DECEMBER 2022

Interface for Data Exchange between MNOs and the UAS Ecosystem

Aerial Connectivity Joint Activity
Work Task #2

Contents

1. Preface to Version 2

Almost two years have passed since the release of version 1 of this document, then named "Network Coverage Service Definition". During that time, learnings were made, developments progressed and new uses for mobile network operator (MNO) data have been identified that go beyond the initial "connectivity coverage" use-case.

MNOs have, due to the nature of their technology, excellent information about *where people are* - an ideal source of data for ground risk assessment. Therefore, the concept of "population density data" was added to the interface, at the same level as "connectivity data" from version 1. Because of this the name of the interface is changed from "Network Coverage Service" to the broader "Network Data Service" term, to reflect that *connectivity coverage* *and population density data* are being handled by the interface definition.

It also emerged that, for the sake of air risk mitigation, cross border operations and other reasons driven by the various concepts of operation for drone missions (ConOps), the combination of data from multiple MNOs, or more generically, *communication service providers (CSPs) or in short Communication Providers*, will be sought after. The interface now facilitates delivering *combined* data coming from multiple connectivity service providers.

For connectivity, the learnings from the past years and the feedback from the majority of users so far led to a slight change in the output of the connectivity determination: while in version 1 the result was a binary "yes/no", whether the requested service level was met, in version 2 it is changed it to a ternary "yes/marginal/no", to account for a middle ground between the two existing levels. This way, requirements to submit the exact antenna and communications equipment configuration could be relaxed, as it is often not precisely known, or in the case of the large-scale area calculations on "Volumes" antenna information at the UAV may not even be available.

Another learning was that flight route alteration capabilities ("auto-routing") are not considered useful by Aviation users on the level that this service operates, since not all information that is necessary for route finding decisions are available to it. Therefore, it was decided to drop this functionality from the data interface definition.

Important for the tactical aspects of a flight, the subscription model has been enhanced as well, providing finer-grained ways of keeping up to date for certain data. Other services that monitor flights can subscribe to updates to data sources and be informed if anything significant happens to them in their area of interest or along a specific flight route.

Last, but not least, the interface evolved by adding the *temporal* aspect to its methods. While version 1 supported only a current-time view on the data, the new version includes methods to *predict or forecast* data, e.g., for flight planning.

2. Introduction

2.1. Overview

In order to enable Beyond Visual Line of Sight (BVLOS) operations at scale, drones need reliable connectivity. For Ground Risk assessment, information about people on the ground, or "population density", is required as well. To ensure that flight planning and flight clearing can include such information, additional data from communication providers is required.

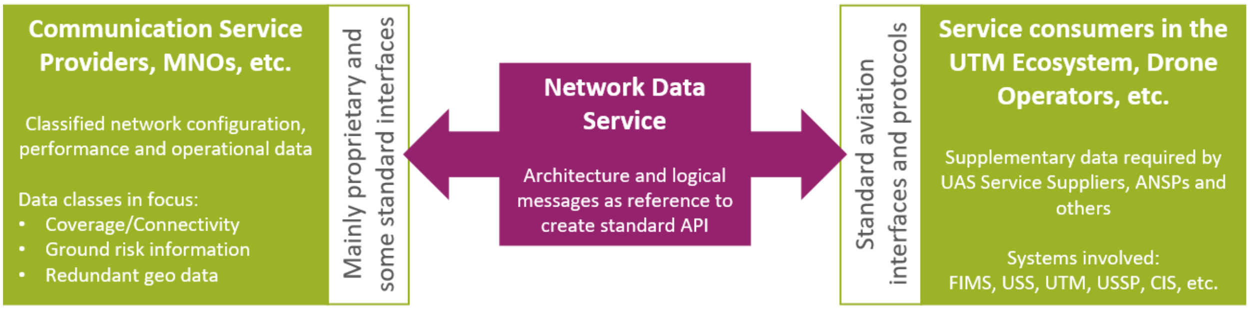

Figure 1 - Operational model diagram

In order to benefit from the fact that cellular networks are utilizing managed spectrum, some communication must be established between the manager of the spectrum (the mobile network operator, "MNO") and the consumer of such data (the aviation operator and/or traffic manager). As a by-product of their technology, MNOs have dynamic population density information as well.

In general, digital data from communication providers, becoming Supplemental Data Service Providers[1], can support a drone operator's risk management.

In particular, for safety it is necessary to understand where cellular coverage is available to support the needs of the mission. "Coverage[2]" implies a range of requirements such as signal level, interference, dynamic handover/switchover behaviour and others to enable a minimum connectivity performance along a flight route in a technology and spectrum independent manner. It is equally important to know where significant accumulations of people are, to avoid overflying those.

Presently, BVLOS flights using cellular Command and Control (C2) must only be conducted after a manual process has been performed to assess coverage. This process

[1] Third party information provided by a Supplementary Data Service Providers (SDSP) increases knowledge of the operational flight area for a UAV with data and analysis delivered using web services.

[2] "Coverage" for an MNO is also a synonym for "signal availability", whereas in aviation terms it is typically a combination of sufficient availability, continuity, latency and integrity [19].

is difficult with current data sharing limitations held by the MNOs. In order to scale, it is necessary to automatically exchange data between MNOs and USS (UAS Service Supplier) or the respective UAS operator.

There are some products and efforts in the market along these lines. However, there is a lot of diversity regarding vendors and eco-system players on the market. Pairwise integration would be slow, laborious, and error prone. Therefore, standard APIs are recommended as a means to enable the market, promote inter-vendor interoperability, and ease reliable integration.

Such coverage and flight path exchange are crucial to arrive at performance-based communication metrics and should assist regulators in defining the role of cellular in aviation.

This document describes a general architecture comprising stakeholders, services, interfaces and data models. The Network Data Service provides three-dimensional (actually four-dimensional, as it also changes over time) information about data connectivity conditions and two-(three-)dimensional information about population density along a flight route or in an area of interest. It provides information where connectivity conditions are, or are not, good enough for safe and reliable data connectivity that adheres to a certain service level, provided by individual communication providers. It gives also an overview of the ground risk related to people presence or activity along the planned flight path.

2.2. Scope

The Network Data Service described in this document provides a general mechanism between the various stakeholders, interfaces and data models that enable and allow the automated data exchange between the respective parties.
The scope includes the following aspects:

- Operational Context
- Service Interfaces
- Service Interface Definition
- Service Dynamic Behaviour
- Service Data Model

There are a number of goals defined that this paper aims to achieve:

1. A goal is to define logical messaging that might be exchanged between a traffic management system (or drone operator, USS/USSP or equivalent) and an MNO. A goal is to identify architectures that will be amenable to expedient implementation by a variety of MNOs, given that MNOs have various operating procedures and means of managing their networks.

2. A goal is to identify architectures that would support a variety of business models and data-sharing models in a technology-independent way (i.e., limiting and avoiding the exchange of proprietary and/or sensitive data).

3. A goal is to provide coverage information primarily for C2 but also for payload traffic.
   A goal is to provide population density information for Ground Risk assessment.

4. A goal is to maintain synchronization with other ACJA Work Tasks, such that the entirety provides regulators and users with confidence in performance-based requirements.

5. A goal is to organize those needs that require standards input from ASTM, EUROCAE, RTCA, 3GPP or other standards developing organizations (SDO) to help close the gap between standards orgs. For example, flight plans may come from ASTM, but Key Performance Indicator (KPI) analysis methods may come from 3GPP, EUROCAE and RTCA.

