OpenADR 3 to Matter interworking reference specification

Version v1.0, 2025-03-28 10:59:51 +0000: Approved

Copyright Notice, License and Disclaimer

13th January 2025

Participants

Harrow, James

Piercy, Neil

Document Control

The OpenADR 3 and Matter interworking reference specification is made of individual chapters such as this one.

Revision History

Revision	Date	Details	Editor
0.5	Feb 7, 2025	First draft for comment	James Harrow
0.7	Mar 3, 2025	Second draft for comment	James Harrow
1.0	Mar 28, 2025	Final document	James Harrow

Table of Contents

Chapter 1. Introduction

1.1. Background

The drive towards Net Zero requires a move of most consumer energy consumption away from fossil fuels being used for vehicles and home heating towards electrical energy derived from renewable sources, including local electricity generation and storage in the home with solar PV and storage batteries. In turn, this requires a significant increase in electrical supply to consumer premises.

Traditionally the electricity supply has been sized to cope with the peak demands of all consumers, with supply side response to peaks in demand, and a distribution grid sized to cope with peak supply. With the large increase in electrical power needed for EVs and home heating it becomes uneconomic and logistically difficult to increase the electricity supply and distribution to match these higher peak demands.

In response to this, governments around the world have been promoting the need for Demand Side Response (DSR) to manage these peaks of demand (and peaks of local generation back into the distribution grid) by carefully balancing the demand of consumers by controlling the Energy Smart Appliances (ESAs). It has been estimated that flexible energy use can save between £30-70 billion on system costs in the period 2020 to 2050 in the UK alone[1]. The UK's National Energy System Operator (NESO) has modelled that at least 10 GW of demand response will be needed by 2030[2].

Consumer adoption is key for the success of such domestic DSR strategies, and consumers will rightly demand the ability to have an EV charge point at home, and the right to choose other Low Carbon Technologies (LCTs) to heat their homes and hot water. If, however, consumers do not also sign up to have their new LCT assets controllable during peak times of excess solar and wind, or during peak demand events, then domestic DSR may fail to deliver the promise.

In order to ensure a mass-market solution, it is imperative to choose the standards which are likely to have mass-market appeal and adoption. Matter (developed by the Connectivity Standards Alliance) is proving to be the unifying standard for smart homes and is adopted by the tech giants and appliance manufacturers and supported natively by both Android and iOS to enable App developers to have a seamless integration experience. Its extensive capabilities allow control of multiple device types, networked via Wi-Fi, Ethernet or Thread within the home.

As of November 2024, there were over 790 Connectivity Standards Alliance member companies, with numerous certified products in the market, just two years after the first specification was published.

Manufacturers are increasingly moving to adopt Matter, and with the release of Matter 1.4 in November 2024, all devices can potentially be controlled by an energy management system (EMS) (sometimes known as a Home Energy Management System - HEMS) to help save consumers money on their bills as well as helping to reduce their carbon footprint by shifting when they use energy using 'Time of Use' pricing to optimize their running costs.

A single home can therefore reduce the energy bills for its occupants with an EMS optimizing the ESAs, however this home is working in isolation, without knowledge of what impact it and the neighboring properties and local renewable generation (on-shore solar and wind farms) are having on the Low Voltage (LV) grid infrastructure.

These homes therefore need to also be connected to a Demand Side Response Service Provider (DSRSP) which can coordinate the control of thousands of homes in a local area.

To ensure scalability, the architecture model assumed in this specification makes use of an EMS in the home communicating with a DSRSP server using the widely established Open Automated Demand Response (OpenADR) standard. [OADR2] was published in 2013 and subsequently as an IEC specification in 2018. Version 2.0 used SOAP/XML to define the message format, and in 2023 the OpenADR Alliance released a newer version 3.0, [OADR3], which updates this to use JSON formatted messages.

1.2. Scope and Purpose

This document provides a reference set of architectures and procedures by which a DSRSP based on [OADR3] may manage a set of ESAs operated by the user using [Matter]. It is primarily aimed at domestic premises, but may equally be applied to other small non-residential premises, but it is not intended to be applicable to larger enterprises or industrial premises.

Both Matter and OpenADR 3.x include many capabilities in their permitted use of the protocols, which whilst providing the ability to allow innovation, has left industry the challenge of guaranteeing interoperability and ensuring devices perform in an expected and repeatable way to help implement domestic DSR at scale.

This document aims to:

- highlight key example use-cases which the DSR industry aims to tackle
- demonstrate how Matter can be used stand-alone to optimize ESAs energy use to save cost and reduce carbon
- show how Matter and OpenADR can be used together to map the data requirements from each protocol and example internal business logic that the EMS is expected to implement
- act as a companion specification to help profile both standards to aid interoperability

It also aims to ensure that the approach taken minimizes data use outside of the home, to enable compliance to international data privacy regulations (for example GDPR), and examples of how best practices in cyber-security in OpenADR and Matter can help protect the grid which is considered critical national infrastructure.

1.3. Acknowledgements

The UK Government’s Department of Energy Security and Net Zero (DESNZ) have sponsored Green Energy Options (**geo**) to help develop this specification in conjunction with the OpenADR Alliance and the Connectivity Standards Alliance experts.

This specification brings together two existing technical standards that could be adopted by ESA manufacturers and DSRSPs. Rather than re-inventing new concepts and ideas from scratch, it

builds upon the use-cases demonstrated in the DESNZ Interoperable Demand Side Response (IDSR) Demonstration Programme (2023-2025) incorporating key learnings and suggested improvements.

We gratefully acknowledge the support and guidance from the wider energy industry who have helped shape the key use-cases and provided their input and feedback in creating this document.

1.4. Future of this specification

The first version of this specification is intended to demonstrate the possibilities offered by joining together of two complementary standards. This work has been undertaken by **geo** who is a member of both Connectivity Standards Alliance and OpenADR Alliance.

This specification may continue to evolve as the Matter and OpenADR standards are updated.

We recommend that this document may become adopted and developed further by the Connectivity Standards Alliance, the OpenADR Alliance or another standards body and aligns to the future needs of governments, DSRSPs and manufacturers to build and test their products and services.

This specification itself does not provide any formal testing regimes, or complete profiling of the Matter and OpenADR specifications. These are in themselves additional specifications, which may need development and validation with a wider set of peer reviewers.

1.5. Acronyms and Abbreviations

Acronym	Meaning	Origin	Explanation
BESS	Battery Energy Storage System		
BL	Business Logic	[OADR3]	Application logic embodied in one or more software applications deployed by a utility, retailer, or other 'program owner' of the VTN that typically produces Events and consumes Reports.
BLE	Bluetooth Low Energy		A profile of the Bluetooth communications protocol designed for low power devices
BSI	British Standards Institute		The public body responsible for the production of standards used in UK legislation
CL	Customer Logic	[OADR3]	Application logic that requests and responds to Program and Event objects, produces Reports, and may provide human facing features to support configuration and monitoring.
CSA	Connectivity Standards Alliance		A standards body which produces the Matter and Zigbee specifications

Acronym	Meaning	Origin	Explanation
DEM	Device Energy Management	[Matter]	A Cluster which permits forecast and control of energy usage of an ESA
DEMM	Device Energy Management Mode	[Matter]	A Cluster controls the mode of operation of the DEM
DESNZ	Department of Energy Security and Net Zero		A UK government department
DNO	Distribution Network Operator		
DRLC	Demand Response and Load Control		A feature to allow the direct control of energy consumption devices for demand response
DSO	Distribution System Operator		
DSR	Demand Side Response	[PAS1878]	Shifting (in time) and/or modulation (increase or decrease) of electricity consumption and/or production through the controlled operation of ESAs, in line with user preferences, in response to signals from, and acting in agreement with, regulated electricity market participants
DSRSP	DSR Service Provider	[PAS1878]	A centralized actor which can provide a digital service to help balance the grid by using DSR capabilities on behalf of a grid utility operator (e.g. National grid or DSOs/DNOs)
EEBUS			A communications interface connecting energy management devices
EEM	Electrical Energy Measurement	[Matter]	A Matter Cluster to report electrical energy usage which can be measured or estimated
EMS	Energy Management System		The system managing energy on the premises
EPM	Electrical Power Measurement	[Matter]	A Matter Cluster to report electrical power (and optionally voltage, current etc.) which can be measured or estimated
ESA	Energy Smart Appliance		An electrical appliance that can interact with an EMS to provide control of and/or information about its energy usage

Acronym	Meaning	Origin	Explanation
ESAG	ESA Gateway	[PAS1878]	A gateway device in the premises between the protocol used from the EMS to that used by the ESAs.
EV	Electric Vehicle		
EVSE	EV Supply Equipment		The equipment connecting the EV to the premise electricity supply, controlling the charging of the EV
GHG	Green House Gas		The emissions measured typically in grams of "CO2 equivalent emissions" per kWh of energy
HDP	Highly Dynamic Pricing		A ToU tariff which is updated frequently - typically on a daily basis
HEMS	Home Energy Management System		An EMS which is intended for use in homes to optimize energy
HVAC	Heating, Ventilation, and Air Conditioning		
JSON	JavaScript Object Notation		A lightweight data-interchange format easy for humans to read and write and for machines to parse.
LV	Low Voltage		The final part of the electricity distribution network
mDNS	multicast Domain Name System		A protocol to discover addresses of specific types of devices
MHHS	Market-wide Half-hourly Settlement		The UK scheme for managing the balancing market
NESO	National Energy System Operator		The UK body responsible for planning and operating the UK energy system
OCPP	Open Charge Point Protocol		An application protocol for communication between EV charging stations and a central management system
PV	Photo Voltaic		
SOAP	Simple Object Access Protocol		A messaging protocol for exchanging structured information (such as XML)
TLS	Transport Level Security		
ToU	Time of Use		Tariffs which vary over time
V2G	Vehicle to Grid		The ability for an EV to provide power back to the premises or grid by discharging its battery (see also V2X)

Acronym	Meaning	Origin	Explanation
V2X	Vehicle to "X"		The ability for an EV to provide power back to the premises or grid by discharging its battery (see also V2G)
VEN	Virtual End Node	[OADR3]	A software application that consumes Events, generates Reports, and directly or indirectly causes changes in energy consumption patterns. This is a client of a VTN.
VTN	Virtual Top Node	[OADR3]	An application that implements the OpenADR 3 APIs.
XML	eXtensible Markup Language		A markup language similar to HTML, but with the ability to define custom tags
YAML	Yet Another Markup Language		A human-readable data serialization language commonly used for configuration files and data exchange. Some others define it as 'YAML Ain't Markup Language' to emphasise that it is for data not documents.
Zigbee			An IEEE 802.15.4-based specification of communication protocols for small low power devices, such as used for home automation.

1.6. Definitions

Term	Origin	Meaning
Cluster	[Matter]	A specification defining one or more attributes, commands, behaviors and dependencies, that supports an independent utility or application function.
Consumer	[PAS1878]	The person responsible for the energy usage in the home.
Device	[Matter]	A piece of equipment containing one or more Nodes.
Device Type	[Matter]	The specification of the child Device Types and Clusters needed to support the Device behavior over Matter.
Event	[OADR3]	A notification created by a DSRSP towards a VEN to give it information or request a Report
Matter	[Matter]	A specification defining an interoperable application layer solution for smart home devices over the Internet Protocol.
Program	[OADR3]	The business context for a given usage of the VTN. May be a Demand Response program, tariff, or other business construct.
Report	[OADR3]	A notification with information created by a VEN towards the VTN.
Resource	[OADR3]	An object representing an ESA, consuming or producing energy.

Term	Origin	Meaning
User		The end use of the devices and energy in the premise.

1.7. Style

The above defined terms and acronyms are used with capitalization as above when referring to the defined meanings.

When referring to specific objects, properties, attributes etc. defined in the `[Matter]` or `[OADR3]` specifications, this `style` of text will be used.

Note that this results in similar acronyms in different styles, for example, the VEN is represented by a `ven` object in the VTN data model.

1.8. Conformance Levels

The key words below are usually capitalized in the document to make the requirement clear.

Key Word	Description
MAY	A key word that indicates flexibility of choice with no implied preference.
NOT	A key word that used to describe that the requirement is the inverse of the behavior specified (i.e. SHALL NOT, MAY NOT, etc.)
SHALL	A key word indicating a mandatory requirement. Designers are required to implement all such mandatory requirements.
SHOULD	A key word indicating flexibility of choice with a strongly preferred alternative. Equivalent to the phrase is recommended.

1.9. References

The following standards and specifications contain provisions, which through reference in this document constitute provisions of this specification. All the standards and specifications listed are normative references. At the time of publication, the editions indicated were valid. All standards and specifications are subject to revision, and parties to agreements based on this specification are encouraged to investigate the possibility of applying the most recent editions of the standards and specifications indicated below.

1.9.1. External Reference Documents

Reference	Title	URL
`[OADR2]`	OpenADR 2.0 Specification	https://openadr.memberclicks.net/specification
`[OADR3]`	OpenADR 3 Specification	https://openadr.memberclicks.net/openadr-3-0

Reference	Title	URL
[PAS1878]	PAS1878 Specification v1	https://www.bsigroup.com/en-GB/insights-and-media/insights/brochures/pas-1878-energy-smart-appliances-system-functionality-and-architecture/
[Matter]	Matter Specifications v1.4	https://csa-iot.org/developer-resource/specifications-download-request/
[EN303645]	EN 303 645 v3.1.3 Cyber Security for Consumer Internet of Things: Baseline Requirements	https://www.etsi.org/deliver/etsi_en/303600_303699/303645/03.01.03_60/en_303645v030103p.pdf

1.10. Informative References

Reference	Title	URL
[Matter_Handbook]	Matter Handbook	https://handbook.buildwithmatter.com/
[OpenADR 3 User Guide]	OpenADR 3 User Guide	https://openadr.memberclicks.net/openadr-3-0

[1] BEIS: Smart Systems and Flexibility Plan 2021

[2] Advice on achieving clean power by 2030, NESO, 2024

Chapter 2. Markets

Energy Flexibility Markets exist around the world in various forms today. In most markets, the customer pays their energy bills to their local energy utility and they have little choice based on where they live. These energy companies deal with generation supply, transmission and customer billing.

However, in some markets, such as UK and notably in Texas in USA, the role of energy retailer (who interacts with the customer and the billing), generators and transmission network operators are split into devolved organizations. This split creates competition, but can also create complexities in how the end customer may need to interact.

As the need to decarbonize towards a Net Zero future accelerates, governments are encouraging customers to buy an Electric Vehicle (EV) and move away from burning natural gas to heat their homes to using a heat pump. These increased number of electrically powered devices will put pressure on the grid, and in particular the Low Voltage (LV) networks at a localized level.

Furthermore the amount of renewable and intermittent generation that is being added to power the grid, often with on-shore solar and wind, means that the network transmission cables will be under more pressure to use the excess solar or wind at a more localized level, meaning that customers homes are set to benefit from lower cost energy when it is available.

2.1. Energy trading (Wholesale Markets)

In the UK and many parts of Europe supply of energy is traded on the energy markets on a half-hourly basis or even 15-minute resolution. This trade is between generators (suppliers) and retailers (buyers who sell energy to their end customers). The amount of energy purchased is deemed to be correct ahead of time based on statistical model customer types today. However if an energy retailer purchases too much, or too little energy, then this can create an imbalance on the grid.

2.1.1. Balancing markets

In the UK, the National Energy System Operator (NESO) needs to ensure the supply and demand is balanced every second of the day, and may have to pay generators to curtail their power or ask standby generators to turn on or turn up. These short-term balancing actions have an associated cost which is passed onto the retailers who had a mis-match in that actual energy use as penalty cost when the actual energy usage is settled using metering.

In late 2025, the UK is moving to using actual customer smart meter data when settling energy costs using the so-called Market-wide Half-Hourly Settlement (MHHS) scheme. The impact of this change is expected to cause some energy retailers to produce new Time of Use (ToU) tariffs in the market.

2.1.1.1. Alternative strategies used by energy retailers

Some energy retailers have been exploring mechanisms to avoid these balancing costs, by load shifting their customer's assets (for example EV charging). This allows the energy retailer to avoid penalties on their own trading position, but they can also trade this flexibility on the balancing markets.

2.2. Customer Tariffs

The challenge today is that customers have no easy way to know when there is surplus energy, and when there are constraints.

Customers pay for energy (kWh) and not the instantaneous peak power that they use.

Traditionally most customers have a so called 'flat tariff' which is constant based on the energy (kWh) used, and not based on the peak power used.

However the mass market of customers do not get exposed to these complex markets, with the notable exception of the Octopus Agile tariff which provides an API and a mobile App to allow those customers who can develop their own integrations to control their appliances, or if the ESA supports this can automatically fetch this data and optimize its operation against this.

Demand Side Response (DSR) and Flexibility is something that most customers have not heard of, and have little interest or understanding of, but may be impacted by.

2.2.1. Tariff types

A Tariff is often composed of various elements: fuel cost, network costs, metering costs, policy costs (for example levies applied).

They typically have a unit cost as well as a daily standing charge.

Tariffs can also be geographic based on which area you live in (for example the UK has 14 grid connection points which determine the tariff offered by an energy retailer) and the cost of a kWh of energy varies based on the transmission costs.

Whilst these are localized, they cover very large areas and do not take into account LV network constraint areas.

Classification of tariffs:

Tariff Type	Description
Flat	The price of energy is constant throughout the day

<table>
<tr><th>Tariff Type</th><th>Description</th></tr>
<tr><td>2-Tier</td><td>The price of energy changes twice per day (peak and off-peak).
Customers can keep simple tariffs in their mind and manually control their appliances to save money.
Classic examples include Economy 7 which was used in the UK with a radio controlled teleswitch to switch on thermal storage heaters overnight to charge up when grid energy usage was low.
Today energy retailers offer similar schemes overnight for EV charging, recharging of home batteries etc.
Some also offer low-cost tariffs over the weekend.</td></tr>
<tr><td>Dynamic</td><td>The price of energy changes every day (based on day-ahead pricing publication). These may also be referred to as Highly Dynamic Pricing (HDP).
These are typically published by an energy retailer in the middle of the afternoon the day before and only include the next 24 hours.
The pricing can change every half-hour during the day.
These tariffs require some automation to ensure ESAs are avoiding use at peak pricing and are too complex for a human to interact with on a daily basis.
The customer may benefit from periods where the price is much lower (sometimes negative pricing - customers are paid to use energy).
A notable example of this is the UK Octopus Agile tariff.</td></tr>
<tr><td>Block</td><td>The energy company may charge different rates for the 1st block of energy, and may increase the price if the energy used crosses a usage threshold.
These can also be comprised with multiple tiers (different prices throughout the day) based on how much energy has been used.
These tariffs can help energy companies constrain how much energy is sold at a lower rate.
Consider the case of EV charging - some retailers today may limit how much time is allowed at an off-peak rate (for example a 4 hour window), knowing the typical maximum charge rate of an EV is 7kW, this implies the maximum energy is 28kWh. However this may steer all customers to turn on their EV at the same time causing higher peak loads within a short time window.

Instead, if a block tariff of 28kWh was used, but the time window for off-peak rate energy was 8 hours, then the EV chargers could be switched on at any time within the off-peak period and would be given an incentive to limit energy use to 28kWh. The benefit to the grid is that the charging rate could be reduced, or different EV chargers across multiple homes may randomly start at different times, resulting in a lower peak load in the LV network.</td></tr>
</table>

2.3. Demand Flexibility rewards

In the UK, the Demand Flexibility Service (DFS) started in the winter of 2022/2023 which allowed customers and businesses to receive incentives to manually control their energy usage at peak times. Customers opt into the scheme, and receive notifications (email or via an App) about planned events. These events may only happen around 10-20 times in the winter season.

In return, the customer may be offered credits on their bill for turning down their energy.

The service relies upon the customer having a smart meter, and uses a base-lining methodology to assess if the event resulted in a reduction of energy use compared to the customers baseline usage.

2.4. Incentive Signals

Incentive signals can be thought of as a mechanism for a Energy Management System (EMS) or ESA to optimize their power and energy use based on time of day.

For example, a customer may pay for a flat tariff that does not change during the day, but on the grid the `carbon intensity` may fluctuate throughout the day where at peak times the grid needs to call upon fossil fuel generation to make up the shortfall from renewable energy sources.

The carbon intensity can often be predicted a day or two ahead (based on weather forecast) which if known to an ESA may allow the customer to reduce their implicit carbon footprint by using energy when there is more renewable energy available.

Similarly, the local DSO/DNO may have a specific constraint in a local area (for example a substation transformer). In order to help reduce peak loads, it may be possible to send an incentive signal to one specific EMS or ESA (or a group of EMSs or ESAs in a local area) to encourage them to either increase or decrease their power consumption at certain times of the day.

NOTE Customers are charged based on how much energy (kWh) they use, however the DNO/DSOs care more about the peak load power (kW). Whilst highly related - energy is power x time - these different priorities can be addressed using Matter and OpenADR if correctly signalled to homes.

2.4.1. Peak load management

One use-case that has recently come into law in Germany (Jan 1st 2024), is the 'Paragraph 14a', which mandates that ESAs must be able to receive a signal from a DNO/DSO to limit the peak power of the property at certain times. This acts like an emergency brake where the DNO/DSO can ensure that the power stays on at all times. The law came about because DNOs were stopping customers from getting an EV charger or new heat pump added to their homes, the onus is now on the home owner to ensure that they have a load limitation control so that they can prioritize what they want to happen (for example charging their EV or heating their home but not both).

It is expected that other markets will adopt a similar approach, and as such the ability to ask an EMS to perform peak load limitation via OpenADR (and then control the assets in the home using Matter) is a key use-case that we describe later (see UC 2.6.3).

Chapter 3. Architecture

3.1. What is Matter?

Matter is a unifying smart home protocol that allows compatible devices and systems to connect to one another. Smart home devices should be secure, reliable, and seamless to use and Matter helps to enable a consumer-friendly experience using a choice of multiple apps or controllers. Matter is available as a royalty-free open-source SDK for Connectivity Standards Alliance members in products that have been certified.

Matter 1.0 was published by the Connectivity Standards Alliance in November 2022, and has had several releases to update the specification, adding new features and support of new device types. Matter 1.4 was published in November 2024 and included the support of key new generic energy management features.

3.1.1. Benefits for manufacturers in adopting Matter

Prior to the development of Matter, companies and their ecosystem partners were developing and testing smart home products that connected back over proprietary protocols to cloud infrastructure that allows users to use apps or smart assistants to interact with them.

Partner companies use cloud-to-cloud APIs to enable new services, but these proprietary APIs are subject to change, meaning that cloud developers have to track and maintain them. This has been manageable at a small scale when there are relatively few integrations, but as more partners are supported, the ability to support these bespoke APIs has become increasingly challenging, often resulting in broken services, which then impact the end users and damage the reputation of those involved.

This has also led to a fragmented market where users can buy some products which may work well together in one ecosystem, but will not work with another controller or app, ultimately causing user frustration. Smart home IoT deployment has had some early success with early adopters, but has yet to cross the divide into the early majority and mass market.

Matter brings several key advantages to manufacturers and ecosystem providers:

- Brand adoption - used by tech giants and major OEM product manufacturers, supported by a number of silicon vendors and technology service providers
- Consumer 'frustration free setup' using QR code / BLE to join devices
- Consumer has choice of which app / smart assistant they want to use
- Data stays in the home (for the most part) - reducing cloud OPEX and maintenance costs for manufacturers and partner service providers, and helping with Data privacy.
- Open source & royalty free
- Strong certification requirements through Approved Test Labs (ATLs) to help ensure products are interoperable
- Supports existing Wi-Fi, Ethernet or Thread as a link-layer

- Legacy devices can be 'bridged' from their existing control protocol to support Matter via a standard data model
- Any device type can potentially support Energy Management
- ESA manufacturers can avoid the need to develop their own cloud infrastructure for the purposes of meeting ESA regulations and providing flexibility services
- ESA manufacturers can help their customers save money on energy bills and reduce their carbon footprint

3.1.2. Matter Devices Types and Capabilities

As of Matter 1.4 (November 2024), there are a large number of certifiable device types, which may include one or more application specific 'clusters' to allow a user via an app or controller to interact with the device using a standard data model.

For example, the EVSE cluster allows the user to set their charging preferences (allowing the EV charger to determine the best charging schedule), as well as describing the basic state of the system including any errors. It also allows the charging rate to be adjusted.

Similarly the Water Heater device re-uses the existing Thermostat cluster (used to set the temperature set point as well as schedules) but includes extra capabilities to report the percentage of hot water in the tank, and allows the normal schedule to be boosted.

By combining clusters together, manufacturers can make their products behave and report their data in a standardized manner.

There are also several basic functions that all Matter devices MUST implement in the base device features, such as providing basic information, access control, secure commissioning & decommissioning, general and network diagnostics as well as over-the-air updates (OTA) functions.

From an energy management perspective, devices can use the Electrical Power and Electrical Energy Measurement (EPM and EEM) clusters to report their actual power and energy consumption or production. The Device Energy Management (DEM) cluster allows devices to both advertise their energy forecast and flexibility capabilities and be adjusted in terms of power and time.

Table 1. Table of Device Types in Matter 1.4

Section	Device type
Lighting	On/Off Light
	Dimmable Light
	Color Temperature Light
	Extended Color Light

Section	Device type
Smart Plugs/Outlets and Other Actuators	On/Off Plug-in Unit
	Dimmable Plug-in Unit
	Mounted On/Off Control
	Mounted Dimmable Load Control
	Pump
	Water Valve
Switches and Controls	On/Off Switch
	Dimmer Switch
	Color Dimmer Switch
	Control Bridge
	Pump Controller
	Generic Switch
Sensors	Contact Sensor
	Light Sensor
	Occupancy Sensor
	Temperature Sensor
	Pressure Sensor
	Flow Sensor
	Humidity Sensor
	On/Off Sensor
	Smoke CO Alarm
	Air Quality Sensor
	Water Freeze Detector
	Water Leak Detector
	Rain Sensor
Closures	Door Lock
	Door Lock Controller
	Window Covering
	Window Covering Controller
HVAC	Thermostat
	Fan
	Air Purifier

Section	Device type
Media	Basic Video Player
	Casting Video Player
	Speaker
	Content App
	Casting Video Client
	Video Remote Control
Robotic Devices	Robotic Vacuum Cleaner
Energy Management	EVSE (EV charger)
	Water Heater
	Solar Power
	Battery Storage
	Heat Pump
Appliances	Refrigerator
	Temperature Controlled Cabinet
	Room Air Conditioner
	Laundry Washer
	Dishwasher
	Laundry Dryer
	Cook Surface
	Cooktop
	Oven
	Extractor Hood
	Microwave Oven
Network Infrastructure Devices	Network Infrastructure Manager
	Thread Border Router

3.1.3. General Matter concepts

More information on Matter can be found in the Matter Handbook.

3.1.3.1. Networking & Discovery

Matter makes use of IP networks, and uses TCP and UDP to communicate to devices.

Matter supports:

- Wi-Fi - A well known in-home high bandwidth WLAN technology

- Thread - Using a narrow-band IEEE 802.15.4 radio layer (2.4GHz) it is optimized for low-power sleepy devices and can use mesh networking to provide greater coverage range and long battery life
- Ethernet

In the case of Thread, an OpenThread Border Router (OTBR) is required to allow Thread devices to communicate with Wi-Fi and Ethernet connected devices. An OTBR is typically embedded into a Hub, Smart TV, Set-top box, Home router etc.

Matter uses mDNS discovery to discover other Matter compatible devices and find the IP address to establish peer to peer communication.

The use of mDNS means that devices are ONLY able to have a peer-to-peer connection within the home. The fact the devices communicate directly, helps to reduce the need for home-to-cloud connections, reducing the cloud hosting costs, improving reliability and helping to improve data privacy.

An in-home Hub which is cloud connected enables connectivity to an ecosystem provider's cloud which in turn can allow out-of-home control (for example, via a mobile phone app) when you are away.

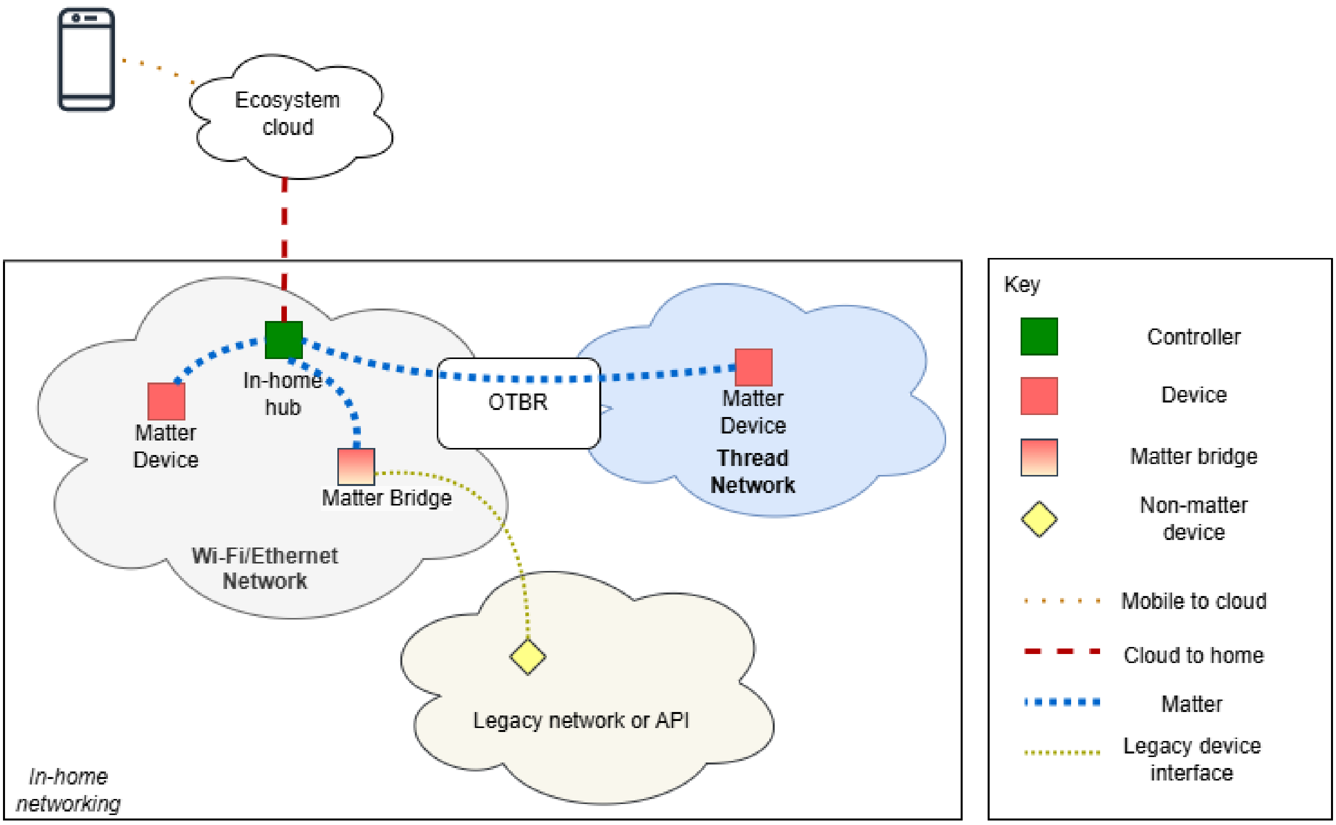

Figure 1. Networking

> This figure shows how a Wi-Fi/Ethernet network can allow Matter devices to communicate locally within the home. Matter also supports low-power mesh networking Thread radio devices, and Matter devices on the Wi-Fi/Ethernet network can communicate via an OpenThread Border Router (OTBR) to Matter devices on the Thread network via IPv6.
>
> Matter controllers can also communicate with legacy devices using a Matter bridge (see

Bridging to existing devices).

Note that outside the scope of Matter, a mobile app outside the home can communicate via an Ecosystem cloud to an in-home hub, which in turn then translates these requirements into Matter commands and interactions with other Matter devices.

3.1.3.2. Bridging to existing devices

Matter can support users who have already invested in products, by offering the concept of 'bridging'. So-called 'bridges' provide a standardized Matter interface to Matter controllers and the bridge can translate the Matter messages into the communication protocol used by the legacy product (for example Zigbee, via cloud REST APIs, or other proprietary interfaces).

3.1.3.3. Commissioning, ACL and Device Binding

Matter devices securely communicate over a local in-home network (Wi-Fi, Thread or Ethernet). They can be commissioned and securely provided with the Wi-Fi or Thread network credentials and given a 'Fabric' certificate by a commissioner (typically using BLE).

The commissioner can then setup ACL (Access Control Lists) which allows a device to know if it should accept a command or request from another device.

The commissioner can also bind devices together - for example a light switch device can directly communicate to a smart light bulb (if the light switch has been configured with the information about the device it should control).

3.1.3.4. Fabrics & Nodes

Matter devices can securely communicate with other Matter devices which are in the same 'root of trust' - this is called a 'Fabric'. The commissioner provides each device in the Fabric with a 'Node Operational Certificate' (NOC) which is signed by the Fabric Root CA certificate (RCAC) (or Intermediate Root CA certificate - ICAC).

When devices communicate they check that the NOC of the other device is signed by an RCAC in its list of trusted Fabrics, if it is valid then they can communicate.

NOTE Matter allows devices to belong to multiple Fabrics simultaneously allowing different ecosystems to observe and control the same device at the same time. This allows users a choice of how they interact with the devices by using their different preferred ecosystems at that point of time.

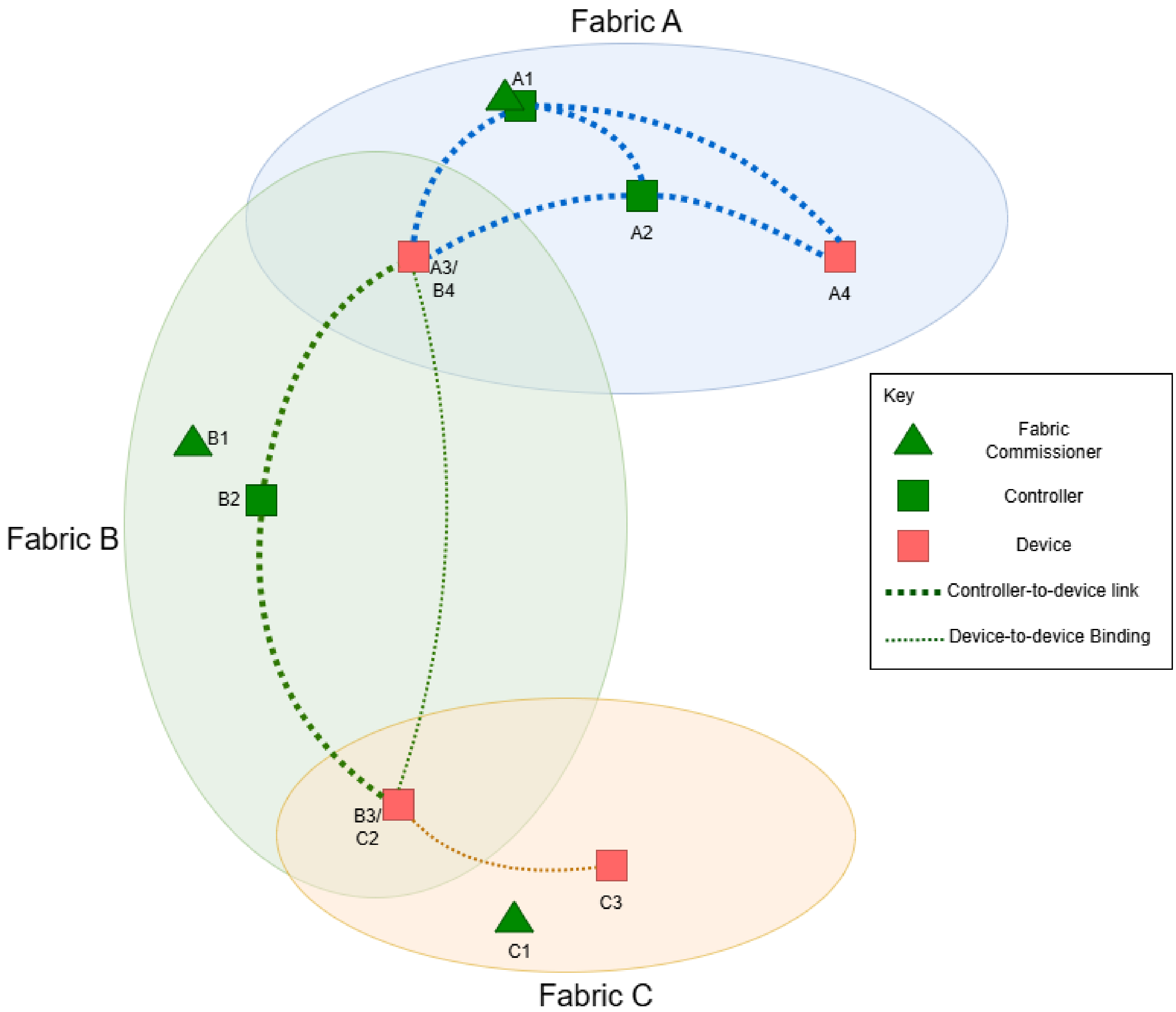

Figure 2. Matter Fabrics, Commissioners, Controllers and Devices

This figure shows 3 Fabrics (A, B, C).

There are multiple 'Nodes' in each Fabric with the notation '<Fabric><Node ID>' (for example 'A1' refers to Node ID:1 in Fabric:A). In practice the Node ID and Fabric ID are stored as uint64 types, but for illustration we have shown the Fabric as a letter code.

Each Fabric has a Commissioner (A1, B1, C1) which when commissioning a new device onto the Fabric:

- Checks that the new device being added is from a trusted (Matter certified) supplier
- Joins the device to Wi-Fi or Thread network (if not already on the network)
- Allocates a new unique Node ID
- Signs the new NOC with the Fabric RCAC or ICAC
- Provides the signed NOC and the RCAC to the new device
- Sets up the device (including its Access Control Lists - ACLs) which allow other devices in the Fabric to interact with it.

