DroC2om - 763601 - D3.2 Reference simulation scenario

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DroC2om

DRONE CRITICAL COMMUNICATIONS

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Abstract

The purpose of Work Package 3 (WP3) is the assessment of the projects' technical contributions by means of realistic simulations. To this end, an environment for realistic simulations of combined cellular-satellite UAS communication at system/network level is developed.

In deliverable D3.1 [1], the DroC2om project devised an architecture for the scenario-based simulation environment to be developed. This architecture is based on three components: a generator of scenario data as input for the simulation, the simulation module for the combined link, and a visualization/evaluation module. To support this modular architecture, data is to be exchanged between the modules in a well-defined format.

In this context, the key objectives of this deliverable D3.2 "Reference simulation scenario" document are to:

- describe the general scenario setup that is used to assess and demonstrate the performance of a combined cellular-satellite link for UAS communication,
- describe the details (of the initial version) of the reference scenario that is used to establish and test the workflow for the simulation environment,
- fix the format of the data to be exchanged between the Work Packages.

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1 Introduction

1.1 Purpose and Scope

The DroC2om project designs and evaluates an integrated cellular-satellite system architecture concept for data links in order to support reliable and safe operation of Unmanned Aerial Systems (UAS). The project's approach is based on real drone measurements, modelling experimental radio investigations, and system simulations. The four main building blocks of the project are mostly developed in parallel in close cooperation across the different Work Packages (WPs):

1. Definition of scenarios and requirements (WP2)
2. Software-based evaluation environment for aerial drone communication (WP3)
3. Aerial communication system architecture (WP4)
4. Drone flight and measurements (WP5)

Work Package 3 (WP3) focuses on the assessment of the projects' technical contributions by means of realistic simulations. It is responsible for developing a software eco-system for realistic simulations of UAS communication over cellular or satellite radio links. The modelling as well as the establishment of simulation scenarios is driven by the requirements imposed by WP2 (as contained in Deliverable D2.1 [2] and forthcoming in Deliverable D2.2 "Overall System Architecture"). The verification and calibration of the radio link model is carried out as a joint activity together with WP5. The combined cellular-satellite evaluation of selected concepts from WP4 will be performed using the calibrated simulations models and the simulation scenario.

The purpose of this deliverable, D3.2, is to describe the general scenario setup that is used to assess and demonstrate the projects' technical contributions and to fix the data formats for exchanging information within the software eco-system.

According to the architecture proposed in deliverable D3.1 [1] (cf. Figure 1), there are two interfaces between distinct components that are provided by files. In a first step, all input data necessary to simulate the performance of a cellular/satellite/combined link for UAS communication is generated based on the scenario descripton. This scenario input data is passed to the simulation module via suitable files. In a second step, this data is augmented by KPIs describing the performance of the respective link, the KPIs being obtained from the simulation. This KPI data may be used e.g. by the visualization module for evaluating the performance.

The workflow of the software eco-system is to be established by considering a so-called reference scenario that is used by the work packages WP4 and WP5 to develop and test their contributions. It is envisioned to extend this reference scenario in the course of the project to demonstrate various aspects of (combined) link performance.