6. A goal is to understand what real-time metrics, non-real-time and aggregated data can come from the MNO, which could be useful in predicting risk and/or performance-based metrics.

The overall objective is to provide a minimum set of descriptions to standardize the way data between MNOs and the UTM ecosystem can be exchanged. The Network Data Service does not limit any entity, by any means, to deploy or implement other data exchange in addition to the defined service definitions.
This document is not anticipated to be a complete set of functions and definitions for an implementable API.
This service specification is intended to be read by service architects, system engineers and developers in charge of designing and developing an instance of the Network Data Service.

2.3. Background, Principles, References

The fact that ensuring robust communications is essential for safe drone operations is not new. Other projects and papers have been looking into that extensively.
For example, the CORUS Project [2] identifies a so-called Communication Coverage information service (see CORUS ConOps Volume 2, chapter 5.1.7.6).
This service is described there as "The service to provide information about the communication coverage. It can be specialized depending on the communication infrastructure available (e.g., ground or satellite based). This service is used to plan to rely on required coverage."

The CORUS consortium and other references [13] depict the service as U-space[3] level 2 service, likely to be available mid-future.

General principles and research basis

A key principle of the U-spaces architecture is applying a service-oriented architecture approach, where open, interoperable and standard based interfaces are offered based on SWIM principles[4].
This document is based on both research and commercial environments outlined in a range of references such as [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [18], [19], [20], [21], [22], [23].

2.4. Definitions of Acronyms and Terms

List of Acronyms

Acronym	Explanation
3GPP	3rd Generation Partnership Project
ACJA	Aerial Connectivity Joint Activity (by GSMA + GUTMA)
AIXM	Aeronautical Information Exchange Model
AMQ	Advanced Message Queuing
API	Application Programming Interface
ASTM	American Society for Testing and Materials
ATM	Air Traffic Management
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CIS	Common Information Service
CTR	Controlled Traffic Region
DL	Downlink connection, data transmission from a base station to a mobile device
DSS	Discovery and Synchronization Service
ETD	Estimated Time of Departure
FIXM	Flight Information Exchange Model

[3] U-space is a set of new services relying on a high level of digitalization and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones in Europe [2].

[4] Note that by SWIM principles the general concept including not only AIXM, FIXM, WIXM via SOAP are meant, but also web services / rest / messaging (JMS, AMQ) as considered in the SWIM Yellow profile [4].

FPL	Flight Plan
GSM	Global System for Mobile Communication
GSMA	GSM Association
GUTMA	Global UTM Association
JMG	Java Message Service
KPI	Key Performance Indicator
MEP	Message Exchange Pattern
MNO	Mobile Network Operator
NAF	NATO Architectural Framework
NOTAM	Notice To Air Man
REST	Representational State Transfer
RF	Radio Frequency
RSRP	Reference Signal Received Power
SDO	Standards Developing Organization
SINR	Signal to Interference and Noise Ratio (in communication networks)
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SSD	Service Specification Document
SWIM	System Wide Information Management
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UL	Uplink connection, data transmission from a mobile device to a base station
UML	Unified Modelling Language
URL	Uniform Resource Locator
URN	Uniform Resource Name
USS	UAS Service Supplier
UTM	UAV Traffic Management
UUID	Universally Unique Identifier
WXXM	Weather Information Exchange Model
WSDL	Web Service Definition Language
XML	Extensible Mark-up Language
XSD	XML Schema Definition

Terminology

Term	Definition
External Data Model	Describes the semantics of the domain (or a significant part thereof) by defining data structures and their relations. This could be at logical level (e.g., in UML) or at physical level (e.g., in XSD schema definitions), as for example standard data models.
Message Exchange Pattern	Describes the principles how two different parts of a message passing system (i.e.: the service provider and the service consumer) interact and communicate with each other. Examples: In the Request/Response MEP, the service consumer sends a request to the service provider in order to obtain certain information; the service provider provides the requested information in a dedicated response. In the Publish/Subscribe MEP, the service consumer establishes a subscription with the service provider in order to obtain certain information; the service provider publishes information (either in regular intervals or upon change) to all subscribed service consumers.
Operational Activity	An activity performed by an operational node. Examples of operational activities are Route Planning, Route Optimization, Logistics, Safety, Weather Forecast Provision, …
Operational Model	A structure of operational nodes and associated operational activities and their inter-relations in a process model.
Operational Node	A logical entity that performs activities. Note: nodes are specified independently of any physical realization. Examples of operational nodes are Control Centre, Authority, Weather Information Provider, …
Service	The provision of something (a non-physical object), by one, for the use of one or more others, regulated by formal definitions and mutual agreements. Services involve interactions between providers and consumers, which may be performed in a digital form (data exchanges) or through voice communication or written processes and procedures.

Service Consumer	A service consumer uses service instances provided by service providers.
Service Data Model	Formal description of one dedicated service at logical level. The service data model is part of the service specification. Is typically defined in UML and/or XSD. If an external data model exists (e.g., a standard data model), then the service data model shall refer to it: each data item of the service data model shall be mapped to a data item defined in the external data model.
Service Design Description	Documents the details of a service technical design (most likely documented by the service implementer). The service design description includes (but is not limited to) a service physical data model and describes the used technology, transport mechanism, quality of service, etc.
Service Implementation	The provider side implementation of a dedicated service technical design (i.e., implementation of a dedicated service in a dedicated technology).
Service Implementer	Implementers of services from the service provider side and/or the service consumer side.
Service Instance	One service implementation may be deployed at several places by same or different service providers; each such deployment represents a different service instance, being accessible via different URLs.
Service Instance Description	Documents the details of a service implementation (most likely documented by the service implementer) and deployment (most likely documented by the service provider). The service instance description includes (but is not limited to) service technical design reference, service provider reference, service access information, service coverage information, etc.
Service Interface	The communication mechanism of the service, i.e., interaction mechanism between service provider and service consumer. A service interface is characterized by a message exchange pattern and consists of service operations that are either allocated to the provider or the consumer of the service.
Service Operation	Functions or procedure that enables programmatic communication with a service via a service interface.

Service Physical Data Model	Describes the realization of a dedicated service data model in a dedicated technology. This includes a detailed description of the data payload to be exchanged using the chosen technology. The actual format of the service physical data model depends on the chosen technology. Examples may be WSDL and XSD files (e.g., for SOAP services) or swagger (Open API) specifications (e.g., for REST services). If an external data model exists (e.g., a standard data model), then the service physical data model shall refer to it: each data item of the service physical data model shall be mapped to a data item defined in the external data model. In order to prove correct implementation of the service specification, there shall exist a mapping between the service physical data model and the service data model. This means, each data item used in the service physical data model shall be mapped to a corresponding data item of the service data model. (In case of existing mappings to a common external (standard) data model from both the service data model and the service physical data model, such a mapping is implicitly given.)
Service Provider	A service provider provides instances of services according to a service specification and service instance description. All users within the domain can be service providers, e.g., authorities, organizations (e.g., meteorological), commercial service providers, etc.
Service Specification	Describes one dedicated service at logical level. The Service Specification is technology independent. The Service Specification includes (but is not limited to) a description of the Service Interfaces and Service Operations with their data payload. The data payload description may be formally defined by a Service Data Model.
Service Specification Producer	Producers of service specifications in accordance with the service documentation guidelines.
Service Technical Design	The technical design of a dedicated service in a dedicated technology. One service specification may result in several technical service designs, realizing the service with different or same technologies.
Service Technology Catalogue	List and specifications of allowed technologies for service implementations. Currently, SOAP and REST

	are envisaged to be allowed service technologies. The service technology catalogue shall describe in detail the allowed service profiles, e.g., by listing communication standards, security standards, stacks, bindings, etc.
Spatial Exclusiveness	A service specification is characterized as "spatially exclusive", if in any geographical region just one service instance of that specification is allowed to be registered per technology. The decision, which service instance (out of a number of available spatially exclusive services) shall be registered for a certain geographical region, is a governance issue.