- Enables device-to-device binding if required

Fabric A’s Node A1 is a commissioner and a controller, whereas in Fabric B the commissioner (B1) and controller (B2) are separate Nodes. In Fabric C there is a commissioner (C1), but no controller. In practice most Fabrics would always have a basic controller (for example embedded into a mobile app and coupled with the commissioning logic).

Fabric A also has a second controller (A2), and two simpler devices (A3 and A4).

Multi-Admin: Note that device A3 is also commissioned in Fabric B and also has a designation B4. This means that any changes to its state can be observed in both Fabric A and B and if the appropriate ACLs were set up, then A1, A2 & B2 could interact with this single device.

Fabric B has a separate controller (B2) and two simple devices (B4 & B3). In this Fabric a binding has been set up by the commissioner B1 to allow B3 and B4 to communicate directly. For example B3 may be a light switch, and B4 a smart light and can communicate directly without needing a controller involved.

Similarly in Fabric C, there is a commissioner C1 and two devices C2 & C3 which are set up with device binding. This fabric may not need a controller for very simple use-cases and is shown here to illustrate multiple fabrics and simple devices communicating directly.

Adding devices to a 2nd Fabric: In Matter it is necessary to use the initial Fabric to ask the device to 'Open a commissioning Window' to allow the 2nd Fabric’s commissioner to securely connect to the device. Since the device is already on the Wi-Fi, Ethernet or Thread network, this can happen without using BLE.

Devices are addressed as a Node within a Fabric, and each device is allocated a unique Node ID. The Node ID and Fabric are used to look-up the IP address using mDNS when the devices wish to communicate and these data elements are included in the subject field in the NOC.

3.1.3.5. Decommissioning

A device can be decommissioned from a Fabric which essentially removes its NOC and trusted root CA certificate, using a secure command from an authorized controller. This results in the device no longer being part of the fabric and being unable to trust other devices on the fabric (and other devices will no longer trust it).

This can also be achieved if a device is factory reset manually by the user and as a result it loses its stored NOCs.

Note that the peer devices may not be directly informed that this device has been de-commissioned, but when they try to contact the device using mDNS discovery to lookup the previously commissioned device on the fabric they will not be able to resolve its IP address and will eventually realize that it has lost connectivity.

`Decommissioning` is therefore a term used within Matter to remove the device from the Matter fabric.

3.1.3.6. Nodes, Endpoints and Clusters

A Device (or Node) is made up with multiple addressable Endpoints. A special 'Root node Endpoint' (0) is mandatory on all Matter devices, and must contain the basic clusters needed to understand what the device is, its properties, and how to commission and set up the device in the first place.

A Cluster is a data model grouping which allows a client to interact with the device via a data model. Clusters contain Attributes (which can be of any common type: boolean, integer, string, list, structs, lists of structs etc.), which can be read-only or writable. ACL permissions can be granted by the commissioner to specific Attributes on a case-by-case basis. Clusters also define supported commands that can be invoked against a specific cluster type. Clusters also allow specific Event types to be logged.

A Cluster type can only appear ONCE on a single Endpoint to ensure the commands are addressed to the correct part of the device. It is common that a device may have multiple endpoints. For example, a lighting device could have two lights, implemented using the OnOff cluster on Endpoints 1 and 2. The 'On' command to Endpoint 1 may control the downstairs light, whereas Endpoint 2 may control the upstairs light.

3.1.3.7. Controllers, Cluster Clients and Servers

Devices (or Nodes) act as Cluster Servers. These Cluster Servers allow a Cluster Client to:

- interact with data Attributes held in the Cluster Server
- receive Events from the Cluster Server
- invoke Commands on the Cluster Server.

A controller is any device which is able to act as a Cluster Client and has permissions to interact with another Node’s Cluster Server(s). An EMS in the context of this document is just a Matter controller.

3.1.3.8. Subscriptions

One feature of Matter is the ability to use subscriptions. These allow a client device to subscribe to Attributes or Events on a specific Node, Endpoint, Cluster and receive automatic updates when the Attribute or Event is updated by the device. The subscription parameters also allow a minimum and maximum update rate (in seconds) to be specified. This allows a client to throttle how many updates are transmitted by the Cluster Server, whilst ensuring that data is always sent every so often. For example, an EMS may want to get periodic power readings from a device at most every 3s, and at least every 60s.

This helps to ensure that the client does not need to implement polling to re-read the attribute over and over again, which helps to reduce in-home network traffic.

3.1.3.9. Certifiable Application Device Types

Device types in the Matter specification dictate which clusters MUST be included and which are optionally included. These rules can be found in the [Matter] device type library specification. This allows a client (controller or commissioner or other device) to make assumptions about the device and how to interrogate its capabilities and then interact with it.

There are a limited set of recognized device types that can be certified as Matter devices. Each new release of Matter may add new device types, but the non-exhaustive list included here are likely to be used in energy management applications due to their relatively high power consumption and ability to be flexible, and indicates for which the Device Energy Management (DEM) capability is mandatory (leaving it optional in the others).

Table 2. Table of Device Types suitable for energy management in Matter 1.4

Section	Device type	DEM Required
HVAC	Thermostat	
Energy Management	EVSE (EV charger)	Yes
	Water Heater	
	Solar Power	
	Battery Storage	Yes
	Heat Pump	Yes
Appliances	Refrigerator	
	Room Air Conditioner	
	Laundry Washer	
	Dishwasher	
	Laundry Dryer	
	Cook Surface	
	Cooktop	
	Oven	
	Microwave Oven	

Note that there are also lighting, smart plug, and pump device types that could potentially be used in energy management use-cases, however these should be carefully considered with respect to safety and applicability in a DSR market.

For example a smart plug 'On/Off plug-in unit' does not know what is plugged into it, nor can it forecast how the device will behave and what its future energy requirements are.

3.1.3.10. Utility Device Types

A utility device type defines a useful common set of functions which can be embedded into any device. For example the `Electrical Sensor` utility device type mandates that the Electrical Sensor Endpoint in the device MUST include the `Power Topology` cluster and MUST include at least one (or both) of the `Electrical Power Measurement (EPM)` or `Electrical Energy Measurement (EEM)` clusters.

The Electrical Sensor utility device type MAY then be replicated into the Laundry Dryer devices which enables users to understand how much instantaneous power is being drawn by the Laundry Dryer, and how much energy over time it is consuming.

Another Utility Device type is the Device Energy Management device type (see Device Energy Management (DEM)). Since it is a utility device type it can be embedded into any Matter certifiable device. Note that some application device types mandate that the DEM is always included (see Table of Device Types suitable for energy management in Matter 1.4 above).

3.1.4. Device Energy Management (DEM)

Matter 1.4 introduced Device Energy Management (DEM) which allows potentially any current or future device type to inherit the capabilities to be controlled by using basic primitives of power, time and energy. This means that it is relatively easy to make a normal smart home appliance an Energy Smart Appliance (ESA).

There are certain basic requirements for using the DEM utility device type within a product.

In particular there are 2 clusters that should be implemented:

- `Device Energy Management cluster` - this is the main control logic to be embedded into the ESA. The cluster supports several optional Features which manufacturers can choose to implement in the device. It allows the EMS to determine how best to control the device.
- `Device Energy Management Mode cluster` - this allows users to select an Opt-Out mode on the ESA. This allows different levels of optimization: device only optimization (using Time of Use pricing), coordination within the home (using local solar generation or using a Battery Storage device) and for supporting grid-side control use-cases.

3.1.4.1. DEM Features

The `[Matter]` Device Energy Management (DEM) Cluster supports the following features as summarized in the table below.

Feature	Meaning	Explanation
PA	Power Adjustment	The device can have its power usage directly controlled by the EMS.
PFR	Power Forecast Reporting	The device can supply a forecast of its current intended power usage over time (a.k.a "power profile").
SFR	State Forecast Reporting	The device can supply a forecast of its likely state over time, but cannot accurately predict is power usage. This is typically used for thermostats which do know the state they are asking the HVAC system to be in (for example Heating), but do not know if they are controlling a gas or oil powered furnace, or an electrically powered device.
STA	Start Time Adjustment	The device can move its whole forecast power profile to start at a later or earlier time.
PAU	Pausable	The device can pause some of all of its forecast power profile for a period.
FA	Forecast Adjustment	The device can accept commands to change the power and/or duration of its forecast power profile over time.

Feature	Meaning	Explanation
CON	Constraint-based adjustment	The device can optimize itself to create a new forecast power profile as a result of receiving data about grid events or local in-home energy constraints. The data sent to the device includes a series of desired power settings with time intervals.

3.1.4.2. Forecasts

Forecasts are a fundamental part of DEM, and allow a device (even if it cannot be adjusted) to help an EMS understand the future power requirements that the appliances in the home are likely to need over the next few hours.

These allow the EMS to either work around the individual ESA's requirements (potentially by flexing other ESAs) to help manage peak load in the home, and use available local Solar or Battery Storage (or V2G if available).

Being able to forecast power use typically involves needing to understand the user preferences (for example how many miles of range they want to add to the EV by a set time, or their thermostat's heating or cooling schedule). White goods appliances typically follow a standard program and can also provide a time-based power profile and so can readily inform an EMS about their intended operation.

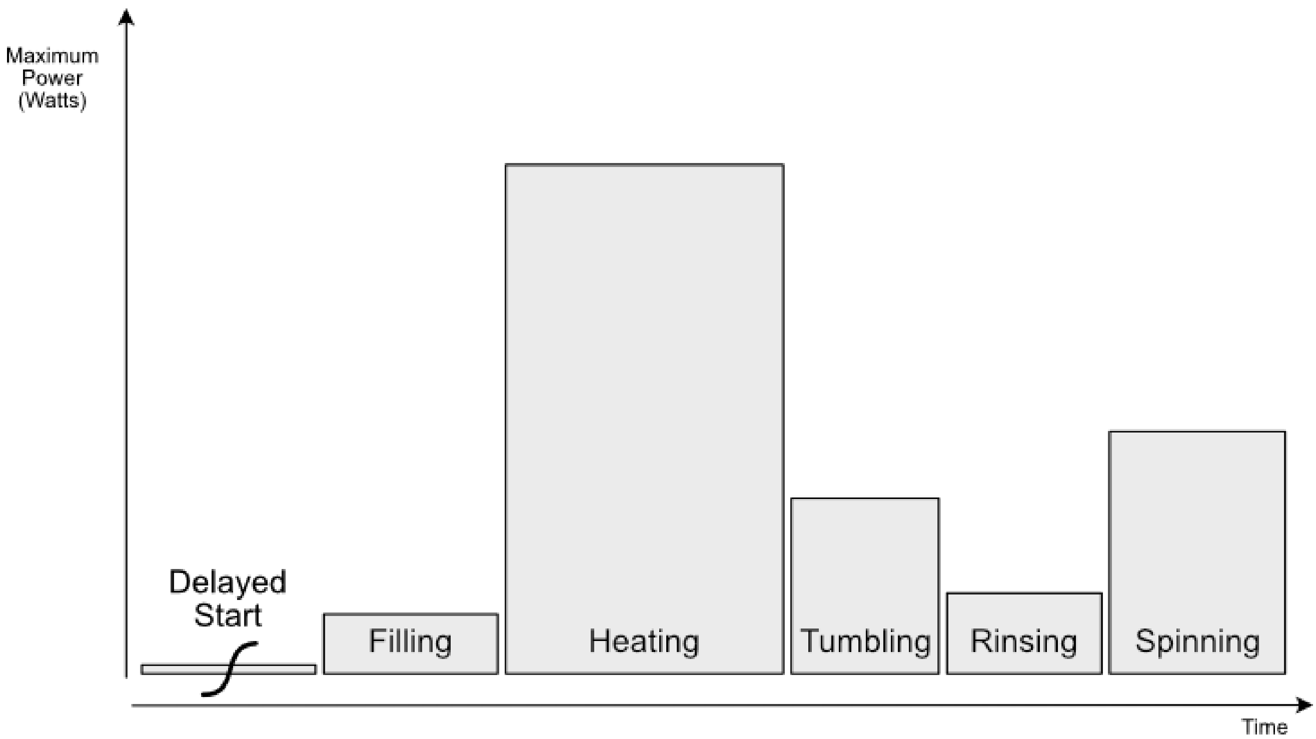

Figure 3. Forecasting power use over time with a washing machine as an example

The EarliestStartTime and LatestEndTime allow the ESA to indicate if its start time can be adjusted using the StartTimeAdjustment command.

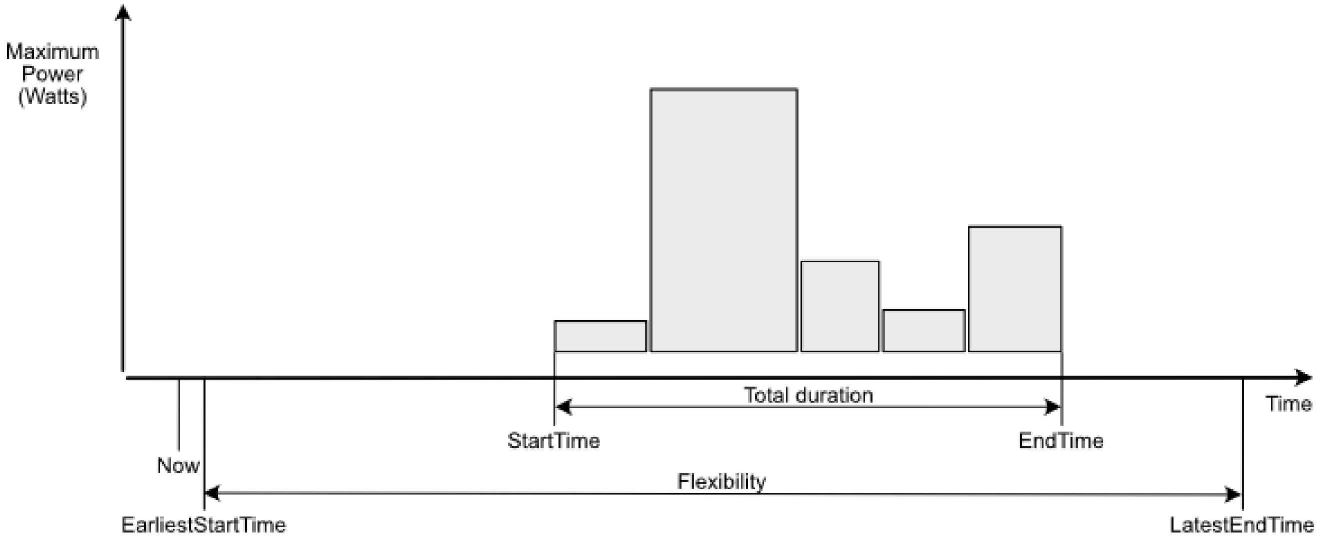

Figure 4. Example of Start Time Adjustment used to time-shift entire Forecast

The ForecastStruct type in Matter 1.4 includes data that allows a device to share:

- ForecastID - an incrementing ID that allows an EMS to track updates
- StartTime - the overall start time for the entire forecast
- EndTime - the overall end time for the entire forecast
- EarliestStartTime (STA) - the earliest time that the entire Forecast can be shifted to
- LatestEndTime (STA) - the latest time that the entire Forecast can be shifted to
- IsPausable - Can any part of the forecast be paused
- ActiveSlotNumber - which slot in the forecast is currently active
- List of up to 10 Slots each containing:
  - MinDuration
  - MaxDuration
  - DefaultDuration
  - ElapsedSlotTime
  - RemainingSlotTime (PAU)
  - SlotIsPausable (PAU)
  - MaxPauseDuration (PAU)
  - ManufacturerESAState (SFR)
  - NominalPower (PFR)
  - MinPower (PFR)
  - MaxPower (PFR)
  - NominalEnergy (PFR)
  - Costs (O)
  - MinPowerAdjustment (FA & PFR)

- MaxPowerAdjustment (FA & PFR)
- MinDurationAdjustment (FA)
- MaxDurationAdjustment (FA)

> The feature name in brackets, for example (PAU), indicates the Pausable feature and denotes if the data field is required when that feature is supported by the ESA.

3.1.4.3. ESA Types

There are many types of ESA now available, with more being developed over time. This section describes the main types of ESA considered for this interworking specification, and provides a basic characterization of them in terms of how predictable and controllable they are.

Electric Vehicles

Electric Vehicle (EV) charging consumes a large amount of energy, and in order to do this quickly requires a high current drawn from the grid or local generation. The wall charger (sometimes called a wallbox) is an EVSE (Electric Vehicle Supply Equipment). The EVSE manages the EV charging current to ensure it is safe and within the limits of the supply.

The charging current (and therefore power) can be controlled, and scheduled to occur at different times of the day, which can help to manage the peak load on the local generation and the grid.

In Matter 1.4, a new Charging Preference feature (PREF) was added to the EVSE cluster, enabling the user to simply set the required range (energy) to be added to the vehicle by a set time. The EVSE can then compute its optimized charging power profile based on time of use tariffs and other factors (for example solar generation).

The EV charger in [Matter] is represented by the EVSE (Electric Vehicle Supply Equipment) device type. This device type is mandated to support the EVSE cluster and also the DEM cluster with the PFR feature.

Several of the other optional features are included in the table below.

Table 3. Table of recommended DEM features to be supported by EVSEs based on use-case

Use-case	DEM Features	Description
Solar charging	PA	Power adjustment (PA) allows the instantaneous charging rate to be adjusted based on fluctuations in solar generation, and can avoid importing power from the grid if a grid supply meter or current transformer (CT) clamp can measure the premises import / export power.

Use-case	DEM Features	Description
ToU scheduling	STA, FA / CON	The Start Time Adjustment (STA) can provide a simple mechanism to shift the power forecast. The Forecast Adjustment (FA) can provide a more complex adjustment of charging rates over time. Constraint based forecast adjustment (CON) can allow a series of constraints to enable the EVSE to compute a new Forecast working around any power limitations if it has the ability to perform this.
Grid triggered time shifting	PA, STA, FA / CON	This is similar to the ToU scheduling use-case but instead of the optimized schedule being based only on a baseline energy tariff, the utility can overlay a stronger incentive for the device to shift when it charges.
Grid peak load limitation	PA, STA, FA / CON	Here the EMS may dynamically adjust the EV charging rate using PA to avoid peak load exceeding a pre-set limit. Alternatively the EMS may defer the charging session to later using STA, FA / CON.
Vehicle-to-X (V2X)	PA*	*In order to implement V2X in Matter, the dynamic discharging power which adapts to the home load or grid requested power makes use of the Power Adjustment (PA) commands. It is mandatory for EVSEs supporting V2X feature to implement PA.

Heat Pumps

Heat Pumps operate much like air-conditioners working in reverse and use a gas refrigerant and a compressor to extract the ambient heat in the surrounding air or ground. This means that unlike a direct electric resistive heating element where all of the electrical energy is converted into heat, only the electricity used to power the compressor is consumed. The use of the ambient heat means that the heat pump’s heat output can be 3-5 times the electrical energy used by the compressor, and is therefore much more efficient than direct electric heating and fossil fuel based boilers.

Modern heat pumps use inverter driven compressor motors which allows the compressor speed to be modulated (typically in the range 20-100%), which also means that the heat output can be controlled to set the heating systems water flow temperature to an optimal setpoint. It is therefore possible to ask the heat pump control system to temporarily adjust the electrical power used by the compressor for a period without having too much impact on operational efficiency.

Most heating systems which use a heat pump also have a buffer tank which can store the heat in hot water and this water can be pumped around the heating circuit whilst the compressor is temporarily switched off. Similarly a buffer tank could be pre-heated at times when there is excess power on the grid to shift the electrical load from peak periods.

Heat pumps can be used to heat spaces via underfloor heating, radiators or direct to air, but are also used to heat hot water for showers and baths.

The Heat Pump in [Matter] is represented by the Heat Pump device type. This device type is mandated to support the DEM PA feature, will typically support the DEM PFR feature, and may support the STA, PAU, FA and/or CON features too.

Water Heaters

In [Matter] the Water Heater device type can optionally include the DEM cluster (since some water heaters will be heated by a gas or oil fired boiler). Where they use an electrically powered immersion heating element(s), then they should use DEM to make them ESAs and controllable.

Some hot water heaters can be heated by a heat pump (as a stand-alone) system that is not involved in heating spaces and in this scenario would use the Water Heater device type (not the Heat pump device type).

The Water Heater device optionally supports the DEM device type, and if it does, is mandated to support its PFR feature.

Direct Electrical Heaters

Direct Electrical Heaters, such as room storage heaters, air space heaters, convert electric power directly to heat using a resistive element. The power taken is typically either on or off, or has a few power settings (by including multiple switched heating elements).

In the case of storage heaters, they are typically feeding energy into a large thermal mass, so are typically turned on at times of cheapest electricity (e.g. overnight), and may be switched off or to a lower power setting at times of high cost or demand.

Matter 1.4 does not have a specific device type for storage heaters, or direct electric heating, but does include Thermostat device type and On/Off device types which could potentially be used.

Direct Electrical Heaters may not support DEM, but may typically support the DEM PFR and STA features when coupled with their own control system, and optionally (for at least on/off control) the PAU, FA and/or CON features, or may just be controlled by a more general home EMS.

Solar PV Arrays

Solar PV Arrays convert the solar energy into electrical energy, using an inverter to feed the energy into the premises electrical wiring. The amount of electrical power they produce may be forecast on average from knowledge of the weather, historical readings or by knowing the orientation and capacity of the array. The actual level of cloud or other shading may vary the power produced significantly in the short term in manner that cannot be forecast accurately.

In some markets where there is a potential for too much generation and not enough demand (for example Australia and California), the solar inverter may need to be curtailed to reduce the amount of power that it feeds into the home electrical wiring (and any excess that then feeds out to the grid).

The Solar PV Arrays in [Matter] are represented by the Solar Power Device Type. This device type optionally supports the DEM device type, and if it does, is mandated to support its PA feature, and may support the PFR feature too.

Battery Storage

Battery Storage devices typically allow a range of power values to charge or discharging the batteries. This is often a signed number in Watts where negative values indicate a discharging power, and a positive value for charging the batteries. The battery inverter will have maximum charging and discharging power limits which can be impacted by the temperature of the battery cells and inverter electronics.

Since the inverter is not 100% efficient, energy is lost through heat when charging or discharging the battery, so optimal use of the battery storage system needs to be carefully managed. For example it may be more efficient to charge a battery at a lower power which will take more time.

Battery Storage is often coupled with Solar PV so that excess solar in the home is used to charge the battery automatically at the exact power level so as not to accidentally import power from the grid. Due to fluctuations in solar production as clouds move over the solar panels, this power needs to be adjusted dynamically.

Batteries can discharge to the home, but if the home appliances are not consuming all of the power, then this power can be exported to the grid, which allows home batteries to act as a 'Virtual Power Plant (VPP)' during grid events. In periods of excess renewable generation on the grid, they can also be charged with the power that would otherwise go to waste.

The Battery Storage in `[Matter]` is represented by the Battery Storage device type. This device type is mandated to support the DEM PA feature. Due to the dynamic nature of power adjustments on a home battery, whilst it could generate a forecast (PFR and FA/CON) for controlling charging periods (like an EVSE), it may simply be controlled directly by an EMS and rely on the EMS to schedule its charging and discharging using PA as a direct control capability.

White Goods

Whilst white Goods typically consume less energy than the other ESAs considered above, they can in some instances (for example heating water or drying stages) switch on a ~2kW heating element. When several appliances such as an oven, induction hob, microwave, washing machine and dishwasher are all active at the same time, these loads add up to a significant total.

It is unlikely that a user will accept that their oven and microwave can be paused, however these appliances may be able to indicate to the EMS that they are switched on and in some instances how much longer they need to be on for using the DEM PFR feature, or may simply report their instantaneous power via the Electrical Power Measurement cluster. This can allow an EMS to plan around these white good appliances and coordinate other more flexible ESAs (such as a heat pump temporarily reducing its power) to limit peak load.

Some white goods, such as dishwashers and washing machines and refrigeration appliances can also support delayed start operations, or be paused temporarily during their operation without significantly impacting the performance of the appliance. These devices are likely to support the DEM STA, PAU, PFR, FA/CON features.

These features can allow an EMS to schedule the best time for the devices to operate, for example to take advantage of Time of Use tariffs, or understanding when the solar PV production is at its peak.

3.1.5. Matter Pricing

Future releases of Matter may include the ability for a ToU tariff, or GHG to be shared with an ESA so that it can optimize its own operation. This could also allow the ESA to indicate to the user how much they have saved by shifting their energy use, reinforcing positive benefits to the user for being flexible.

3.2. What is OpenADR?

OpenADR is an open standard that allows grid operators to communicate Demand Response (DR) actions in an 'Automated' way (hence the name OpenADR). It is an application layer protocol that is typically transported over a secure IP network.

A Utility or Distribution System Operator (DSO) can use the OpenADR protocol to enable its Distributed Energy Resources Management System (DERMS) to request control of 3rd party assets.

OpenADR has been widely deployed in industrial and commercial applications since 2011, and has been progressively updated since then. [OADR3] was first published in 2023, and brought the older OpenADR 2.0 version which used SOAP/XML up to date with more modern JSON based message formats.

It enables a DSRSP to communicate with a variety of Demand Response assets and importantly allows aggregation layers to be built up.

The two main actors in OpenADR are the Virtual Top Node (VTN) and the Virtual End Node (VEN). The VTN can send `Events` to VENs, and VENs respond with `Reports`.

The DSRSP has a Business Logic (BL) client that can trigger the issuing of Events and handling of incoming Reports via the VTN to the VEN. At the VEN side, Customer Logic (CL) can implement the necessary operations to comply with the requests of the VTN (and BL) to represent the flexible loads.

In [OADR3], the VTN uses RESTful HTTP APIs, using the Create, Read, Update, Delete (CRUD) methods to manage a Resource Server. The VEN and the BL in the VTN can both access these resources.

Note that a VEN at one layer can aggregate other layers of VENs beneath it, and in doing so is a VTN to those child VENs.

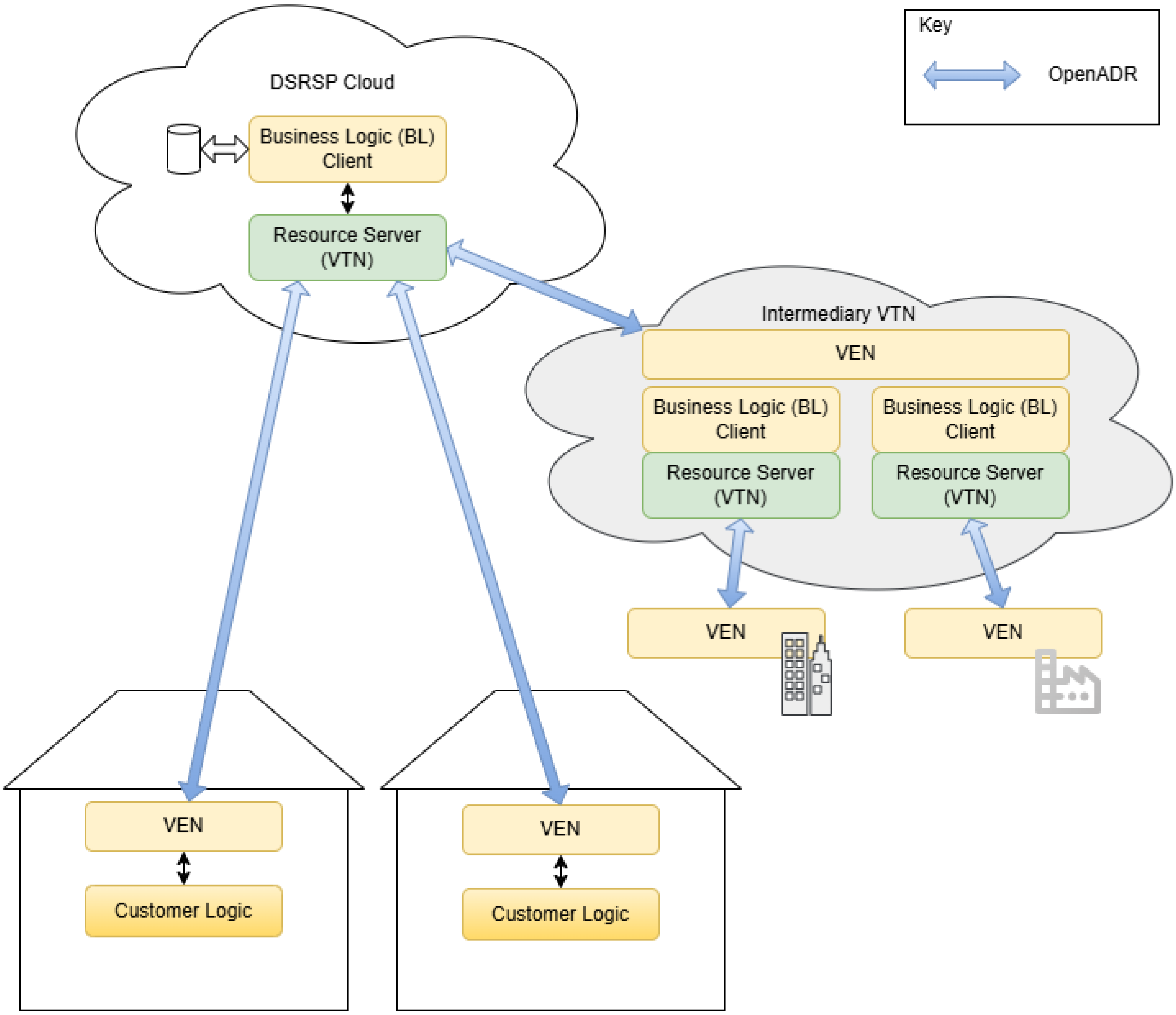

Figure 5. OpenADR Architecture showing VTN and VEN

The top VTN (in the DSRSP cloud) can directly handle multiple domestic property VENs, but can also have an Intermediary VTN which is a child VEN of the top VTN. This Intermediary VTN can have its own business logic to control its child VENs (for example commercial buildings or industrial use-cases). This demonstrates the principles of aggregation layers.

3.2.1. Events (VTN → VEN)

Events are sent by a VTN to the VENs to communicate some information (for example, Pricing, GHG, Grid Events). They are also used to configure the Reports that the BL wants the VEN to send.

3.2.2. Reports (VEN → VTN)

Reports are configured by the VTN to request information from the VEN, and specify what information is to be reported, at what interval the data should be sampled and how often the data is transmitted.

Reports can be used to send meter readings, usage forecasts, baseline data, flexibility information and a host of other information that the VEN can provide.

3.2.3. Subscriptions

When information changes at the VTN, the VEN can be notified about the change and therefore does not need to perform periodic polling of the VTN. In OpenADR 3.0 this uses a web-hook callback URL, however typically callback URLs do not work for devices behind a firewall, and would require a VPN tunnel to allow the VTN to call the VEN.

A future version of [OADR3] may add MQTT from the VTN as an alternative mechanism to allow devices to subscribe to MQTT topics and then receive notifications about changes, and this has been assumed in this document. This would permit the notifications to be delivered to an EMS which is located behind a home router with a firewall and NAT.

3.3. What is an Energy Management System?

3.3.1. Features of an EMS

It is difficult to define what an EMS is since it may embody many possible functions and features. Several different standards may refer to them as Building Management Systems which may control the HVAC and lighting (typically for larger offices, hotels and commercial buildings), or HEMS which may also perform similar functions but for homes. This specification deliberately does not try to define what an EMS is but it may be useful to outline some of the key features that an EMS may support.

Feature	Description	Requirement
ESA Control	The ability to control an ESA in some way to affect a change in use of power.	M
Price Optimization	The ability to use a ToU tariff to schedule operation of an ESA to reduce the cost of energy for the user.	M
GHG Optimization	The ability to use grid GHG forecast to schedule operation of an ESA to reduce the user's GHG carbon emissions.	O
User opt-out	The ability that allows a user to opt-in/opt-out of optimization grid level control, or at the home level via a UI.	M
Solar Optimization	The ability to understand the solar production forecast which may use historical data and weather forecast information, and understanding of net import/export at the meter point to schedule or dynamically adjust power of one or more ESAs.	O
Energy Forecast	The ability to connect to a DSRSP to share forecasted intended operation as a power profile to help the grid understand the likely future network load. This allows the DSO the ability to trade with lower pricing, resulting in network operational cost savings, that in turn can be passed onto users.	M

Feature	Description	Requirement
Grid Control	The ability to connect to a DSRSP to share forecasted intended operation as a power profile, and allow the DSRSP to influence a change in behavior based on incentive signals.	O
Peak load limitation	The ability to monitor and limit the peak load to the premises at times configured by the DSO via a DSRSP. This requires use of a DSRSP connection to set this constraint.	O
Energy Reduction	The ability to use smart home automation to automatically reduce the overall energy demands in the premises. For example, automatically controlling window shades to avoid overheating the home thereby reducing the future HVAC energy requirements.	O

3.3.2. Core components of an EMS

An EMS is likely to need to comprise of several key components:

Component	Description	Requirement
Secure Storage	The ability to store cryptographic keys and private user data and settings in a secure way, likely to be encrypted at rest.	M
Gateway functionality	The EMS is likely connected to a DSRSP and to multiple ESAs and potentially to a smart meter. If the EMS is a physical device in the home it may use a combination of wired or radio connections such as Wi-Fi, Ethernet, Thread, Zigbee.	M
Bridge functionality	The EMS may need to bridge to legacy protocols (for example Zigbee, Z-Wave), or physical layers (for example MODBUS) in order to be able to communicate with existing ESAs.	O
User Interface	The EMS is likely to need a user interface (for example a local display, cloud-based Web UI, mobile app etc.) to allow the user to: • join their EMS to a DSRSP • join their ESAs to the EMS • set up their preferences • opt-in/opt-out • check the system operational status • check connectivity to the ESAs and DSRSP for trouble-shooting • review historic operation • review cost and carbon savings made to date	M
Optimization engine	The EMS will need a system to compute the best outcomes so that it can schedule the operation of ESAs to meet the goals of the user and the DSRSP (grid).	M

Component	Description	Requirement
Remote Diagnostics	The EMS may need a mechanism to allow remote support by the EMS manufacturer.	O
Safe Operation	Whilst the EMS is not directly able to ensure safety of the ESAs it may be attempting to control, it may have an impact on the overall operation of the premise. It should attempt to ensure that there are no conflicting requests to its ESAs, and that if one or more of its ESAs have entered a failure state that it may need to adapt operation of other ESAs (for example to stay within the peak load limitation constraints of the premises). It should log any such action it has taken and notify the user to inform them about irregular or unexpected operation.	M

3.4. Matter & OpenADR - Standardized Interoperable Interfaces

3.4.1. Interoperability goals

A key design choice made by the developers of Matter's Energy Management features was to keep the details of the appliances state and application specific logic separate from the basic information about energy management.

In other words, whilst Matter includes many clusters and detailed data models for EVSE, heat pump, water heaters, thermostats with schedules etc, these make it complex to integrate into a simple energy optimization algorithm.

A simple optimization function needs only to deal in terms of **Power**, **Time** and **Energy**. The optimization function also needs a cost curve, which may be comprised of a ToU Tariff or GHG forecast, in order to minimize such costs.

The ESA only communicates its forecast and ability to be flexible, within its operating constraints and the user's preferences.

By keeping the data shared between the ESA, EMS and DSRSP to these base units, brings several benefits:

- a DSRSP does not need to understand the detailed needs of an individual ESA
- a DSRSP does not need to integrate to proprietary manufacturer APIs
- a DSRSP does not need be specialized in handling different optimization algorithms based on ESA type (for example EV charging, Heating, or Battery management). These can remain within the realm of the ESA manufacturer and removes the concerns raised by ESA manufacturers having to pick up the warranty cost of repairs caused by a 3rd party flexibility provider's actions.
- a DSRSP can control more types of ESA, creating a wider pool of ESAs to trade with
- ESA manufacturers can comply with a simpler Matter Device Energy Management (DEM)

cluster to implement their energy management features

- EMS manufacturers can easily aggregate and translate Matter DEM into OpenADR Flexibility Forecast Reports
- Data privacy is improved by not needing to share details of user preferences, schedules, and other ESA specific data
- Integration and testing regimes can be simplified, thereby accelerating market adoption

3.4.2. Scope of Matter vs OpenADR - EMS acts as translator

Matter deals with devices in the home, and is only designed to work on a local LAN, relying upon mDNS to discover the IPv6 addresses of the Nodes in the Fabric. An EMS can be considered a Matter controller, communicating with ESAs on the Fabric to be able to understand the ESAs Forecasts, and using the features in DEM to control or adjust their behavior to optimize cost, reduce carbon footprint whilst ensuring the user preferences are met.

The EMS is also an OpenADR VEN which allows the EMS to communicate with the grid (DSRSP) and implements the VEN customer logic to translate the OpenADR requests into Matter commands.

The EMS may also operate in a stand-alone mode without needing to be connected to the grid, in which case the VEN functionality is dormant.