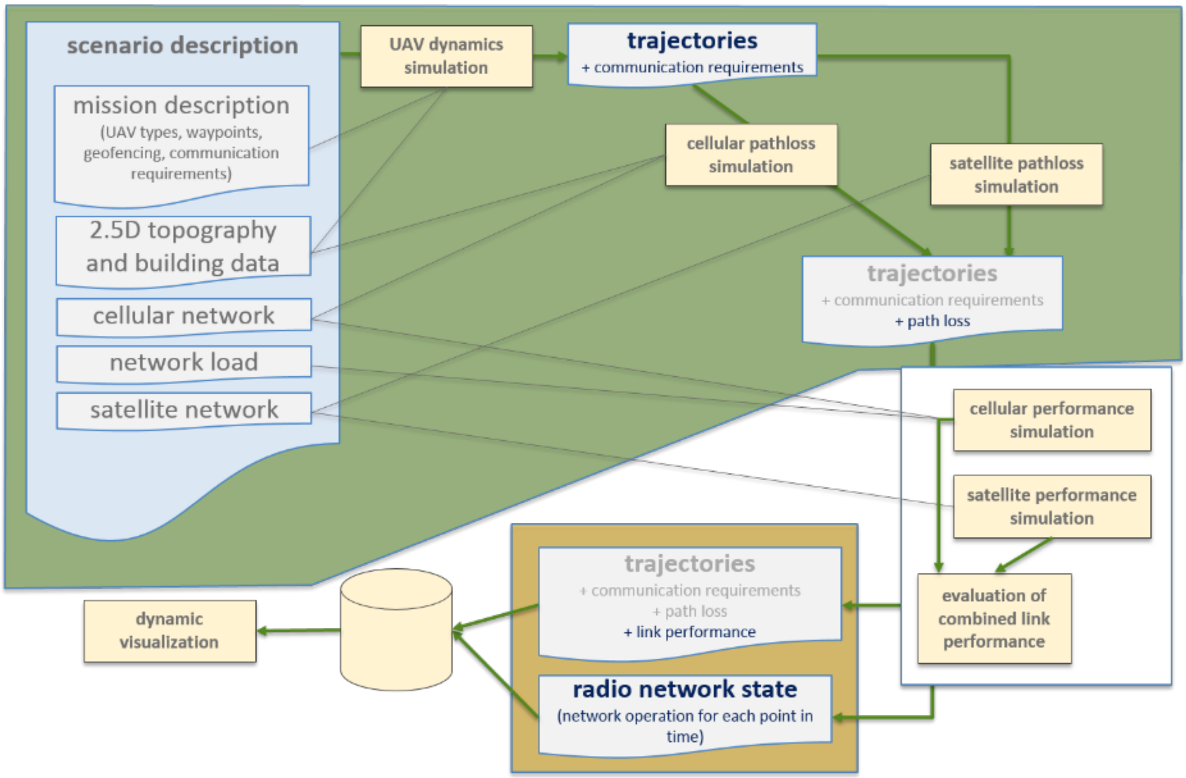

Figure 1 Architecture for the overall simulation environment proposed in [1]. The highlighted parts are addressed in this deliverable. The green part concerns the generation of scenario data as an input for the simulation module, the brown part concerns the simulation results (KPIs).

1.2 Structure of this document

This document is structured as follows:

- This first section describes the context, purpose and scope of the document as well as identify relevant documents and define abbreviations and terms that are specific to the domain used in this document.
- The second section summarizes the setup of the reference scenario, the choice of input data, and the choice of parameters used to generate the data for the reference scenario.
- The third section constitutes the main contribution of this document, detailing the data formats for the scenario data and the performance results obtained from the simulation.
- The final, fourth section contains conclusions and an outlook on future work.

1.3 Abbreviations, terminology and definitions

Abbreviation	Explanation
3G	3GPP UMTS 3rd generation cellular systems
3GPP	3rd Generation Partnership Project (cellular systems)
4G	3GPP UMTS-LTE (E-UTRAN) 4th generation cellular systems (LTE, LTE-Advanced)
5G	3GPP 5th generation cellular systems
5G NR	3GPP 5th generation New Radio cellular systems
AERO	Asymmetric Extended Route Optimization
AFRMS	Airborne Flight and Radio Management System
ANS	Air Navigation Services
AS	Access Stratum (communication protocol)
ATM	Air Traffic Management (manned and unmanned)
ATS	Air Traffic Services
BBF	Broadband Forum
BVLOS	Beyond Visual Line-Of-Sight
C2 (C&C)	Command and Control
CN	Core Network (3GPP networks)
EASA	European Aviation Safety Agency
D&A (DAA)	Detect and Avoid. This term is generally preferred to Sense & Avoid.
DL	Downlink radio communication, Network/Satellite -to- UA
DTM	Drone Traffic Management
FWD	Forward Link. From Cellular Network/Satellite Ground Segment to drone. This term will be used in the document in place of the following domain-specific terms • Cellular Network to drone "Downlink" • Combination of o "Satellite Ground Segment to satellite" link + o "Satellite to drone" link The opposite concept is named RTN (Return Link)
eNodeB (eNB)	E-UTRAN Node B (base station)
ICAO	International Civil Aviation Organization
IP	Internet Protocol
IPv4	IP version 4
IPv6	IP version 6
JARUS	Joint Authorities for Rulemaking of Unmanned Systems
KPI	Key Performance Indicator