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3. Operational Context

Safe operation of UAS / UAM may likely require knowledge of expected end-to-end communications link quality (performance), coverage and population density during planning and flight operation, as well as measurement and monitoring of connectivity parameters during the flight.

Communication coverage is not static information and may be subject to continuous change due to a multitude of factors, in particular for dense urban environments and long flight duration. Consequently, the coverage information comprises real-time and non-real-time data. Real-time data may include live performance indicators, alerts on significant changes, but also real-time network outage information. Non-real-time data for instance could include, but is not limited to, aggregated and historic information as well as planned events (such as planned maintenance outages of the network), which allows connectivity analytics and projections into the future. Both types of data complement each other.

Population density data is also not static information and may be subject to significant changes over the course of each day. While some population density information follows repeating and predictable patterns, singular events, accidents, gatherings and others cannot be forecasted and thus need as live data feeds as possible.

3.1. Planning Phase

Before the start of a flight, there may likely be a need to determine how the planned flight path or flight operations area fits into the following geographic areas:

- Areas with or without cellular network coverage
- Areas where non-cellular RF coverage is bad or non-existent, either due to atmospheric conditions, terrain/building obstruction, or others.
- Areas where, depending on the type of operation, populated or densely populated areas or gatherings of people must be avoided

These factors can be determined via network / surveillance coverage maps, RF propagation modelling, population density calculations as well through public space weather services. Deriving the necessary OK/marginally OK/not-OK information will require automated processing and data exchange.

3.2. Flight Phase

During a flight, adherence to the flight plan needs and limitations to be monitored, and any non-conformance outside of pre-established thresholds and safety margins defined in the operational authorization, should trigger appropriate mitigation actions.

In addition, UTM service providers receive data about the link quality between UAV and ground station / pilot, measuring current signal strength, cumulative signal strength, data transmission latency, number of packet retransmissions, network notifications, etc.

This data indicates the real time link quality and may be used to react to possible deterioration of link quality, or even a complete loss of link. Although the safety criticality of the C2 link depends on characteristics of the UA and the contingency procedures proposed by a UAV operator, some UAV may pose a safety risk in case of C2 outage time beyond the expected availability as they are essentially uncooperative drones that do not respond to commands until the link is re-established.

3.3. Example Use Case

An example of service use is shown in Figure 1 and described in more detail below:

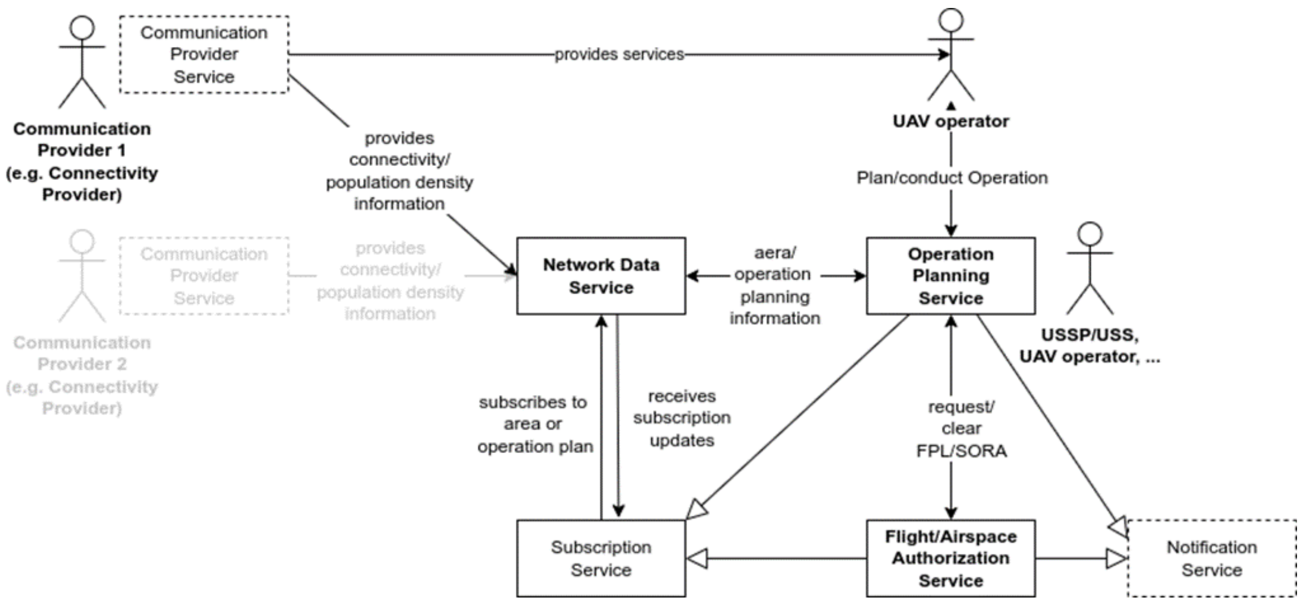

Figure 1 - Operational model diagram

- A UAV operator wants to fly a mission from A to B.
- In order to estimate the general feasibility of the flight, among other things, the connectivity and population density situation in the general area of the flight must be checked with the help of the Operation Planning Service[5]. The Communication Provider provides the area coverage and population density information utilizing the Network Data Service.
- Data from multiple Communication Providers, also known as C2CSP – Command-and-Control Communication Service Providers, may have to be aggregated to a complete picture by the Network Data Service, if the UAV employs redundant communication technologies.

[5] "Operational Planning" is derived from the FAA UTM Conops v2.0 section 2.4.4 [16]: "The Operation Planning service supports the operator to define prior to the operation a four-dimensional (4D) volume of airspace within which the operation is expected to occur, the times and locations of the key events associated with the operation, including launch, recovery, and any other information deemed important (e.g., segmentation of the operation trajectory by time)."

- If the flight is feasible in a given area, a concrete route must be planned. Considering among others the weather, airspace restrictions, aircraft performance, etc., one or more route candidates are created by the drone operator (and/or USS/USSP or equivalent) together with the Operation Planning Service, which are checked with the support of the Network Data Service whether the minimum connectivity service level (for example: continuous C2 availability) and maximum population density is met along the candidate routes. The data from the Network Data Service also assists in finding alternate routes to assure the parameters of the route stay in the mentioned boundaries.
- The drone operator prepares a flight intent plan ahead of ETD in line with the operational limitations of his/her authorization. The operator can be assisted in this task by the Operation Planning Service which may coordinate with the Network Data Service if the planned flight route meets the minimum safety requirements in terms of coverage, capacity, population density etc. If required for the operation, SORA can also be automatically performed.
- Shortly before the flight actually commences, the Operation Planning Service may recheck that the service requirements are still met (together with meteorology, NOTAMs, etc.), and, where necessary, alternate routes can be checked. Then, clearance is requested from Flight/Airspace Authorization Service[6] to commence the flight.
- The Operation Planning Service and the Flight/Airspace Authorization Service are specializations of a general Subscription Service. They can also be implementations of a Notification Service[7]. A Subscription Service can subscribe to the Network Data Service for changes in areas and/or along flight routes, to be notified about significant changes.
- Therefore, if during the flight, due to an outage at the communication provider, a certain segment of the flight planned route ahead of the aircraft loses connectivity,

[6] This service is called "Airspace Authorization" service in FAA UTM Conops v2 section 2.4.3 [16] and "Flight Authorisation" in EASA draft Commission U-Space regulation in Europe, Article 12 [17].