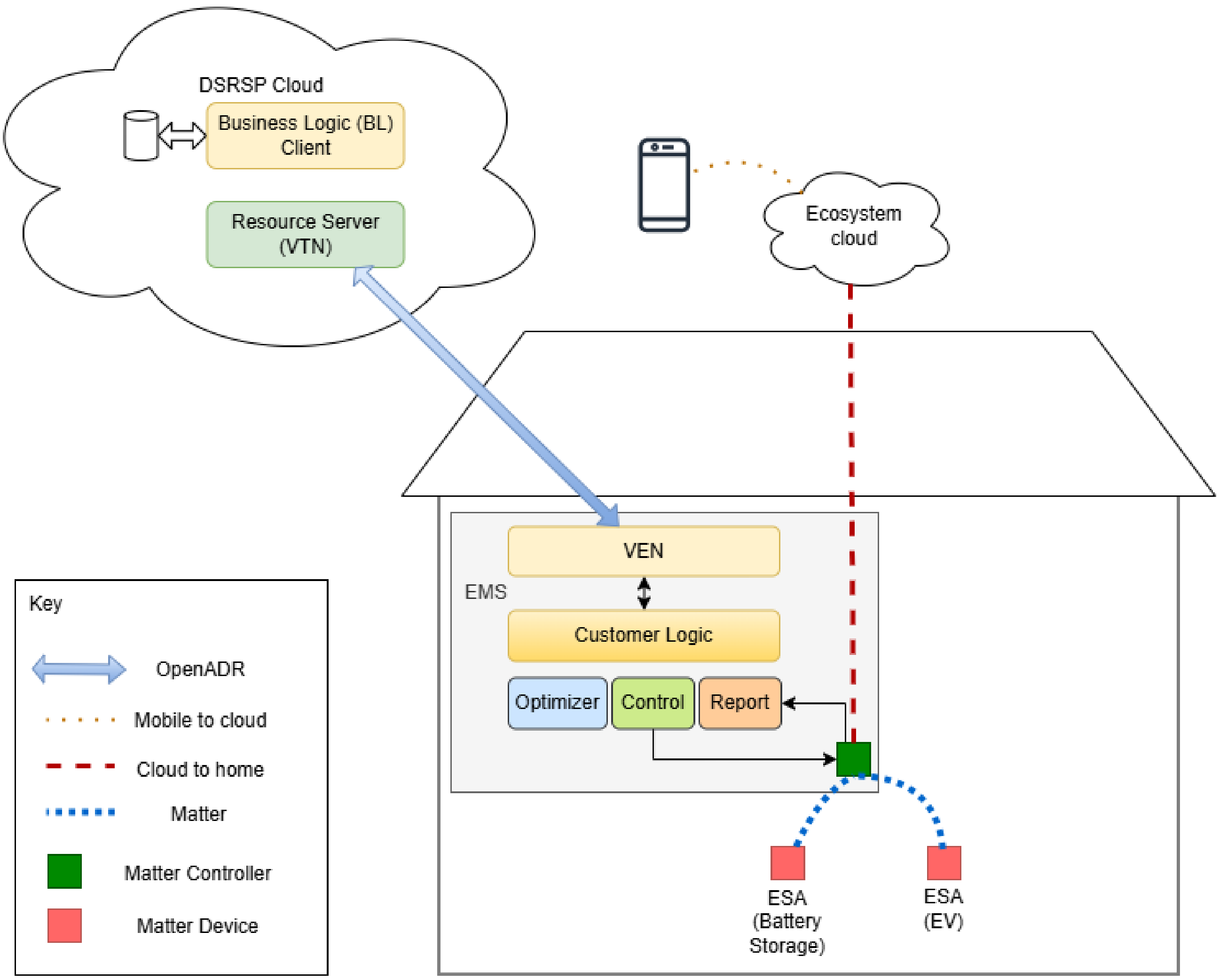

Figure 6. EMS communicates using Matter within the home and connects to the DSRSP using OpenADR

The OpenADR interface from the EMS to the DSRSP provides a standardized and interoperable interface for providing DSR capabilities, allowing the user to configure their EMS to connect to any compatible DSRSP.

The Ecosystem cloud interface (which allows an app out of home to interact with the appliances) is typically implemented as a proprietary interface and is therefore not interoperable with other Ecosystem clouds or Apps.

3.5. Alternative Architectures

There are many possible architectures and physical embodiments and locations for interactions between the various logical entities in a DSR system. In terms of their interactions between [OADR3] and [Matter], the simplest and most common architecture (see Single user EMS with multiple ESAs on premise) as well as other more complex architectures are discussed in the following sections.

3.5.1. Single user EMS with multiple ESAs on premise

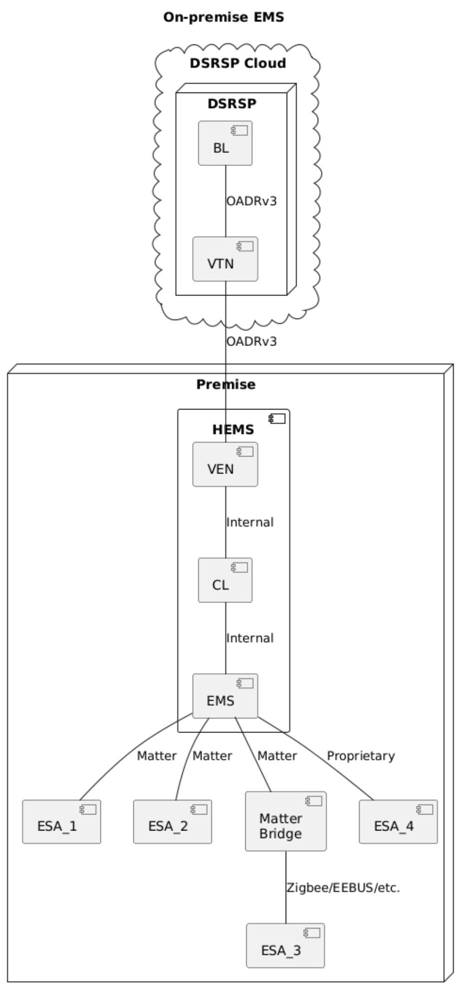

Figure 7. On-Premise EMS

In this architecture there is a single EMS in the user's premises, which acts as the EMS for a set of ESAs, which are served with electricity by a single DSRSP typically through a single electricity meter. The user has a service contract with the associated energy retailer's DSRSP.

The EMS is enrolled via its VEN and associated CL in one or more Programs (e.g. a particular Tariff Program and a particular DSR Program) with the VTN for the DSRSP with which it communicates using [OADR3]. The EMS interacts with a set of Matter Devices that comprise the user's Matter-capable ESAs. The EMS may also interact with other ESA which use other protocols, such as Zigbee or EEBUS, via a Matter Bridge device, or may interact directly with other ESA using other proprietary protocols, although the interaction with these ESA is outside the scope of this document, as the ESA do not support the Matter Energy management devices.

The ESAs which are managed by the EMS are all operated on behalf of the user who has the contract with the DSRSP.

The user may interact with the ESAs directly using their built-in UI, or using an ESA-specific controller, or by interacting with the EMS.

3.5.2. Cloud EMS supporting multiple users

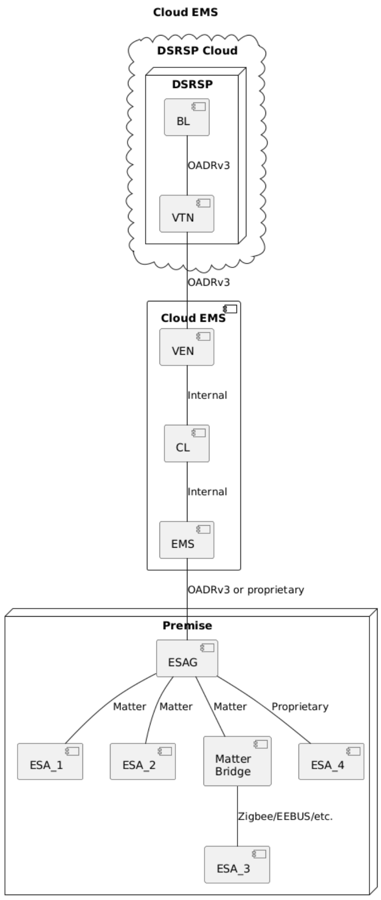

Figure 8. Cloud-based EMS

In this architecture there is a single logical EMS hosted in the cloud which represents multiple users to the DSRSP via a VEN and its associated CL, with each user having multiple ESAs on their premises, each controlled using [Matter] by a local on-premise ESA Gateway (ESAG) (a hub), which provides a gateway between the EMS in the cloud and the ESAs in the home.

The user may interact with the ESAs directly using the ESA's built-in UI, or using an ESA-specific controller (which may use Matter, or may use a proprietary control protocol for that ESA), or by interacting with the EMS in the cloud.

The EMS is managed by an intermediary service provider, which has a contract with each user, and has themselves a contract for flexibility services with the DSRSP. The cloud EMS service provider may have different contract types with its end-users.

The protocol used between the Cloud EMS and the DSRSP is the standardized [OADR3], and between the ESAG and the ESAs is [Matter], optionally via a Matter Bridge, or a proprietary protocol, identical to the standalone EMS architecture above. The protocol used between the Cloud EMS and the ESAG (hub) may be any suitable protocol which allows interworking between the [OADR3] and [Matter].

The most obviously suitable protocol for this is [OADR3], as it is already designed for such a hierarchical system, in which case the OpenADR to Matter interworking is identical to the basic scenario above (and the Cloud EMS DSRSP, as far as the end user is concerned, is the DSRSP).

Another alternative for this intermediary protocol is a proprietary protocol which effectively transports or tunnels Matter messages or their information content at least between the cloud EMS and the ESAG. In this case this architecture is technically out of scope of this document.

3.5.3. Hybrid Cloud and On-Premise EMS

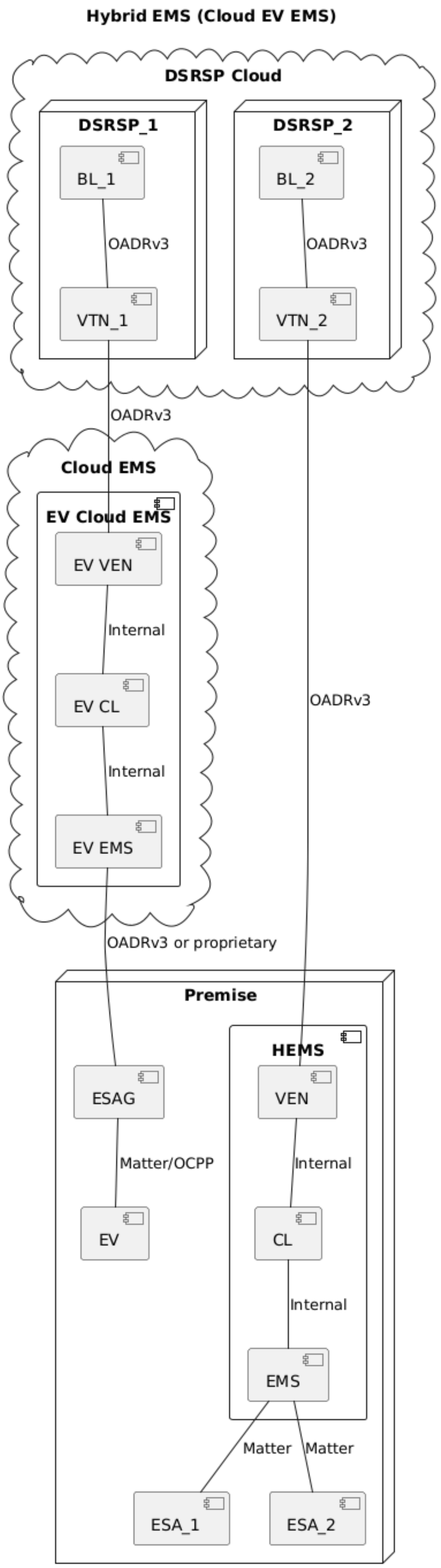

Figure 9. Hybrid Cloud and On-Premise EMS

In this architecture there is a Cloud EMS which provides a specific service to a specific subset of ESAs for a set of users. For example, an EV charging provider may be contracted to manage the EV charging for a set of users, including billing the users. The EV use (and supply if they support V2X) is therefore controlled by this EV DSRSP, using either Matter or other common protocols to the EVSE, such as OCPP. All the other ESAs in the home are controlled by an on-premise EMS as for the basic scenario above, which may be served by the same DSRSP as the cloud EMS, or a different DSRSP.

This architecture becomes essentially the same as the Cloud EMS described above for the EV ESAs, and so has the same limitations of scope described above.

It has a further complication that if the supply to the premises goes through a single meter (of the same or different DSRSP) which cannot distinguish the EV usage from the general usage, the tariffs under which the EV and general consumption is provided must be the same, or any difference must be taken on trust of the EV DSRSP and the measurements from the EVSE, which is unlikely to be acceptable for the DSRSP(s).

If the EV and other usage is metered separately (or uses an accurate sub-meter), this scenario becomes effectively two separate premises, one supplying just the EV (using the cloud architecture above), and one supplying the rest of the electricity (using the basic home scenario above).

3.5.4. Resource Aggregation

The [OADR3] may be used with zero, one, or more Resources contained within the VEN object, each representing a producer or consumer of energy. This allows for different policies regarding how much visibility and control the DSRSP has of the different ESAs under the control of the EMS. These policies may be invoked by national regulation, commercial agreement between DSRSP and user, or private choice by the user within the scope of the commercial agreement with the DSRSP. The main likely policy scenarios are:

1. **Zero Resources**: The DSRSP has no visibility or control of the various ESA that the user has connected in the premises. The EMS has full control of the ESA, and interacts with the DSRSP only at the level of all the devices aggregated into a single Resource in its Reports, giving total forecast or actual energy usage, and the DSRSP only targets the VEN as a whole for its Events. The EMS manages the energy usage of the individual ESA to meet the targets and report the overall usage to the DSRSP. This provides the user with the most privacy, but the DSRSP with the least information and control of user ESA, preferences and behavior.
2. **Per-ESA Resources**: the DSRSP has full visibility and (optionally) control of the ESAs independently, receiving forecasts and readings of the individual ESA energy use, and the ability to target Events at specific ESAs or ESA types to allow different reporting or request different DSR behavior for the different ESAs.
3. **Separate Resources for specific ESAs**: the DSRSP has visibility of one or a few ESA types (e.g. EVs, Battery Storage) which it can target Events at, and thus get separate visibility of energy forecast and actual use, with all remaining ESAs being only visible to and controlled by the EMS. There are also aggregated Reports to provide information about the energy consumption of the other ESAs which do not have separate Resource objects visible to the DSRSP.

3.6. Consideration of multiple controllers

3.6.1. Multiple EMSs in the same home

It is inevitable that there will be some homes where one ESA is controlled by one EMS, and a second ESA may be controlled by another EMS. This is likely to happen for a variety of reasons:

- EMS capability (one EMS may include more advanced features than the other)
- EMS and ESA interoperability (bugs in an ESA or EMS may mean that a particular combination of EMS/ESA work well together whereas others do not)
- User choice (the customer may prefer the user interface of one EMS)
- Location and networking (the ESA may be connected to the same electrical wiring in the home, but the network coverage may not allow it to communicate with the EMS that is controlling the other ESAs in the home - for example the EV charger may be outside the home and unable to reach the Wi-Fi network).

The consequences of this may complicate whole home optimization (such as peak load management for the property). It potentially could cause oscillations where both EMSs may be observing the imported power at the smart meter, each one may observe a higher than permitted load so begins to turn off a load. A few seconds later the imported power level drops and so each one may determine that it is safe to switch the load back on again. This cycle could repeat indefinitely.

Suggested countermeasures to avoid this:

- User awareness - this can be done during the EMS setup process to ask them to check that they do not have an existing EMS in their home, and recommend to them that they do not deploy a 2nd EMS without first deactivating their first EMS. Explaining that it may damage their equipment and mean that they pay more for their energy should provide a strong motivation to avoid this.
- Detection of other EMSs on the network - this could be done using a discovery protocol, however the 2nd EMS may not be visible on the same home network. If another EMS is detected, then the EMS should warn the user and advise them to reconfigure their EMSs.
- Detection of power oscillations - this solution would require an algorithm in each EMS to detect that its actions to turn On / turn Off ESAs seem to be causing a greater than expected power change that is outside its control. It should enter a suitable failsafe state and warn the user as to why it has entered a failsafe degraded state after detecting power oscillations.
- Installation of additional sub-meter and grouping of ESAs based on wiring topology. This solution requires expertise and understanding from a trained installer. It would allow a child EMS to control the ESAs that are wired into a sub-panel and the power meter is measuring the net import / export at this point in the wiring. The child EMS only observes the power changes based on the ESAs under its control. Similarly the whole home EMS would treat the child EMS as a load it cannot control, but sees the downstream impact of power adjustments. This technique is used today with Solar and Battery solutions (typically monitoring at the smart meter grid connection point), and a solar EV charger CT clamp can be added either upstream or downstream of the solar /battery monitoring. This allows the battery or EV charger to get

priority on any excess solar depending on where their respective meters are located in the home wiring. The speed of the control loops in each EMS will also play a part in potential oscillations.

3.6.2. Multiple EMSs controlling the same ESA

With Matter, it is possible that the same ESA is paired to multiple EMSs. These could be separate Matter fabrics, or on a common fabric. As of Matter 1.4 there is no means to prevent this, and indeed for similar reasons as above could be a desirable outcome in some circumstances (such as for allowing the user the convenience of how they choose to interact with their devices).

Since, by definition, Matter allows the ESA to communicate on the same network, there are fewer scenarios, and a greater ability to detect and avoid power oscillations:

- User awareness - when pairing to an ESA, the 2nd Matter commissioner can check if it is already paired to another fabric, and warn the user about potential unwanted side-effects. It may also offer the user the ability to set up a read-only view of the DEM cluster (using the ACL feature in Matter), but may still allow the 2nd controller the option to interact with the application specific cluster (for example changing their EV charging preferences).
- Detection of another controller’s DEM commands - it may be possible in future revisions of Matter to inform controller A that controller B has made a similar adjustment to the ESA, and for the ESA to detect and prioritize which controller it will take commands from.

3.6.3. Multiple DSRSPs controlling the same home

Similarly, there is nothing from a technical perspective to stop a user from signing their home up to connect to multiple DSRSPs. This is subject to local regulations and flexibility market rules.

In terms of OpenADR it is unlikely (and undesirable) that an EMS manufacturer would develop a product with multiple instances of the OpenADR protocol stack which could communicate with multiple DSRSPs simultaneously.

It may be possible that the user has decided to purchase a 2nd EMS to connect to a 2nd DSRSP. As described above, this could be because the ESA may not be able to join the same home network (for example an EV charger outside may use a cellular modem to gain a connection to a 2nd DSRSP).

As above, there is a potential that these two EMSs do not know about each other, other than the fact that they observe unexpected power oscillations.

From the perspective of the grid operator, they may see an unwanted outcome from allowing multiple DSRSPs per home, for example fraudulently using 2 devices: one Battery ESA is switched to discharge by the grid operator (and they are rewarded for doing so), and at the same time another Battery ESA can be switched to charge - resulting in no net power reduction on the grid.

These considerations require more industry review, which in turn may result in local market regulations that do not permit the use of multiple DSRSPs per premises.

3.6.4. Multiple DSRSPs controlling the same ESAs

If multiple DSRSPs per home is allowed, where each DSRSP is connected to a separate EMS, and the user had decided to register the same ESA to multiple EMSs, then the two DSRSPs may be trading the same flexibility to the same grid operator.

It is possible that this has unwanted side effects, for example:

- DSRSP #1 (via EMS #1) decides to shift the forecasted operation earlier - and the ESA is updated.
- DSRSP #2 (via EMS #2) is informed of a change in intended operation (since the forecasted operation has been modified by DSRSP#1 /EMS#1). It in turn decides to offer an incentive to shift the load to its desired trading position.
- DSRSP #1 (via EMS #1) is notified that its trading position has been superseded and it makes a counter offer.
- This process may continue indefinitely unless it can be detected.

The countermeasures to this are:

- to disallow multiple DSRSPs per home (by local market regulation)
- to build a oscillation detection algorithm into the DSRSP so that it can decide that there may be a 2nd DSRSP also controlling the same ESA. It may decide to temporarily blacklist the EMS and inform the user.

3.6.5. 3rd party control of an ESA not using Matter and OpenADR

It is possible that an ESA (for example an EV charger) is able to communicate via another protocol (such as OCPP) as well as Matter. This may mean that the EV charger could be communicating via Matter and OCPP simultaneously.

This scenario, albeit unlikely, could be left due to a configuration issue. The Matter product vendor should ideally ensure that this does not happen by design. The status of the EV charger however could still be represented in Matter via the EVSE cluster, and the power forecast (and if it were allowed to be adjusted) could be shared via the DEM cluster. This information is still useful to the DSRSP even if the ESA cannot be adjusted.

The 2nd control protocol is in effect acting as if the user is directly overriding the operation of the ESA. This results in the ESA opting out of DSRSP control for that period whilst the 2nd control protocol is active. In this case the power forecast in DEM can be updated, but the ability to be flexible (for example Power Adjustment and Forecast Adjustment) should be temporarily disabled.

Chapter 4. Use cases

The [OADR3] and [Matter] specifications both provide a wide range of capabilities which can support a wide variety of use cases and business models.

This document attempts to focus on a subset of use-cases which are applicable in a domestic or small business premises using the features available in Matter 1.4 energy management and the user-friendly set-up flow that Matter enables.

It does not focus on use-cases such as fleet EV charging, public-charging infrastructure, industrial and commercial scenarios since these are not typically directly in the scope of Matter or managed by users.

4.1. Use-case grouping

The tables below provide three broad groups of use-cases:

- EMS is not connected to the DSRSP and can operate in a stand-alone mode
- EMS is connected to DSRSP to enable flexibility service
- General requirements

Table 4. Stand-alone (DSRSP not required)

UC Group	Reference	Description
UC 1.x	**Stand-alone (DSRSP not required)**	
UC 1.1.x	*Commissioning and joining EMS and ESA*	
	UC 1.1.1	User sets up an EMS
	UC 1.1.2	User joins an ESA to an EMS
UC 1.2.x	*Removal of an ESA*	
	UC 1.2.1	User removes an ESA from an EMS
UC 1.3.x	*Setting of ESA preferences*	
	UC 1.3.1	User sets or modifies their preferences
UC 1.4.x	*EMS optimizes time of use to save cost or reduce carbon*	
	UC 1.4.1	ESA can be shifted in time to save cost or reduce carbon (ESA does NOT know ToU Tariff)
	UC 1.4.2	ESA can be shifted in time to save cost or reduce carbon (ESA does know ToU Tariff)
UC 1.5.x	*EMS uses excess solar PV to turn on ESAs*	
	UC 1.5.1	EMS uses excess solar to charge a battery (EV or BESS)
	UC 1.5.2	EMS uses excess solar to schedule operation of ESA

UC Group	Reference	Description
UC 1.6.x	*User opts out of optimization*	
	UC 1.6.1	ESA optimization is disabled (optimization is not performed)
	UC 1.6.2	User opts-out of optimization and overrides EMS

Table 5. DSRSP connected

UC Group	Reference	Description
UC 2.x	**DSRSP Connected mode**	
UC 2.1.x	*Registration (Out-of-band and In-band)*	
	UC 2.1.1	User enrols with DSRSP (account setup)
UC 2.2.x	*De-registration*	
	UC 2.2.1	User terminates their account
UC 2.3.x	*EMS connects to DSRSP*	
	UC 2.3.1	EMS connects to DSRSP for first time
	UC 2.3.2	EMS connects to DSRSP (subsequent connection - for example after power loss or comms outage)
UC 2.4.x	*User changes DSRSP preferences*	
	UC 2.4.1	User selects or changes DSRSP Tariff
UC 2.5.x	*EMS shares forecast of intended operation (with flexibility)*	
	UC 2.5.1	EMS publishes its intended operation indicating if and how it can be flexible
UC 2.6.x	*DSRSP notifies EMS of incentive to change operation*	
	UC 2.6.1	DSRSP sends incentive signal (for whole home)
	UC 2.6.2	DSRSP sends incentive signal (for specific ESA)

Table 6. General requirements

UC Group	Reference	Description
UC 3.x	**General requirements**	
UC 3.1.x	*General reporting*	
	UC 3.1.1	EMS reports in-home voltage, current, active/reactive power at boundary meter
	UC 3.1.2	EMS reports in-home voltage, current, active/reactive power of specific ESA, including its reporting accuracy
	UC 3.1.3	EMS reports in-home temperature and humidity data
UC 3.2.x	*Swap-out of EMS*	
	UC 3.2.1	EMS needs to be changed or swapped out (replacement or upgraded to newer device)

UC Group	Reference	Description
UC 3.3.x	*Change of Tenancy*	
	UC 3.3.1	The tenant of the property has changed, implying a change of contract. The existing equipment may remain.
UC 3.4.x	*Change of Supplier*	
	UC 3.4.1	The user has changed their energy utility base tariff, but the DSRSP remains the same.
UC 3.5.x	*Billing*	
	UC 3.5.1	Informing the utility, DSRSP and user about how much has been awarded as a result of flexibility events.

4.2. UC 1.x Stand-alone (DSRSP not required)

Here the EMS is optimizing home energy use for the user based on its local knowledge and may use ToU tariffs or local solar generation forecasts to optimize when energy is used. It does not require the DSRSP, assuming that the ToU tariff and GHG incentives are provided by other means, but could be provided by a public (non-authenticated) DSRSP interface.

Examples of stand-alone mode could include:

- Optimization of solar generation using internet sourced weather forecast information to predict solar generation
- Understanding of static (2-Tier) tariffs where the cost of energy changes in a peak and off-peak periods (the tariff data could come from a smart meter or other internet server and not via OpenADR).
- Using this information to pre-charge a battery or EV overnight and using the predicted excess solar during the day to charge a battery or heat hot water etc.

4.2.1. UC 1.1.x Commissioning and joining EMS and ESA

4.2.1.1. UC 1.1.1 User sets up an EMS

Here we assume that the EMS (or the local ESAG component of the EMS) is a local Matter device, and will need to be joined to the local LAN. It is assumed that most EMS devices will use Wi-Fi or Ethernet as their primary connection to the internet and that they may also either provide a Thread network or join to an existing Thread network in the home so that they can communicate with low-power devices which may share metering or other sensor data such as temperature and humidity.

Depending upon the architecture of the EMS, it may also be a Matter commissioner in its own right, or may be part of an ecosystem cloud, using an App to commission the EMS (to join the Wi-Fi and Thread Networks) and associate the device with a user account on the ecosystem cloud. The App and ecosystem cloud via a web form may allow the user the ability to set their preferences. Alternatively the EMS may have its own display and the user can directly enter their settings into the EMS.

The user may wish to set up their preferences and provide the EMS with key information such as:

- Energy provider details
- Tariff selection from a list of tariffs
- Location of the home (to allow weather forecast information to be used)
- Property type and size
- Understanding of how the home is currently heated or cooled
- Additional ESAs that they may have such as EV, Solar, Battery (prompting them to join their ESAs to an EMS see UC 1.1.2)
- DSR Offerings from their energy provider (optionally prompting them to join the EMS to the DSRSP see UC 2.1.1)

4.2.1.2. UC 1.1.2 User joins an ESA to an EMS

The user adds a new ESA to the set of devices known to the EMS, and if the EMS is already enrolled with an DSRSP, the Resource is made known to the DSRSP and starts being controlled according to the Programs enrolled and the user preferences provided to the EMS.

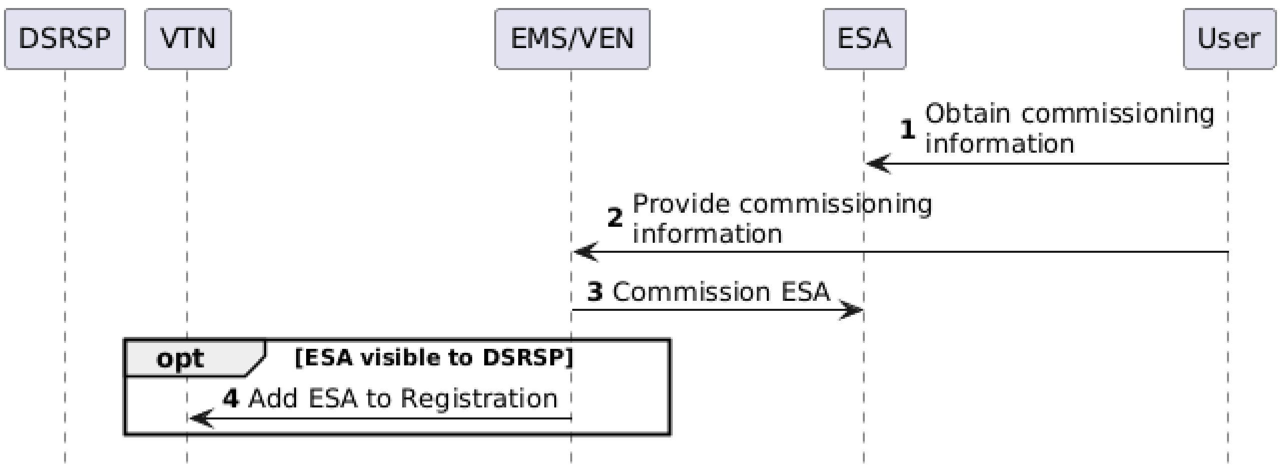

Figure 10. User Setup of an ESA

4.2.2. UC 1.2.x Removal of an ESA

4.2.2.1. UC 1.2.1 User removes an ESA from an EMS

The user removes an ESA from the set of devices known to the EMS. In stand-alone mode the EMS will no longer be able to obtain forecast information or optimize this ESA.

If the ESA is also known to the DSRSP as a specific Resource (see UC 2.6.2), it also needs to be removed from the set of Resources known to the DSRSP, stopping it being controlled according to the Programs enrolled and the user preferences provided to the EMS.

NOTE	The ESA may be established in a secure root of trust with the EMS, and the deletion of any security certificates either explicitly using a command, or accidentally for example as a result of a factory reset of the ESA, may result in the ESA no longer able to communicate with the EMS. This scenario is similar to the EMS explicitly

having the ESA removed from the list of ESAs it is managing by the consumer, except that the EMS is no longer able to communicate with a listed ESA. The latter scenario relies on the EMS detecting a loss of communication with the ESA (rather than explicitly being informed about it). If the EMS can no-longer communicate with the ESA it MAY decide to inform the user about this loss of communication and then if requested by the user, explicitly de-register the ESA (only if it was previously registered with the DSRSP).

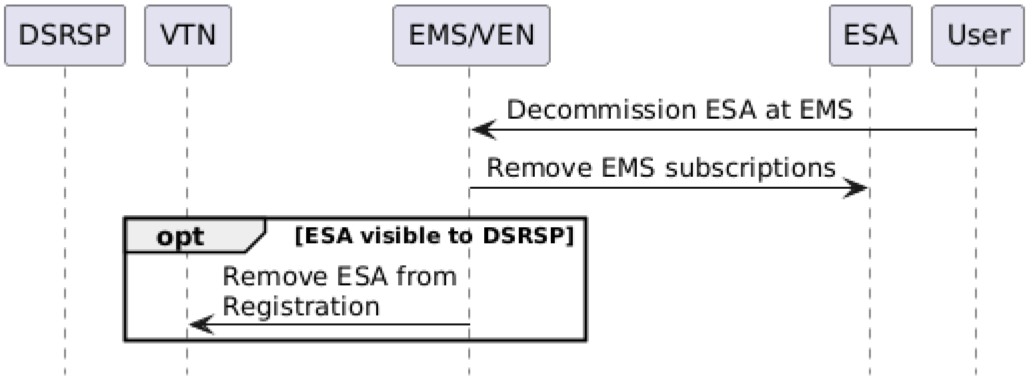

Figure 11. User Removal of an ESA

4.2.3. UC 1.3.x Setting of ESA preferences

4.2.3.1. UC 1.3.1 User sets or modifies their preferences

The user modifies the state of an ESA (for example, plugs in their EV) or changes their preferences (for example adjusts their EV charging requirements), this results in a change in forecast (or immediate) energy consumption.

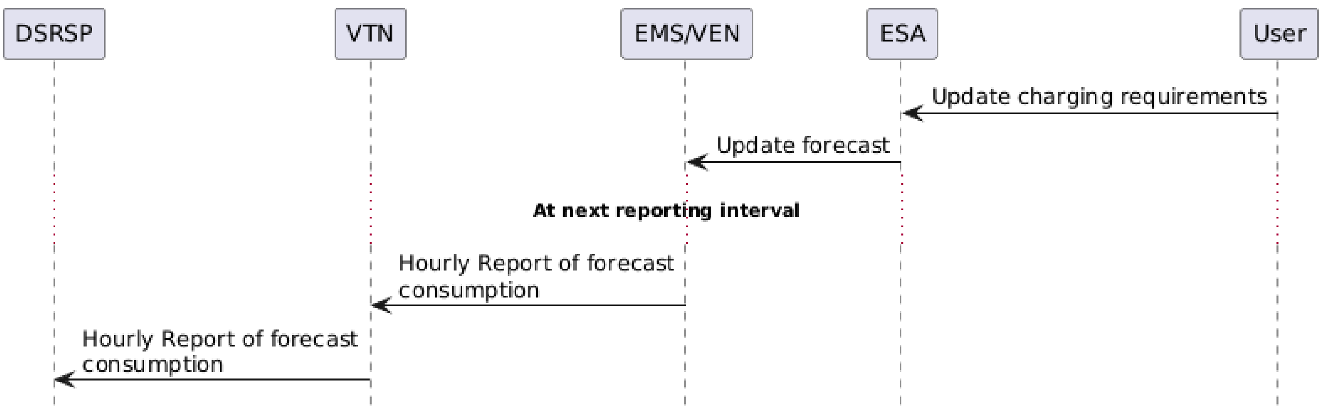

Figure 12. Routine mode fixed tariff

The EMS may optimize the whole-home or the ESA based on this updated information (see UC 1.4.x)

If the EMS is connected to the DSRSP this is reflected in the next Report from the EMS to the DSRSP.

4.2.4. UC 1.4.x EMS optimizes time of use to save cost or reduce carbon

In these scenarios, shifting the operation of the ESA to a different time, can allow a reduction in financial cost. A ToU tariff is shared with the EMS (or ESA) which is analyzed to look for the lowest cost periods and the operation shifted to occur at the cheapest time of day.

Similarly, the grid's carbon intensity measured in kg of CO_2e/kWh, is forecast as part of the overall generation mix. When the cost of energy is flat, the carbon intensity can be used as an additional incentive signal to aid optimal load shifting to reduce GHG.

4.2.4.1. UC 1.4.1 ESA can be shifted in time to save cost or reduce carbon (ESA does NOT know ToU Tariff)

In this scenario the ESA itself does not need to receive the tariff or GHG data, and builds a simple forecast based on the selected program (for example a washing machine may have different power forecasts based on the type of washing cycle requested). The Forecast should be set with a `EarliestStartTime` of the current time or in the near future, but has a short delay until the operation starts (`StartTime` is set a small amount in the future). It also includes an appropriate `LatestEndTime` which meets the user's preferences for needing the operation to be completed.

The `LatestEndTime` could be automatically set based on the current time of day to the next natural break time (such as breakfast, lunchtime, dinner time etc). For example if it was after 8pm, then the default `LatestEndTime` may be 7am, or if it is started at 7am, the `LatestEndTime` could be lunchtime (12pm) etc.

The short delay before the `StartTime` occurs, would allow an EMS sufficient time to compute the best scheduled operation based on its knowledge of tariff, GHG, solar production forecast, local battery conditions etc.

Once it has computed the optimal schedule, it sends a simple `StartTimeAdjustRequest` with the new start time.

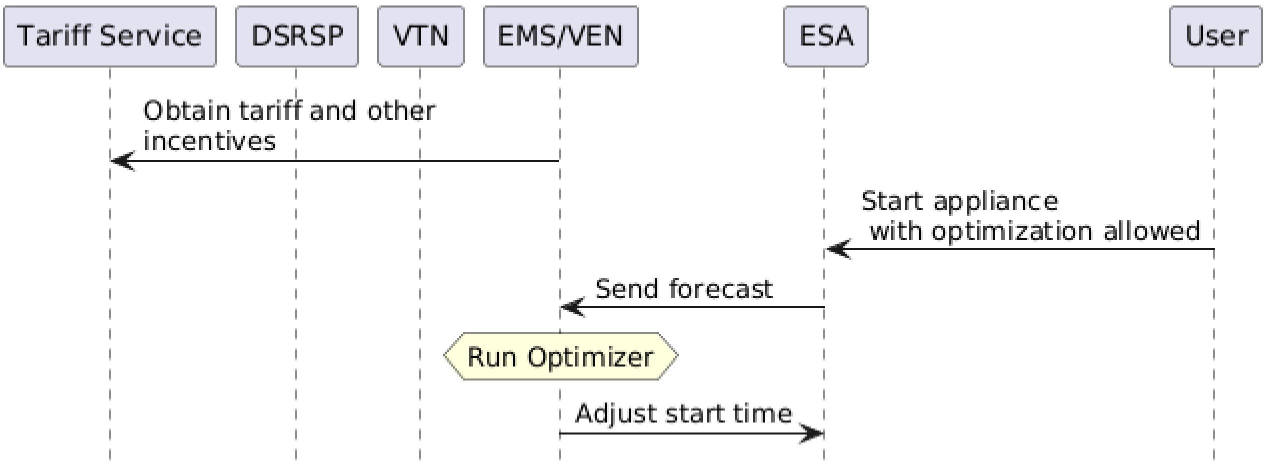

Figure 13. ESA can be shifted in time to optimize usage

4.2.4.2. UC 1.4.2 ESA can be shifted in time to save cost or reduce carbon (ESA does know ToU Tariff)

In this scenario an ESA can obtain the Tariff and GHG from a pricing server and intelligently optimize its `StartTime`. This would also allow the ESA to display information to the user about how much it has saved in both cost and CO_2e by shifting the start time.

The pricing server could be the EMS, which could share a modified virtual tariff that was computed based on the actual grid import tariff and the mix of local solar and battery storage available. This allows the EMS to still influence the ESAs operation, and may or may not need the EMS to send a

StartTimeAdjustRequest command.

The outcome is similar to UC 1.4.1, but uses intelligence in the ESA to perform the scheduling, and requires that the EMS computes a more complex virtual tariff.

In some low-cost ESAs, using the approach in UC 1.4.1 would be simpler. A more capable ESA such as a Heat pump may use the thermal properties of the home to compute a schedule that minimizes cost whilst maximizing comfort and efficiency and therefore would wish to have the tariff information.