L2	Layer 2 communication protocols
LA	Link adaptation (radio)
LISP	A Multi-Homing and Mobility Solutions for ATN using IPv6
LOS	Radio Line-Of-Sight
LTE	3GPP UMTS Long Term Evolution (Release 8-9)
LTE-A, LTE-Advanced	3GPP UMTS Long Term Evolution Advanced (Release 10-12)
GBR	Guaranteed Bit Rate
GRE	Generic Routing Encapsulation
HA	Hybrid Access (BBF)
HAG	Hybrid Access Gateway. A logical function in the operator network implementing the network side mechanisms for simultaneous use of both e.g. SAT and 3GPP access networks
HCPE	Hybrid Customer Premises Equipment (CPE). CPE enhanced to support the access side mechanisms for simultaneous use of both e.g. SAT and 3GPP access
IETF	Internet Engineering Task Force
JSON	JavaScript Object Notation. An open-standard file format that uses human-readable text to represent data.
MAC	Medium Access Control layer (communication protocol)
MLA	MultiLink Adaptor
MLGW	MultiLink Adaptor Gateway
MPTCP	Multipath TCP
NAS	Non-access Stratum (communication protocol)
NLOS	Radio Non-Line-Of-Sight
OWD	One-way delay
PDCP	Packet Data Convergence Protocol (communication protocol)
PGW	Packet Data Gateway
PHY	Physical layer (communication protocol)
PiC	Pilot in Command
QCI	QoS Class Identifier
QoS	Quality of Service
RAN	Radio Access Network
RLC	Radio Link Control layer (communication protocol)
RMa	Rural Macro (3GPP scenario)
RTN	Return Link. From drone to Cellular Network/Satellite Ground Segment. This term will be used in the document in place of the following domain-specific terms • Drone to Cellular Network "Uplink" • Combination of

	o “Drone to satellite” Link + o “Satellite to Satellite Ground Segment” Link The opposite concept is named FWD (Forward Link)
RTT	Round Trip Time
RPAS	Remotely Piloted Aerial System: remotely piloted UAS by human operator
RRC	Radio Resource Control layer (communication protocol)
RRM	Radio Resource Management
SAT	Satellite System/Network
SATPL	Satellite Transparent payload (supported by Platform)
SESAR JU	Single European Sky Air traffic management Research Joint Undertaking
SFRMS	Satellite Flight and Radio Management System
SGW	Satellite Gateway
TCP	Transmission Control Protocol
TR	Technical Report
UA	Unmanned Aerial/Aircraft
UAS	Unmanned Aerial/Aircraft System, including UAV, ground control, and communication link
UDP	User Datagram Protocol
UE	User Equipment (3GPP)
UL	Uplink radio communication, UA -to- Network/Satellite
UMa	Urban Macro (3GPP scenario)
U-Space	See Table 2
VLOS	Visual Line-Of-Sight
VPN	Virtual Private Network

Table 1: Abbreviations

Term	Explanation
C2 Link	"Command and Control" Link, a data link established between the remote "Pilot in Command" (PiC) and the vehicle it is controlling. This link is used to exchange data necessary for the Aviate, Navigate, Communicate functions of the airborne platform and is different from the "Payload Communication" link that is used to carry data related to the mission of the vehicle from a customer point of view.
C-plane	Control plane radio communication protocols; control messages, data packets used to manage the user plane (U-plane)
Drone	UAV with private or commercial application, operating in the EASA Open or Specific category.
Hybrid Access	The coordinated and simultaneous use of two heterogeneous access paths (e.g., LTE and SAT).
Hybrid Access path	Network connectivity instance between HCPE and HAG over a given access network; SAT or 3GPP.
Hybrid Access session	A logical construct that represents the aggregate of network connectivity for a Hybrid Access subscriber at the HAG. It represents all traffic associated with a subscriber by a given service provider, with the exception of Hybrid Access bypass traffic, and provides a context for policy enforcement.
Payload	The term payload designates the equipment that is hosted on a physical aerial/airborne platform for the purpose of performing the mission. The term payload can be used in reference to a UAV Payload (i.e. the equipment aboard the UAV that are used for the UAV to perform its mission, e.g. sensors or cameras used to examine a given geographical area). The term payload can be used in reference to a Satellite Payload (i.e. the equipment aboard a satellite that is used for the satellite to perform its mission, e.g. a transparent signal repeater in a telecommunication satellite or an optical equipment in an earth observation satellite).
Radio adaptation	Adaptation and configuration mechanisms on the PHYsical layer and Medium Access Control layer
Radio capacity	The transmission (DL and UL) radio resources available in the radio system.
Radio link	The DL or UL radio transmission link
Radio mobility	UE changing the serving radio cell (base station, eNB, satellite) due to physical movement, radio channel changes, or explicit commands from the serving cell.
U-plane	User plane radio communication protocols; payload end-user data packets
U-Space	A set of new services and specific procedures designed to support safe, efficient and secure access to airspace for large number of drones.
..	