[7] The Notification Service may provide such information to the “Constraint Information & Advisories” Service as defined in the FAA ConOps v2.0, Section 2.4.5 [16] or equivalent. Similarly, in the SESAR CORUS “U-Space Concept of Operations” [2] there are services defined in sections 5.1.5.1 and 5.1.6.6 that require “… to provide status information about communication infrastructure. … The service should give warnings of degradation of communications infrastructure”.

the Operation Planning Service and the Flight/Airspace Authorization Service can be alerted (who in turn, as Notification Services, could also escalate this to other systems). For this the link quality could be used as key performance indicator. A Connectivity Service at the Communication Provider identifies this situation and informs the Network Data Service.

- The drone operator may have to re-plan the rest of the flight, and coordinate the changes using the Operation Planning Services, again with the assistance of the Network Data Service, to stay on a route that meets the minimum data requirements or apply contingency/emergency procedures in line with the approved Concept of Operations.

Providers and actors might / will be different depending on the local legislation/regulations.

3.4. Additional Definitions

▪ Operational Nodes

Operational Node	Remarks
Communication Provider	A provider of communication services like a Mobile Network Operator or a Satellite Data Communications Provider.
Communication Provider Service	Services deployed close to mobile network operator infrastructure, providing connectivity and population density data for the Network Data Service.

Table 1 - Operational Nodes providing the Communication Provider Service

Operational Node	Remarks
Operation Planning Service	Service defined in FAA UTM Conops v2.0 section 2.4.4 [16]: "The Operation Planning service supports the operator to define prior to the operation a four-dimensional (4D) volume of airspace within which the operation is expected to occur, the times and locations of the key events associated with the operation, including launch, recovery, and any other information deemed important (e.g., segmentation of the operation trajectory by time).".
Flight/Airspace Authorization Service	Service providing authorization for a specific flight. Depending on local regulation this service works with flight trajectories or airspace volumes.
Notification Service	Notifies drone operators of relevant changes that occurred typically in-flight, or pre-flight after the initial planning phase. It could consume events from different services, not only the Network Data Service.
Subscription Service	Service that subscribes to changes in the Network Data Service for certain areas and/or flight routes.

Table 2 - Operational Nodes (directly) consuming the Data Service

▪ Operational Activities

Operational Activity	Remarks
Get area/operation planning data	Returns information about connectivity coverage and/or population density for a certain area or flight route for a particular technology and communication provider for a particular time period in the future
Receive subscription updates	For a given area or flight route, get notifications about changes to connectivity and/or population density.
Provide services	The communication provider provides its infrastructure to the drone operators for data communication. Drone operators use the services (communication, population density, positioning) offered by CSP through Network Data (or Information) Service.

Table 3 – Operational Activities supported by the Network Data service

4. Service Interfaces

The following diagram depicts the Service Interfaces of the Network Data Service, and their allocations to the Service Provider and the Service Consumers, respectively:

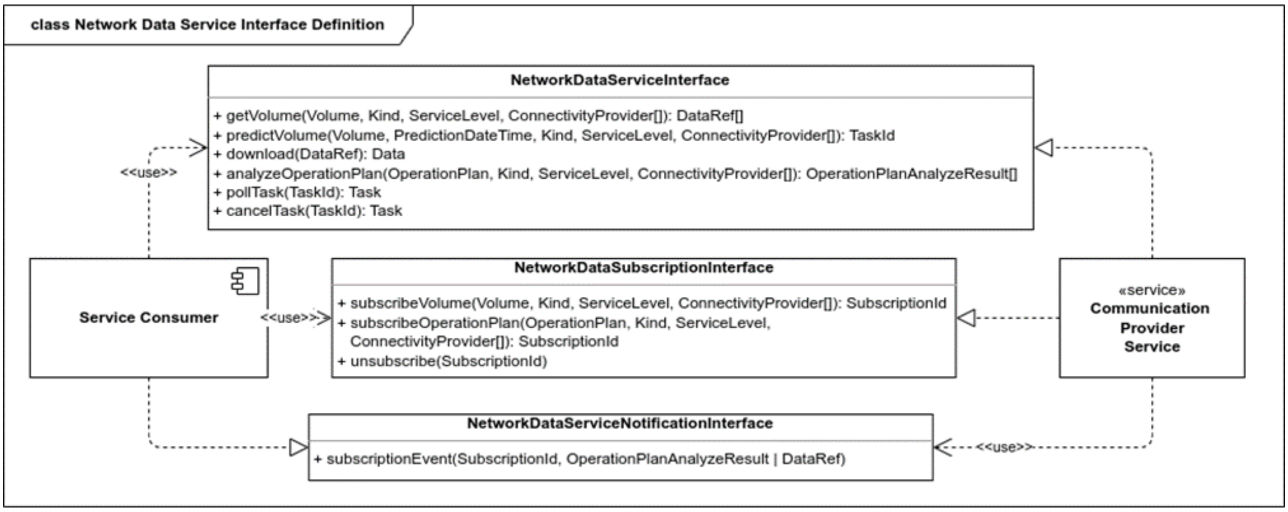

Figure 2 - Network Data Service Interface Definition diagram

Service Interface	Role (from service provider point of view)	Service Operation
Network Data Service Interface	Provided	getVolume predictVolume download analyseOperationPlan pollTask cancelTask
Network Data Subscription Interface	Provided	subscribeVolume subscribeOperationPlan unsubscribe
Network Data Service Notification Interface	Required	subscriptionEvent

Table 4 - Service Interfaces

5. Service Interface Specifications

This chapter describes the details of each service interface. One sub-chapter is provided for each Service Interface.

The Service Interface specification covers only the static design description while the dynamic design (behaviour) is described in a subsequent chapter.

5.1. Network Data Service Interface

This Service Interface is the main point of interaction for service consumers. It provides methods to fetch volume coverage, population density data and conduct operation plan analysis as well as forecasts. It is provided by the Network Data Service.

The NetworkDataServiceInterface realises the Request/Response Message Exchange Pattern (MEP), where the Service Consumer calls Operations at the Service Provider, and the Service Provider answers synchronously with a result. This MEP is most suitable for the synchronous, 1:1 nature of the included Service Operations.

▪ Operation getVolume

The getVolume operation produces information about the current-time three-dimensional area connectivity conditions or two-dimensional population density conditions (distinguished by the "Kind" parameter) for a certain Service Level and a certain combination of Communication Providers.

For connectivity, it basically answers the question where in three-dimensional space can the requested Service Level be provided by the given Communication Providers right now. Note that this is only a high-level overview on the connectivity conditions as other significant factors like aircraft speed and orientation are conceptually not available at the time of requesting large area coverage.

For population density, a two-dimensional structure is returned, that gives a population density value ("sparsely populated/populated/densely populated/gatherings of people" [23]) for each rasterized point on the ground. Availability of such data is subject to accessibility and possible restrictions.

Coverage information is transported in 2D/3D buffer "Data" objects. This operation returns references to such objects for the requested volume. The actual data can then be downloaded via the *download* operation.

▪ Operation predictVolume

The predictVolume operation is the temporal version of the getVolume operation. Input and output are the same, save of the new predictionDateTime parameter, which is the date and time for which the prediction shall be computed.