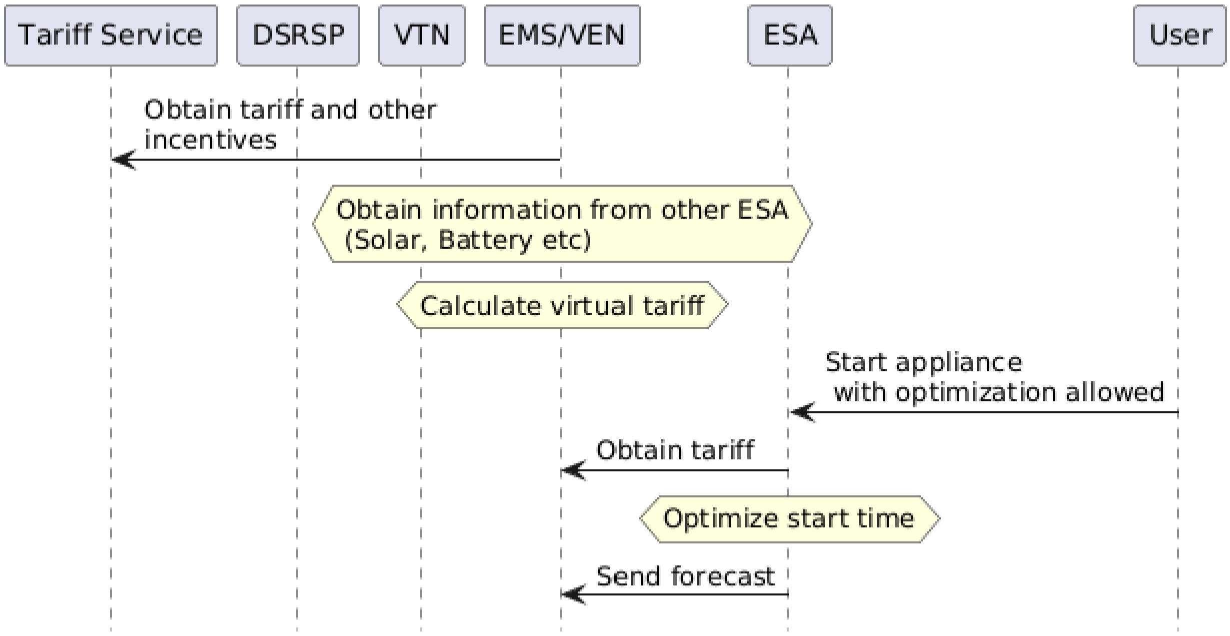

Figure 14. ESA determines start time to optimize usage

4.2.5. UC 1.5.x EMS uses excess solar PV to turn on ESAs

In these scenarios the excess solar is measured in real-time, typically by looking at instantaneous readings at the boundary (smart) meter. These meters must be able to distinguish between import and export of power. A low-cost CT clamp can also be used as a retrofit solution if the Smart meter cannot be read directly.

4.2.5.1. UC 1.5.1 EMS uses excess solar to charge a battery (EV or BESS)

A battery can be charged by using the excess power that would otherwise flow back to the grid when the solar production exceeds the power from other home loads.

It is typical to use a PID control loop to compute the battery charging power, since the PID loop can be used to compute a closed-loop error term to try to achieve 0W at the grid meter point. This allows the charging power to become negative when there is a higher load than the solar generation, and this becomes the discharging power command to be sent to the battery inverter.

Using this technique the DEM PA feature can be used to send continuous PowerAdjust commands to the Battery inverter, which allows the battery to mop up any excess solar until it is full, and discharge to meet any demands from the home until it is discharged.

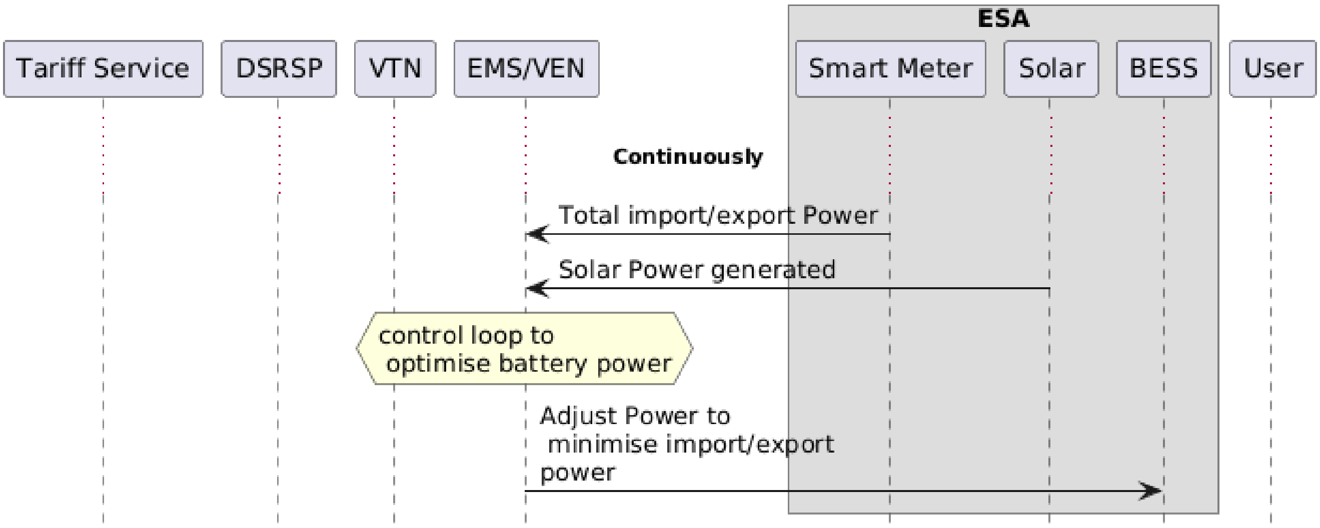

Figure 15. EMS controls Battery to optimize Solar power usage

4.2.5.2. UC 1.5.2 EMS uses excess solar to schedule operation of ESA

In this scenario, the historical solar production is tracked to build a solar prediction model which takes into account any changing weather patterns and seasons. This modelling and weather information could be performed by a smart Solar device itself, (and it generates forecasts to the EMS), or it could be performed by the EMS (as shown here).

Similarly a whole home energy model of historical loads can be used to predict peak loads from all non-smart appliances. Those appliances that are smart (ESAs) and can share their actual power consumption can be modelled separately.

When an ESA switches on and produces a power forecast, the EMS can optimize the best time to operate the ESA considering all of the other loads so that there is likely to be sufficient excess solar power.

Once it has performed this optimization, it can use the `StartTimeAdjustRequest` or `ModifyForecastRequest` commands to request the ESA changes its operation.

These operations can happen several hours ahead of the actual operation. As weather changes may occur during the day and other factors (such as actual battery SoC) may change throughout the day, the optimization may need to be re-run multiple times per day to adapt to changing conditions.

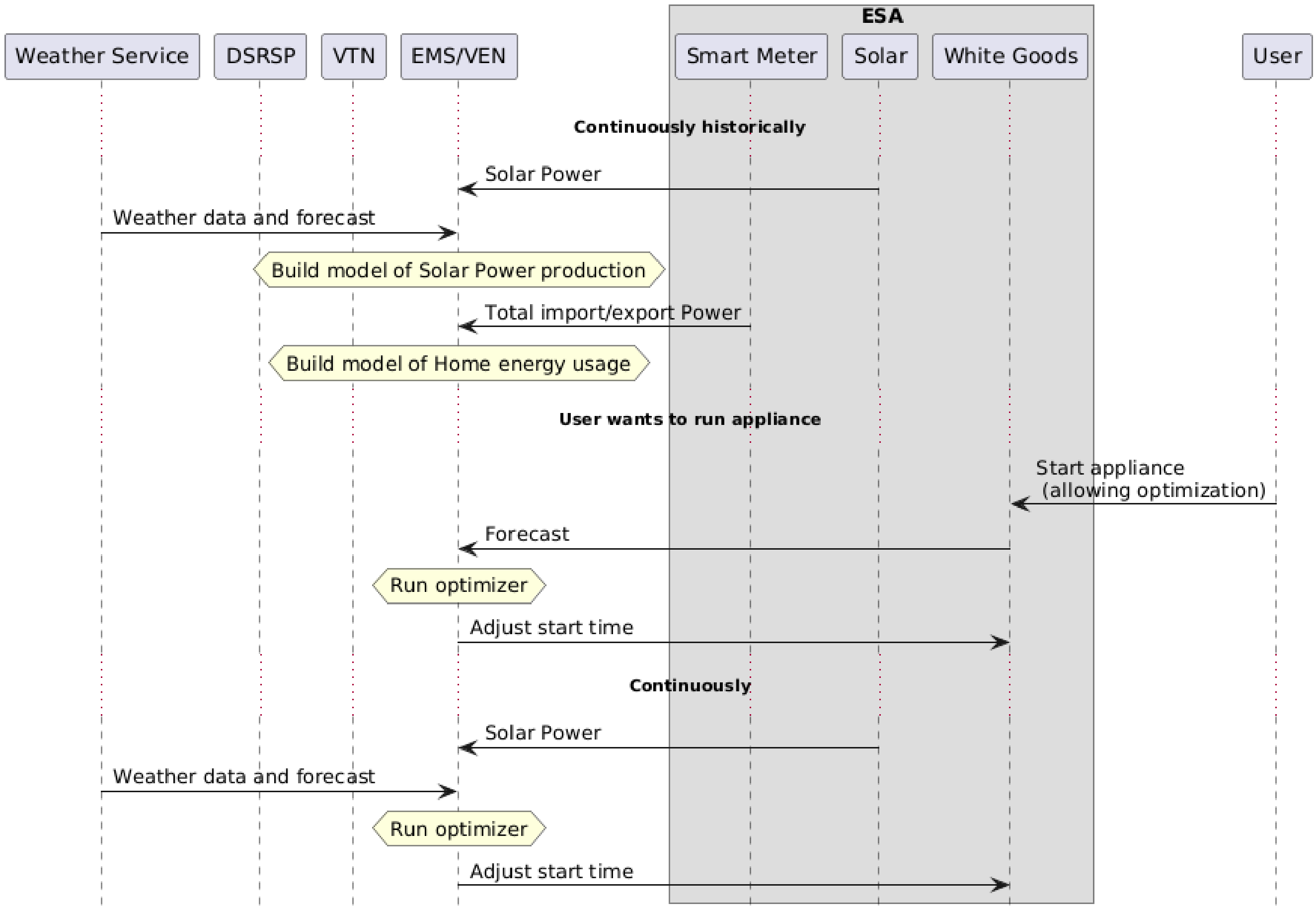

Figure 16. EMS controls appliance to optimize Solar power usage

4.2.6. UC 1.6.x User opts out of optimization

4.2.6.1. UC 1.6.1 ESA optimization is disabled (optimization is not performed)

The user can select the ESA's DEM Mode to be `NoOptimization` which stops the ESA from optimizing itself. They may also select `DeviceOptimization` which allows the device to optimize itself, but stops it from being optimized by the EMS - see UC 1.4.2 vs UC 1.4.1.

The DEM Mode can also be set to `LocalOptimization` (allowing the EMS to optimize for the home) and `GridOptimization` (allowing the EMS to optimize for the grid). These tags can be combined to allow combinations of optimization strategies.

In any case where DEM Mode is set to `NoOptimization`, then the ESA will not perform any optimization and will just begin operating per the user's request.

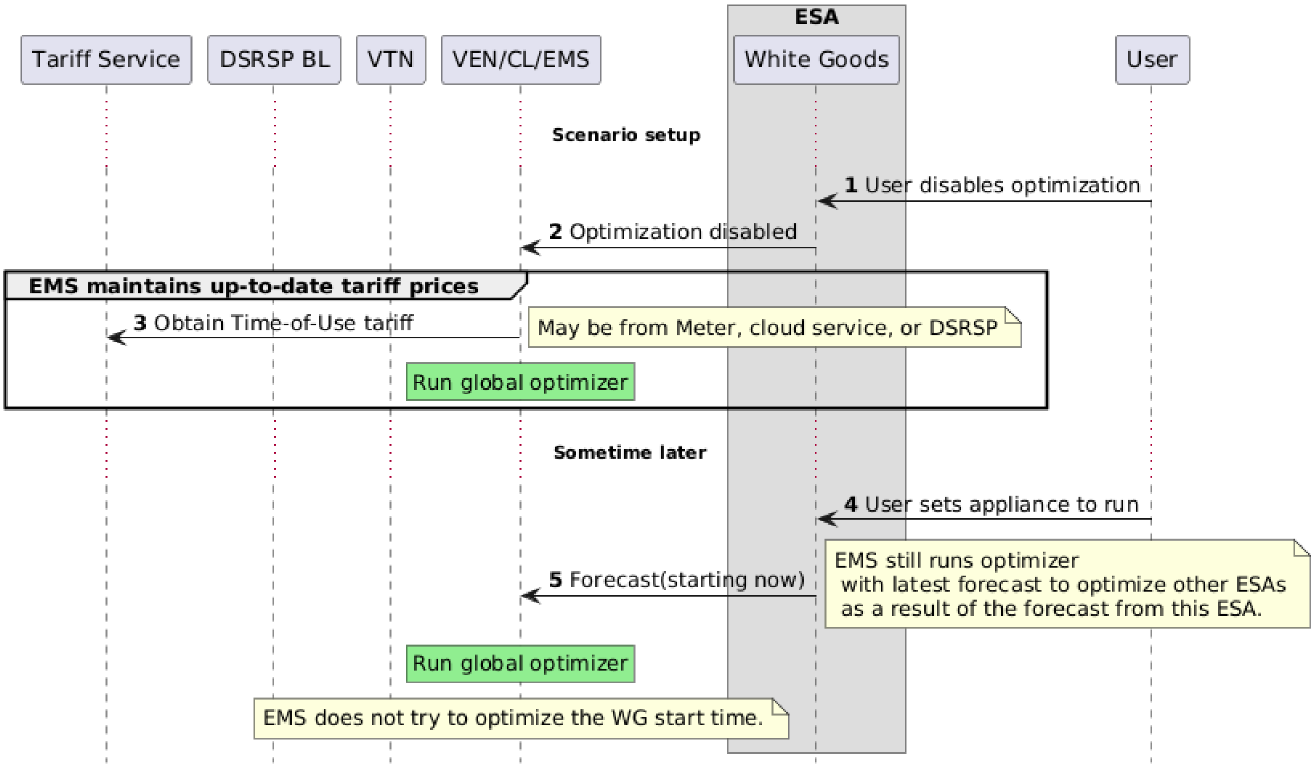

Figure 17. ESA optimization is disabled (optimization is not performed)

4.2.6.2. UC 1.6.2 User opts-out of optimization and overrides EMS

The ESA has previously had the DEM Mode set to something other than `NoOptimization` and has begun to operate under the control of an incentive signal or EMS control. The user subsequently decides to override the operation, and as a result the ESA should generate a new Forecast power and indicating it can no longer be flexible. The DEM Mode may be temporarily changed to `NoOptimization`.

If the EMS is operating connected to a DSRSP, and is already responding to a grid event when the user decides to opt-out the EMS needs to update the Report to the DSRSP with the revised forecast.

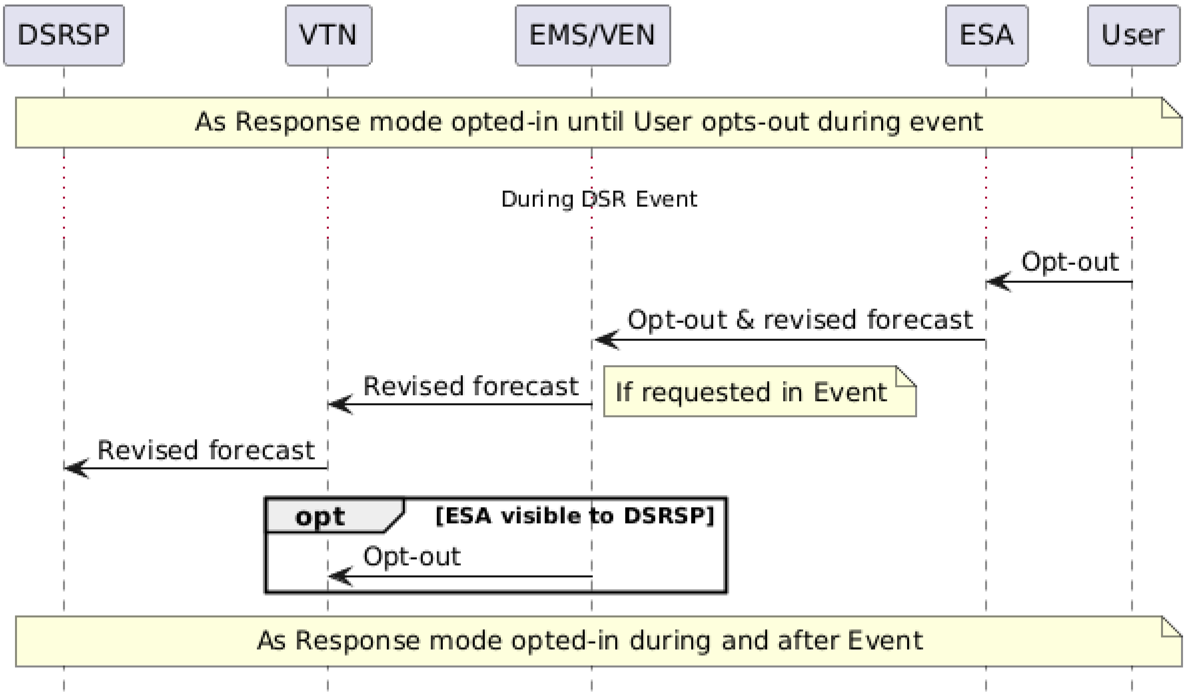

Figure 18. Response mode with user opting-out

4.3. UC 2.x DSRSP Connected mode

If the EMS is enabled to communicate with a DSRSP to offer flexibility services, then it will also be able to provide additional capabilities.

- Sharing of whole home (or per ESA) power forecast data to help the DSRSP understand the likely aggregated network load
- Receive Program-specific pricing or GHG incentives to optimize for the grid or energy retailer
- Respond to specific grid events based on constraints:
  - During or after the response, the EMS may report the actual power usage

4.3.1. UC 2.1.x Registration (Out-of-band and In-band)

Per [OADR3] the user needs to register with the DSRSP out-of-band (i.e. this is not specified how this should be done to allow innovation by energy retailers). This is discussed further in Security & Data Privacy considerations.

4.3.1.1. UC 2.1.1 User enrols with DSRSP (account setup)

The user agrees a supply contract with a DSRSP which includes the need to connect a EMS to a VTN to access the DSRSP Program(s). The user is provided by an out of band means (e.g. email from the DSRSP, data to an app provided by the DSRSP etc.) with an access URL, a user identifier, and security credentials for the access to the Program(s) at the VTN, and the user provides the information to its EMS (which at this point may not be associated with any ESAs, or may already be associated with some ESAs – see below).

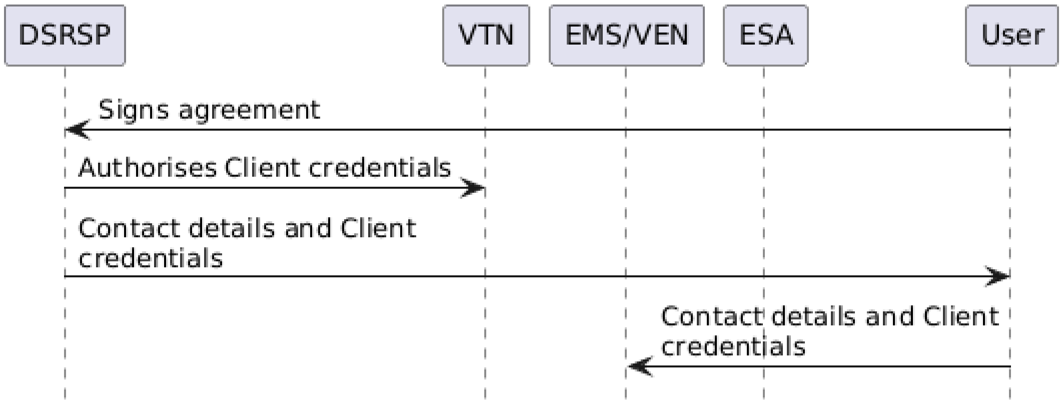

Figure 19. User enrolment and registration with DSRSP

4.3.2. UC 2.2.x De-registration

If a user decides to change their DSRSP, this is effectively the termination of their current DSRSP contract followed by the enrolment with a new DSRSP service.

Users may also wish to terminate their contract with their DSRSP for other reasons, such as moving home.

4.3.2.1. UC 2.2.1 User terminates their account

The user's contract with the DSRSP is terminated. The user removes the access URL, user identifier and security credentials for the DSRSP Program(s) from the EMS (or the DSRSP prevents access to the Program(s) by the EMS), so the EMS manages the ESAs (which remain known to the EMS) just based on the user preferences provided to the EMS.

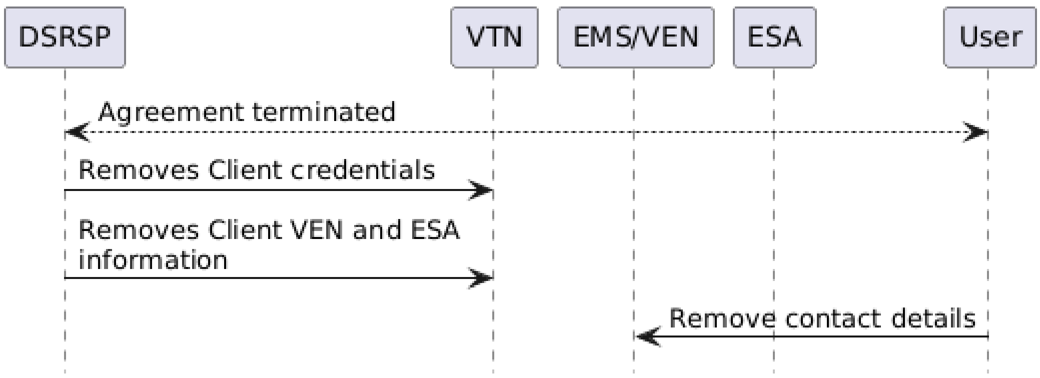

Figure 20. User termination of DSRSP Service

4.3.3. UC 2.3.x EMS connects to DSRSP

4.3.3.1. UC 2.3.1 EMS connects to DSRSP for first time

In this scenario, the EMS contacts the VTN and creates its objects to be associated with the DSRSP Program(s), and starts providing normal service according to the Programs enrolled and the user preferences provided to the EMS.

The EMS (VEN) may optionally provide information to the DSRSP (VTN) about any ESAs that are treated as individual loads to the DSRSP, and not aggregated with the whole home loads.

The VEN receives its initial Events which allows it to create the Reports to share with the VTN.

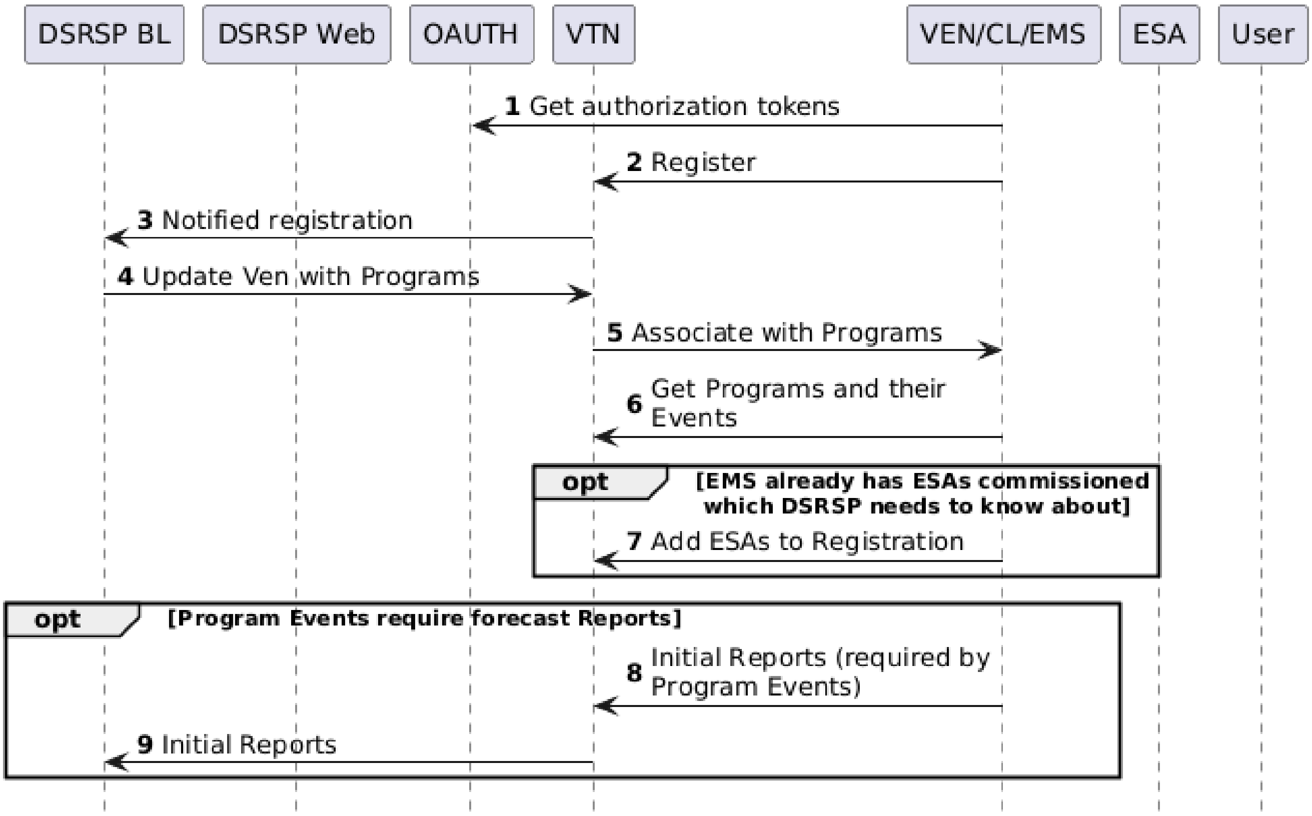

Figure 21. Initial connection to DSRSP

4.3.3.2. UC 2.3.2 EMS connects to DSRSP (subsequent connection - for example after power loss or comms outage)

On subsequent connections, the EMS (VEN) may need to synchronize any changes that may have happened whilst it was not connected to the VTN (DSRSP). This may include creating or deleting Resources for the non-aggregated ESAs that were added or deleted.

Any Events that may be pending for the VEN should be processed, and any pending Reports sent if data is available.

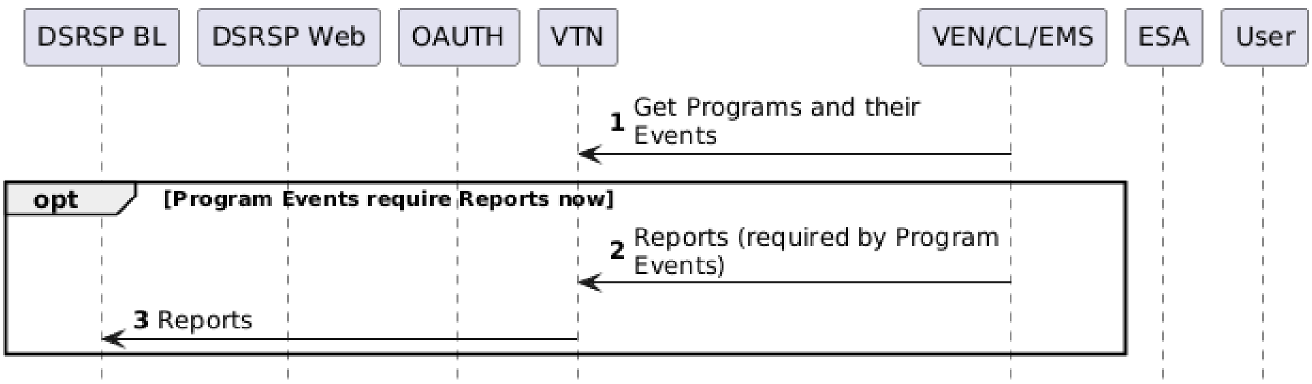

Figure 22. Re-connection to DSRSP

4.3.4. UC 2.4.x User changes DSRSP preferences

4.3.4.1. UC 2.4.1 User selects or changes DSRSP Tariff

The user and DSRSP agree a new contract which requires a change of Program(s) with the VTN. The BL updates the Ven object targets with the new Program information, and the VEN learn of the change and updates its behavior accordingly.

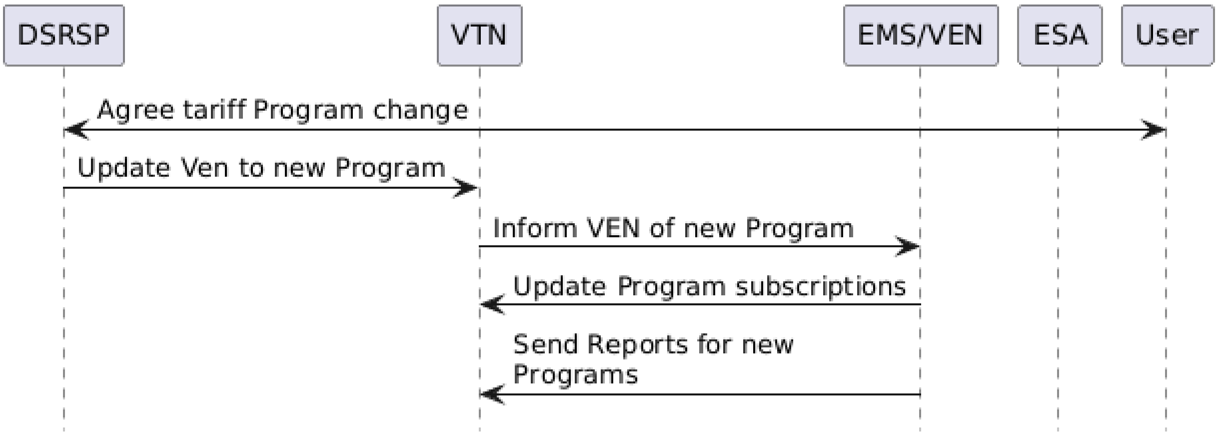

Figure 23. User tariff change

4.3.5. UC 2.5.x EMS shares forecast of intended operation (with flexibility)

4.3.5.1. UC 2.5.1 EMS publishes its intended operation indicating if and how it can be flexible

This scenario represents the typical operation of the VEN. The EMS uses its baseline tariff information to share with the ESAs to allow them to compute their optimal schedule (see UC 1.4.2) or to directly compute the optimal schedule for the ESAs (see UC 1.4.1) within the constraints of the user's preferences.

The EMS using Matter collates Forecast information from its attached ESAs and may aggregate ESAs (or treat some ESAs as separate Resources).

These Forecasts contain the Intended Operation of the combined whole-home or specific ESAs over the subsequent hours.

The Forecasts may optionally contain costs for the Intended Operation.

The VEN may also share its ability to turn up, or turn down loads which it deems come at zero cost. For example if there was a flat tariff throughout the day, the EMS may have arbitrarily scheduled an ESAs operation, but it may allow the ESA to be charged earlier without any real penalty.

NOTE	This specification assumes that if the DSRSP wants to encourage different behavior outside of the optional turn up / turn down capability, then it may need to offer a better incentive to the EMS to do so (see UC 2.6.x).

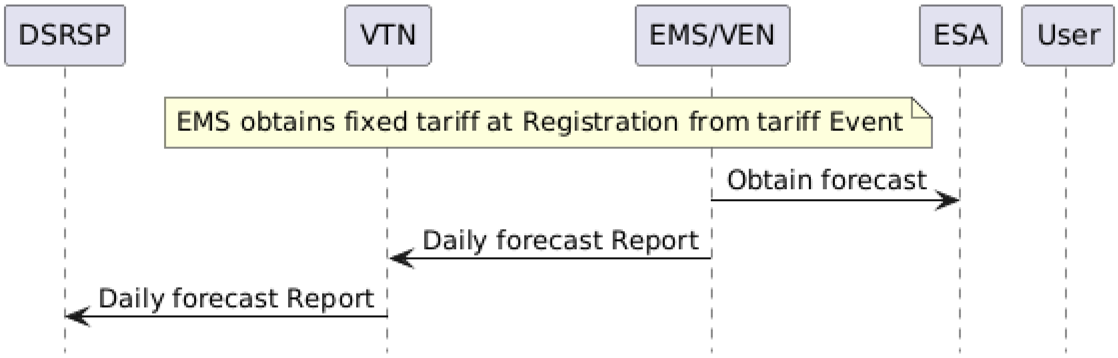

Figure 24. Normal EMS scheduling against baseline tariff

4.3.6. UC 2.6.x DSRSP notifies EMS of incentive to change operation

In markets where a DSRSP can share a dynamic tariff (see Tariff types) and is not using a flat or 2-Tier tariff, the EMS would routinely use the dynamic tariff as its baseline to produce an optimal schedule. Here the user is accepting of the financial risk of being on a dynamic tariff. The DSRSP can publish the day-ahead dynamic tariff (that may vary every 15 or 30 minutes) using a specific Program Event.

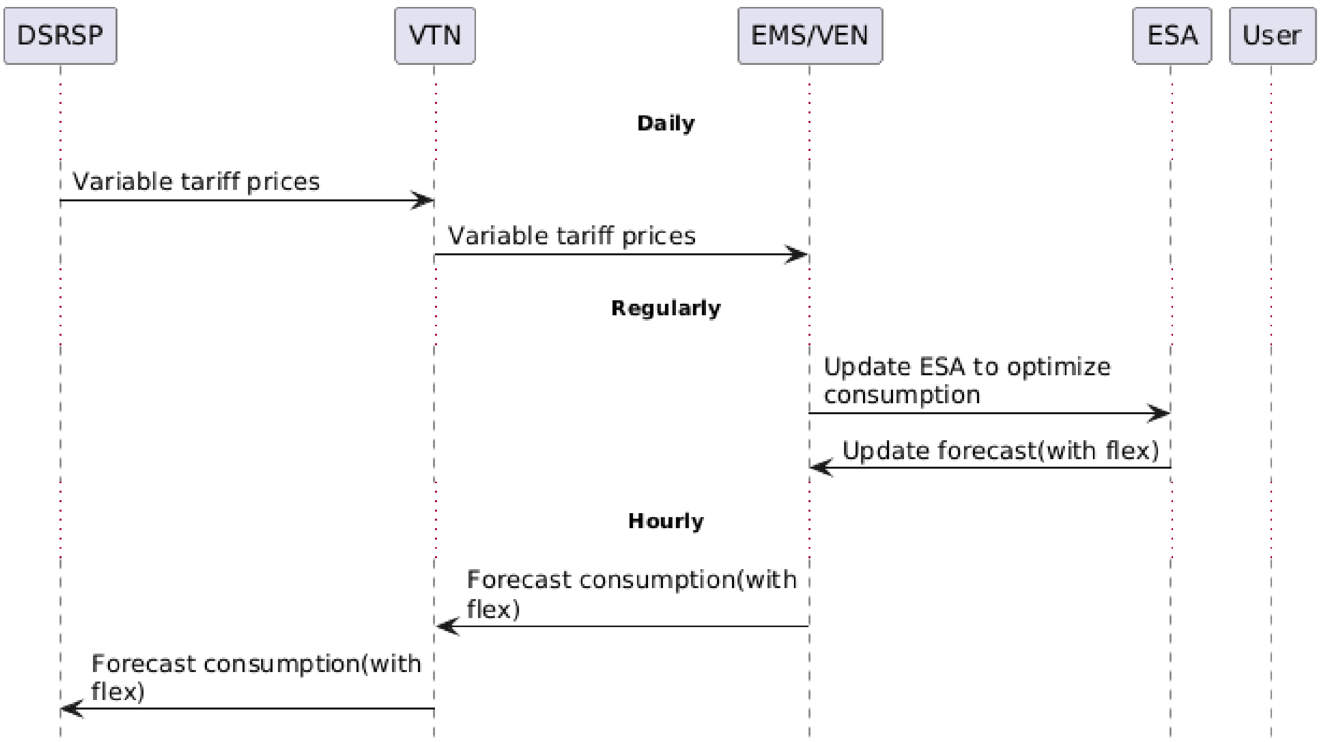

Figure 25. DSRSP shares dynamic pricing via OpenADR

In all cases there is expected to be a secondary finer grained incentive (ultimately this can be resolved to the nearest second) that overlays the baseline tariff.

This secondary incentive may include a price delta and optional GHG amounts.

4.3.6.1. UC 2.6.1 DSRSP sends incentive signal (for whole home)

When the DSRSP needs additional flexibility from an EMS at the whole home level it may need to steer the EMS to change its forecasted Intended Operation initially using the information in the zero cost turn up / turn down capacity reports. The DSRSP must use the secondary incentive signal to try to ask the EMS to re-schedule or adjust its Intended Operation to meet the DSRSPs needs.

DSRSP bidding (Optional)

The DSRSP may need to send candidate incentive signal 'offers' to EMSs. These candidate offers are responded to with a candidate forecast. The actual forecast Intended Operation may be unaffected at this bidding stage, and this bidding mechanism does not reflect an accepted change, but the ability for an EMS to accept the incentive signal should an actual incentive signal be received.

This bidding mechanism allows a DSRSP to stage a group of EMSs in a geographic area to test how they may be able to respond. At this stage there is no commitment from the EMS to respond to this candidate incentive offer.