Table 2: Terminology and definitions

2 The Reference Scenario

2.1 Scenario background

The DroC2om project aims at evaluating the feasibility and reliability of establishing the C2 link of an UAV and the possibility of providing further service via existing radio network infrastructure, i.e. LTE and satellite networks. These capabilities are of particular importance for the Beyond Visual Line-of-Sight (BVLOS) use case for UAV. In addition, the combined usage of the cellular and the satellite network to ensure availability and reliability of the C2 link is to be investigated.

To reflect these aspects in simulations based on realistic data, the DroC2om project selected a region in the Baltic Sea between the German city of Stralsund and the Danish island Bornholm as the theatre for the reference scenario (cf. Figure 2). This choice is mainly due to the public availability of cellular network data (see below). In addition, it offers the following interesting features that can be investigated in the evaluations:

- The cellular network covers only the areas of the Baltic sea that are close to the shore. Thus it is necessary to use the satellite link for the offshore part of UAV missions.
- The region features both urban (Stralsund, Bergen auf Rügen, Rønne) and rural areas.
- There are several areas which may be no-flight zones for UAVs, like the airport, nature reserves, or ferry lines.
- The satellite link consists of two signal paths: the line-of-sight path between the satellite and the UAV and an indirect path where the signal is reflected on the ground. The reflection behavior differs between soil and sea water, affecting the satellite link.

There is a range of interesting UAV missions that can be simulated in this region:

- Urgent deliveries (e.g. blood) from Stralsund to Bornholm.
- Deliveries to vessels at sea, e.g. ships or wind energy plants.
- Video-based inspection of the offshore wind energy plants, requiring a high bandwidth in addition to a reliable C2 link.