It is a separate operation because the prediction computation results are not immediately available; the calculations are computationally expensive (which is also relevant for billing) and may take several minutes to complete. Therefore, not a direct DataRef is returned, but a TaskId of a background task. The result of that Task needs to be polled periodically to learn the outcome and receive the computation results.

The Volume for which such predictions can be calculated may be limited in size, also quotas may apply to calls to this operation.

▪ Operation download

The download operation is used to download the actual data for a given Data reference. Data references can be obtained from the getVolume operation or are reported via the subscriptionEvent call in the NetworkDataServiceNotificationInterface.

▪ Operation analyzeOperationPlan

The analyzeOperationPlan operation answers two questions: “where on the given flight route is the given Service Level met for a certain combination of Communication Providers?” and “what is the population density condition on the given flight route?”.

The Network Data Service brokers with the Communication Provider so that the given flight route is evaluated on their premises (as confidential Communication Provider data is required for the calculation). The Network Data Service then returns the results to the Consumer.

A “service level” in the context of this interface is an abstract name for a combination of connectivity conditions, i.e., combine individual service levels for both UL and DL. For example, a “C2” (command & control) service level might require a certain maximum physical layer latency, whereas a “streaming 4K” service level might require a minimum guaranteed throughput in mbit/s. Additionally, depending on the communication technology, other technical thresholds and limits will be in place for the different service levels (in 4G for example, a minimum RSRP and SINR value). These thresholds and limits are configured on the Communication Provider’s side and likely be specified by standardization. The aviation end user (e.g., UAS operator) does not need to know these; it only requests the service levels by name that are relevant for the planned mission.

- **Operation pollTask**

The pollTask operation allows for polling the result of a running computation task.

- **Operation cancelTask**

The pollTask operation allows to cancel a running computation task.

5.2. Subscription Interface

This Service Interface provides Subscribe operations to Service Consumers. It is provided by the Network Data Service.

The NetworkDataSubscriptionInterface and the NetworkDataNotificationInterface together realize the Publisher/Subscriber MEP. As the connectivity information and population density in a certain area constantly changes, the notification for such changes is posted to a Publisher/Subscriber topic. Service Consumers can attach to those topics and get asynchronously notified about changes to areas of their interest.

- **Operation subscribeVolume**

The subscribeVolume operation allows a Service Consumer to subscribe to changes in area connectivity coverage and/or population density.

Whenever the data for a certain Service Level and (combination of) Communication Providers happens to change, a notification is posted in a dedicated topic. Service Consumers can subscribe to that topic to be notified about those changes.

- **Operation subscribeOperationPlan**

The subscribeOperationPlan operation allows a Service Consumer to subscribe to changes in connectivity coverage and/or population density along a flight route.

Whenever the data for a certain Service Level and (combination of) Communication Providers happens to change, a notification is posted in a dedicated topic. Service Consumers can subscribe to that topic to be notified about those changes.

- **Operation Unsubscribe**

As the opposite Operation of the subscribe operations, this Operation allows a Service Consumer to stop receiving notifications about changes for a certain Service Level and Communication Providers. This removes the Service Consumer from the list of Consumers to be notified.

5.3. Notification Interface

This Service Interface is provided by and implemented on the Service Consumer's side. It is called to notify the Service Consumer about changes it subscribed to via the Operations in the NetworkDataSubscriptionInterface.

The NetworkDataSubscriptionInterface and the NetworkDataNotificationInterface together realize the Publisher/Subscriber MEP. As the connectivity information in a certain area constantly changes, the notification for such changes is posted to a Publisher/Subscriber topic. Service Consumers can attach to those topics and are asynchronously notified about changes to areas of their interest.

- ### Operation subscriptionEvent

This Operation is called on the Service Consumer's side whenever the underlying data for a given subscription changed.

Whenever the connectivity information and/or population density for a certain Service Level and Communication Provider happens to change and exceeds specific thresholds, a notification is posted in a dedicated topic. If the Service Consumer subscribed to that topic, it will receive notifications via this Operation.

6. Service Dynamic Behaviour

The following describes examples for the dynamic behaviour.