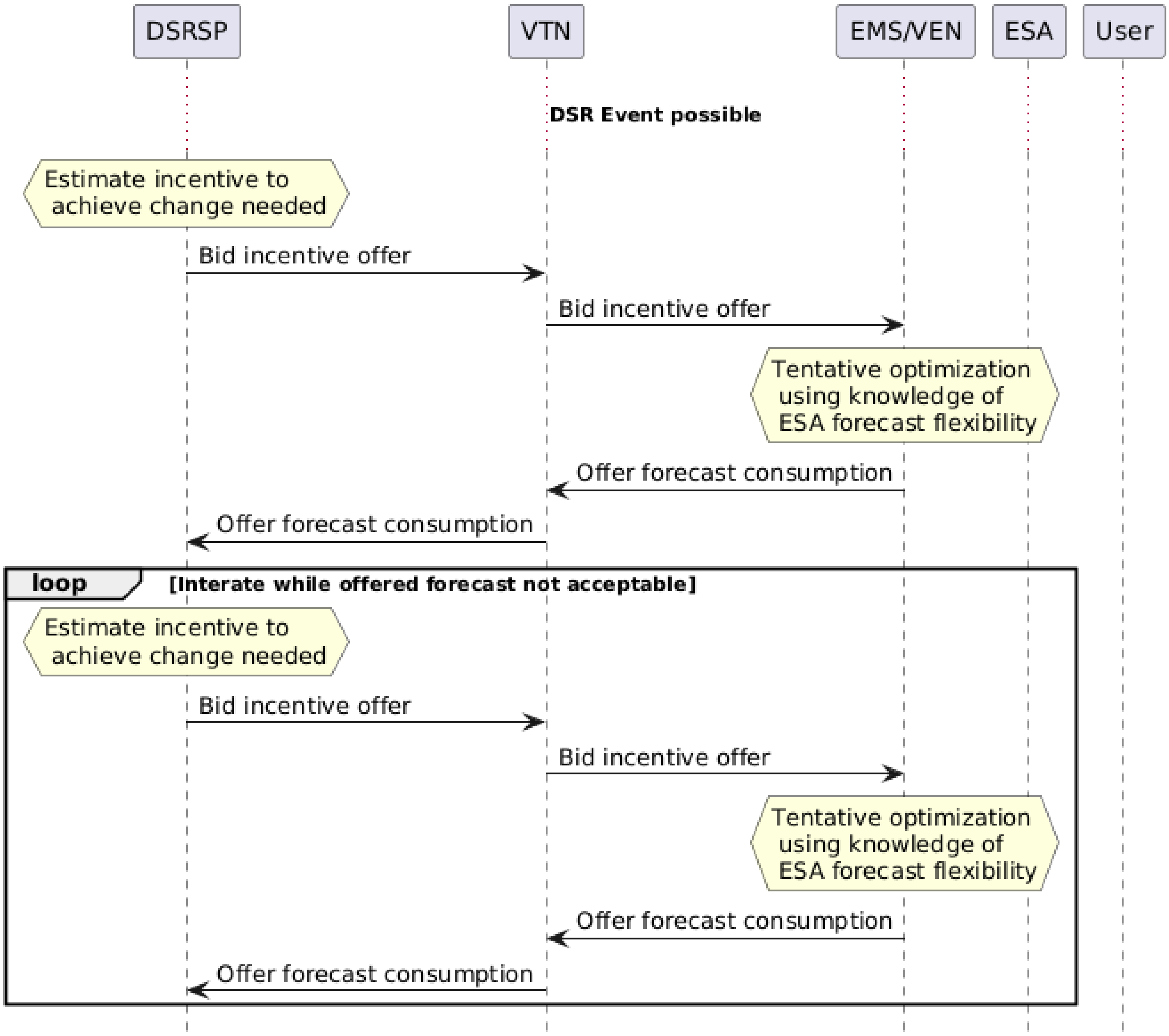

Figure 26. DSRSP send candidate Incentive Signals to determine if an EMS can adjust its behavior

DSRSP contract offer

When the DSRSP has determined the appropriate incentive signal that will result in the desired change of behavior of the EMS, then it sends a formal offer containing the new incentive signals to the EMS.

The EMS may then recalculate its Intended Operation and if it decides to accept this, it shares a revised Forecast and immediately begins to follow the new Intended Operation. This is an indication that it has accepted the new incentive signal (and expects the corresponding billing credits or rewards if appropriate to be credited to the user's account in due course).

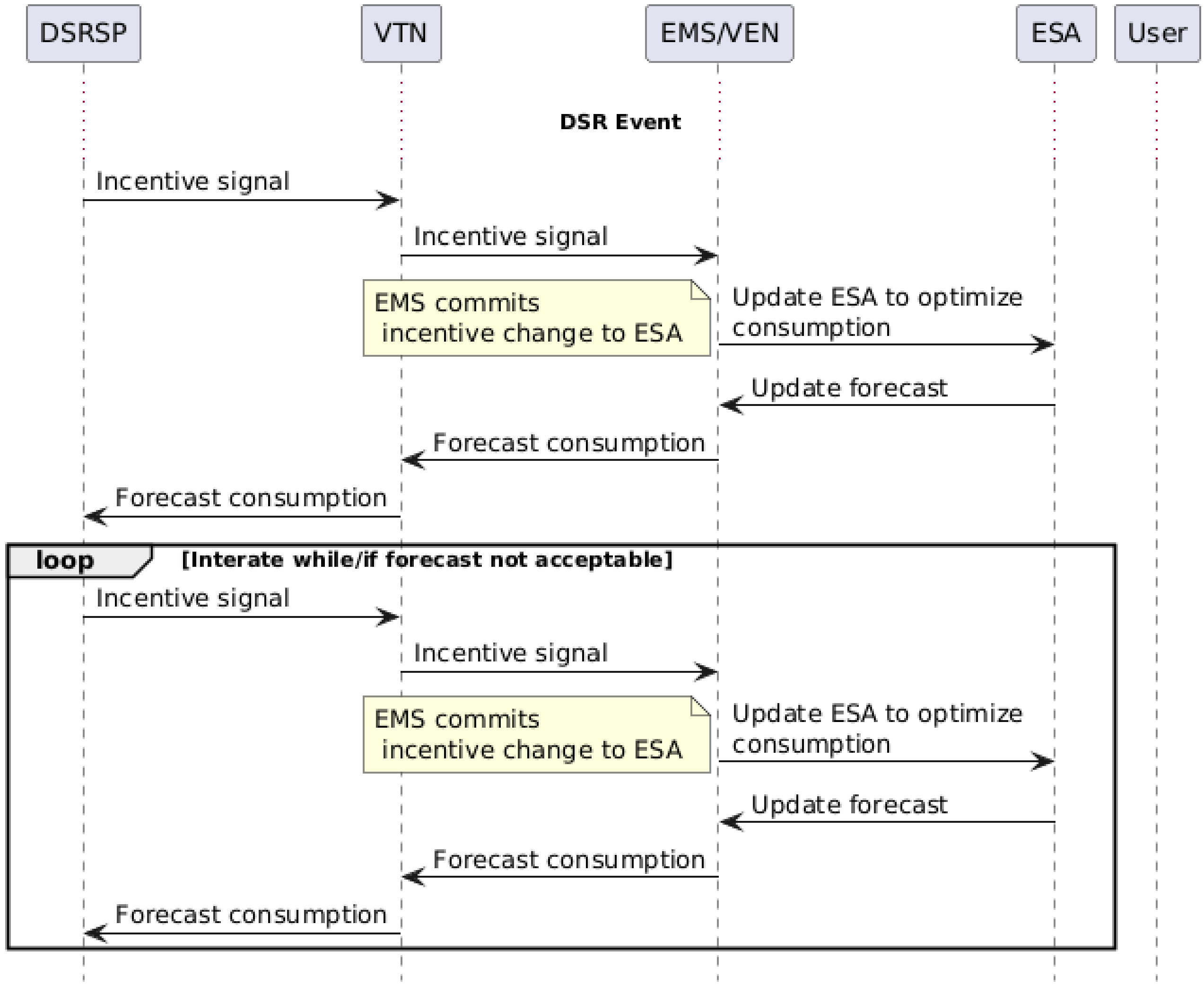

Figure 27. DSRSP sends final Incentive Signals to request an EMS adjusts its behavior

4.3.6.2. UC 2.6.2 DSRSP sends incentive signal (for specific ESA)

The DSRSP may wish to offer different incentive signals or different tariffs to different types of ESA, along with agreement to permit the DSRSP to use them for DSR control. For example, a DSRSP may offer an EV-specific tariff, along with the condition that the DSRSP gets some control over the flexibility of when the EV is charged (and if the EV supports V2X, how much the EV can be used to supply energy back to the grid under DSRSP control).

The home's electrical smart meter at the boundary point of the premise will include the power and energy metering data of the whole-home. To allow ESA specific use-cases typically relies upon the reports of actual usage by the specific ESA (using its sub-meter) in order to be able to bill for the usage by that specific ESA at the different tariff from the rest of the user's usage.

In order to perform billing and to comply with local regulations, the DSRSP may be required to understand the accuracy of the ESA's sub-meter (see UC 3.1.2).

This use case requires separate Resource objects within the single VEN for the ESAs on different tariffs. These Resource objects are associated with the same user account of the specified VEN.

The non-specific ESAs (i.e. the whole home) which are included within the general purpose tariff are not be represented by separate Resources, and are managed through the VEN using aggregated Reports.

The VEN and its child Resource objects (for the specific ESAs) are associated with different Programs to match the tariff under which they are operating.

The procedures for sharing forecasted Intended Operation for a specific ESA are therefore identical to those in UC 2.5.1 except that they are specific to the specific ESA (Resource) within the VEN.

Similarly the ability for a DSRSP to modify the Intended Operation for a specific ESA are also identical to those in UC 2.6.1 except that these are targeted at a specific ESA (Resource) within the VEN.

4.3.6.3. UC 2.6.3 DSRSP sends power limitation constraint for whole home

In extreme events, or in order to protect the Low Voltage (LV) network infrastructure, the DSRSP may need to implement an emergency curtailment on each home in the area. For example it may need to limit all homes to around 5kW peak for a specific time duration.

Here the onus is on the EMS to ensure that the ESAs under it control are managed to avoid using too much power, and the EMS may need to use real-time smart meter readings at the boundary meter to curtail any ESAs it can control, bearing in mind the user may have non ESAs in the home which cannot be curtailed.

As an example there may be an EV charger currently charging at 3kW, and the user switches on a kettle (2.5kW) which would cause the peak load to be exceeded. The EMS can get regular smart meter readings and temporarily reduce the EV charging rate whilst the kettle is boiling.

4.4. UC 3.x General requirements

4.4.1. UC 3.1.x General reporting

4.4.1.1. UC 3.1.1 EMS reports in-home voltage, current, active/reactive power at boundary meter

The DSRSP may need to know the historic power readings from the boundary (smart) meter in order to set a baseline. The power readings will allow a DSO to understand the peak power values over a period of time which can help to assess the impact of diversity factors on the LV infrastructure.

During a grid event when the home has made an adjustment to its baseline Intended Operation, the DSRSP may need to see evidence of a change in power in order to be paid by its upstream contract with the energy network or market.

A DSRSP typically needs to provide fast updates (1 second or faster is not uncommon in Industrial and Commercial DSR flexibility markets) to fulfil its upstream contracts. These readings from multiple homes will need to be aggregated by the DSRSP.

Additionally, other information such as voltage, current and the active/reactive power can help DSOs understand the assets on their networks and may allow network optimizations and diagnostics to be performed using data analytics.

4.4.1.2. UC 3.1.2 EMS reports in-home voltage, current, active/reactive power of specific ESA, including its reporting accuracy

This use case is similar to that described in UC 3.1.1 but may also need to include the sub-meter's accuracy.

Some ESAs (for example in white goods) may not need to be as accurate if they are not used for billing purposes, and may simply estimate their power consumption based on the state they are operating in.

Some use-cases may require an accurate billing grade sub-meter, for example if a company car is being charged in an employee's home and they want to expense the cost of energy from their employer.

4.4.1.3. UC 3.1.3 EMS reports in-home temperature and humidity data

Some energy companies are obligated by their operating license to improve their customer's lives, and may also need to provide evidence that by operating DSR they are not causing harm to their users.

With the user's consent, it may be desirable to share the home's temperature and humidity data periodically so that the energy company can meet their license obligations.

This may rely upon using Matter based sensors (e.g. from a Smart Thermostat) to obtain such readings.

4.4.2. UC 3.2.x Swap-out of EMS

4.4.2.1. UC 3.2.1 EMS needs to be changed or swapped out (replacement or upgraded to newer device)

Inevitably the EMS may need to be upgraded (to a more capable device) or swapped out if the old one has failed.

The new EMS needs to gain knowledge of the ESAs and be configured with the DSRSP URL and user credentials (see UC 2.3.1).

If the current EMS and the new EMS support it, it may be possible for some of this transfer to be performed from EMS to EMS directly. This is only likely to be possible if the old and new EMS are from the same Ecosystem provider, and the Ecosystem has a method to migrate the backed-up settings stored in its cloud.

In other scenarios (such as a different Ecosystem provider), the user may need to re-configure all of the ESAs to communicate with the new EMS, and re-configure the EMS to communicate with the DSRSP.

Since the new EMS will not have the same stored state with the DSRSP as its predecessor, it should follow the initial contact procedure in UC 2.3.1.

4.4.3. UC 3.3.x Change of Tenancy

4.4.3.1. UC 3.3.1 The tenant of the property has changed, implying a change of contract. The existing equipment may remain.

If a tenant moved out of the property, then this would mean that the old user's contract with the DSRSP needs to be terminated (see UC 2.2.1). The new tenant's would require a new contract with the DSRSP (or perhaps a different DSRSP) and is covered by UC 2.1.1.

4.4.4. UC 3.4.x Change of Supplier

If a tenant decided to switch supplier (and potentially DSRSP), then the old contract would need to be terminated (see UC 2.2.1) and a new contract established (see UC 2.1.1).

4.4.4.1. UC 3.4.1 The user has changed their energy utility base tariff, but the DSRSP remains the same.

In this scenario the user stays with their energy utility, and changes their baseline tariff.

If the baseline tariff is not provided by OpenADR (DSRSP), then the EMS will need to be updated with the new tariff. This may come automatically via the smart meter (in the case of a simple flat or 2-Tier tariff), or may be entered manually into the EMS, or may be derived from a new internet server.

If the baseline tariff is provided by the DSRSP using OpenADR, then the user may need to select a new Program and the data is shared automatically to the EMS.

The EMS may need to know the user's new Program, or may be able to use the existing Program and the DSRSP sends different tariff data (the logic to do this is in the DSRSP's BL).

4.4.5. UC 3.5.x Billing

4.4.5.1. UC 3.5.1 Informing the utility, DSRSP and user about how much has been awarded as a result of flexibility events.

The user may want to know how much they have been rewarded for specific events, on a daily, weekly or monthly basis. They may also want to know much they have saved in terms of GHGs because of their engagement in the DSR Program.

This information may be shared out of band, but it is desirable to share this in a well-defined standard format, so that individual ESAs or the EMS can display this to the user directly.

Chapter 5. Example Profile

This section provides a specification level profile for an example domestic DSR program.

It aims to help show how the different use-cases in Chapter 4 are implemented with a subset of both the Matter and OpenADR specifications.

The overall objective is to improve interoperability by explicitly declaring which features of the Matter and OpenADR specifications are deemed in scope for the program.

5.1. Matter Energy Management Profile

The Matter device types most relevant to the ESA which include these clusters in this specification include:

- Device Energy Management
- EVSE
- Water Heater
- Solar
- Battery Storage

The supported clusters and their features of Matter Energy Management for this specification include:

- Pricing (Provisional)
- Device Energy Management (DEM), with features:
  - DEM Power Forecast Reporting (PFR)
  - DEM Start Time Adjustment (STA)
  - DEM Request Constraint based adjustment (CON)
  - DEM Power Adjustment (PA)
  - DEM Forecast Adjustment (FA)
  - DEM Pause (PAU)
- DEM Mode (DEMM)
- Electrical Power Measurement (EPM)
- Electrical Energy Measurement (EEM)
- Power Source (PS)
- Power Topology (PWRTL)
- Electric Vehicle Supply Equipment (EVSE)
  - EVSE User Preferences (PREF)
  - EVSE Vehicle-to-X (V2X)

- EVSE Mode (EVSEM)
- Water Heater Management (EWATERHTR)
- Water Heater Mode (WHM)

The [Matter] specification includes appropriate minimum profiles for these devices and clusters in terms of the features necessary to be supported for each of them.

5.2. OpenADR 3 Profile

As [OADR3] is deliberately designed to be a very flexible protocol suitable for a wide range of Demand Side Response systems, it requires a profile to define how it is to be used in an interoperable manner in any specific system.

This section proposes a profile that would be suitable for a residential DSR system, which is characterized by the need for:

- Interoperability
- Data Privacy
- Grid Stability
- Cybersecurity

The profile is based on the version 3.0 of [OADR3], but includes assumptions about changes likely in future versions uses of [OADR3] which are not supported by the 3.0 version. As such, Interworking Scenarios includes some assumed changes to [OADR3] as noted in those sections.

There are some areas highlighted by the use cases Interworking Scenarios which would benefit from further enhancements to [OADR3], and these are discussed in Future considerations, but not assumed to be currently available.

To be successfully adopted by the mass market, it also requires Plug-and-Play installation and operation, whilst meeting the Interoperability requirement, with minimal input from the user.

5.2.1. Profile Overview

The overview of one possible approach as to how [OADR3] may be used to provide the DSR service with the above goals is:

- The `ven` object is created in the VTN as part of the enrolment process by the VEN itself, with a pre-agreed venName which is communicated between the DSRSP and user out-of-band in advance of this enrolment (alongside the client credentials).
- The Program(s) to which a VEN client belongs are entered into the BL as part of the enrolment process, which then updates the `ven` object `targets` property to include the associated Program(s) by using their `programName` property as the target, and the VEN learns the Program(s) from that.
- access control logic in the VTN only provides visibility to the user of those Programs that the BL has associated with the user account credentials.

- The user opt-in/opt-out state as it applies to each ESA individually (for example to still charge the EV despite there being a DSR Event in progress) is not visible to the DSRSP, only the overall effect it has on the user's energy consumption during the DSR Event.
- The user opt-in/opt-out state can be applied to the EMS as a whole, but is not visible to the DSRSP, only the overall effect it has on the user's energy consumption during the DSR Event.

5.2.2. Interpretation of specification

[OADR3] is intended to be an extensible open standard that allows it to be customized by its users to their specific needs. It can be used in a variety of markets segments for different purposes.

In order to reduce ambiguity and avoid potential different interpretations and in the interest of improving interoperability, this specification aims to clarify and define how aspects of the [OADR3] specification SHALL be used in a domestic DSR framework.

The following table adds specific clarification of usage details for properties defined in the OpenAPI [OADR3] schema.

Property	Object	Usage
`accuracy`	`reportPayloadDescriptors`	This property SHALL be in the same units as the `units` property of the same object.
`confidence`	`reportPayloadDescriptors`	This property SHALL be the percentage probability that the actual value was within the value range of the `value`+`accuracy` to `value`-`accuracy`.
`programType`	`program`	The enumerations for this property are undefined, but there are currently no use cases which require distinction between Program types, so this property SHOULD be omitted.

5.2.3. Plug-and-Play installation

The current [OADR3] defines an initial enrolment process which involves the user creating a client account with the DSRSP (for example on their web portal) and through that having shared information (client_id, client_secret, venName and VTN URL) which the user then has to provide to the EMS through a UI.

The enrolment provides the EMS with the information it needs to obtain the OAuth bearer tokens, and using them, contact and interact with the VTN. This manual enrolment process will require a usable UI on the EMS (possibly via a web browser or app), but is not suitable for mass deployment in its current form.

- Further work is required to create an enrolment flow which can be handled more automatically

5.2.4. Operation behind home router firewalls

The version 3.0 of [OADR3] can deliver notifications using webhooks (not suitable for use by VEN clients on a residential network behind a residential router), but future versions are likely to add using MQTT as an alternative notification delivery mechanism, which is suitable for such EMS.

- The VEN SHALL use MQTT for all subscriptions for notifications from the VTN.

5.2.5. Creation and ownership of objects

The current [OADR3] permits the `ven` and any child `resource` objects to be created, updated and read by both the VEN client and the BL client. For interoperability only one client should create these objects, and both client types should be able to subscribe to them so that they are notified by changes made by the other client.

- The VEN client SHALL create the `ven` and, if used, `resource` objects.
- The BL client SHALL update the `targets` property of the `ven` objects to include a VEN_NAME value, with the value being the same as the `venName` property of the same `ven` object.
- The BL client SHALL update the `targets` property of the `resource` objects to include both VEN_NAME and RESOURCE_NAME values, with the values being the same as the `venName` property of the parent `ven` object, and `resourceName` property of the `resource` object respectively. Both names are needed here, as the `resourceName` is only locally unique within the VEN.

The current [OADR3] does not provide the EMS with knowledge of which `program` object(s) it should be using for the DSR services it is part of. The BL has this knowledge from the enrolment creation of the client account and associating that account with the services the user has selected to take.

- The BL client SHALL update the `targets` property of the `ven` and `resource` objects to include PROGRAM_NAME values, which are the same as the `programName` property of the relevant `program` object.
- The BL client SHALL update the `targets` property of each `program` object to include a PROGRAM_NAME value which is the same as that object's own `programName` property. This is to allow a VTN (which simply matches the targets property name-values maps entries) to allow the VENs to find the correct `program` objects by reading its own `ven` object to obtain the PROGRAM_NAME from its targets, and then obtain the correct `program` objects by a targeted GET of `\programs`.

The current [OADR3] does not provide any definition of the generic types of resources, nor of any method for a Program to define which resources should be created as separate `resource` objects under the `ven` object, so currently assuming out of band information transfer. This could be obviated by:

- The BL client SHALL update the `targets` property of the `program` objects to include RESOURCE_TYPE values for any resource types for which it requires the VEN client to create `resource` objects for during enrolment (or later if the devices are only installed and commissioned at a later date) using the RESOURCE_TYPE enumerations defined in Resource Type enumerations.
- The VEN client SHALL create `resource` objects for all ESAs it manages of the RESOURCE_TYPEs indicated in the `program` objects with which it is associated.
- The VEN client SHALL include the `targets` property of the `resource` objects it creates to include a

RESOURCE_TYPE value relevant to that object.

- The VEN client SHALL include the `attributes` property of the `resource` objects it creates to include a RESOURCE_TYPE value relevant to that object.

5.2.6. Data Privacy

The current `[OADR3]` has been designed with the assumption that any VEN or BL client my read any object, including the `ven` and `resource` objects associated with other VEN client accounts. There is a general security access control example statement that "*Both [BL and VEN clients] can read an event, but a VEN can only read events associated with the programs it is entitled to access.*", but there is currently no support in the protocol and data model to make such VTN access control explicitly defined (e.g. the `client_id` is not a property of the `ven` object, but a VTN would know the `client_id` of the account which created that `ven` object, so could keep that association, and prevent other VEN client accounts from accessing that `ven` object). Explicit support for data privacy for `ven` and `resource` objects may be included in a future version of `[OADR3]`.

- The VTN MAY reject any `GET` of the list of any `ven`, `resource`, `report` or `subscription` objects by a VEN client which would return information about objects not created by the same client, and SHALL NOT return such objects unless they were created by the same VEN client.
- The VTN SHALL reject any `PUT`, `POST` or `DELETE` command on any `ven`, `resource`, `report` or `subscription` objects by a VEN client if the requested object was not created by the same client.

The current `[OADR3]` permits any client to subscribe to notifications for any action on any object. The VEN clients should only be permitted to subscribe to notifications of actions performed by the BL on the `ven` and `resource` objects created by that same client. There is no requirement for the VEN client to be able to subscribe to its own `report` or `subscription` objects, as they are read-only to BL clients, but there is no data privacy reason to prevent such subscriptions provided they too are only to the objects created by that same client.

- The VTN MAY reject the creation or modification of a `subscription` object by a VEN client which subscribes to any `ven`, `resource`, `report` or `subscription` objects not created by that client, and SHALL NOT return notifications of such objects unless they were created by the same VEN client. Targeting of the `ven` and `resource` subscriptions may be achieved by the inclusion of RESOURCE_NAME and/or VEN_NAME targets in the `subscription` object.
- The VTN SHALL reject any MQTT subscriptions by VEN clients for `ven`, `resource`, `report` or `subscription` topics that are not limited to objects created by that client.

Data privacy mechanisms to restrict access of VEN clients to `program` and their associated `event` objects may be included in a future version of `[OADR3]`.

5.2.7. Event, Report, and other enumerations

The `[OADR3]` specification defines a large number of Event, Report, and other enumerations, suitable for a wide range of systems and scenarios. This section defines a small subset of these enumerations that are necessary for a residential DSR system as described above.

5.2.7.1. Event enumerations

Only the following standard enumerations need be supported for the scenarios given in this document. Additional standard enumerations may be supported for other scenarios.

Event Payload Type	Definition
PRICE	The price of energy. Payload value is a float. Units and currency defined in associated `eventPayloadDescriptor`.
GHG	An estimate of marginal GreenHouse Gas emissions, in g/kWh. Payload value is float.
IMPORT_CAPACITY_SUBSCRIPTION	The amount of import capacity a customer has subscribed to in advance. Payload is a float, and meaning is indicated by units in associated `eventPayloadDescriptor`. Used here to indicate a constraint on total import power to be permitted.
EXPORT_CAPACITY_SUBSCRIPTION	The amount of export capacity a customer has subscribed to in advance. Payload is a float, and meaning is indicated by units in associated `eventPayloadDescriptor`. Used here to indicate a constraint on total export power to be permitted.

The following extension enumerations need to be supported for the scenarios given in this document.

Event Payload Type	Definition
BID_PRICE	An unconfirmed bid of a changed price, typically used in conjunction with an OFFERED_DEMAND Report. Payload value is a float. Units and currency defined in associated `eventPayloadDescriptor`.

5.2.7.2. Report enumerations

Only the following standard enumerations need be supported for the scenarios given in this document. Additional standard enumerations may be supported for other scenarios.

Report Payload Type	Definition
READING	An instantaneous data point, as from a meter. Same as pulse count. Payload value is a float and units are defined in payloadDescriptor.
DEMAND	Power usage for an interval, i.e. Real Power. Payload value is a float, units defined in payloadDescriptor. Reading type indicates MEAN, PEAK, FORECAST.
USAGE	Energy usage over an interval. Payload value is a float and units are defined in payloadDescriptor.

The following extension enumerations need to be supported for the scenarios given in this document.

Report Payload Type	Definition
DEMAND_FLEX_MIN	The minimum forecast average power usage for an interval if incentivized to reduce usage, i.e. Real Power. Payload value is a float, units defined in payloadDescriptor. Reading type indicates FORECAST.
DEMAND_FLEX_MAX	The maximum forecast average power usage for an interval if incentivized to increase usage, i.e. Real Power. Payload value is a float, units defined in payloadDescriptor. Reading type indicates FORECAST.
OFFERED_DEMAND	Payload values array contains a single float indicating expected resource usage for the associated interval if the BID_PRICE is confirmed as the PRICE. Units of Real Power defined in payloadDescriptor.

The DEMAND_FLEX_MIN/MAX could alternatively be implemented by having new readingType values of FORECAST_FLEX_MIN/MAX and applied to the DEMAND payloadType. This is probably a better natural solution (and could then be applied to USAGE etc.), but has the drawback that currently the OADR specification does not permit more than one payload of the same payloadType (with different readingType or units) in the same Report, so would lead to 3 separate Reports for the IO, MIN and MAX values. Mechanisms to permit a single report to carry such multiple payloads may be included in a future version of `[OADR3]`: see Protocol efficiency and consistency.

5.2.7.3. Reading Types

Only the following standard enumerations need be supported for the scenarios given in this document. Additional standard enumerations may be supported for other scenarios.

Reading Type	Definition
DIRECT_READ	Payload values have been determined by direct measurement from a resource.
PEAK	Payload value represents the highest measurement over an interval.
FORECAST	Payload value is a forecast of future values, not a measurement or estimate of actual data

The following extension enumerations need to be supported for the scenarios given in this document.

Reading Type	Definition
NONE	

5.2.7.4. Target enumerations

Only the following standard enumerations need be supported for the scenarios given in this document. Additional standard enumerations may be supported for other scenarios.

Label	Definition
POWER_SERVICE_LOCATION	A Power Service Location is a utility named specific location in geography or the distribution system, usually the point of service to a customer site.
SERVICE_AREA	A Service Area is a utility named geographic region. Target values array contains a string representing a service area name.
GROUP	Target values array contains a string representing a group.
RESOURCE_NAME	Target values array contains a string representing a resource name.
VEN_NAME	Target values array contains a string representing a VEN name.
PROGRAM_NAME	Target values array contains a string representing a program name.

The following extension enumerations need to be supported for the scenarios given in this document.

Label	Definition
RESOURCE_TYPE	The type the Resource. The value is from the Resource Type enumerations

5.2.7.5. Attribute enumerations

Only the following standard enumerations need be supported for the scenarios given in this document. Additional standard enumerations may be supported for other scenarios.

Label	Definition
None	

The following extension enumerations need to be supported for the scenarios given in this document.

Label	Definition
RESOURCE_TYPE	The type the Resource. The value is from the Resource Type enumerations

5.2.7.6. Resource Type enumerations

Resource Type enumerations are need for the RESOURCE_TYPE used in targets and attributes. Further enumerations may be defined as needed for future use case scenarios.

Label	Definition
EVSE	Electric Vehicle Supply Equipment
BATTERY_STORAGE	Battery Electrical Storage System
HVAC	Heating, Ventilation, and Air Conditioning
SOLAR_PV	Solar PV Inverter

Label	Definition
WATER_HEATER	Water Heating appliance

5.2.7.7. Unit enumerations

Only the following standard enumerations need be supported for the scenarios given in this document. Additional standard enumerations may be supported for other scenarios.

Label	Definition
KWH	kilowatt-hours (kWh)
GHG	Greenhouse gas emissions (g/kWh)
VOLTS	volts (V)
AMPS	Current (A)
CELSIUS	Temperature (°C)
KW	kilowatts (kW)
KVA	kilovolt-amperes (kVA)
KVAR	kilovolt-amperes reactive (kVAR)

The following extension enumerations need to be supported for the scenarios given in this document.

Label	Definition
RH	Relative Humidity (%)

Chapter 6. Interworking (IW) scenarios

This section provides detailed message sequences for how the distinct Use Cases may be interworked between [OADR3] and [Matter]. There are many possible ways in which individual ESAs may be controlled, depending on the exactly which Matter Device Types and their contained Clusters and optional Features and Attributes they support. This section provides a typical example of such interworking based on the mandatory and/or typical features of such Matter devices.

The message sequences shown in these scenarios have been abridged by only including the key parameters explicitly, and by omitting most of the success responses unless important to the understanding of the scenario.

6.1. IW 1.x Standalone mode

This section provides the basic building-block use scenarios of some of the standalone mode use cases which are later reused when the EMS is connected to the DSRSP for optimization of the grid as well as the local energy usage.

6.1.1. IW 1.1.x Commissioning and joining EMS and ESA

6.1.1.1. IW 1.1.1 User sets up an EMS

This scenario is setting up and bringing into service the EMS, including commissioning the EMS onto the Matter fabric. There are several ways in which a device can be commissioned in Matter, as described in [Matter_Handbook], so these are not repeated here.

6.1.1.2. IW 1.1.2 User joins an ESA to an EMS

This scenario commissions the ESA to the matter fabric, and then configures the EMS to manage the newly connected ESA (see [Matter_Handbook]).

If the EMS is already enrolled and setup with the DSRSP, and the terms of the DSRSP Program require that this ESA be made individually visible to the DSRSP as a separate Resource (such as may be required for EVs for example, due to their peak power usage and large flexibility) then it also requires the creation of the new `resource` object and its associated subscriptions over [OADR3] as described in IW 2.3.1.

6.1.2. IW 1.2.x Removal of an ESA

6.1.2.1. IW 1.2.1 User removes an ESA from an EMS

This scenario reconfigures the EMS to stop managing the ESA using its GUI, and decommissioning the ESA from the Matter fabric (see [Matter]).

If the EMS is already enrolled and setup with the DSRSP, and this ESA has been made individually visible to the DSRSP as a separate Resource then it also requires the deletion of the `resource` object and its associated subscriptions over [OADR3] as described in IW 2.4.1.

NOTE	As discussed in UC 1.2.1 this scenario has some overlap with when an ESA device is factory reset (accidentally or deliberately), or in the case of [Matter] is explicitly removed from the fabric and decommissioned - see Decommissioning.

6.1.3. IW 1.3.x Setting of ESA preferences

6.1.3.1. IW 1.3.1 User sets or modifies their preferences

In this scenario the user updates their preferences, either on the EMS managing that ESA, or directly on the ESA concerned, using its built-in UI or via an associated app (and the EMS learns of the updates through its subscriptions to the updates to the ESA cluster attributes). As a result of these preference changes, an ESA with `DeviceOptimization` mode support may run its optimizer with the new preference values, and if necessary adjust the forecast. The EMS may also run its global optimizer to optimize the usage of this ESA and any other ESA which permit `LocalOptimization`.

If the EMS is already enrolled and setup with the DSRSP, this may change the forecast to the DSRSP, either immediately if the Program Events require it, or at the next standard reporting interval.

6.1.4. IW 1.4.x EMS Time of use optimization

6.1.4.1. IW 1.4.1 ESA time shifted

In this scenario a white goods (e.g. a dishwasher) appliance is allowed by the user to be optimized in `LocalOptimization` mode to have its start time adjusted by the EMS.

The ESA does not directly have access to the tariff data, but knows that it is after 8pm, and implicitly assumes that the user wants the dishwasher completed by 7am the next morning. The ESA produces a default Device Energy Management `Forecast` that includes a sensible default delayed start.

The EMS is informed that the ESA has been switched on by the updated power DEM `Forecast` attribute. The EMS re-optimizes the home energy use to take into account Time of Use tariff and determines a better time to start running the dishwasher program cycle using the DEM `StartTimeAdjustRequest` command.

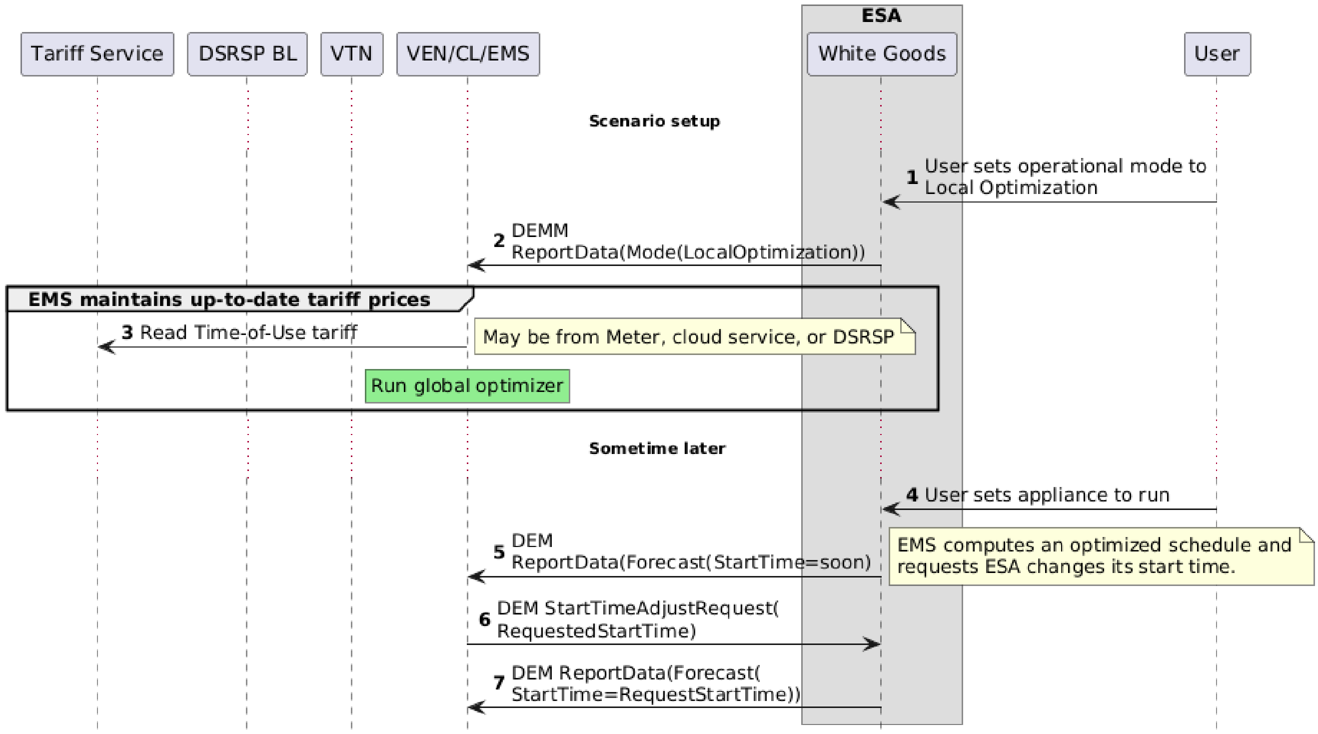

Figure 28. ESA time shifted to optimize cost based on Time-of-Use tariff

6.1.4.2. IW 1.4.2 ESA with tariff knowledge time shifts

In this scenario a white goods (e.g. a dishwasher) appliance has knowledge of the time of use tariff, and is allowed by the user to be optimized in `DeviceOptimization` mode to have its start time adjusted by its own knowledge of the tariff.

The ESA has direct access to the tariff data, and implicitly assumes that the user wants the dishwasher completed by 7am the next morning. The ESA produces a default Device Energy Management `Forecast` that delays the start until the time of use tariff gives the lowest cost time to run the appliance.

The EMS is informed that the ESA has been switched on by the updated power DEM `Forecast` attribute, but because the mode does not include `LocalOptimization`, the EMS does not attempt to change the schedule for the appliance. The EMS does re-optimize the rest of the home energy use to take into account the planned usage of the appliance.