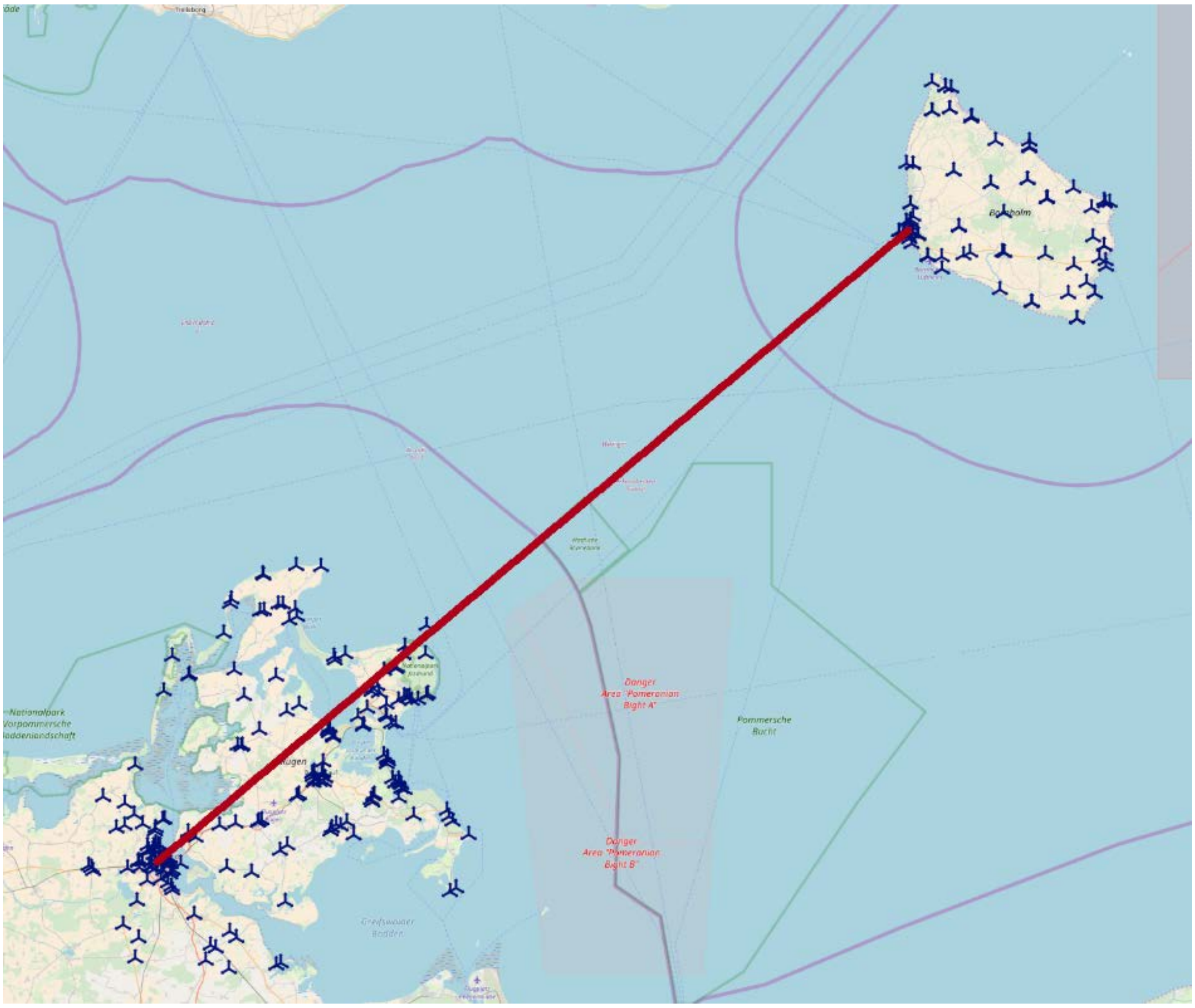

Figure 2: The geographic region considered in the reference scenario. Shown are the LTE base stations of both the German and the Danish network that may provide radio links for the UAV. The dark red line indicates the UAV flight path investigated in the reference scenario.

2.2 Data sources

As a basis to generate the scenario data, the data from the following sources is used.

- Cellular network data

  Nokia provided data for the Danish LTE network on Bornholm extracted from the public Danish data base http://www.mastedatabasen.dk. atesio provided data for the German LTE network in the Rügen area obtained from https://emf3.bundesnetzagentur.de/karte/Default.aspx. This data has been combined to constitute the overall cellular network for the scenario which is shown in Figure 2.

- Satellite network data

Thales provided data for a geostationary satellite covering the requested region. The satellite features a multi beam antenna. Among the available beams, two adjacent beams were selected in order to be able to simulate a handover between beams. The two beams are shown in Figure 3.

