via a secure connection. Before, the transaction of the data exchange can be executed, the DEUC has to create the SCD file which will be transferred to the VPPOP or DEUOP.

4.2.2 Actor Roles

Table 12: Actor Roles for Send DRCT

Role	Description	Actor
Transaction Initiator	The transaction initiator starts and sends the values of the SCD file to a receiving actor's transaction responder actor via TCP/IP. If specified, the transaction initiator uses the IHE ATNA profile to establish a secured connection before the data transmission actually starts, if it is not already in place.	The following actors may play the role of transaction initiator: VPPOP and DEUOP
Transaction Responder	The transaction responder receives the values of the SCD file. In case a secure connection is required, it cooperates with the transaction initiator in establishing security.	The following actors may play the role of transaction responder: DEUC

4.2.3 Referenced Standards

- IEC 61850-7-420 (logical nodes)
- IEC 61850-7-2 (data objects, services)

4.2.4 Interaction Diagrams

The transaction “Send DRCT” includes two steps to transmit the measured values from the DEUC as a client to the servers.

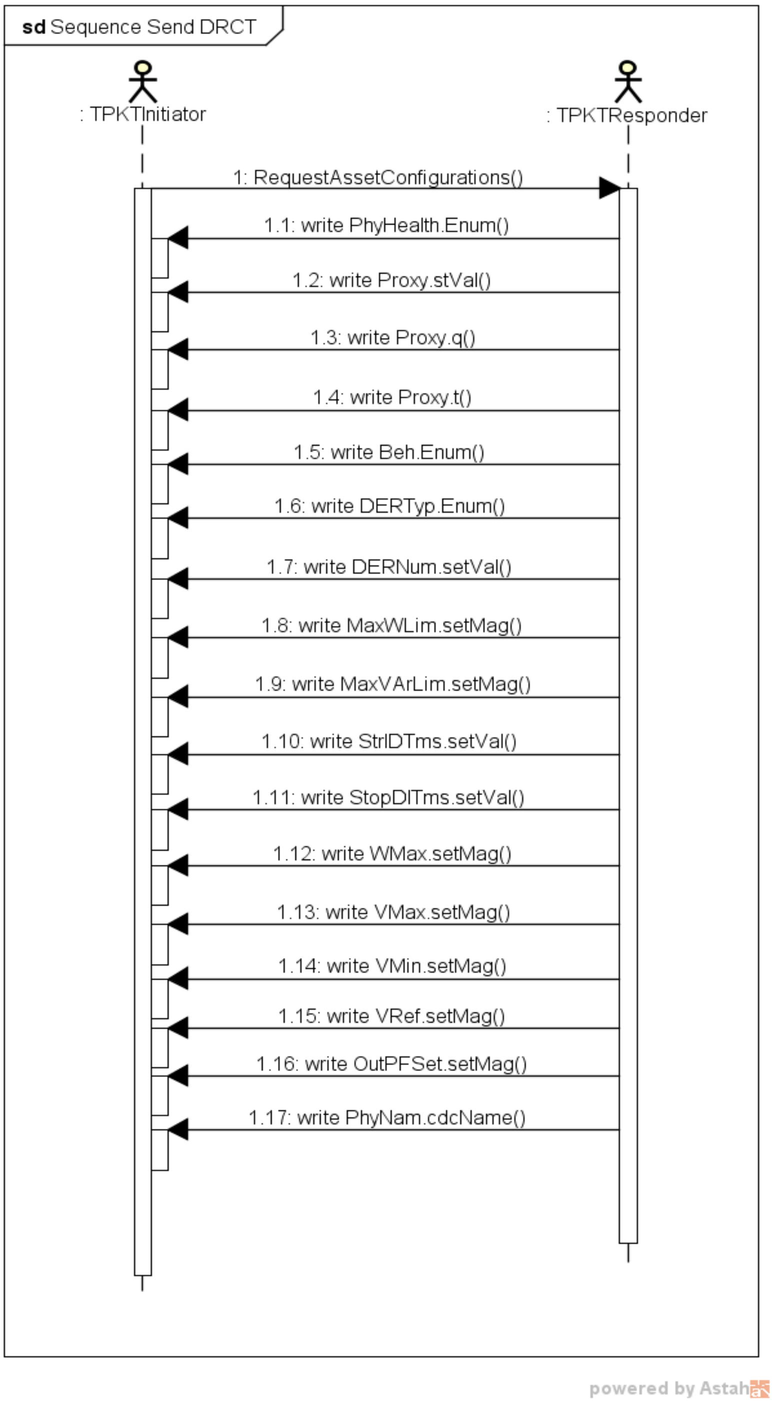

Figure 13: Data flow for Send DRCT

4.2.4.1 Establish Secure Connection

Refer to Section 4.1.4.2

4.2.4.2 Provide Asset Configurations

4.2.4.2.1 Triggering Event

The transaction initiator triggers the responder to receive the SCD file. A secure connection between the transaction initiator and responder addressed in the SCD file has been created or is already established.