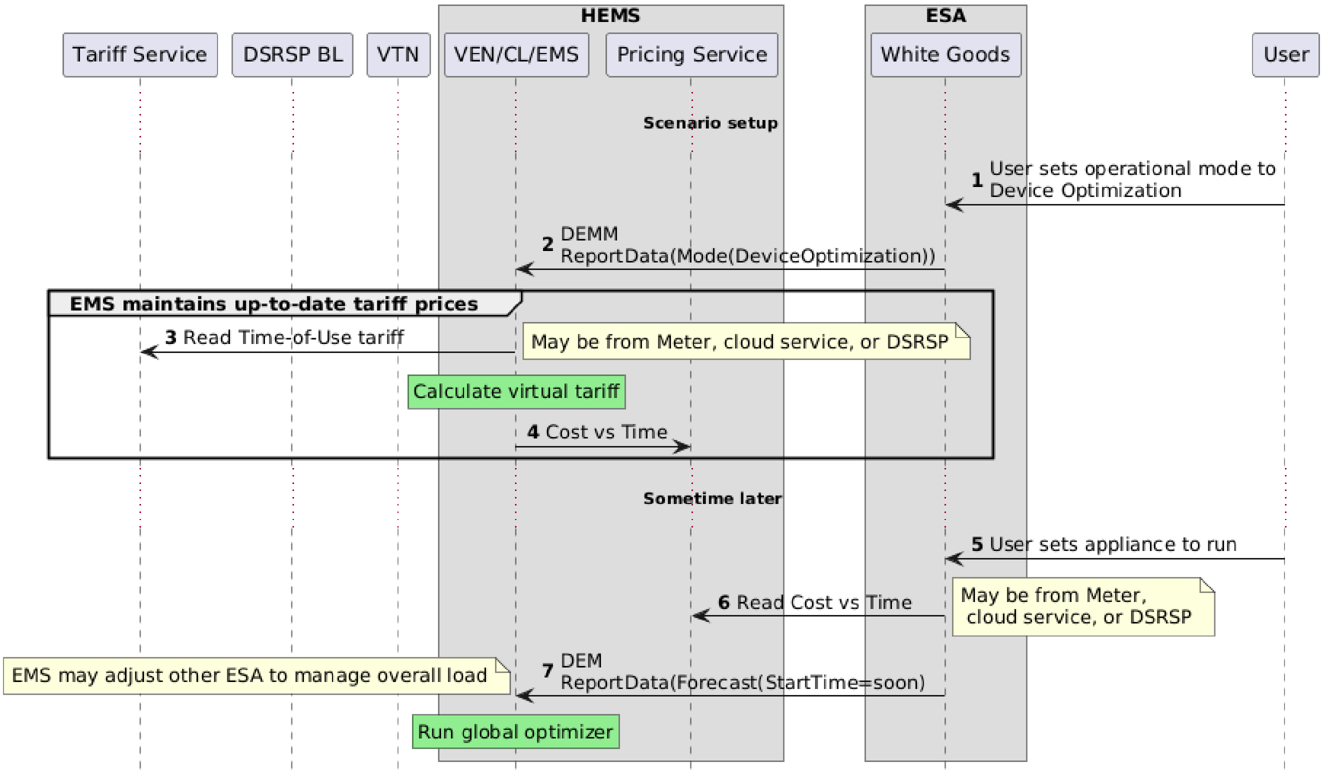

Figure 29. ESA time shifted to optimize cost based on Time-of-Use tariff

6.1.5. IW 1.5.x EMS using Solar energy

6.1.5.1. IW 1.5.1 EMS using Solar energy to charge Battery

In this scenario a BESS is controlled by the EMS to store any excess solar energy generated, and to discharge to avoid the need for energy import from the grid. The EMS continuously monitors the energy flowing at the smart meter using the Electrical Power Measurement cluster of the Smart Meter, and adjusts the battery charge/discharge rate continuously using the Device Energy Management `PowerAdjustRequest` commands in order to maintain the grid power close to zero.

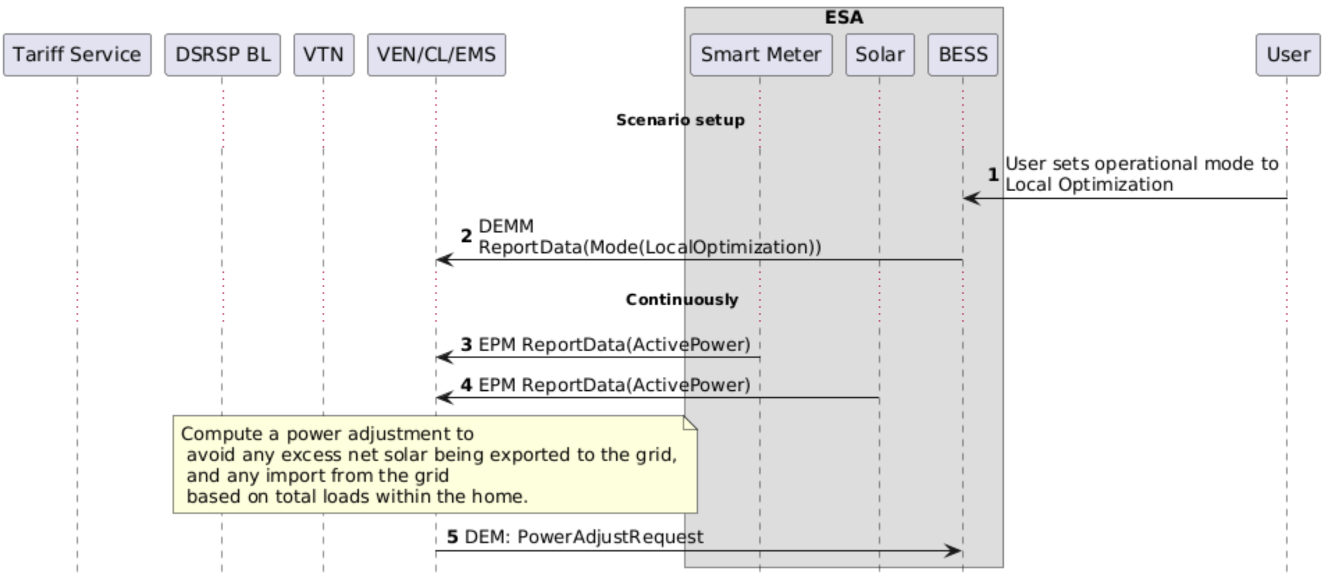

Figure 30. EMS manages battery charging to store excess Solar power

6.1.5.2. IW 1.5.2 EMS using Solar energy to schedule ESA operation

In this scenario a white goods appliance is controlled to make best use of the available solar power. The solar power device supports the DEM PFR feature using an external weather service to allow it to forecast its likely power production capability. The user permits the EMS (as a local optimizer) to optimize energy usage of the appliance. When the user starts the appliance, it forecasts its energy usage over the usage cycle, and the EMS decides to delay the start time until there is a forecast of sufficient solar power to run the appliance, and updates the appliance with this start time.

The appliance then starts at the scheduled time, but when it is part way through its cycle, the EMS receives an update from the solar power device that its power output has dropped (e.g. due to being in shade from cloud). Since the white goods is at a point in the cycle at which it permits a pause for a limited period, the EMS pauses the white goods cycle for that duration. When the solar power again increases as the cloud reduces, the EMS cancels the pause, and the normal cycle resumes to completion.

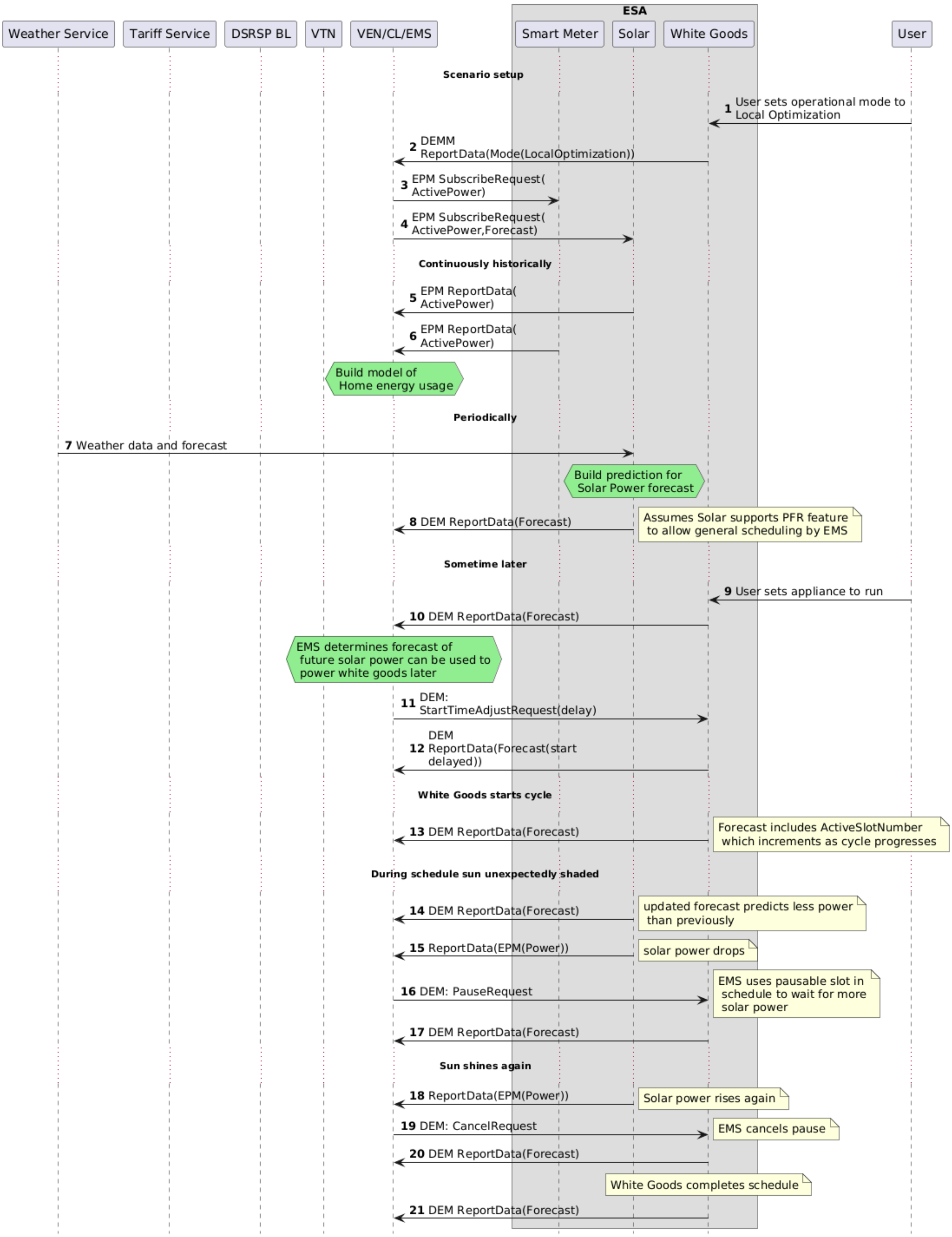

Figure 31. EMS schedules ESA to make use of Solar power

6.1.6. IW 1.6.x User opts out of optimization

6.1.6.1. IW 1.6.1 ESA optimization is disabled

In this scenario the user decides that they do not want to have any energy optimization on their white goods appliance, and so it runs immediately it is started by the user. The optimizer still maintains tariff data, and runs to optimize the other ESA in the house.

When the user starts the white goods appliance, the appliance updates its forecast to the EMS, which triggers it to run its optimizer for other ESA, but it does not alter the appliance for which the user has opted out of optimization.

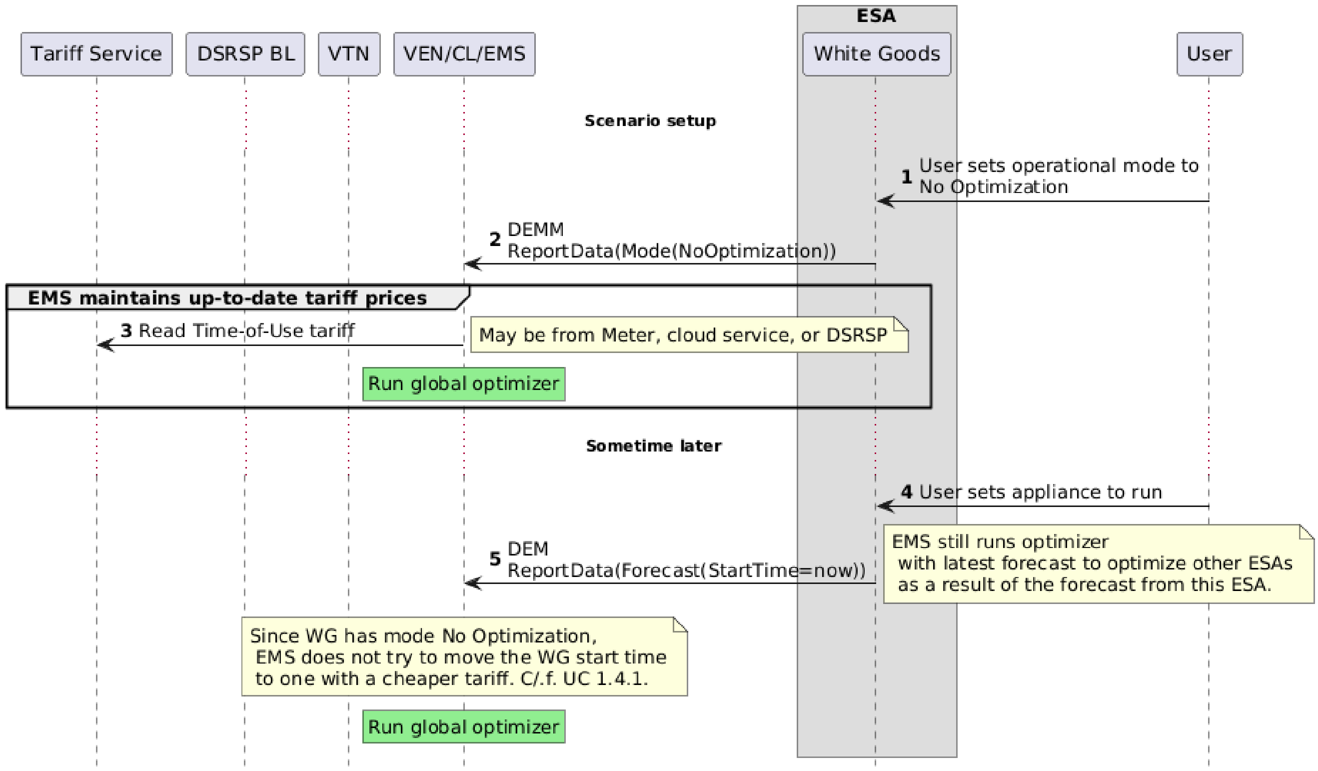

Figure 32. User opted out of optimization, so ESA optimization is disabled

6.1.6.2. IW 1.6.2 User opts-out of optimization

In this scenario the user has the appliance configured for local optimization by the EMS, and the optimizer maintains tariff data to allow optimization.

The user sets the appliance to start, which causes it to send its forecast of energy usage to the EMS, which triggers the optimizer to run, and determine the best time to start the appliance, and so requests a new start time to the appliance, which accepts it and updates its forecast to match.

Sometime later the user realizes that they do not want to wait for the appliance to run at a later time, so opts out of the optimization. This triggers the appliance to start immediately and update its forecast to the EMS. The EMS receives the revised forecast, and once again runs the optimizer to determine whether to make any changes to other ESA as a result.

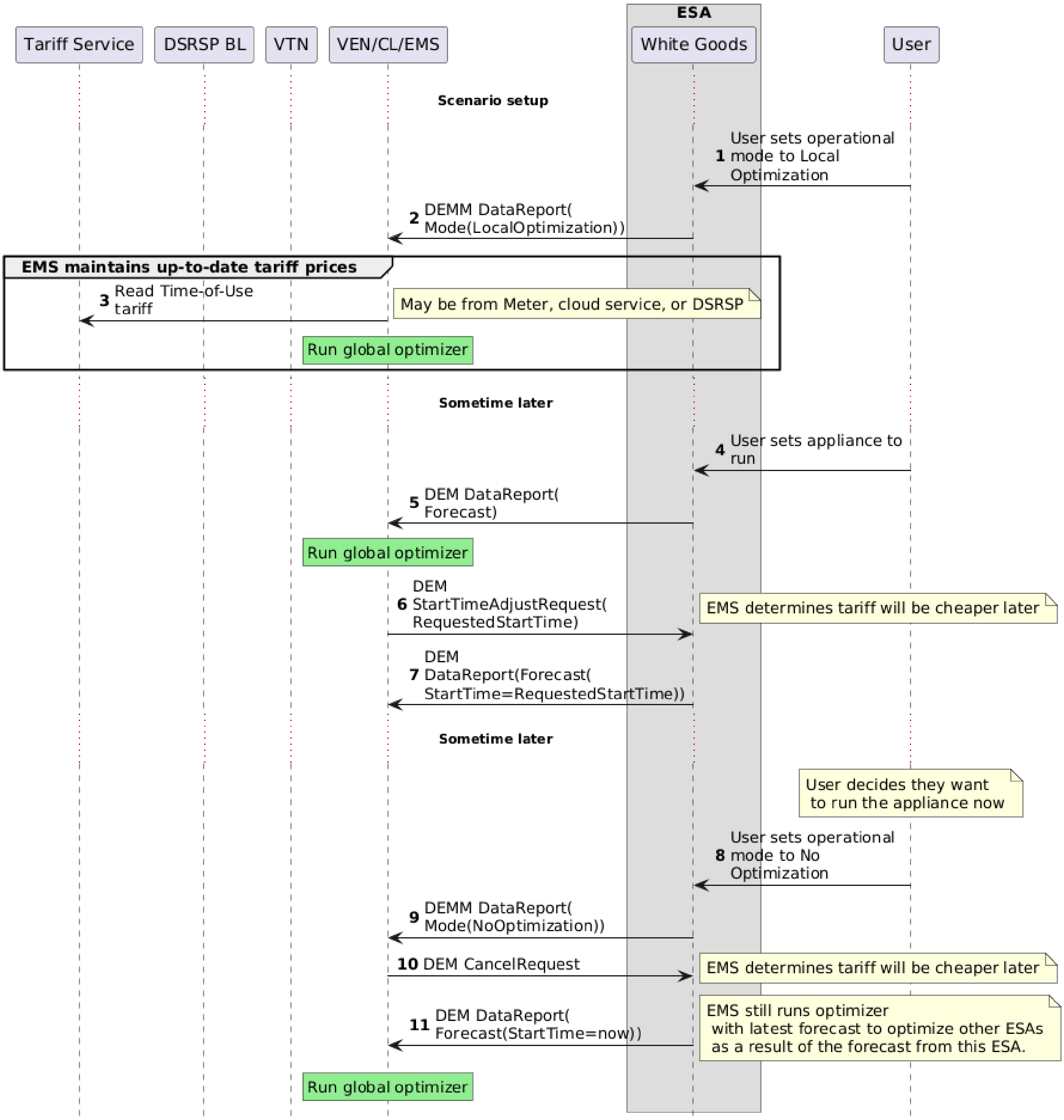

Figure 33. User opts out of optimization, so ESA optimization is cancelled

6.2. IW 2.x DSRSP-connected mode

6.2.1. IW 2.1.x Registration (OOB and In-band)

This section provides message sequences for the initial setup interactions between the user and the DSRSP over [OADR3]. The initial setup interactions between the user and the ESA in the home over [Matter] are generally speaking separate and asynchronous, and could occur in either order: establishing the interactions between EMS and DSRSP first or between EMS and the various ESA first (and may be different for the different ESA involved). Whilst strictly they do not provide any direct message interworking between the two sides of the EMS, they nevertheless have to be consistent in how the relationships are established in order for the later interworking scenarios to work. The details of the EMS to ESA setup interactions are shown in IW 1.x, and are assumed to have happened first in these scenarios unless otherwise shown.

6.2.1.1. IW 2.1.1 User enrolment with DSRSP

The first part of establishing a relationship between the user, its EMS, and the DSRSP uses standard web services and flows which are outside the scope of this document (but which will need agreement for overall system interoperability and security). A basic example of these flows are provided below, and possible alternative examples of these flows are given in the later section OAuth flow. The result of these is that the EMS has the URL for the VTN used by the DSRSP, and the user has an account created and associated login credentials with the DSRSP for the service also provided to the EMS.

The user creates a client account with the DSRSP on their web portal using a unique `clientName` and establishes the `client_secret` for authentication. The DSRSP establishes a unique `client_id` for the account, and configures the OAuth server with the account credentials and access rights, and returns the `client_id` (which may be different from the user-friendly `clientName`) to the user, along with the `venName` for their EMS (VEN), and the DSRSP service VTN URL.

The user configures their EMS with the client credentials, `venName`, and VTN URL to enable it to contact the VTN and create the initial objects in the VTN (see IW 2.3.1).

Changes to remove the need to share the venName out of band may be included in a future version of `[OADR3]`.

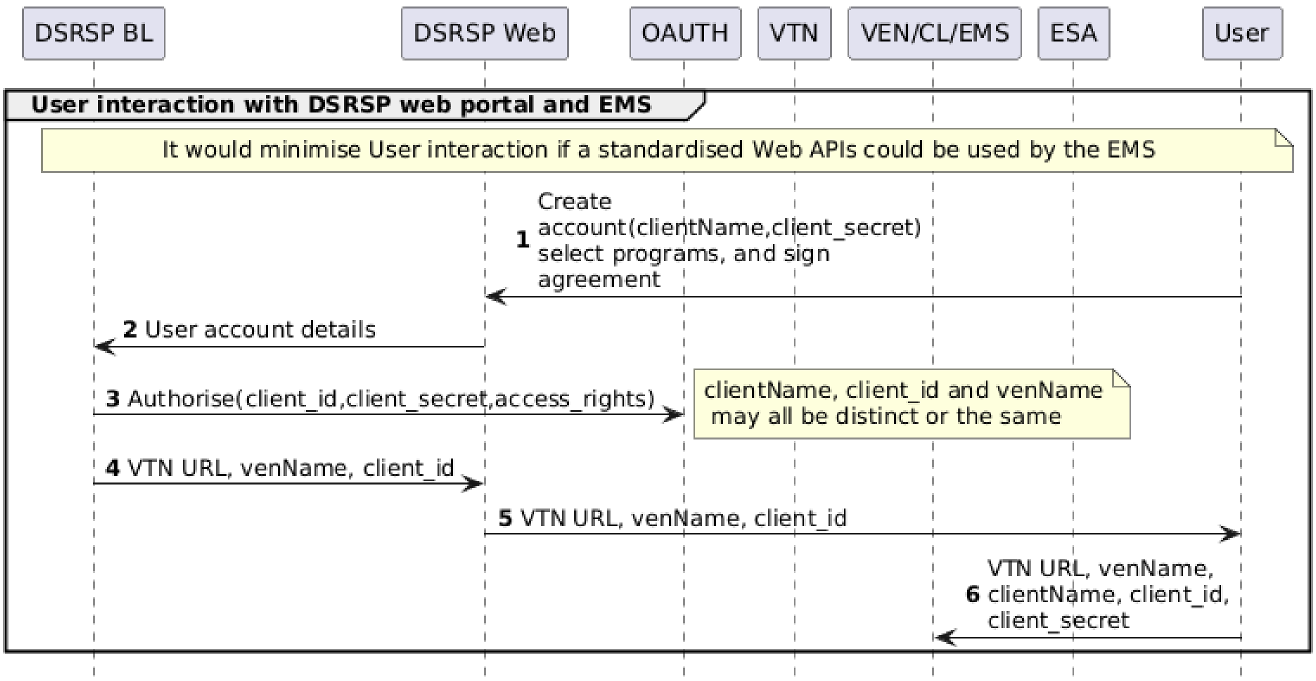

Figure 34. User enrolment with a DSRSP

6.2.2. IW 2.2.x User service termination

6.2.2.1. IW 2.2.1 User terminates their account

This scenario does not rely on an interworking between `[OADR3]` and `[Matter]`, as the EMS and DSRSP are each updated independently to remove the service knowledge of the other by the user and DSRSP BL respectively. Once the BL has removed the client contact details from the VTN (and/or OAuth server), any attempt by the EMS to contact the DSRSP will be rejected.

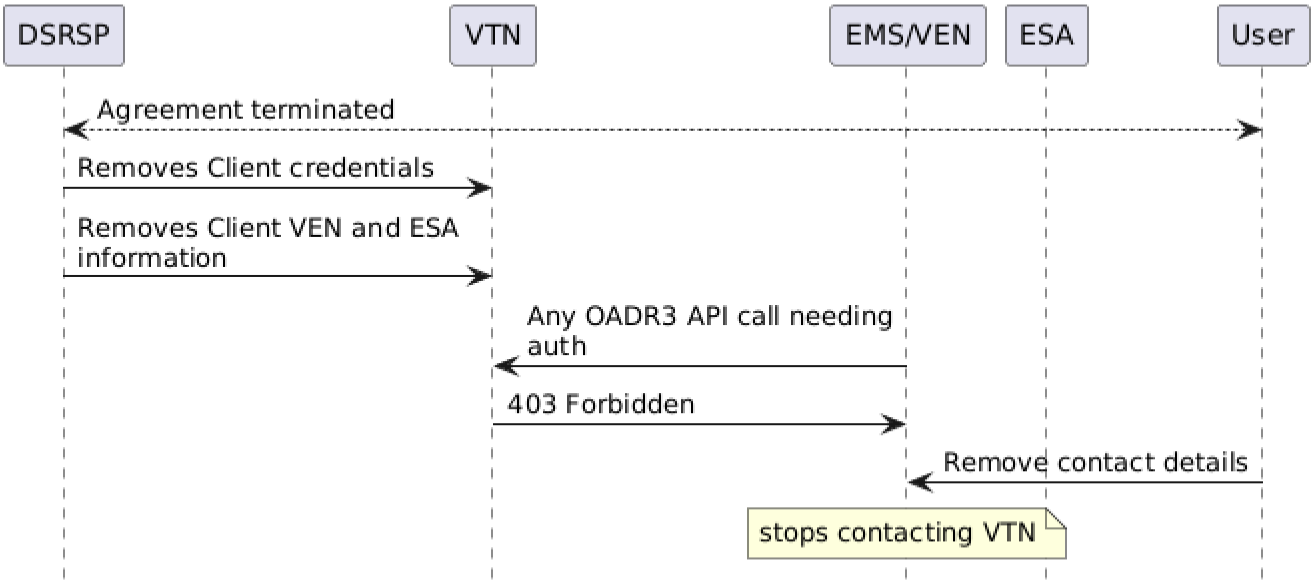

Figure 35. User terminates service with a DSRSP

6.2.3. IW 2.3.x EMS connects to DSRSP

6.2.3.1. IW 2.3.1 EMS initial connection to DSRSP

In this scenario the EMS makes first contact with the DSRSP VTN, creates the necessary objects in the VTN for the service as a whole (the `ven` object) and for ESA that are going to be individually visible to the DSRSP (if any), such as an EV (using `resource` objects).

Firstly the EMS contacts the authorization endpoint of the service, and uses its client credentials to obtain the OAuth bearer tokens used to identify and authenticate itself for all future interactions with the DSRSP VTN. See Security & Data Privacy considerations for more details on how these tokens are obtained, used and renewed, but further details of the OAuth interactions (e.g. for token renewal) are omitted from the future message sequences presented here. Possible alternative examples of these flows are also given in the later section OAuth flow.

The main part of this scenario is how the `[OADR3]` objects should be created and configured to provide the correct VTN and VEN environments for the later energy management scenarios.

The EMS creates the `ven` object which represents itself to the DSRSP, which the VTN authenticates using the presented bearer token, and responds with the `venId` for the new object.

> The use of the `targets` properties as described below goes beyond what is specified in OADRv3, but provides a plug-and-play method for a VEN to learn about the Programs to which it is associated without relying on more out-of-band information set by the user. See Creation and ownership of objects for further details.

The EMS then creates a subscription for its own `ven` object, so that it is notified whenever the DSRSP updates it.

On learning of the new `ven` object created by the VEN client account associated with the user, the DSRSP BL updates the `targets` property of the `ven` object to include the appropriate Programs and other Groups (and other targets) with which the VEN is associated. The VEN learns of this change through its subscription notification, and obtains the list of associated Programs, which it then uses to read and subscribe to the `event` objects associated with those `program` objects, filtered by the Group and any other targets that are relevant to itself.

The EMS then subscribes to any future updates to these `program` objects and reads them to display any useful information about them to the user.

If the EMS already has any ESA which are of a RESOURCE_TYPE which is required to be directly visible to the VTN (e.g. an EV for which the user has enrolled into a Program to permit the DSRSP to influence when it is charged in exchange for a cheaper tariff - see Creation and ownership of objects and Resource Type enumerations), the EMS at this point will also create the `resource` object(s) for the ESA under the `ven` object, and subscribes to them to learn of updates from the DSRSP. Once again the DSRSP updates the `resource\targets` property with the associated Program(s), Groups, etc., and the EMS subscribes to the `event` objects associated with those Program(s).

As for the `ven` object, the DSRSP learns of the new `resource` objects, and updates their `targets` to associate them with Programs, Groups and other targets, and the EMS subscribes to updates about any new Programs that it learns are associated. It also subscribes to future `event` objects associated to these Programs, filtered by the targets that are relevant to itself.

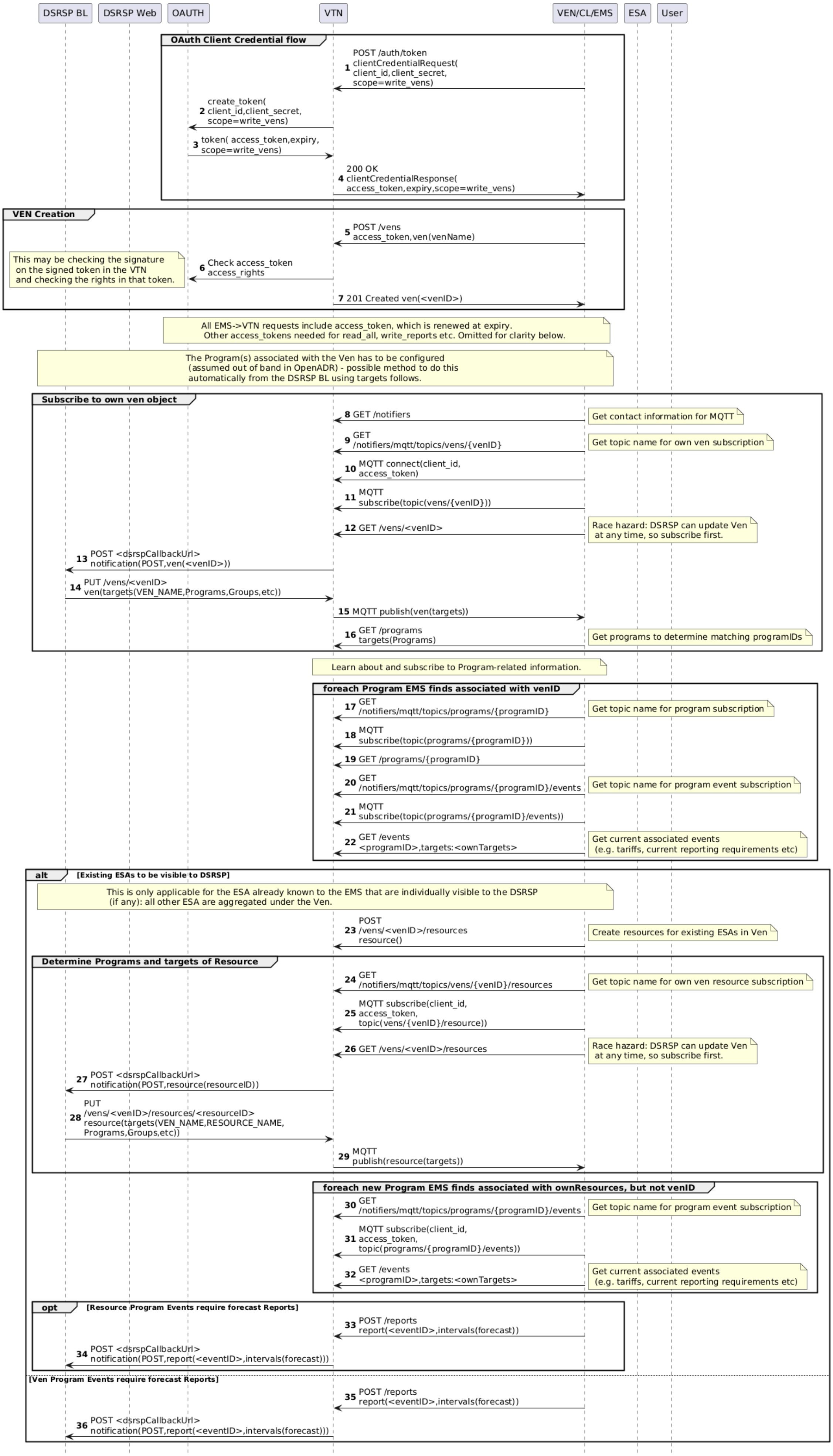

Figure 36. EMS initial connection to DSRSP

6.2.3.2. IW 2.3.2 EMS reconnection to DSRSP

In this scenario the EMS has lost its connection with the DSRSP (for example a power or networking outage). It has all its user credentials, Matter commissioning data, [OADR3] object identifiers saved in non-volatile storage. Using these, it reconnects to the Matter devices and re-subscribes to the relevant cluster attributes, and obtains their current values.

It also reconnects to the VTN MQTT broker and re-subscribes to the relevant MQTT topics for the object update notifications, and obtains the current status of those objects (to synchronize its state with any changes made by the DSRSP BL whilst it was offline).

When using MQTT for the delivery of notifications, the VTN does not need to retain the published messages. It also does not matter if the notification messages are received multiple times by the EMS, but message loss could cause problems, so the MQTT QoS level 1 is appropriate for both VTN and EMS to use.

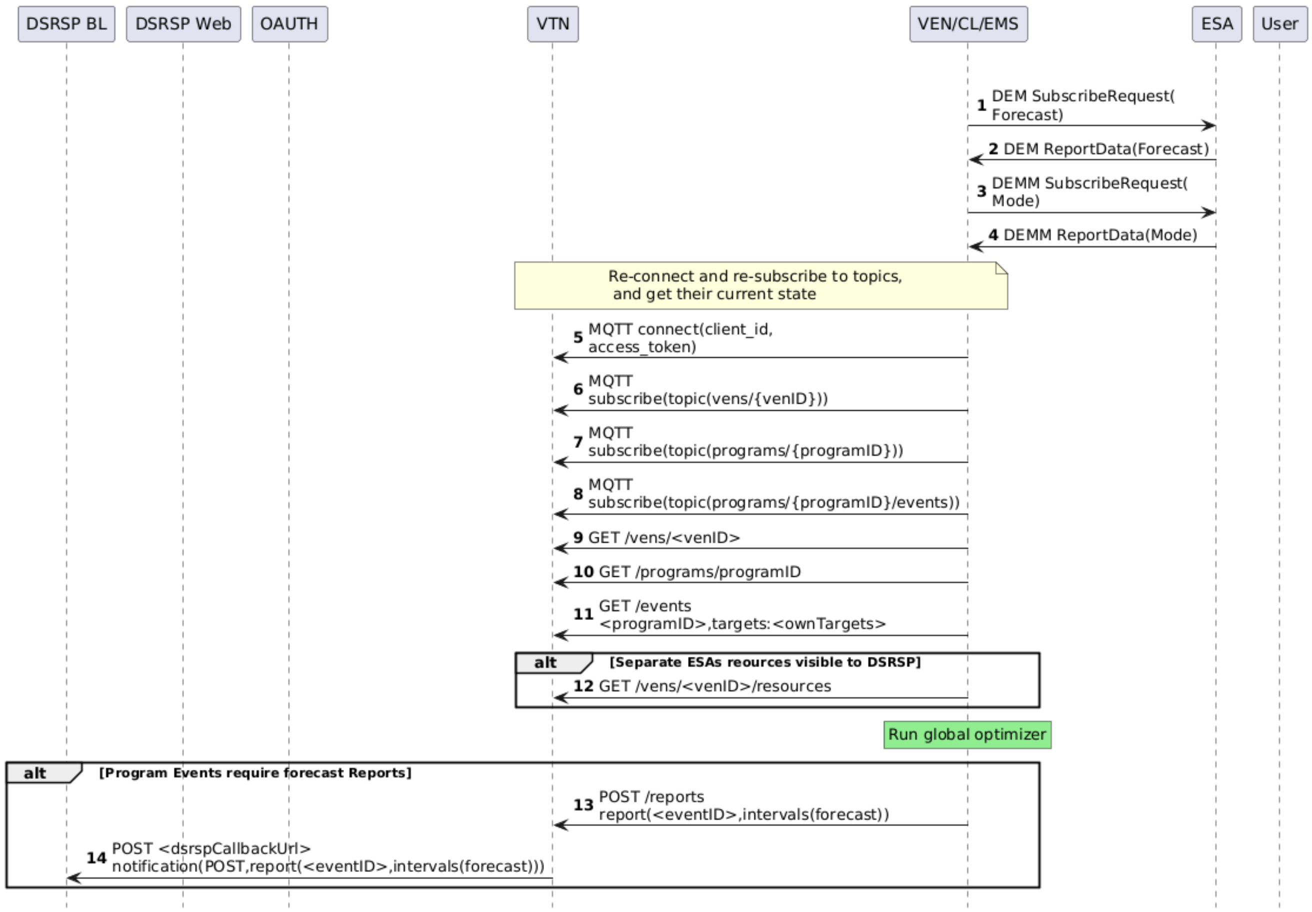

Figure 37. EMS reconnection to DSRSP

6.2.4. IW 2.4.x User changes DSRSP preferences

6.2.4.1. IW 2.4.1 User changes DSRSP tariff

In this scenario the user first uses the DSRSP web portal to change the tariff their account is using, which may cause the DSRSP to update the access rights of the client account to gain access to the new Program.

The DSRSP updates the `ven` (and `resource`) `target` properties to reflect the change in Programs, which are notified to the EMS, allowing it to create subscriptions to its newly associated Programs and its relevant Events. The EMS also deletes subscriptions to Programs and their Events and their associated Reports that it is no longer associated with.