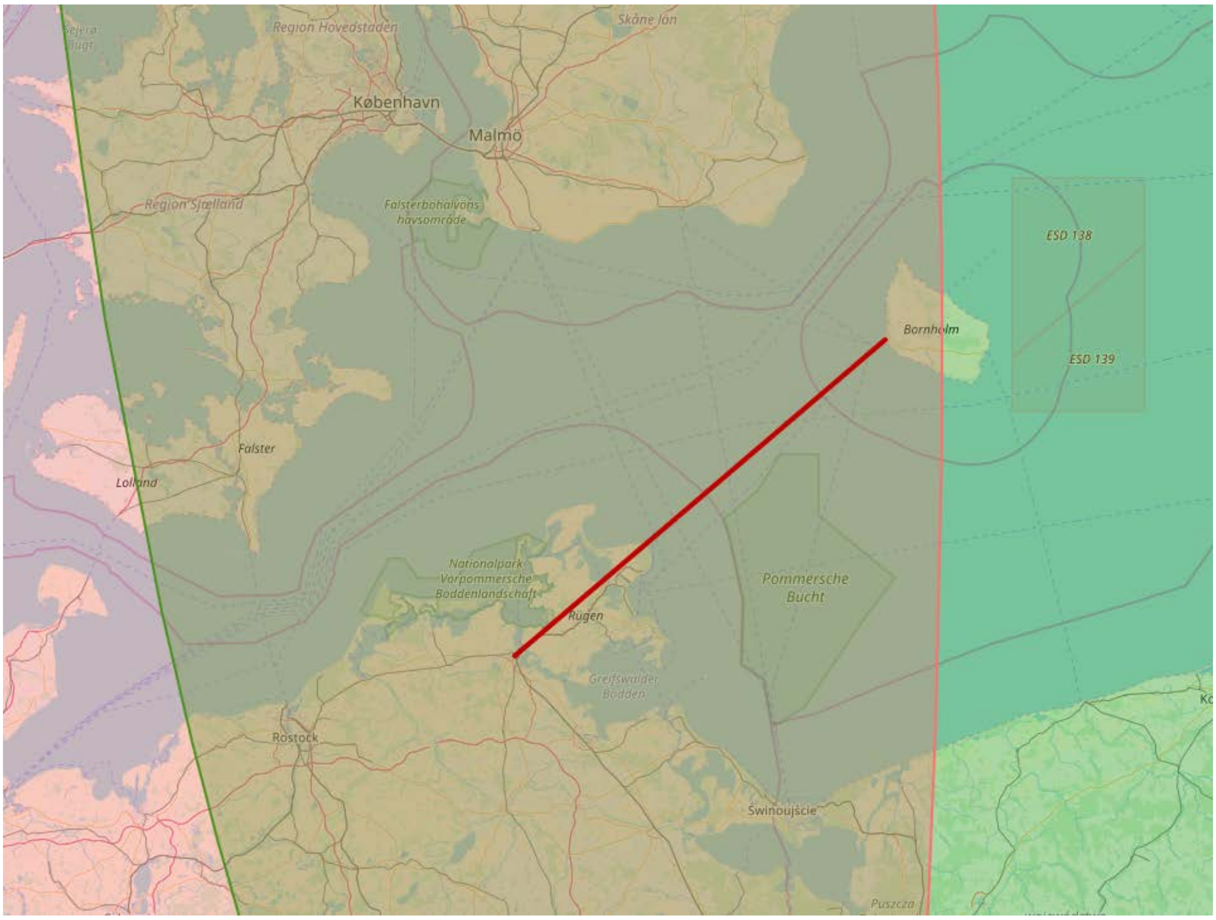

Figure 3: The two beams of the geostationary satellite that provide coverage for the scenario regions. The red area corresponds to the western beam whose signal level fades away in eastern direction until the beam becomes invisible over Bornholm. Likewise the green area corresponds to the eastern beam whose signal level increases in west-east direction. Again, the dark red line indicates the UAV flight path investigated in the reference scenario.

2.3 Data files for the reference scenario

Based on the above considerations and the available network data, data files for the reference scenario have been generated. The reference scenario is a simple scenario that is used by the DroC2om project to drive the development of both the simulation and visualization/evaluation modules (cf. Figure 1). The data for the reference scenario including a more detailed description will be available from the project's homepage and comprises the following information (see Section 3.2):

- UAV trajectories
- UAV radio access requirements
- Cellular network connectivity
- Cellular network traffic

- Satellite network connectivity

The initial setup for the reference scenario has deliberately been kept simple, e.g. by considering only a single UAV flying on a straight line from Stralsund to Rønne (see Figure 2 and Figure 3) at a constant altitude of 50 meters. This simple trajectory is sufficient for obtaining data to perform initial simulations and evaluations of the link performance. Starting from this initial version it is envisioned to incrementally refine the scenario to increase the degree of realism. Moreover, the setup of the reference scenario serves as a basis for more detailed demonstration scenarios focussing on specific interesting aspects.

3 Data Formats

3.1 General

Scenario data is provided as a set of JSON files that are collected in a zip archive. This choice has the advantage of a data format that is human-readable and extensible (JSON) while keeping the scenario data file size within reasonable limits due to the compression. Indeed, preliminary experiments for a JSON file describing a UAV trajectory from Stralsund to Bornholm at a resolution of 10 milliseconds resulted in a 6MB archive for the 192MB JSON file.

Note that the keys of subdicts in the JSON file are not ordered. Whenever order does matter, the formats use a list to make this explicit.