4.2.4.2.2 Message Semantics

Table 13: LPHD & DRCT Data Objects

Logical Device	**Logical Node**	**Data Object**	**Common data class**	**Data Attribute**	**Functional Constraint**	**Description**
DEUC / DEUOP / VPPOP	LPHD	PhyNam	DPL	cdcName	EX	Name of the physical device. Details are written in IEC 61850-7-1.
		PhyHealth	ENS	EnumType	ST	The current health status of the device. Its status can be: Ok, Warning, or Alarm.
		Proxy	SPS	stVal	ST	Indicates if the LN is a proxy, i.e. stVal is only a Boolean.
				q	ST	Quality of the proxy
				t	ST	TimeStamp of the proxy
	DRCT	Beh	ENS	EnumType	ST	The current status of the logical device. Its behaviour can be: on, on-blocked, test, test/blocked, or off.
		DERNum	ING	setVal	SP	Number of DER units connected to the controller
		DERTyp	ENG	EnumType	ST	Type of DER unit: virtual or mixed DER, reciprocating engine, fuel cell, photovoltaic system, combined heat and power, unknown, other.
		MaxWLim	ASG	setMag	SP	Analogue value for the nominal max output power
		MaxVArLim	ASG	setMag	SP	Analogue value for the nominal max output reactive power
		StrDITms	ING	setVal	SP	Nominal time delay before starting or restarting
		StopDITms	ING	setVal	SP	Nominal time delay before stopping
		WMax	ASG	setMag	SP	Analogue value for the setting for maximum active power and reference value for functions

		VMax	ASG	setMag	SP	Analogue value for the setDERpoint for maximum voltage
		VMin	ASG	setMag	SP	Analogue value for the setpoint for minimum voltage
		VRef	ASG	setMag	SP	Analogue value for the reference voltage for functions using grid voltage as input
		OutPFSet	ASG	setMag	SP	Analogue value for the setpoint for maintaining fixed power factor.

The SCD file has to contain at least the following LN type for implementing the transaction:

```
<LNodeType desc="DER controller characteristics" lnClass="DRCT" id="DRCT">
        <DO desc="Behaviour" name="Beh" type="ENS_BehaviourModeKind"/>
        <DO desc="Name plate" name="NamPlt" type="LPL_lnNs"/>
        <DO desc="Number of DER units connected to controller or number of units connected to an ECP"
name="DERNum" type="ING"/>
        <DO desc="Type of DER unit managed by controller or connected at the ECP" name="DERTyp"
type="ENG_DERUnitKind"/>
        <DO desc="Nominal max output power at controller or ECP" name="MaxWLim" type="ASG"/>
        <DO desc="Nominal max output reactive power at controller or ECP" name="MaxVArLim" type="ASG"/>
        <DO desc="Nominal time delay before starting or restarting" name="StrDITms" type="ING"/>
        <DO desc="Nominal time delay before stopping" name="StopDITms" type="ING"/>
        <DO desc="Setting for maximum active power and reference value for functions" name="WMax"
type="ASG"/>
        <DO desc="Setpoint for maximum voltage" name="VMax" type="ASG"/>
        <DO desc="Setpoint for minimum voltage" name="VMin" type="ASG"/>
        <DO desc="Reference voltage for functions using grid voltage as input" name="VRef" type="ASG"/>
        <DO desc="Setpoint for maintaining fixed power factor" name="OutPFSet" type="ASG"/>
</LNodeType>
```

The SCD file header and the values of the LN types are available in the prior transaction “Send FSCH” (see Section 4.1.4.4.2) or in the IEC 61850-7-3 standard.

4.2.4.2.3 Expected Actions

The TPKTResponder provides its SCD file.

4.2.4.3 Transmit Asset Configurations

The TPKTResponder writes the values of its SCD file to the SCD file of the TPKTInitiator via a secure TCP/IP connection.