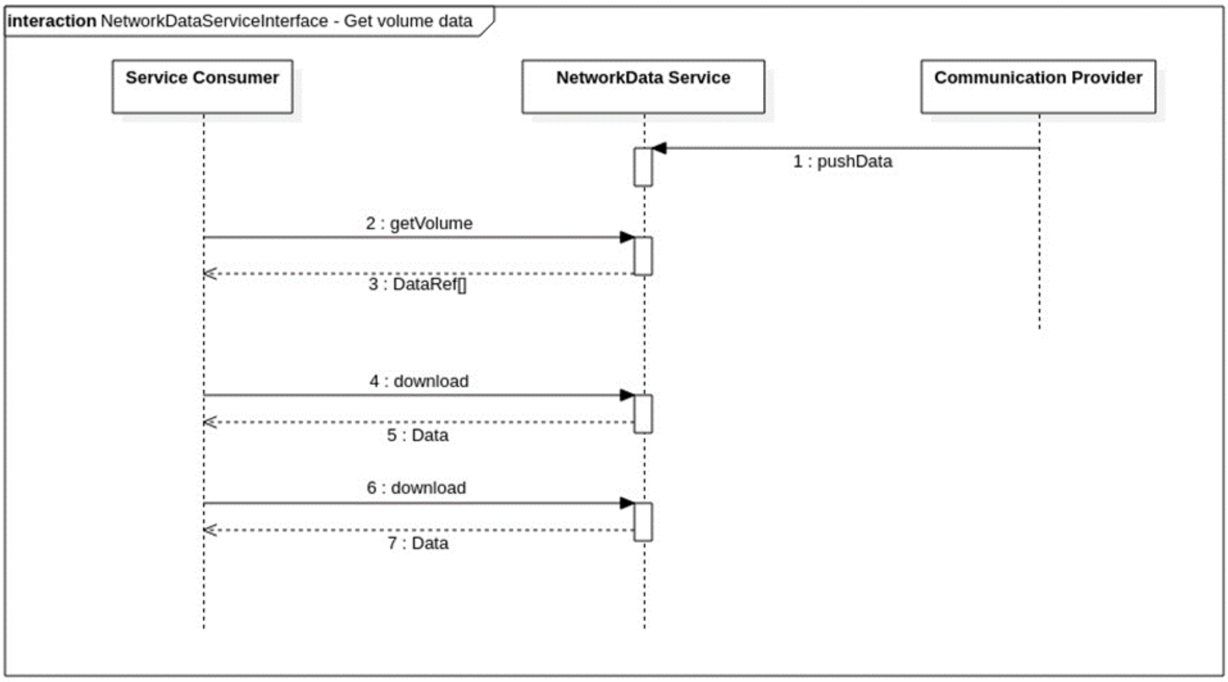

Figure 3: Network Data Service Operation Sequence Diagram – Get area coverage

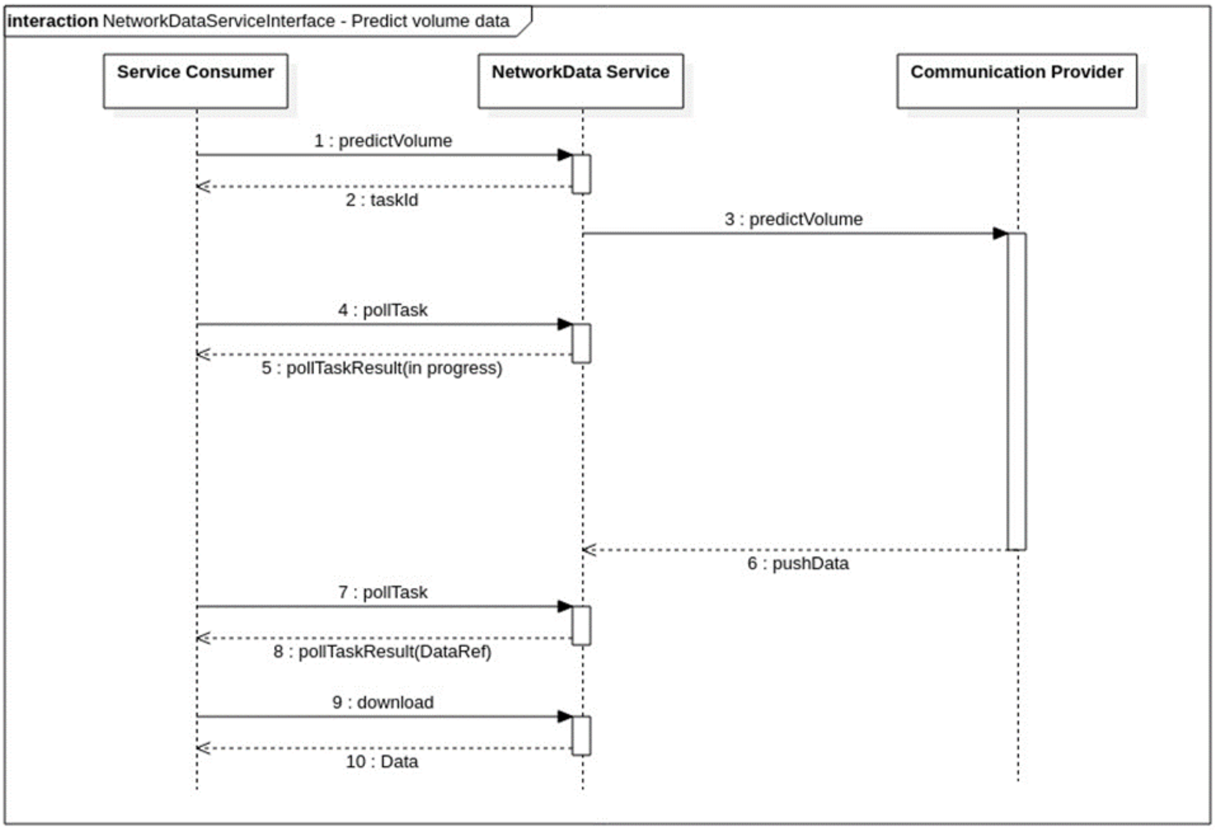

Figure 4: Network Data Service Operation Sequence Diagram – Predict area coverage and pollTask

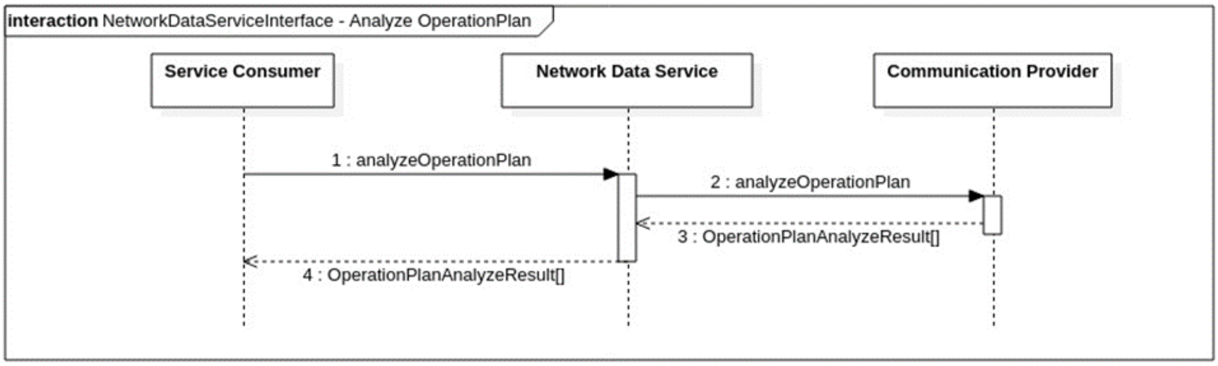

Figure 5: Network Data Service Operation Sequence Diagram – Analyse flight

Please note that the interface between the Communication Provider and the Network Data Service are out of scope of this document, however, to indicate the dynamic behaviour they are shown here.

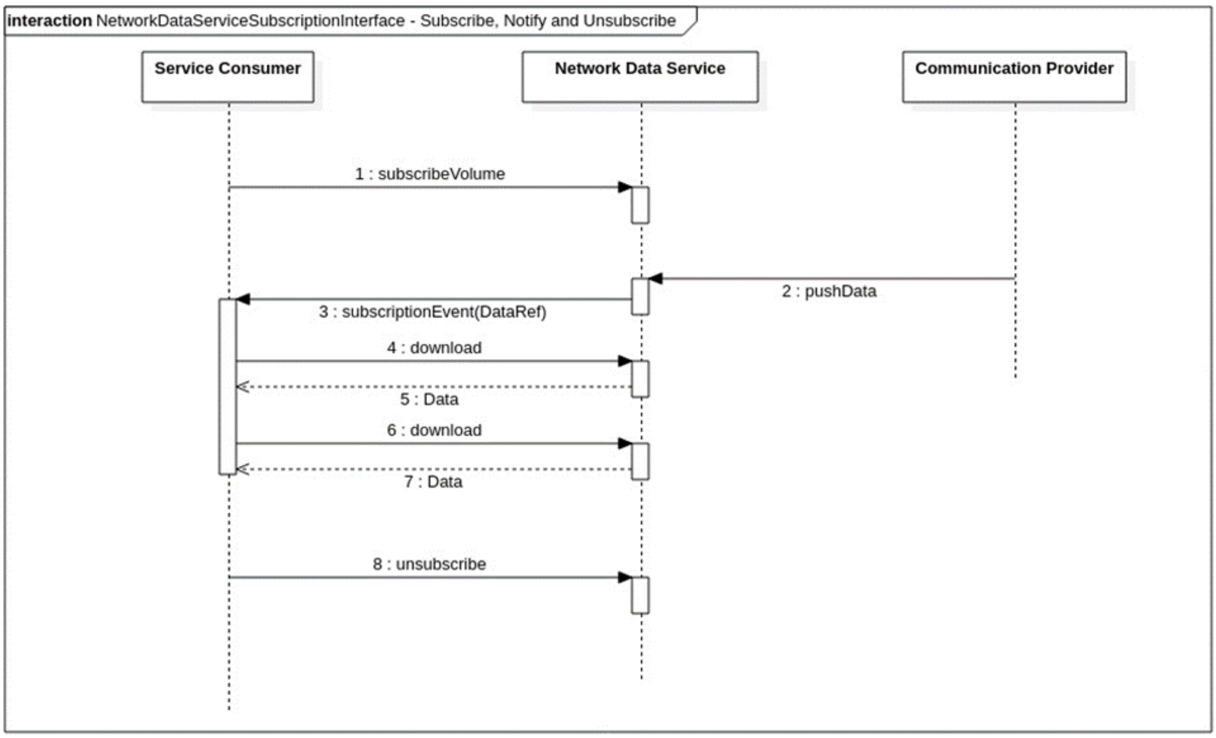

Figure 6: Network Data Service Operation Sequence Diagram – subscribeVolume, subscriptionEvent and unsubscribe