The position of an UAV is described in the WGS84 coordinate system, enhanced with the altitude of the vehicle in meters above sea level. These values are provided in a dict with keys `lat` (latitude), `lon` (longitude), and `altitude_m` (altitude). Example:

```
{"lat" : 54.3 , "lon" : 13.08333 , "altitude_m" : 50.0 },
```

The simulation instance (point in time) is given as a time stamp with at least millisecond resolution. This time stamp is time passed relative to the start of the mission, starting at `00:00:00.000`. Example:

```
"02:15:42.345"   // 2 hours, 15 minutes, 42.345 seconds after start of simulation
```

General information about the scenario is provided in the file `scenario_info.json`. The following keys are defined:

- `UAV_IDs`: List of ID strings naming the UAVs in the scenario.
- `time_step_s`: Time step (in seconds) used for generating the data (traces).
- `start_time`: Time stamp indicating the beginning of the simulation.
- `end_time`: Time stamp indicating the end of the simulation.
- `map_bbox`: Bounding box for all UAV trajectories, given by the south east and north west corner.
- `cellular_info`: Info on the LTE network, comprising the frequency band and the bandwidth.
- `satellite_info`: Info on the Satellite network, comprising the position of the (single) satellite and the names of the beams used in the scenario.

Example:

```
{"UAV_IDs": ["drone1", "drone2"],
 "time_step_s": 0.050,
 "start_time": "00:00:00.000",
 "end_time": "02:10:00.000",
 "map_bbox": {"south_east": {"lat": 54.25, "lon": 13.10},
              "north_west": {"lat": 55.10, "lon": 14.10}
    },
 "cellular_info": {"band": "LTE800",
                   "bandwidth_MHz": 10.0,
                  },
 "satellite_info": {"position": {"lat": 0.0, "lon": 12.0, "altitude_m": 35786000.0},
                    "beams": ["beam1", "beam2"]
                   }
}
```

Additional metadata may be stored in this file later on as the need arises.

3.2 Input data for the cellular and satellite simulation module

3.2.1 UAV trajectories

The trajectory data for each UAV is provided in the file `uav_trajectories.json`. The file contains a dict of dicts, where the top-level keys are timestamps specifying the point in time at which the UAV positions are sampled. For each point in time, there is a dict with the following keys:

- <UAV_id>: Dict specifying the position of the UAV with this ID. Valid IDs are the strings provided in the file `scenario_info.json`.

Example:

```
{"00:00:00.000": {
   "drone1": {"lat": 54.3, "lon": 13.08333, "altitude_m": 50.0},
   "drone2": { ... }
 },
 "00:00:00.010": {
   "drone1": {"lat": 54.3, "lon": 13.08333, "altitude_m": 50.0},
   "drone2": { ... }
 },
 // ...
}
```

3.2.2 UAV radio access requirements

During its flight the UAV has certain requirements for the performance of the communication link. These may change during the mission according to the services performed in each phase of the flight. The link requirements for each UAV are listed in the file `uav_link_requirements.json`.

The general idea is to specify for each service performed by the UAV time windows along with the communication requirements by this service. The most basic service is, of course, the C2 link, but there may be additional ones, e.g. video streaming. The top-level keys of the JSON file are the IDs of the

UAVs, the second-level keys symbolic names for each service, which is described by the following information:

- start_time, end_time: Timestamps specifying one or more time windows in which the service is performed.
- downlink, uplink: Link performance requirements: packet size, throughput, and latency. We assume that the data comprising the throughput arrives with a constant interarrival time in packets of the specified size.

Example:

```
{"drone1": {"C2": {"time_windows": [{"start": "00:00:00.000",
                                      "end": "02:10:00.000"}],
                   "downlink": {"packet_size_bytes": 100,
                                "throughput_kbps": 17.0,
                                "latency_s": 0.2},
                   "uplink": {"packet_size_bytes": 100,
                              "throughput_kbps": 7.0,
                              "latency_s": 0.2}
                  },
            "video": {"time_windows": [{"start": "00:00:00.000",
                                         "end": "00:15:00.000"},
                                        {"start": "01:55:00.000",
                                         "end": "02:10:00.000"}
                                       ],
                      "downlink": {"packet_size_bytes": 100,
                                   "throughput_kbps": 10.0,
                                   "latency_s": 0.05},
                      "uplink": {"packet_size_bytes": 1250,
                                 "throughput_kbps": 300.0,
                                 "latency_s": 0.05}
                     },
           }
  // data for remaining UAVs
}
```

3.2.3 Cellular network connectivity

Radio connectivity data for the cellular network is provided for each UAV in the file cellular_connectivity.json.