4.2.4.4 Validate LN DRCT

4.2.4.4.1 Triggering Event

The transaction initiator of the VPPOP or DEUOP has received a SCD file containing asset configurations.

4.2.4.4.2 Message Semantics

The values of the SCD file described in Section 4.2.4.2 were transmitted and the same LN structure like in Table 13 shall result from the values.

4.2.4.4.3 Expected Actions

The TPKTInitiator got the LN DRCT data.

4.2.5 Security Considerations

See Section 4.1.5

4.3 Transaction: “Send MMXU”

4.3.1 Scope

The DEUCs provide measured values for the DEUOP, VPPOP, and DSO to support these actors in their tasks at the electric market and power system. At this point, the interoperability issue is the data exchange for the measured values from the DEUCs to the DEUOP, VPPOP and DSO via a secure connection. Before, the transaction of the data exchange can be executed, the DEUC has to create the SCD file which will be transferred to the DEUOP, VPPOP, and DSO.

4.3.2 Actor Roles

Table 14: Actor Roles for Send MMXU

Role	Description	Actor
Transaction Initiator	The transaction initiator starts and sends the values of the SCD file to a receiving actor’s transaction responder actor via TCP/IP. If specified, the transaction initiator uses the IHE ATNA profile to establish a secured connection before the data transmission actually starts, if it is not already in place.	The following actors may play the role of transaction initiator: DEUC
Transaction Responder	The transaction responder receives the values of the SCD file. In case a secure connection is required, it cooperates with the transaction initiator in establishing security.	The following actors may play the role of transaction responder: DEUOP, VPPOP, DSO

4.3.3 Referenced Standards

- IEC 61850-7-420 (logical nodes)

4.3.4 Interaction Diagrams

The transaction “Send MMXU” includes the following steps to transmit the measured values from the DEUC as a server to the clients. Therefore, the client requests the measured values and the server transfers the values to the client.