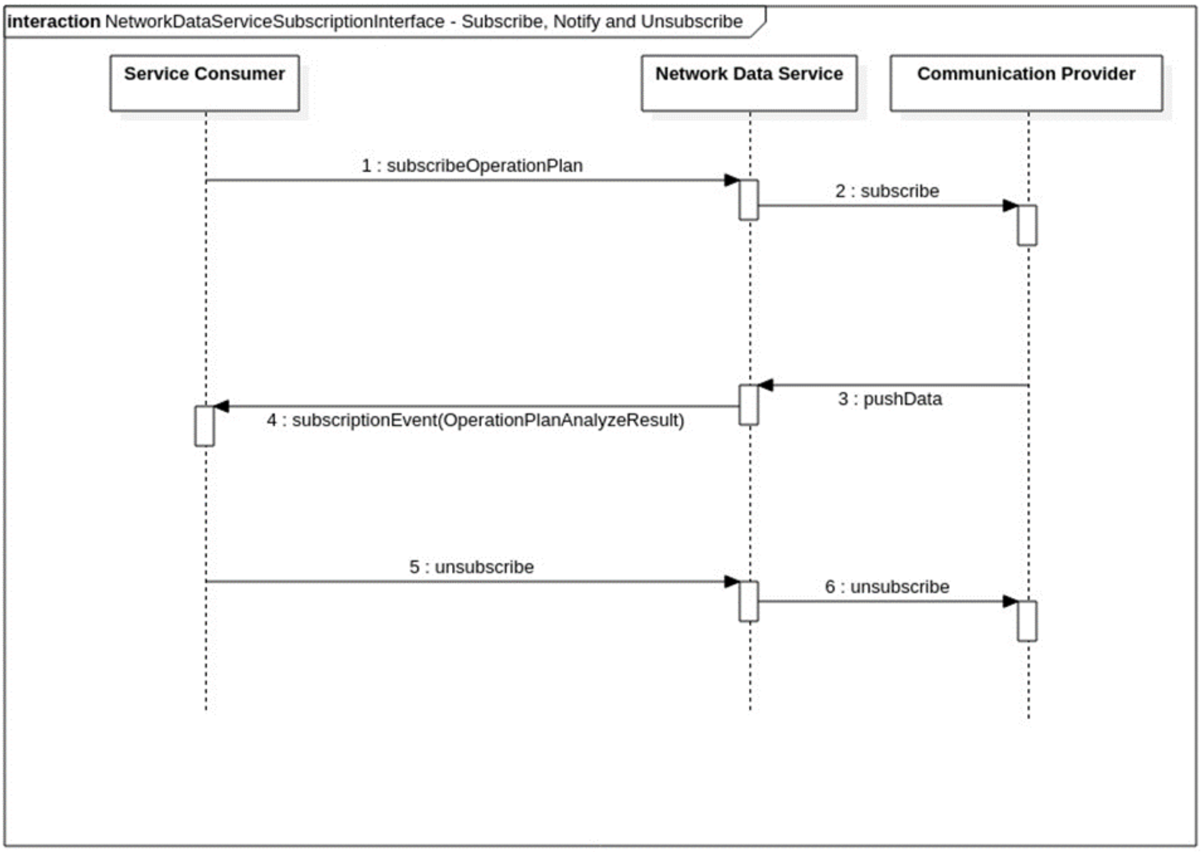

Figure 7: Network Data Service Operation Sequence Diagram – subscribeOperationPlan, subscriptionEvent and unsubscribe

7. Service Data Model

This section describes the information model, i.e., the logical data structures to be exchanged between providers and consumers of the service

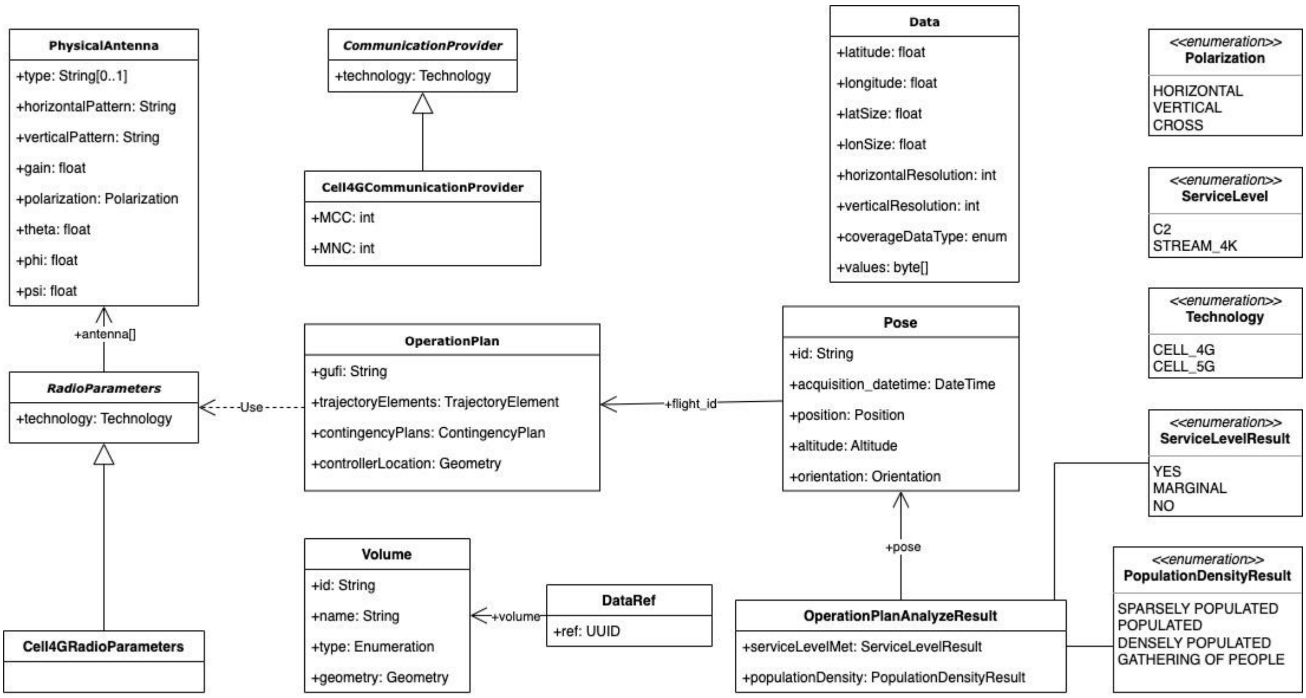

Figure 8 – Network Data Service Data Model diagram

The Service Data Model focuses on the core service model and the diagram includes structures (OperationPlan, Volume, Pose), whose detailed specification are out of scope of this document.

The data model supports and is compatible with a number of industry standards, such as ICAO, ASTM F3411-19 [18], EUROCAE ED-269 [20], FIXM, etc. It is important to note that the data model can be extended, for example for future requirements and additional information that may need to be exchanged.

The following tables describe the entities and their attributes in more detail.

7.1. The OperationPlan Data Structure

The *OperationPlan* represents a complete flight plan. It refers to Pose instances providing spatial orientation of the aircraft for positions along the planned flight trajectory.

Note: Selected attributes of the *OperationPlan* are listed here to provide context for better understanding. For implementation, a fully described *OperationPlan* is to be provided in a separate Operation Plan service specification.