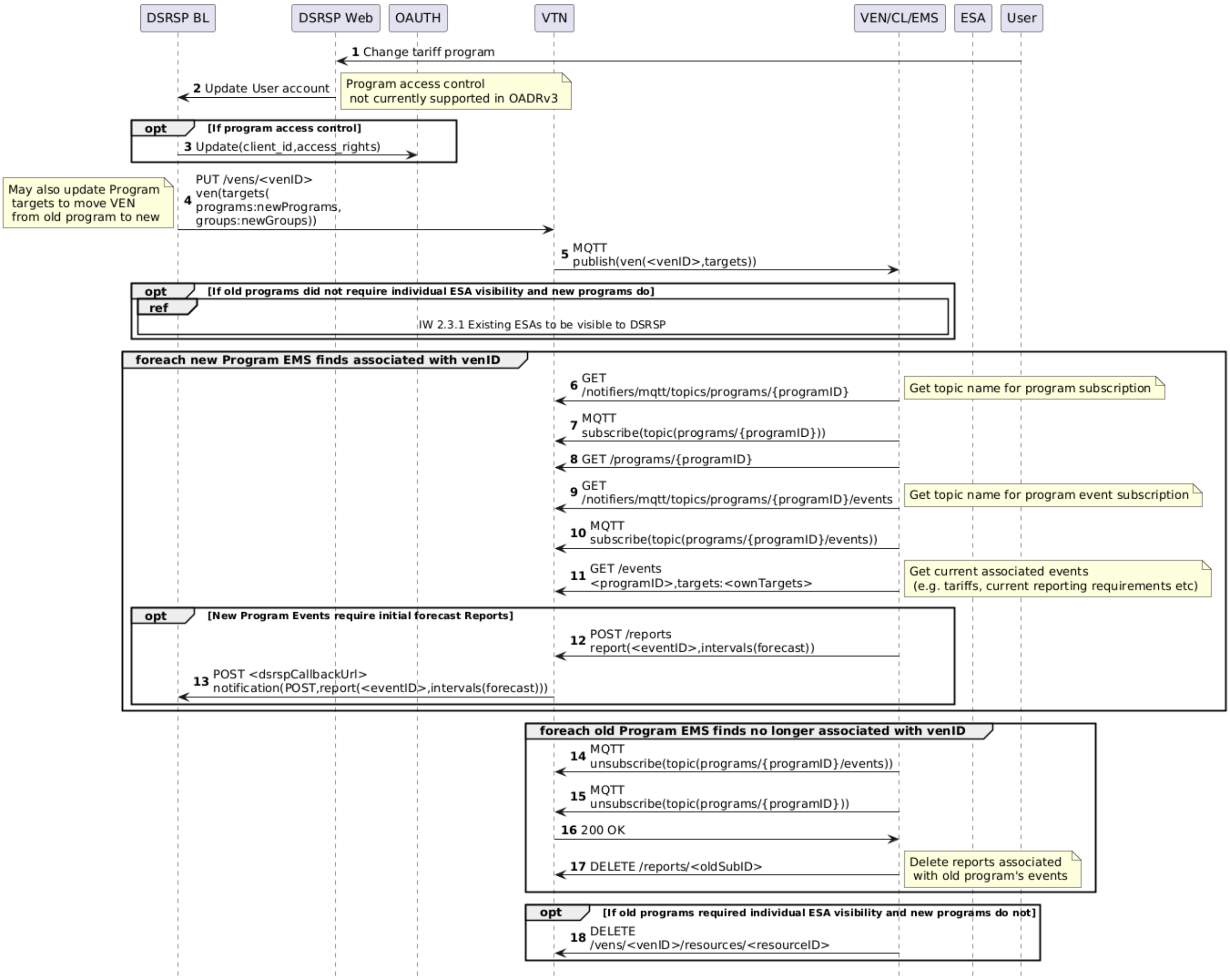

Figure 38. User tariff change

6.2.5. IW 2.5.x EMS provides forecast

6.2.5.1. IW 2.5.1 EMS provides forecast with flexibility

In this scenario the EMS is associated at enrolment with a Program which has a fixed Event which publishes a fixed tariff, and a second fixed Event which requires the EMS to provide regular (e.g. hourly) forecasts of energy usage, including indication of the flexibility it has in that usage (e.g. due to changes it could make to when an EV is charged).

The EMS maintains the current forecasts of the ESAs, which includes the amount of flexibility they have in their future usage, as described in:

- the `PowerAdjustmentCapability` attribute, within which the `PA` feature has to work. Although this describes the real-time adjustment capability of the device rather than anything about its forecast usage (e.g. it may be present on a battery storage device, which has no forecast capability, but the EMS can determine its state of charge), the EMS may predict the use of this adjustment capability in the future when optimizing the forecast of the future usage of the premise as a whole.

- the `EarliestStartTime` and `LatestEndTime` elements of the `Forecast` attribute, within which the `STA` features has to work. The EMS may offer flexibility by assuming it could start the device at times between these limits.
- the `MinDuration`, `MaxDuration`, `MinPowerAdjustment`, `MaxPowerAdjustment`, `MinDurationAdjustment`, `MaxDurationAdjustment` elements of the individual `Slot` elements of the `Forecast` attribute, within which the `FA` and `CON` features have to work. The EMS may offer flexibility by assuming it could adjust the device using those features between these limits to modify its future forecast and usage.
- the `SlotIsPausable`, `MinPauseDuration`, `MaxPauseDuration` elements of the individual `Slot` elements of the `Forecast` attribute (and the `IsPausable` element of the `Forecast` attribute), within which the `PAU` feature has to work. The EMS may offer flexibility by assuming it could pause the device using this features between these limits during the relevant slot times.

The EMS runs its optimizer, and may adjust the ESA usage using the DEM features to locally optimize the overall usage, as described in IW 1.4.1, IW 1.5.1, and IW 1.5.2.

To determine the flexibility to report to the DSRSP, the EMS uses the flexibility information in the `Forecast` attribute from the ESA as described above. Depending on exactly which DEM features each ESA supports, the EMS can be confident that it could make adjustments for the future schedules (using the `CON`, `FA`, or `STA` features, in that preference order), or could adjust the ESAs usage at future times (using the `PAU` or `PA` features as appropriate) if required to do so, and so reports the available flexibility in aggregate usage to the DSRSP.

At enrolment the EMS gets the Events associated with the Program, which may include updated prices, and also finds that one of the Events requires hourly reporting of forecast with flexibility, and so it maintains forecast updates from the ESA, and provides an initial aggregate forecast and subsequent hourly updates to the DSRSP.

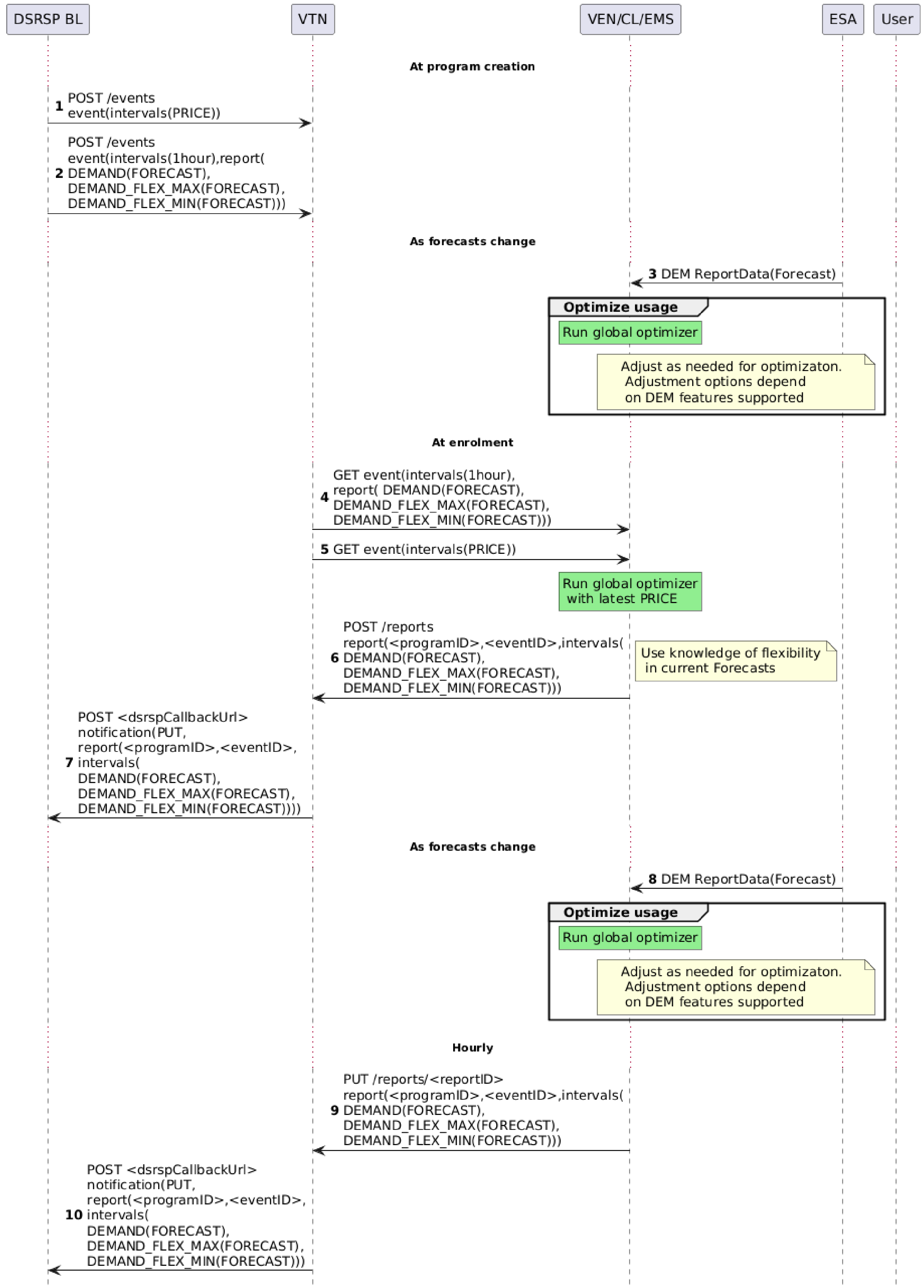

Figure 39. EMS provides regular flexibility reports

The Event in message 1 would typically contain a set of intervals that define the tariff price for every repeating 24 hour period, and no `reportDescriptor`. This could be a fixed Event for the Program which never changes.

> The ability to have a repeating set of intervals and the Event `duration` property may be included in a future version of [OADR3].


```
{
   "eventName": "FixedTariffEvent",
   "programID": "42",
   "duration": "P9999Y",
   "intervalPeriod": {
      "start": "2024-08-01T00:00:00",
   },
   "payloadDescriptors": [
      {
         "payloadType": "PRICE",
         "units": "KWH",
         "currency": "GBP"
      },
   ],
   "intervals": [
      {
         "id": 0,
        "intervalPeriod": {
            "duration": "PT6H"
        },
         "payloads": [
            {
               "type": "PRICE",
               "values": [
                  0.115
               ]
            }
         ]
      },
      {
         "id": 1,
        "intervalPeriod": {
            "duration": "PT18H"
        },
         "payloads": [
```

```
            {
               "type": "PRICE",
               "values": [
                  0.356
               ]
            }
         ]
      }
   ]
}
```

The Event in message 2 would typically contain a single one hour interval without a payload, and a `reportDescriptor` requesting the forecast, with maximum and minimum flexibility bounds (for if the DSRSP were to modify the incentive without changing the tariff), to be reported at hourly intervals for the next 24 hours, with reporting forever in the future, and using intervals to match the demand profile rather than the intervals in the Event. This could be a fixed event for the Program which never changes.

> The ability to have `intervals` to match the demand profile rather than the `intervals` in the `event`, and the `reportIntervals` property to control this, may be included in a future version of [OADR3].

```
{
   "eventName": "ForecastRequestEvent",
   "programID": "42",
   "duration": "P9999Y",
   "intervalPeriod": {
      "start": "2023-12-01T00:00:00.000",
      "duration": "PT1H"
   },
   "reportDescriptors": [
      {
         "payLoadType": "DEMAND",
         "readingType": "FORECAST",
         "units": "KW",
         "aggregate": true,
         "startInterval": 0,
         "historical": false,
         "frequency": 1,
         "reportIntervals": "OPEN_INTERVALS",
         "numIntervals": 24,
         "repeat": -1
```

```
      },
      {
         "payLoadType": "DEMAND_FLEX_MAX",
         "readingType": "FORECAST",
         "units": "KW",
         "aggregate": true,
         "startInterval": 0,
         "historical": false,
         "frequency": 1,
         "reportIntervals": "OPEN_INTERVALS",
         "numIntervals": 24,
         "repeat": -1
      },
      {
         "payLoadType": "DEMAND_FLEX_MIN",
         "readingType": "FORECAST",
         "units": "KW",
         "aggregate": true,
         "startInterval": 0,
         "historical": false,
         "frequency": 1,
         "reportIntervals": "OPEN_INTERVALS",
         "numIntervals": 24,
         "repeat": -1
      }
   ],
   "intervals": [
      {
         "id": 0,
         "payloads": [
            {
               "type": "REQUIRED_BUT_NOT_USED",
               "values": [
                  0
               ]
            }
         ]
      }
   ]
}
```

The Reports which are produced in message 6 refer to the event by its eventId (added by the VTN when the event was originally created), give the forecast data requested for the next 24 hours using payload intervals to match the times of demand change. The VEN uses the single value payloads with several intervals to match the forecast needs (only the first 2 shown below). The VEN sends the Report from the `AGGREGATED_REPORT` resource, which is defined to mean the aggregation of all usage under control of that VEN, which would typically be the whole premise usage.


```
{
   "reportName": "ForecastReport",
   "eventID": "2",
   "clientName": "venClientName",
   "payloadDescriptors": [
      {
         "payLoadType": "DEMAND",
         "readingType": "FORECAST",
         "units": "KW"
      },
      {
         "payLoadType": "DEMAND_FLEX_MAX",
         "readingType": "FORECAST",
         "units": "KW"
      },
      {
         "payLoadType": "DEMAND_FLEX_MIN",
         "readingType": "FORECAST",
         "units": "KW"
      }
   ],
   "resources": [
      {
         "resourceName": "AGGREGATED_REPORT",
         "intervalPeriod": {
            "start": "2025-02-03T08:00:00.000Z",
            "duration": "PT24H"
         },
         "intervals": [
            {
               "id": 0,
               "intervalPeriod": {
                  "duration": "PT32M"
               },
               "payloads": [
                  {
                     "type": "DEMAND",
```

```
            "values": [
              3.5
            ]
          },
          {
            "type": "DEMAND_FLEX_MAX",
            "values": [
              5.8
            ]
          },
          {
            "type": "DEMAND_FLEX_MIN",
            "values": [
              0.4
            ]
          }
        ]
      },
      {
        "id": 1,
        "intervalPeriod": {
          "duration": "PT3H15M"
        },
        "payloads": [
          {
            "type": "DEMAND",
            "values": [
              15.5
            ]
          },
          {
            "type": "DEMAND_FLEX_MAX",
            "values": [
              17.8
            ]
          },
          {
            "type": "DEMAND_FLEX_MIN",
            "values": [
              8.4
            ]
          }
```

```
                ]
            }
        ]
    }
  ]
}
```

6.2.6. IW 2.6.x DSRSP provides updates

6.2.6.1. IW 2.6.1 DSRSP provides incentive signal for whole premise

In this scenario the DSRSP is updating a variable tariff and other incentives such as GHG for the next hour, and a forecast of estimated incentives for subsequent hours, which the EMS receives via its subscription notification. The intervals in these Events may be to any granularity and timing, and may be customized to individual EMS to incentivize specific timing of their demand to manage the overall network load.

Having previously received forecasts from the various ESA, the EMS runs its optimizer with the new tariff information, and decides to adjust some of the ESA's energy usage using the DEM features. Depending on exactly which DEM features each ESA supports, the EMS can make adjustments for the future schedules (using the `FA`, `CON`, or `STA` features, in that preference order), or can adjust the ESAs current usage (using the `PAU` or `PA` features as appropriate) as required, any of which will cause the ESA to update its Forecast accordingly.

As part of such a tariff Program, the DSRSP Event also requires the EMS to report its updated demand forecast, which is delivered to the DSRSP by its subscription notification.

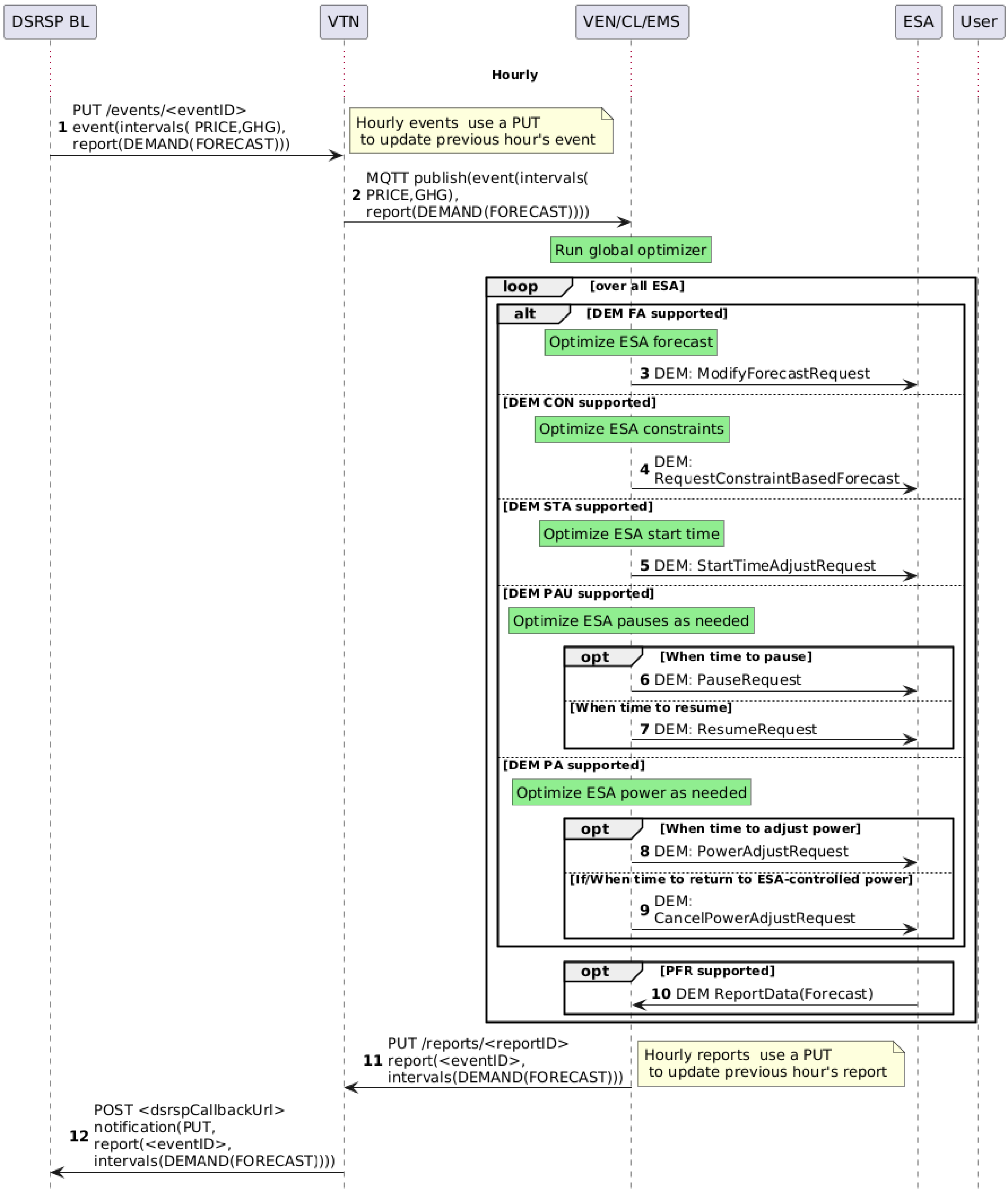

Figure 40. DSRSP sends incentive signal to EMS

The Event message 1, which is high priority, so overrides the normal standing tariff price Event, carries an interval with a specific start time for the incentive price for that EMS lasting for 5 hours, with the periods before and after this defaulting to the standing tariff prices. It requests a single Report in response with the forecast demand using VEN-determined `intervals`.

> The ability to have `intervals` to match the demand profile rather than the `intervals` in the `event`, and the `reportIntervals` property to control this, may be included in a future version of

[OADR3].


```
{
   "eventName": "IncentiveEvent",
   "programID": "42",
   "priority": 1,
   "intervalPeriod": {
      "start": "2025-02-13T00:00:00",
   },
   "payloadDescriptors": [
      {
         "payloadType": "PRICE",
         "units": "KWH",
         "currency": "GBP"
      },
   ],
   "reportDescriptors": [
      {
         "payLoadType": "DEMAND",
         "readingType": "FORECAST",
         "units": "KW",
         "aggregate": true,
         "startInterval": 0,
         "historical": false,
         "reportIntervals": "OPEN_INTERVALS",
         "repeat": 1
      },
   ],
   "intervals": [
      {
        "id": 0,
         "intervalPeriod": {
            "duration": "PT38M23S"
         },
         "payloads": [
            {
               "type": "PRICE",
               "values": [
                  0.155
               ]
            },
```

```
        {
          "type": "GHG",
          "values": [
            0.1
          ]
        }
      ]
    },
    {
      "id": 1,
      "intervalPeriod": {
        "duration": "PT5H"
      },
      "payloads": [
        {
          "type": "PRICE",
          "values": [
            0.085
          ]
        },
        {
          "type": "GHG",
          "values": [
            0.1
          ]
        }
      ]
    },
    {
      "id": 2,
      "intervalPeriod": {
        "duration": "PT18H21M37S"
      },
      "payloads": [
        {
          "type": "PRICE",
          "values": [
            0.155
          ]
        },
        {
          "type": "GHG",
```

```
                "values": [
                    0.1
                ]
            }
        ]
    }
  ]
}
```

The Report in message 11 carries the requested forecast with VEN-determined intervals (only the first 2 shown here).


```
{
    "reportName": "ForecastReport",
    "eventID": "5",
    "clientName": "venClientName",
    "payloadDescriptors": [
        {
            "payLoadType": "DEMAND",
            "readingType": "FORECAST",
            "units": "KW"
        }
    ],
    "resources": [
        {
            "resourceName": "AGGREGATED_REPORT",
            "intervalPeriod": {
                "start": "2025-02-13T00:00:00",
                "duration": "PT3H",
            },
            "intervals": [
                {
                    "id": 1,
                    "intervalPeriod": {
                        "duration": "PT38M23S",
                    },
                    "payloads": [
                        {
                            "type": "DEMAND",
                            "values": [
                                3.3
                            ]
```

```
                }
            ]
        },
        {
            "id": 2,
            "intervalPeriod": {
                "duration": "PT3H25M",
            },
            "payloads": [
                {
                    "type": "DEMAND",
                    "values": [
                        40.0
                    ]
                }
            ]
        },
    ]
  }
 ]
}
```


DSRSP Bidding to check demand flexibility

If the DSRSP wants to determine how the EMS will update its forecast if the DSRSP were to offer a different incentive, it can issue an Event to the EMS including a bidding offer. This bidding offer includes incentives signals (e.g. price and GHG) over time, and the DSRSP requests a Report back which would provide a new candidate forecast if those incentives were to be made firm.

The DSRSP may iteratively make incentive offers to multiple EMSs that are connected until it has achieved its upstream market position, and at this point may decide to commit these incentives to its preferred EMSs. This contract offer procedure is similar to the above, however in this case the ESAs are requested by the EMS to alter their behavior.

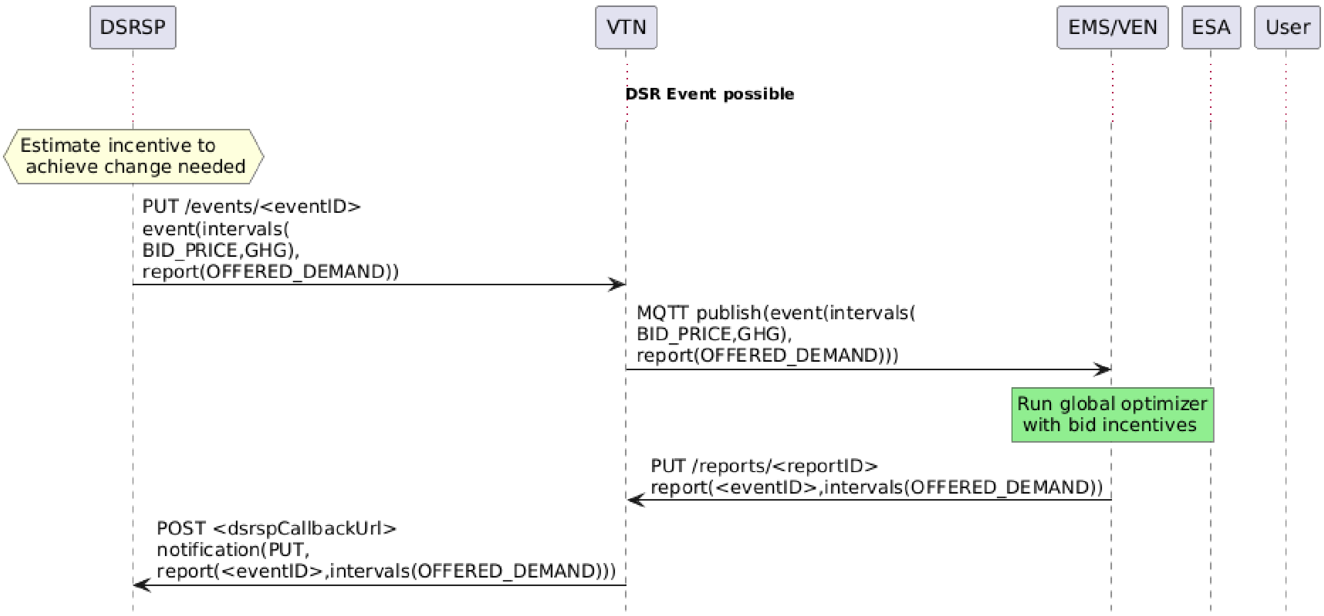

Figure 41. DSRSP sends EMS incentive signals to bid for a change in behavior

The Event and Report messages are essentially the same as used for variable incentive signals above, except that the Event interval `payloadType` in the event `payloadDescriptors` is a custom enumeration BID_PRICE rather than PRICE (see Event enumerations), to indicate that this is currently only a bid rather than a committed price. Additionally, the `payloadType` requested for the Report in the `reportDescriptors` is the OFFERED_DEMAND rather than DEMAND (see Report enumerations), to indicate that this is only the forecast if the BID_PRICE were to become a committed PRICE.

6.2.6.2. IW 2.6.2 DSRSP provides incentive tariff for specific ESA

In this scenario the DSRSP has direct visibility of the energy usage of an ESA such as an EV, so that it can offer a favorable tariff for the EV at certain times of the day (either at fixed times, or at a dynamically varying time depending on overall grid usage). The user configures the EVSE to permit Local Optimization of the charging, and plugs in the EV, which causes it to update its Forecast, which the EMS reports to the DSRSP.

The DSRSP (either periodically, or in response to the Forecast it has just received) sends an Event which provides the EV-specific tariff targeting the `resource` object representing the EV (or targeted at several EV within a local area group). The EMS uses the tariff information together with the flexibility included in the Forecast from the EVSE (as well as e.g. any other overall power constraints for the premise as a whole) to determine the best time to charge the EV, and uses the DEM features supported by the EVSE to control the charging to this schedule.

When the time comes to start charging the EV, the EMS subscribes to updates to the Electrical Energy Measurement cluster of the EVSE in order to get the energy usage over time for the EVSE.

At the end of charging, the EMS reports the energy usage over time to the DSRSP for the charging session, and unsubscribes from the EEM cluster updates. The EVSE updates its forecast (typically to no planned energy usage for the EV), and the EMS forwards this forecast to the DSRSP.

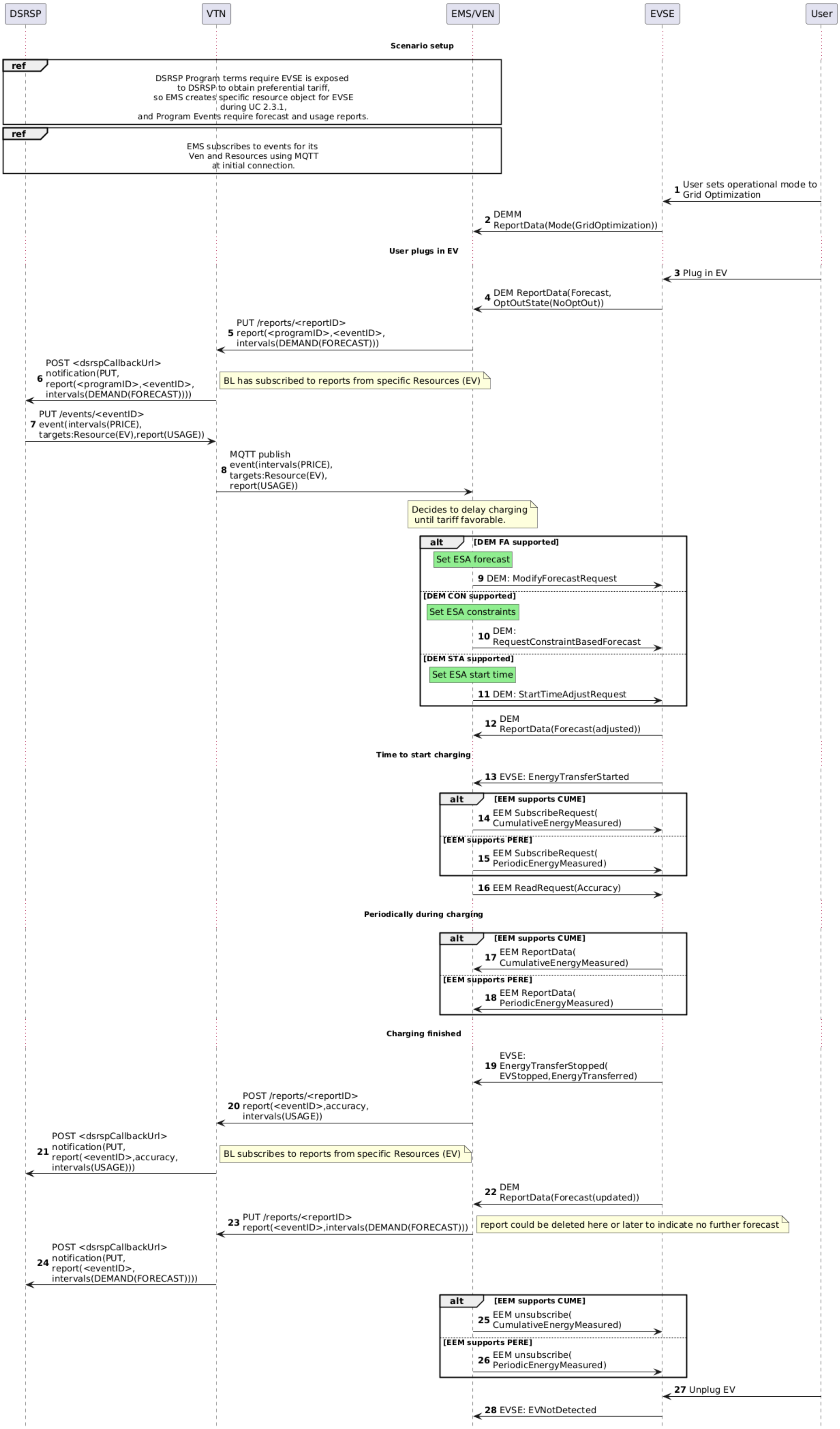

Figure 42. Incentive tariff for EV

6.2.6.3. IW 2.6.3 DSRSP provides power constraint for whole premise

In this scenario the DSRSP is providing a power constraint on the whole premise, which varies over time.

The Program that controls this scenario typically includes the EMS regularly reporting its historical actual energy usage over time, so that the DSRSP can build a baseline of typical usage.

When the DSRSP realizes the need to reduce the energy consumption in an area in the near future, it sends an Event with targets using area Group, Location, or Area targets of the `ven` objects, which the EMS has subscribed to, so is delivered as a notification.

The EMS already has all the current Forecasts of the ESA, which includes the amount of flexibility they have in their future usage from the current Forecasts, as described in IW 2.5.1.

The EMS runs its optimizer, and determines what changes need to be made to the ESA to meet the constraints requested. Depending on exactly which DEM features each ESA supports, the EMS can make adjustments for the future schedules (using the `CON`, `FA`, or `STA` features, in that preference order), or can adjust the ESAs current usage (using the `PAU` or PA` features as appropriate) as required now or in the future, any of which will cause the ESA to update its Forecast accordingly, and this is updated to the DSRSP in a new `report` object.

When the time of the DSR Event is reached, the EMS uses the `PAU` and `PA` DEM features to reduce the energy usage of those ESA that support those DEM features and may also make further adjustments with the `CON`, `FA`, or (for forecasts not yet started) `STA` features, and these too cause an updated forecast to be sent to the EMS. The EMS aggregates these forecasts and sends the aggregate forecast to the DSRSP in a periodic Report during the Event period.

At the end of the DSR Event period, the EMS sends an overall usage Report for the period, which the DSRSP can compare to the normal baseline consumption if needed to determine the overall effect of the Event.

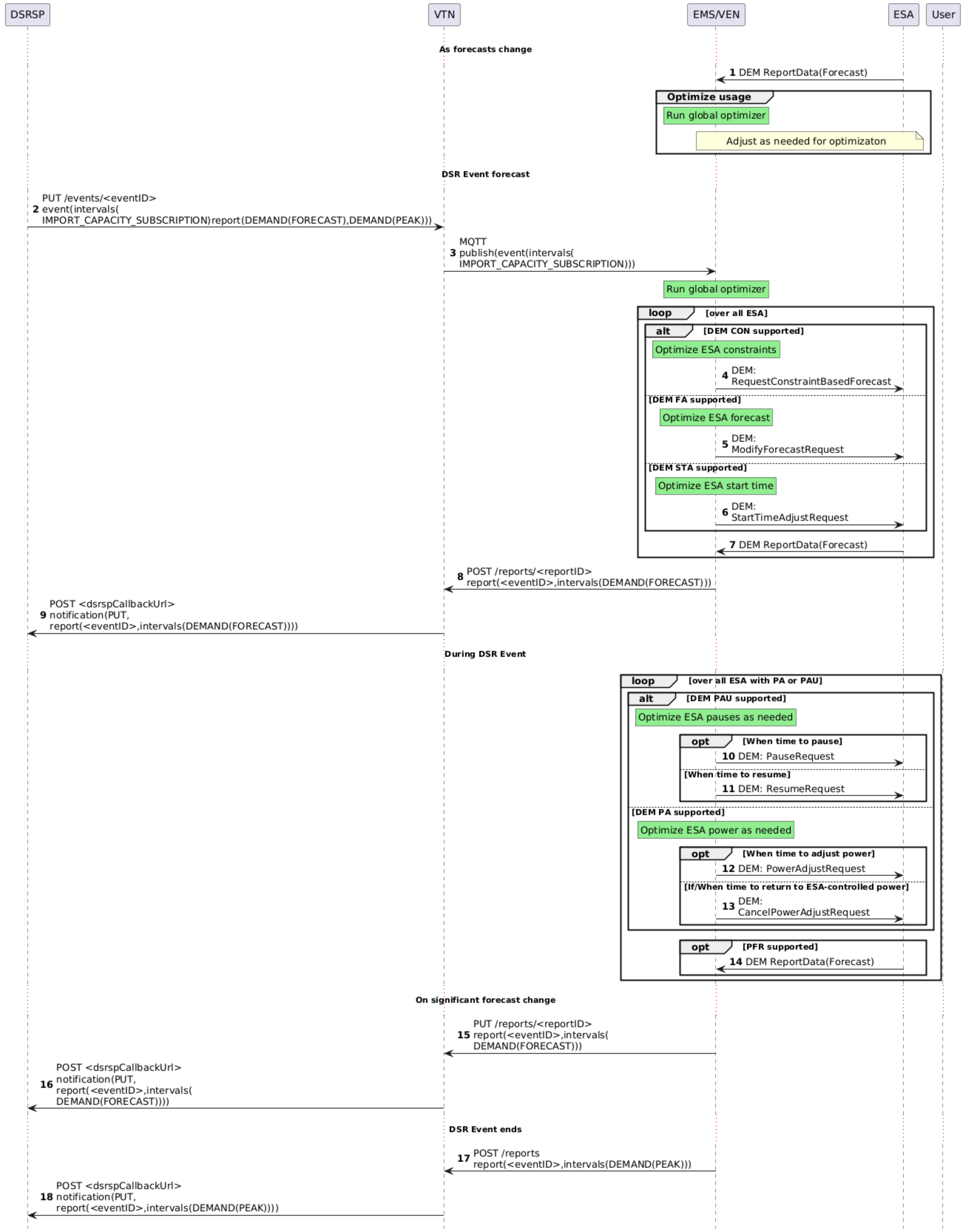

Figure 43. DSRSP requests constraints with User opted-in

The Event in message 1 is sent to many EMS within the constraint area, which is defined using the `targets` property of the `event`, which can be matched to the `targets` properties of the `ven` and `resource` objects to determine which objects the Event is aimed at. The `targets` property of the `ven` objects can be configured by the DSRSP with arbitrary labels, such as a single `VEN_NAME`, a set of one or more arbitrary GROUP`s, a `SERVICE_AREA (typically the reference to the LV network the premise is connected to) or `POWER_SERVICE_LOCATION` (typically a single connection point identifier, such as MPAN identifier). The DSRSP typically determines the targets to label the `ven` objects using its customer and network topology records at enrolment.

The message contains an interval that defines the constraint for a set of 18 evenly-spaced 15 minute sub-intervals for a three hour period in the near future. A 3 minutes randomization is applied to the start time of the constraint so that the changes to consumption that the constraint gives are spread over a period by the different EMS receiving the Event. The Event requests that the EMS reports the forecast demand at the start of the Event, and whenever the EMS chooses to (because it has changed), as often as it sees fit, and with whatever intervals (within the total duration of the Event) are appropriate for the payload values being reported. It also request a Report at the end for all the intervals in the Event of the actual peak demand in each interval of the Event intervals.