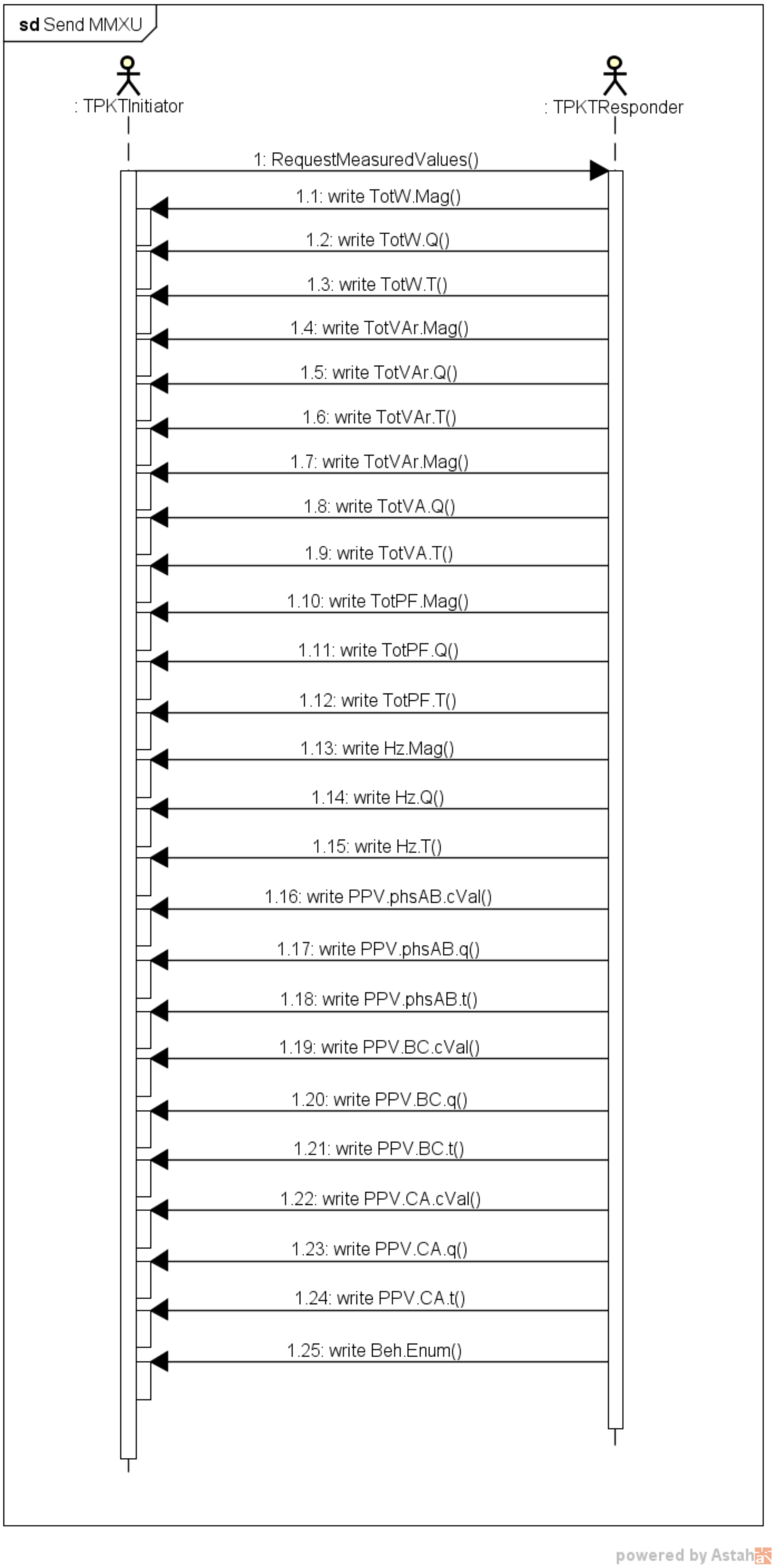

Figure 14: Data flow for MMXU

4.3.4.1 Establish Secure Connection

Refer to Section 4.1.4.2 Establish Secure Connection

4.3.4.2 Request Measured Values

4.3.4.2.1 Triggering Event

The TPKTInitiator triggers the TPKTResponder to transmit the measured values with the LN MMXU.

4.3.4.2.2 Message Semantics

The trigger only contains an instruction from client to server to transmit the MMXU values.

4.3.4.2.3 Expected Actions

The TPKTResponder of the DEUC sends the data object values from the MMXU to the TPKTInitiator.

4.3.4.3 Provide Measurement Values

4.3.4.3.1 Triggering Event

The measured values were requested and a secure connection to the transaction responder addressed in the SCD file has been created or is already established.

4.3.4.3.2 Message Semantics

Table 15: MMXU Data Object

Logical Device	Logical Node	Data Object	Common data class	Data Attribute	Functional Constraint	Description
DEUC / DEUOP / VPPOP	MMXU	Beh	EnumType	ENS	ST	The current status of the logical device. Its behaviour can be: on, on-blocked, test, test/blocked, or off.
		TotW	MV	Mag	MX	Analogue value of the real power in a three-phase circuit [W].
				Q	MX	Quality of the real power value
				T	MX	Timestamp
		TotVAr	MV	Mag	MX	Analogue value of the reactive power in a three-phase circuit [VAr].
				Q	MX	Quality of the reactive power value
				T	MX	Timestamp
		TotVA	MV	Mag	MX	Analogue value of the total apparent power in a three-phase circuit [VA].
				Q	MX	Quality of the total apparent power value
				T	MX	Timestamp
		TotPF	MV	Mag	MX	Analogue value of the average power factor in a three-phase circuit.
				Q	MX	Quality of the average power factor
				T	MX	Timestamp

		Hz	MV	Mag	MX	Analogue value of the frequency [Hz]
				Q	MX	Quality of the frequency value
				T	MX	Timestamp
		PPV	DEL / CMV	phsAB.cVal	MX	A complex value (vector) for the phase to phase values of a three phase system
				phsAB.q	MX	Quality of the phsAB value
				phsAB.t	MX	It specifies at which time the value was determined. Note: phsAB.t == phsBC == phsCA
				phsBC.cVal	MX	A complex value (vector) for the phase to phase values of a three phase system
				phsBC.q	MX	Quality of the phsBC value
				phsBC.t	MX	It specifies at which time the value was determined. Note: phsAB.t == phsBC == phsCA
				phsCA.cVal	MX	A complex value (vector) for the phase to phase values of a three phase system
				phsCA.q	MX	Quality of the phsCA value
				phsCA.t	MX	It specifies at which time the value was determined. Note: phsAB.t == phsBC == phsCA