The information about the communication equipment used on the aircraft is provided when requesting a network coverage analysis.

Property	Type	Multiplicity	Description	Note
gufi	String	1	A gufi: globally unique flight identifier in form of a UUID	More information for a flight could be retrieved using a respective Flight Information Service
trajectoryElements	TrajectoryElement	1..*	The positions (locations and orientation in space) that represent the flight route.	
contingencyPlans	ContingencyPlan	0..*	Holds information on preplanned contingency situations, especially regarding volumes and when they are used.	

controllerLocation	Geometry	0..1	Location of controller (e.g., the ground control station)	
radioParameters	RadioParameters	0..*	Information about the communication equipment used during the flight.	

Table 5 - The Flight data structure

7.2. The Pose Data Structure

The *Pose* provides a location in space (3D), orientation of an aircraft and time applicable.

Note: Selected attributes are listed here to provide context for better understanding. For implementation, a fully described *Pose* is to be provided in a separate Service Specification.

Property	Type	Multiplicity	Description	Note
aquisitionDateTime	DateTime	1	UTC point in time when the position was measured by the positioning unit of the device in flight.	For flight planning purposes this will be a time in the future.
position	Position	1	Carries the position data of the object being reported about in this *Pose*. There shall be exactly one position contained in the *Pose*.	
altitude	Altitude	1..*	There shall be one or more complete *Altitude* data structure provided for every *Pose*. The first of the *Altitude* data structures provided shall contain the value which subsequent processing stages may rely on as accurate and binding.	

orientation	Orientation	0..1	If provided, carries the orientation data of the object being reported about in this *Pose*. There may be none or one *Orientation* data structure provided for every *Pose*, providing all, or a subset, of the data it may carry.	

Table 6: The Pose data structure

7.3. The OperationPlanAnalyzeResult Data Structure

The *OperationPlanAnalyzeResult* holds an analysis in regard to connectivity coverage for an *OperationPlan*.

Property	Type	Multiplicity	Description	Note
serviceLevelMet	ServiceLevelResult	0..1	Whether the requested service level is met (yes/marginal/no) at the given Pose.	
populationDensity	PopulationDensityResult	0..1	The population density determination on the ground below the Position.	
pose	Pose	1	Reference to a Pose instance of an *OperationPlan* for which the service level was tested.	

Table 7: The OperationPlanAnalyzeResult data structure

7.4. The CellRadioParameters Data Structure

The CellRadioParameters provides communication equipment (physical) and logical communication information for mobile communication.

Property	Type	Multiplicity	Description	Note
Technology	Technology	1	The technology of the radio parameters. Fixed CELL_4G, CELL_5G, …	
…	…		List of required attributes is likely subject to change.	

Table 8: The CellRadioParameters data structure

7.5. The PhysicalAntenna Data Structure

The *PhysicalAntenna* provides information about the physical antenna used for communication on the aircraft. There can be more than one such antennas. The orientation of the antenna on the aircraft is modelled using Euler angles (more specifically, the orientation of the antenna *pattern*).

Property	Type	Multiplicity	Description	Note
type	string	0..1	A type of specifier of the antenna. Optional; can be used instead of specifying the pattern, gain and polarization attributes if the antenna type is well-known.	
horizontalPattern	string	1	Horizontal antenna pattern string.	
verticalPattern	string	1	Vertical antenna pattern string.	
gain	float	1	Antenna gain, in dBi.	
polarization	Polarization	1	Antenna polarization.	
theta, phi, psi	float	1	Orientation angles of the antenna	

Table 9: The PhysicalAntenna data structure

7.6. The CommunicationProvider Data Structure

The Communication Provider represents a communication provider, e.g., a provider of communication services like a Mobile Network Operator or a Satellite Data Communication Provider.

Property	Type	Multiplicity	Description	Note
technology	Technology	1	The technology of the radio parameter.	

Table 10: The CommunicationProvider data structure

7.7. The Cell4GConnectivityProvider Data Structure

The Cell4GConnectivityProvider is an example specialization of the ConnectivityProvider class. It contains additional attributes to identify a Mobile Network Operator that offers 4G cellular connectivity services.

It works the same for 5G, while for satellite or other connectivity technology providers the attributes might be different.

Property	Type	Multiplicity	Description	Note
MCC	int	1	Mobile Country Code.	
MNC	int	1	Mobile Network Code. MCC and MNC together uniquely identify the Mobile Network Operator globally.	

Table 11: The Cell4GConnectivityProvider data structure

7.8. The RadioParameters Data Structure

The RadioParameters provides communication equipment (physical) and logical communication information. This is an abstract class, needs technology-aware specialized implementation.

Property	Type	Multiplicity	Description	Note
technology	Technology	1	The technology of the radio parameters.	
antenna	Antenna	1..*	The used antenna parameters.	

Table 12: The RadioParameters data structure

7.9. The Data Structure

The *Data structure* contains 2D (AGL: 0) population density or 3D aerial coverage information in a raster of a certain resolution. Full capabilities are to be described in an external Data specification document for further processing.

It is essentially a 2D/3D grid where each grid cell has an assigned a value. Data is like a bitmap, where the pixel content represents attributes relevant for exchanging network coverage or population density information, e.g., to describe whether the requested service level is met at that particular point or not.

In future versions of this data structure, Data could support exchange of numeric values or other types that can be encoded in a byte, allowing to transport e.g., minimum throughput in a grid cell.

How exactly values are encoded in the byte array has to be described in a separate document specific to and available for an implementation of Data.

Property	Type	Multiplicity	Description	Note
latitude	float	1	Latitude of the upper-left corner of the area covered in WGS84.	
longitude	float	1	Longitude of the upper-left corner of the area covered in WGS84.	
latSize	float	1	Height of the data structure, in WGS 84 degrees. Typically, 1.0	
lonSize	float	1	Width of the data structure, in WGS 84 degrees. Typically, 1.0	
horizontalResolution	int	1	Horizontal resolution of the raster, in arc seconds (WGS 84). Typically, 2.	
verticalResolution	int	1	Vertical resolution of the raster, in meters. Typically, 15.	
coverageDataType	CoverageDataType	1	Enumerated value describing the data type of the data encoded in values.	
values	Byte[]	1..*	The actual 3D bitmap that contains the raster's values.	

Table 13: The CoverageData structure

7.10. The DataRef Structure

The *DataRef structure* contains a reference to a Data object. Actual data can be downloaded by passing a DataRef object to the *download* method.

Property	Type	Multiplicity	Description	Note
ref	UUID	1	Unique reference.	

Table 14: The CoverageDataRef structure

7.11. The Volume Structure

The Volume structure describes a geographic 3D volume in space. Additional details are to be covered in greater detail in an external Volume specification. Typical volumes are cylinders with a certain radius and height or polyhedrons.

Property	Type	Multiplicity	Description	Note
Id	String	1	Unique identifier in form of a UUID	
type	enum	1	The type of volume (cylinder, polyhedron, …)	
geometry	Geometry	1	The geometry that describes this volume.	

Table 15: The Volume Structure

About the GSMA

The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators and nearly 400 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organizations in adjacent industry sectors. The GSMA also produces the industry leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

For more information, please visit www.gsma.com

About the GUTMA

The Global UTM Association (GUTMA) is a non-profit consortium of worldwide Unmanned Aircraft Systems Traffic Management (UTM) stakeholders. Its purpose is to foster the safe, secure and efficient integration of drones in national airspace systems. Its mission is to support and accelerate the transparent implementation of globally interoperable UTM systems. GUTMA members collaborate remotely.

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