> The ability to have sub-intervals and a set of `payload` values defined within a single interval (rather than separate intervals for each payload value) may be included in a future version of `[OADR3]`.

```
{
   "eventName": "ConstraintEvent",
   "programID": "42",
   "intervalPeriod": {
      "start": "2025-02-01T18:00:00",
      "duration": "PT3H",
      "randomizeStart": "PT3M"
   },
   "payloadDescriptors": [
      {
         "payloadType": "IMPORT_CAPACITY_SUBSCRIPTION",
         "units": "KW",
      },
   ],
   "targets": [
      {
         "type": "SERVICE_AREA",
         "values": [
           "LV_NET_3", "LV_NET_5"
         ]
      }
   ],
   "reportDescriptors": [
      {
         "payLoadType": "DEMAND",
         "readingType": "FORECAST",
```

```
        "units": "KW",
        "aggregate": true,
        "reportIntervals": "OPEN_INTERVALS",
        "startInterval": 0,
        "numIntervals": -1,
        "historical": false,
        "frequency": 0,
        "repeat": -1
      },
      {
        "payLoadType": "DEMAND",
        "readingType": "PEAK",
        "units": "KW",
        "aggregate": true,
        "startInterval": -1,
        "numIntervals": -1,
        "historical": true,
        "frequency": 1,
        "repeat": -1
      }
    ],
    "intervals": [
      {
       "id": 0,
        "intervalPeriod": {
          "start": "2024-02-01T18:00:00",
          "duration": "PT3H",
          "randomizeStart": "PT3M"
        },
        "payloads": [
          {
            "type": "IMPORT_CAPACITY_SUBSCRIPTION",
            "values": [
              20.0, 18.0, 16.0, 15.0, 15.0, 15.0, 15.0, 15.0, 15.0, 15.0,
              15.0, 15.0, 15.0, 15.0, 15.0, 16.0, 18.0, 20.0
            ]
          }
        ]
      }
    ]
}
```

The Reports which are produced in message 7 refer to the Event by its `eventId` (added by the VTN when the `event` was originally created), give the forecast data requested for the next 3 hours, starting at the randomized start of the Event. The VEN uses individual intervals with timing to match the changes in power it is forecasting to demand over the Event period. Its demand is expected to start low, but then jump to the constrained demand profile for almost an hour before falling back to the low steady level for the rest of the Event duration.


```
{
   "reportName": "ForecastReport",
   "eventID": "5",
   "clientName": "venClientName",
   "payloadDescriptors": [
      {
         "payLoadType": "DEMAND",
         "readingType": "FORECAST",
         "units": "KW"
      }
   ],
   "resources": [
      {
         "resourceName": "AGGREGATED_REPORT",
         "intervalPeriod": {
            "start": "2025-02-01T18:02:12",
            "duration": "PT3H",
         },
         "intervals": [
            {
               "id": 1,
               "intervalPeriod": {
                  "duration": "PT13M30S",
               },
               "payloads": [
                  {
                     "type": "DEMAND",
                     "values": [
                        3.3
                     ]
                  }
               ]
            },
            {
               "id": 2,
               "intervalPeriod": {
```

```
            "duration": "PT6M30S",
          },
          "payloads": [
            {
              "type": "DEMAND",
              "values": [
                18.0
              ]
            }
          ]
        },
        {
          "id": 3,
          "intervalPeriod": {
            "duration": "PT10M",
          },
          "payloads": [
            {
              "type": "DEMAND",
              "values": [
                16.0
              ]
            }
          ]
        },
        {
          "id": 4,
          "intervalPeriod": {
            "duration": "PT38M",
          },
          "payloads": [
            {
              "type": "DEMAND",
              "values": [
                15.0
              ]
            }
          ]
        },
        {
          "id": 5,
          "intervalPeriod": {
```

```
                "duration": "PT1H52M",
              },
              "payloads": [
                {
                  "type": "DEMAND",
                  "values": [
                    3.3
                  ]
                }
              ]
            }
          ]
        }
    ]
}
```


The Report in message 14 would be similar, but have intervals and values to match the new forecast demand.

The Report in message 16 at the end of the constraint period would report the peak demand aligned to the original Event intervals, as requested, and could use the compact array form of the Report for the interval where there is significant change, and a single interval where the usage was flat.

> The ability to have sub-intervals and a set of payload values defined within a single `interval` (rather than separate `intervals` for each payload value) may be included in a future version of [OADR3].


```
{
  "reportName": "ForecastReport",
  "eventID": "5",
  "clientName": "venClientName",
  "payloadDescriptors": [
    {
      "payLoadType": "DEMAND",
      "readingType": "PEAK",
      "units": "KW"
    }
  ],
  "resources": [
    {
      "resourceName": "AGGREGATED_REPORT",
      "intervalPeriod": {
```

```
            "start": "2025-02-01T18:02:12",
            "duration": "PT3H",
          },
          "intervals": [
            {
              "id": 0,
              "intervalPeriod": {
                "duration": "PT1H10M",
              },
              "payloads": [
                {
                  "type": "DEMAND",
                  "values": [
                    3.3, 18.0, 16.0, 15.0, 15.0, 15.0, 3.3
                  ]
                }
              ]
            },
            {
              "id": 1,
              "intervalPeriod": {
                "duration": "PT1H50M",
              },
              "payloads": [
                {
                  "type": "DEMAND",
                  "values": [
                    3.3
                  ]
                }
              ]
            }
          ]
      }
    ]
}
```


6.3. IW 3.x General requirements

6.3.1. IW 3.1.x General reporting

6.3.1.1. IW 3.1.1 EMS reports in-home voltage, current, active/reactive power at boundary meter

In this scenario the DSRSP is requesting spot measurements of the state of the supply to the premises. The EMS makes the specific measurements requested at the meter and reports them.

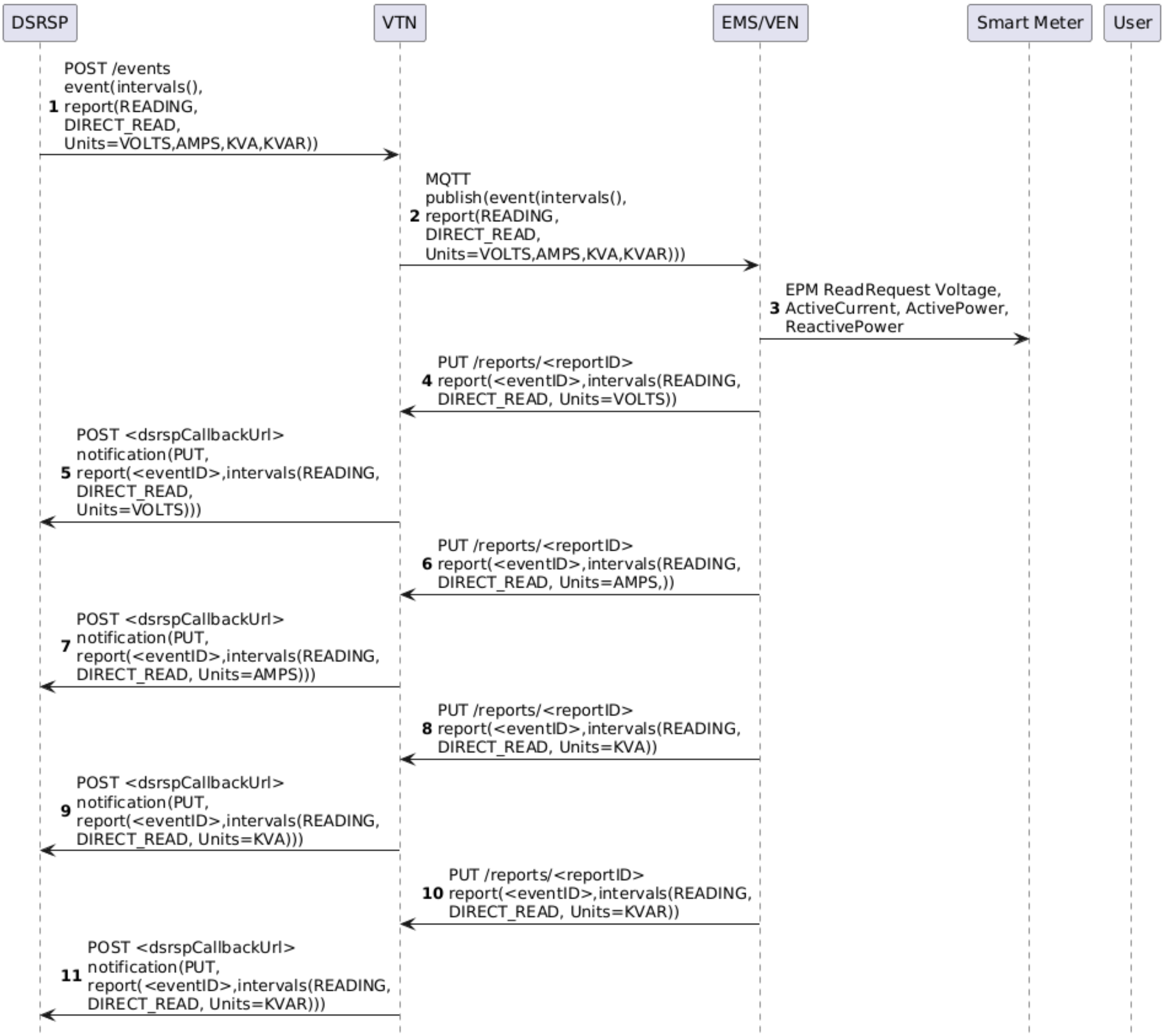

Figure 44. General Reporting

The DSRSP could establish this as a general Report at specific sampling intervals, or could request averaging of these measurements over intervals, and the EMS makes the corresponding changes to the reporting and measurements, but the basic scenario is as above.

The Event message 1 has a default start of immediately, carries no Event data, so has no intervals, and requests a single immediate Report of the measurements.

```
{
   "eventName": "MeasureSupplyEvent",
   "programID": "42",
   "intervalPeriod": {
```

```
      "start": "0000-00-00",
      "duration": "P9999Y"
   },
   "reportDescriptors": [
      {
         "payLoadType": "READING",
         "readingType": "DIRECT_READ",
         "units": "VOLTS",
         "aggregate": true,
      },
      {
         "payLoadType": "READING",
         "readingType": "DIRECT_READ",
         "units": "AMPS",
         "aggregate": true,
      },
      {
         "payLoadType": "READING",
         "readingType": "DIRECT_READ",
         "units": "KVA",
         "aggregate": true,
      },
      {
         "payLoadType": "READING",
         "readingType": "DIRECT_READ",
         "units": "KVAR",
         "aggregate": true,
      }
   ]
}
```


The Reports in messages 4, 6, 8 and 10 carry the requested measurements. A report cannot contain multiple payloads of the same payloadType, only distinguished by their units. The resulting response is therefore carried in 4 separate messages, each with one of the requested payloads. The first of these is given below for illustration.

> The ability to include multiple values with the same payloadType but differing in readingType and/or units in a single report may be included in a future version of [OADR3].


```
{
   "reportName": "MeasureSupplyReport",
   "eventID": "6",
```

```
    "clientName": "venClientName",
    "payloadDescriptors": [
      {
        "payLoadType": "READING",
        "readingType": "DIRECT_READ",
        "units": "VOLTS"
      }
    ],
    "resources": [
      {
        "resourceName": "AGGREGATED_REPORT",
        "intervalPeriod": {
          "start": "2025-02-13T00:00:00",
        },
        "intervals": [
          {
            "id": 0,
            "payloads": [
              {
                "type": "READING",
                "values": [
                  244.6
                ]
              }
            ]
          }
        ]
      }
    ]
}
```


6.3.1.2. IW 3.1.2 EMS reports in-home voltage, current, active/reactive power of specific ESA, including its reporting accuracy

This scenario is identical to IW 3.1.1 above, except that the EMS includes the optional accuracy property in the payloadDescriptors of the reports. The accuracy is in the same units as the payload values.

> There is currently no method in `[OADR3]` for the DSRSP to request in the event that the VEN client includes the optional accuracy property in the reports.


```
{
```

```
    "reportName": "MeasureSupplyReport",
    "eventID": "6",
    "clientName": "venClientName",
    "payloadDescriptors": [
      {
        "payLoadType": "READING",
        "readingType": "DIRECT_READ",
        "units": "VOLTS",
        "accuracy": 0.75
      }
    ],
    "resources": [
      {
        "resourceName": "AGGREGATED_REPORT",
        "intervalPeriod": {
          "start": "2025-02-13T09:31:17",
        },
        "intervals": [
          {
            "id": 0,
            "payloads": [
              {
                "type": "READING",
                "values": [
                  244.6
                ]
              }
            ]
          }
        ]
      }
    ]
  }
```


6.3.1.3. IW 3.1.3 EMS reports in-home temperature and humidity data

This scenario is identical to IW 3.1.1 above, except that the EMS requests the temperature and humidity data from the sensors on the relevant Matter devices, rather than the energy values from the EPM cluster on the smart meter. If the Event is sent to the general `ven` object (which represents the whole premise) this may be Temperature Sensor and Humidity Sensor devices associated with HVAC devices for the premise, whereas if it is sent to a specific `resource` object (which represent a specific ESA) it should be measured by similar devices or measurement clusters associate with the specific ESA.

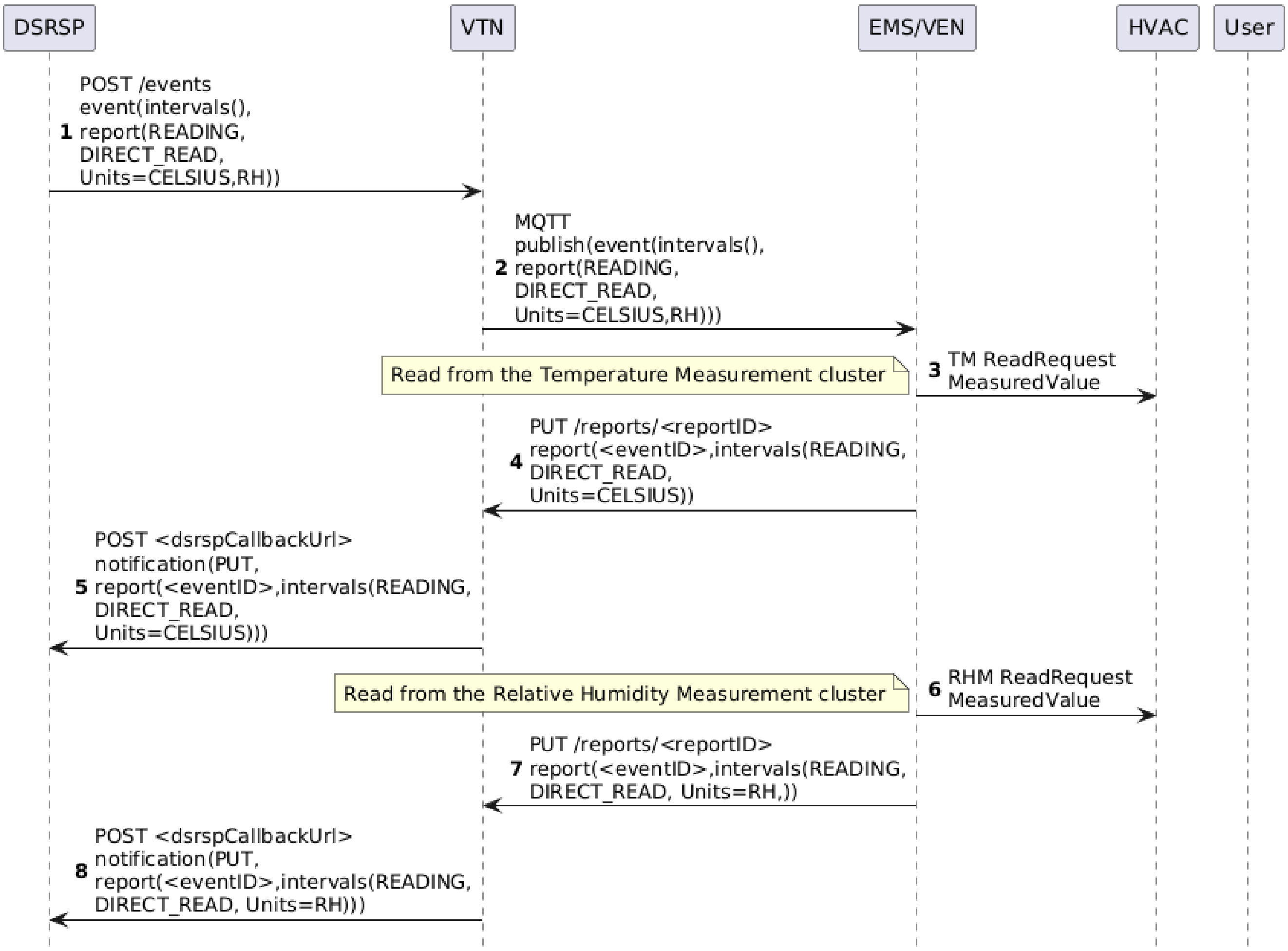

Figure 45. Temperature and Humidity Reporting

The Event message 1 has a default start of immediately, carries no Event data, so has no `intervals`, and requests an immediate single Report of the measurements.

```
{
   "eventName": "MeasureEnvironmentEvent",
   "programID": "42",
   "intervalPeriod": {
      "start": "0000-00-00",
      "duration": "P9999Y"
   },
   "reportDescriptors": [
      {
         "payLoadType": "READING",
         "readingType": "DIRECT_READ",
         "units": "CELSIUS",
         "aggregate": true,
      },
      {
         "payLoadType": "READING",
         "readingType": "DIRECT_READ",
```

```
            "units": "RH",
            "aggregate": true,
        }
    ]
}
```


The Reports in messages 4 and 6 carry the requested measurements. The first of these is given below for illustration.


```
{
    "reportName": "MeasureEnvironmentReport",
    "eventID": "7",
    "clientName": "venClientName",
    "payloadDescriptors": [
        {
            "payLoadType": "READING",
            "readingType": "DIRECT_READ",
            "units": "CELSIUS"
        }
    ],
    "resources": [
        {
            "resourceName": "AGGREGATED_REPORT",
            "intervalPeriod": {
                "start": "2025-02-13T09:53:22",
                "duration": "PT0H"
            },
            "intervals": [
                {
                    "id": 0,
                    "payloads": [
                        {
                            "type": "READING",
                            "values": [
                                19.6
                            ]
                        }
                    ]
                }
            ]
        }
    ]
```

```
}
```

6.3.2. IW 3.2.x Swap-out of EMS

6.3.2.1. IW 3.2.1 EMS needs to be changed or swapped out (replacement or upgraded to newer device)

This scenario either involves no interworking between OpenADR and Matter, because all the EMS information is transferred from the old EMS to the new one, or essentially requires the initial setup to be performed identical to IW 2.3.1.

6.3.3. IW 3.3.x Change of Tenancy

6.3.3.1. IW 3.3.1 The tenant of the property has changed, implying a change of contract. The existing equipment may remain.

This scenario requires a change of contract, so is a complete termination of service (IW 2.2.1) followed by enrolment (IW 2.1.1) and initial setup (IW 2.3.1) of a new service.

6.3.4. IW 3.4.x Change of Supplier

6.3.4.1. IW 3.4.1 The user has changed their energy utility base tariff, but the DSRSP remains the same.

In this scenario, if the tariff information is provided by means other than [OADR3] then there is no difference from any of tariff update and optimization scenarios above.

If the tariff information is provided over [OADR3] then this is identical to the change of tariff above (IW 2.4.1).

6.3.5. IW 3.5.x Billing

6.3.5.1. IW 3.5.1 Informing the utility, DSRSP and user about how much has been awarded as a result of flexibility events.

Since this scenario is sharing out of band information, there is no interaction over [OADR3] or [Matter] for this.

Chapter 7. Security & Data Privacy considerations

7.1. Matter security

The [Matter] specification includes comprehensive security and data privacy requirements in its chapter 13, which aim to comply with international regulations on cyber security for IoT devices. It includes features that are built into the specification itself regarding:

- Device Attestation Certificates - that prove the device is certified by the Connectivity Standards Alliance and manufactured by a Connectivity Standards Alliance member.
- Advertising - ensuring that devices do not continue to broadcast BLE advertising for long periods which may give away data privacy details
- Commissioning - ensuring that devices can be securely paired to join a fabric, and that only permitted other devices can communicate and access specific clusters and attributes.
- Firmware management
- Storage and protection of keys on the device
- Anti-tampering features both once installed and in manufacturing processes
- Distributed Compliance Ledger (DCL) capability so that product vendors can post data about their product in a standard format, including firmware update URLs

[Matter] chapter 13 also includes a detailed list of threats and countermeasures. Each new feature that is developed is peer reviewed by experts as part of the Connectivity Standards Alliance specification development process.

7.2. OpenADR 3 security

The [OADR3] specification mandates the use of TLS for transport security for both the OpenAPI interface and the MQTT interface. Version 1.2 of TLS is currently mandatory, with version 1.3 optional. A future version of [OADR3] may increase this TLS version requirement.

- It is recommended that TLS v1.3 be mandated for system security.

The [OADR3] specification use of TLS effectively mandates the use of X.509 certificates for the VTN, but currently does not mandate any particular profile for them.

- It is recommended that a profile for VTN certificates and minimum validation of them by the VEN clients be established to ensure secure interoperability.
- It is recommended that use of a well-defined set of root of trust certificates from reputable certificate authorities be required for all VENs to use in the VTN certificate validation.

7.2.1. OAuth flow considerations

The [OADR3] specification states the use of OAuth v2 for authentication and access control to the

VTN, includes in the YAML specification support for the standard Client Credentials flow, i.e. access control based on a client_id and client_secret, and mandates that all clients support that flow. It does not preclude other flows being supported by clients too. The user interactions to perform the client credentials flow are described in the figure below.

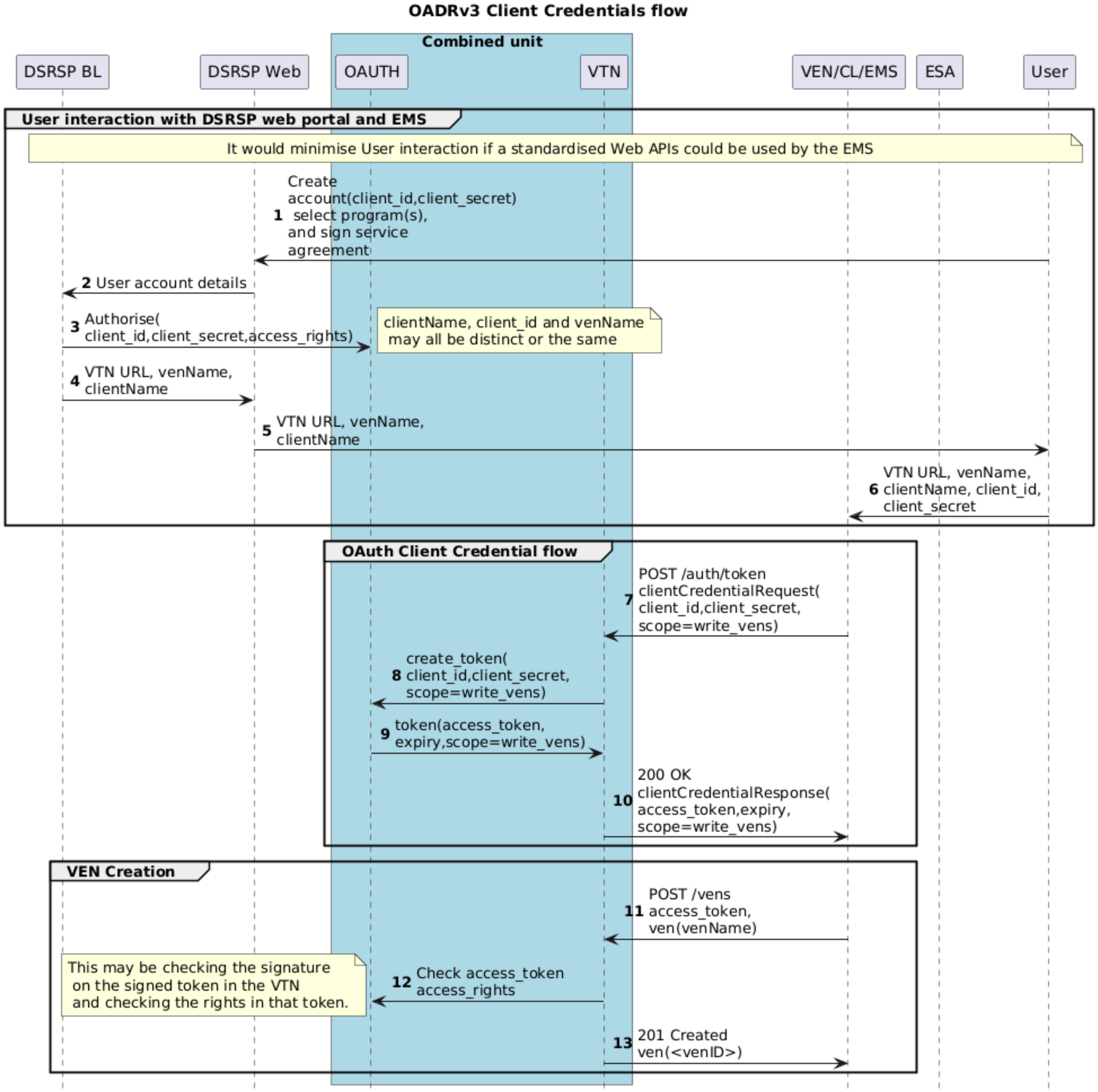

Figure 46. OAuth Client Credentials flow for enrolment

This flow does however require the user to transfer several pieces of information between the EMS and the DSRSP manually, which is off-putting for the user, error prone, and requires a textual UI for input and output on the EMS.

Since the [OADR3] specification does not preclude other flows, an additional standard OAuth v2 flow which may be beneficially used by the VEN and VTN is the Device flow, which is designed for devices with low capability UIs, especially poor text input UIs, such as smart TVs. It permits the user to perform the authorization of the device on a separate web browser (or smart phone app) using only a device code displayed on the user device, ideally as a QR code. When used for the EMS, the device flow requires the EMS UI to be used for selecting one of a set of pre-configured DSRSPs. For this flow the [OADR3] venName would have to be input to the EMS if this is still required to be used as the key to associating the ven with the client account by the BL. A change to remove need to share the venName out of band and input it to the EMS may be included in a future version of [OADR3].

This alternative flow is illustrated below.

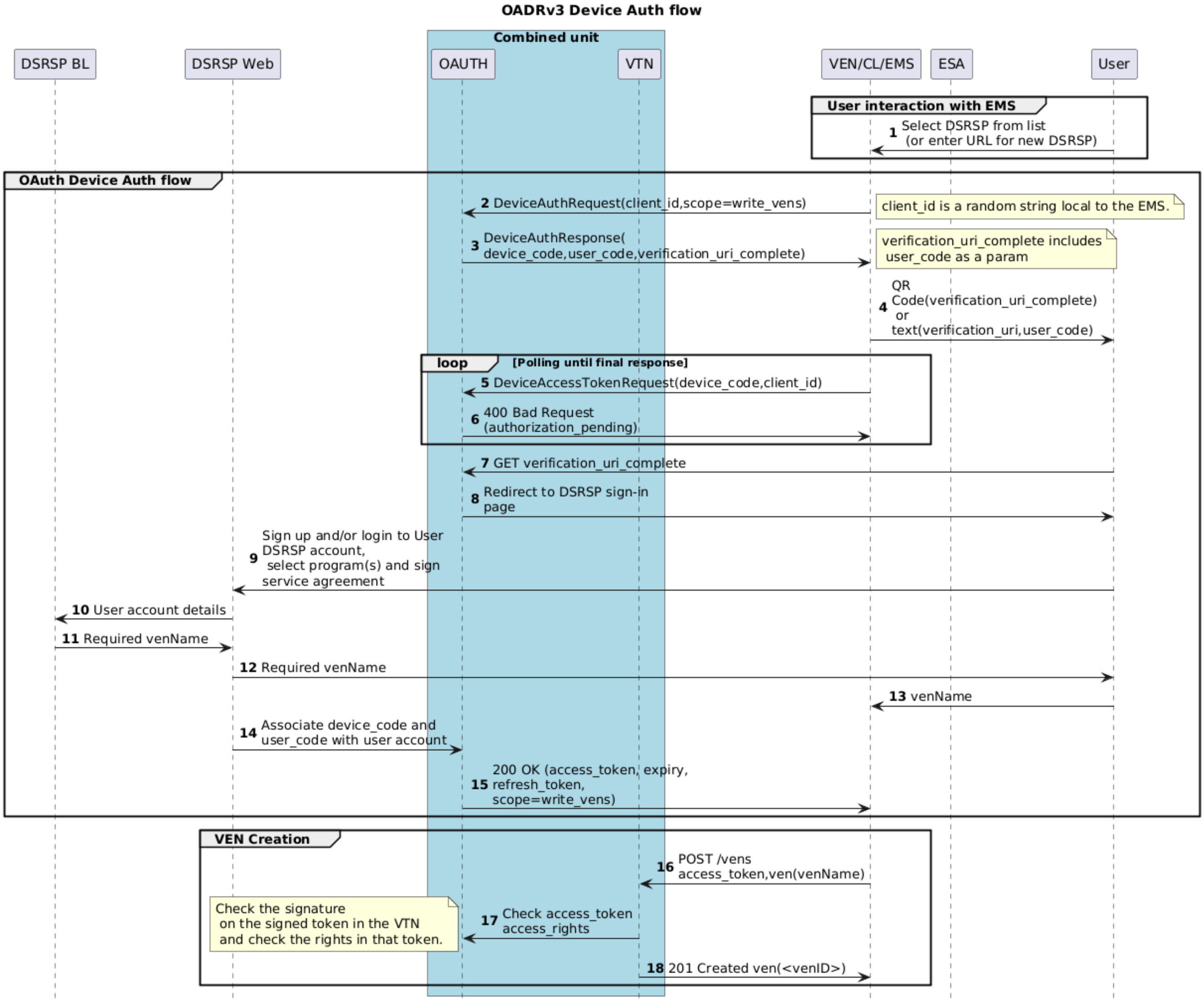

Figure 47. OAuth Device flow for enrolment

In both cases the user must still create a suitable account (with account password or similar authentication method) with the DSRSP for the EMS to be associated with, and for the user to select and accept the terms and conditions of the required services provided by the DSRSP.

Further enhancements to the enrolment process are required to minimize and simplify the user interaction with the EMS and DSRSP during this enrolment and authentication flow: see Plug-and-Play auto-configuration.

7.3. EMS Security

The security models used by [Matter] and by [OADR3] are quite different, and the nature of the system and the multiple operators and component suppliers into the whole system, including the consumers themselves and the need for ease of deployment and use of ESA, effectively precludes the use of uninterrupted end-to-end security. Effectively the EMS is a member of both the [Matter] security domain and the [OADR3] security domain, and interworks the secure information from one domain to the secure information in the other domain. In order to maintain overall system security, the EMS must therefore use a similar level of device security to the end ESA themselves. This includes the need to maintain device credentials such that it is not possible to extract them without the penetration of security barriers commensurate with the value of such a breach.

As automated consumer devices which must operate autonomously, and be able to enter operations automatically on startup without user input of security credentials, the EMS, like the ESAs it represents, cannot realistically perform any meaningful multi-factor authentication to the DSRSP without a significant change to the design and manufacture of such devices, and so the DSRSP may always be subject to fraudulent behavior by individual EMS and ESA. The most effective way to mitigate such risks is likely to be by using behavior pattern monitoring at the DSRSP to notice patterns of behavior which are unexpected or unusual either for the individual node over time, or when compared to similar nodes in other parts of the network.

Chapter 8. Future considerations

8.1. OpenADR Enhancements

This section describes some possible future enhancements to [OADR3] to allow more efficient, simpler, more capable, and more secure DSR operations.

8.1.1. Security and Data Privacy

The methods of targeting and filtering the GETs and subscriptions to objects should include a capability for the VEN clients and BL clients to request only those objects that they need to access for the system to work, and the VTN should use suitable access control based on the client_id (or equivalent identifier in the bearer tokens) to reject any requests that would return data that the client is not permitted to obtain. To keep this filtering secure, the properties of the various objects used by the VTN for this filtering and access control need to be prevented from being changed by the VEN clients, only by the BL clients or VTN directly.

The following clauses add details of how this may be achieved with minimal changes to the [OADR3]. There may be other (and better) ways of achieving this same goal, such as additional objects or properties specifically for access control for data privacy, but this sets out a possible approach.

The current [OADR3] includes a mandatory property `clientName` for `subscription` and `report` objects, which can be used to filter reads of these objects to only those created by a specific clientName, but does not indicate where the VEN gets such a `clientName` from, how the BL comes to know about it, or how it is ensured to be unique.

- The [OADR3] specification may be updated to add a read-only unique client identifier to all objects created by the VEN clients, which is set by the VTN at object creation, which the VTN and BL uniquely associates with a VEN client account.

The current [OADR3] assumes that all Programs are public, and that all Events that they create are also public, and thus readable by all authenticated VEN clients. Whilst this is acceptable for Programs and Events offering effectively public information, such as common tariffs, it may not be suitable as DSRSPs become more targeted in their use of Programs and Events. For example, if a DSRSP wishes to incentivize small groups of EVs to charge at particular times, the information in such Events may become private information, (especially if they can be correlated with an externally visible indication of charging of the EV) and in the extreme may be considered Personally Identifiable Information.

The Event privacy may be achieved by enforcing that the VEN client's access to `event` objects must be targeted to Events that intended for it, i.e. those Events that are targeted at VENs or resources of the VEN client. The use of targets for Events towards VENs is very flexible, with the ability of the BL client to associate `ven` and `resource` objects with targets by VEN_NAME, RESOURCE_NAME, LOCATION, and even general GROUP targets, which allow arbitrary collections of target objects. Any of these targets may match and indicate that the Event should be available to the targeted object.

- The VTN MAY reject any `GET` of the list of, or `GET` of, `event` objects by a VEN client which does not include a filter by any of the targets in the `targets` property of the `ven` or `resource` objects which were created by that VEN client, and SHALL NOT return such `event` objects unless they are targetted to such objects.

If Program privacy is also required, it may be achieved by enforcing the same targeting (which will here be by the PROGRAM_NAME) `targets` property of the `ven`, `resource`, and `program` objects.

- The VTN SHALL reject any `GET` of the list of, or `GET` of, `program` objects by a VEN client which does not include a filter by any of the targets in the `targets` property of the `ven` or `resource` objects which were created by that VEN client, and SHALL NOT return such `program` objects unless they are targetted to such objects.

The same restrictions may be applied to `subscription` objects.

- The VTN MAY reject the creation or modification of a `subscription` object by a VEN client which subscribes to any `event` or `program` objects which are not targeted to include `ven` and/or `resource` objects which were created by that VEN client, and SHALL NOT return such `event` or `program` objects unless they are targetted to such `ven` and/or `resource` objects. This targeting may be achieved by the inclusion of targets in the `subscription` object for the `event` matching targets in the `ven` and/or `resource` objects associated with the VEN client account.
- The VTN SHALL prevent the VEN clients from obtaining the targets property of the `program` objects.

The MQTT notifier does not support targets for server-side filtering, which limits the available data privacy to access control at the topic level (e.g. the subscriptions and reports topics can be blocked to all VEN clients, as there is no need for a VEN to subscribe to objects of which it is the only client with create, update and delete privileges).

If the same data privacy is extended to the Programs and their Events too, including privacy for targeted Events to only those clients managing the targeted objects, the topic filtering requirements become essentially the same as the subscription filtering requirements described above.

- The VTN SHALL reject any MQTT subscriptions by VEN clients for topics which may include notifications of `program` or `event` objects without matching targets in the `ven` and/or `resource` objects associated with the VEN client account.

The `[OADR3]` specification may be updated to use `subscription` objects to create custom (i.e. server-side filtered) MQTT topics (as an alternative notifier to webhooks), which the VTN can implement access control to limit subscriptions to restrict access to the appropriate VEN clients which created a matching `subscription` object. This would ensure that all access controls are applied equally to both the webhook and MQTT methods of notification delivery.

The current `[OADR3]` assumes that there is only a single security scope for the BL clients, i.e. that all BL clients can manage all Programs, Events etc: there is no multi-tenancy support for the DSRSPs on a given VTN platform. With the current use cases this is not an issue: different DSRSPs may run different VTNs (i.e. on different VTN URLs), and a VEN client is configured to support only the single VTN URL. This is unlikely to need to change, as the complications of dealing with multiple DSRSPs at the same time for a single EMS are significant.

8.1.2. Protocol efficiency and consistency

The [OADR3] Reports identify the payload values in the intervals from the payloadType enum in the payloadDescriptors, but the same payloadType may be used for different types value (e.g. a DEMAND type can have readingTypes of PEAK, MEAN, etc, or a READING can be of different units such as VOLTS, AMPS, etc). It is therefore necessary for several report objects to be created, one for each distinct readingType or units enums of the same payloadType - see IW 3.1.1 for an example. An enhancement to permit all such values in a single Report would simplify both VEN and BL clients (e.g. by adding an explicit label for the payload values in the payloadDescriptors instead of only using the payloadType).

The [OADR3] event objects do not have the equivalent of the readingType enum used in report objects, which could qualify any eventType value (e.g. to indicate that it was an uncommitted offer price). Currently therefore new eventType enum values are needed for each eventType which could be offered in this manner. This is not a significant issue currently as there are very few eventType which would need such qualification (e.g. GHG unlikely to ever be indicated as such).

8.1.3. Plug-and-Play auto-configuration

There is currently no method in OADR for an Event to request or require the corresponding Report to include the optional accuracy or confidence properties in the report: it requires out-of-band configuration to determine whether to include the accuracy and confidence properties in any given report. In some use cases the inclusion of the accuracy and confidence is important (e.g. when the user is being offered financial incentives for the change of their energy usage patterns, and their VEN is reporting actual usage over a period). Such a method may be added to the data model.

There is currently no method in OADR to define the type of a resource object (see Creation and ownership of objects for a workaround to this). The specification may be updated to include a separate resourceType property on the resource object so as to allow the targets property to be entirely controlled by DSRSP for reasons of data privacy and security, as it is used to control the distribution of Events.

The venName is currently required to be shared between DSRSP and VEN so that the DSRSP can identify which client account a new ven object should be associated with. This both complicates the user interaction, and leaves the system open in a small window during the enrolment process to (deliberate or accidental) masquerade attacks (if a VEN client B creates a ven objects with the venName agreed between DSRSP and VEN client A). The use of venName for this purpose, and thus the need to share it out of band, should be avoided by having the VTN include a read-only property in the ven object on creation that the DSRSP can associate with the VEN client, such as a VEN client account identifier from the token. This could leave the venName as something which could be assigned by the VTN.

8.2. Matter Enhancements

This section describes some possible future enhancements to [Matter] to allow more capable operations.

8.2.1. Demand Response and Load Control (DRLC)

The current [Matter] specification does not support DRLC devices, which were supported in Zigbee. It would be possible to add DRLC support to [Matter] in a similar manner to support such devices, either directly for new devices or via a Matter Bridge device for the existing Zigbee DRLC devices. The nature of such DRLC devices however is such that the data exchanged is essentially one way: the devices are directly controlled from the DSRSP, but cannot provide information back to the DSRSP about their future intended usage. As such, the DRLC capabilities would primarily be useful to the UC 2.6.3 (DSRSP sends power limitation constraint for whole home).