The SCD file has to contain at least the following LN type for implementing the transaction:

```
<LNodeType lnClass="MMXU" id="MMXU">
        <DO desc="Behaviour" name="Beh" type="ENS_BehaviourModeKind"/>
        <DO desc="Total active power (total P)" name="TotW" type="MV"/>
        <DO desc="Total reactive power (total Q)" name="TotVAr" type="MV"/>
        <DO desc="Total apparent power (total S)" name="TotVA" type="MV"/>
        <DO desc="Average power factor (total PF)" name="TotPF" type="MV"/>
        <DO desc="Frequency" name="Hz" type="MV"/>
        <DO desc="Phase to phase voltages (VL1,VL2, …)" name="PPV" type="DEL"/>
        <DO desc="Phase currents (IL1, IL2, IL3)" name="A" type="WYE"/>
</LNodeType>
```

The SCD file header and the values of the LN types are available in the prior transaction “Send FSCH” (see Section 4.1.4.4.2) or in the IEC 61850-7-3 standard.

4.3.4.3.3 Expected Actions

The content of the LN has been transmitted as a SCD file via message to the addressed TPKTResponder. Additionally, the message was read out by the addressed actor.

4.3.4.4 Transmit Measurement Values

The TPKTResponder writes the values of its SCD file to the SCD file of the TPKTInitiator via TCP/IP connection.

4.3.4.5 Forward Measurement Values

4.3.4.5.1 Triggering Event

The transaction initiator of the VPPOP, DEUOP, or DSO has received the SCD file containing measured values from the DEUC.

4.3.4.5.2 Message Semantics

The SCD file described in Section 4.2.4.2 was transmitted and the same LN structure like in Table 13 shall result.

4.3.4.5.3 Expected Actions

The TPKTInitiator got the LN MMXU data.

4.3.5 Security Considerations

See section 0

5 Abbreviations

ATNA	Audit Trail and Node Authentication
BER	Basic Encoding Rules
CDC	Common Data Classes
CHP	Combined Heat and Power generators
CIM	Common Information Model
cVPP	commercial VPP
DER	Distributed Energy Resource
DEU	Distributed Energy Unit
DEUC	Distributed Energy Unit Controller
DEUOP	Distributed Energy Unit Operator
DO	Data Objects
DR	Demand Response
DSCC	LN: DER energy schedule controller
DSCH	LN: DER energy and / or ancillary service schedule
DSO	Distributed system operator
ECP	Electrical Connection Point
EEX	Energy Exchange
e-Sens	Electronic Simple European Networked Services
FFG	Austria Research Promotion Agency
FSCC	LN: Schedule Controller
FSCH	LN: Schedule
GOOSE	Generic Object Oriented Substation Events
GPL	General Public License
IDE	Intelligent Electronic Device
IEC	International Electrotechnical Commission
IES	Integrating the Energy System
ISO	International Organization for Standardization
IT	Information Technology
LAN	Local Area Network
LD	Logical Device

LN	Logical Node
MMS	Manufacturing Message Specification
PDU	Payload Data Unit
PICOM	Piece of Information for Communication
PV	Photovoltaic Plants
SCD	Substation Configuration Description
SCL	Substation Configuration description Language
SCSM	Specific Communication Service Mapping
SGAM	Smart Grid Architecture Model
SO	System Operator
TCP/IP	Transmission Control Protocol/Internet Protocol
TLS	Transport Layer Security
TPDU	Transport Protocol Data Unit
TPKT	Transport Packet
TS	Transport Service
tVPP	technical VPP
UCMR	Use Case Management Repository
VM	Virtual Machine
VMD	Virtual Manufacturing Device
VPP	Virtual Power Plant
VPPOP	VPP Operator

6 References

[1] IEC, "IEC 61850-7-420 -Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes." .

[2] IEC, "IEC 61850-7-4 Edition 2.0 - Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatible logical node classes and data object classes." 2016.

[3] IEC, "IEC 61850-8-1: Communication networks and systems in substations - Part 8-1: Specific Communication Service Mapping (SCSM) - Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3." 2004.

[4] ISO/IEC 88241: 1999, Information technology – Abstract Syntax Notation One (ASN. 1) ITU X.690 (07/2002), Information technology

[5] RFC 5246: The Transport Layer Security (TLS) Protocol Version 1.2 – Communication security over the Internet

[6] IEC 62351: Power systems management and associated information exchange - Data and communications security

[7] IEC 61850-5: Communication requirements for functions and device models.

[8] M. Janssen, C. Andersen, C. Brunner, J. Dall: „Modelling of DER schedules using IEC 61850" in "20th International Conference on Electricity Distribution" 2009.