Again, the file contains a dict of dicts, where the top-level keys are timestamps matching the timestamps from the trajectory file. The dict for each timestep describes for each UAV the connectivity to the up to 32 best servers at this simulation instance. The UAV dicts contain the following information for each of the best servers:

- server_<rank>: ID of the best server with the given rank. Rank 01 denotes the best server, rank 32 the worst of the up to 32 servers (if visible). If this key is present for a given rank, then so are the following additional keys.

- `signal_<rank>_dBm`: Downlink/Forward link wideband signal level of server received at the UAV (in dBm), i.e. transmit power plus serving antenna gain plus (negative) pathloss.
- `h_angle_u2c_<rank>`: Horizontal angle between UAV and cell in degrees. The angle is measured clock-wise to the *north* direction which corresponds to 0.0 degrees.
- `v_angle_down_u2c_<rank>`: Vertical angle between UAV and cell in degrees. Positive values indicate that the UAV "looks down", i.e. is above the antenna, whereas negative values indicate that the UAV is below the antenna.

All angles are provided rounded to one decimal place.

Example:

```
{"00:00:00.000": {
  "drone1": {// best server:
             "server_01": "528991_240",
             "signal_01_dBm": -41.1,
             "h_angle_u2c_01": 120.3,
             "v_angle_down_u2c_01": 3.4,
             // 2nd-best server:
             "server_02": "528991_0",
             "signal_02_dBm": -44.1,
             "h_angle_u2c_02": 120.3,
             "v_angle_down_u2c_02": 3.4,
             // ...
            },
  // data for remaining UAVs
 },
 // data for other time steps
}
```

3.2.4 Terrestrial cellular network traffic

Traffic data for the cellular network is provided for each relevant cell in the file `cellular_traffic.json`. A cell is considered a relevant cell at a simulation instance if it is among the best servers for any UAV at this instance.

Again, the file contains a dict of dicts where the top-level keys are the timestamps from the trajectory file. Each second-level dict describes the traffic for each relevant cell at this point in time, the keys being of the form `<server_id>`, where `<server_id>` is the ID of a relevant cell. Each dict contains the following information for the traffic of the corresponding cell:

- `DL_loaded`: A zero-one value indicating whether the downlink is loaded (1) or not (0). The downlink is considered to be loaded if there is at least one call served by the cell (see Chapter 4 of [1]).
- `UL_interference_dBm`: Uplink interference contributions (in dBm) from all considered terrestrial UEs to this cell, computed as described in Chapter 4 of [1].

Example:

```
{"00:00:00.000": {
    "server_01": {"DL_loaded": 0,
                  "UL_interference_dBm": 12.3},
    "server_02": {"DL_loaded": 1,
                  "UL_interference_dBm": 34.6},
    // data for remaining cells
   },
 // data for remaining simulation instances
}
```

3.2.5 Satellite network connectivity

Connectivity data for the satellite network is provided for each UAV in the file `satellite_connectivity.json`.

The file contains a dict of dicts where the top-level keys are the timestamps from the trajectory file. Each second-level dict describes the connectivity to the geostationary satellite for the corresponding simulation instance. The keys of these dicts are <UAV_id> as for the trajectory data (see above). The UAV dicts contain the following information:

- `Es_N0_dB`: The value of the ratio $E_s N_0$ (Symbol-Energy-to-Noise-Density Ratio, SNR) for the forward link from the satellite to the UAV, computed as described in the forthcoming Deliverable D4.2 [3]. This value is provided for each beam of the satellite.
- `groundtype_specular`: Type of ground at specular point for the indirect satellite/UAV link. Either `land` or `sea`.

Example:

```
{"00:00:00.000": {
    "drone1": {"Es_N0_dB": {"beam1": 69.2,
                            "beam2": 72.1},
               "groundtype_specular": "land"
              },
    // data for remaining UAVs
    },
 // data for remaining simulation instances
}
```

3.3 Results of the cellular and satellite simulation module

The results of the simulation module are a set of KPIs that characterize the link performance (cf. Figure 1). They are produced in an archive of JSON files just as the reference scenario data. A result archive may then be used e.g. for visualization.

The following is a proposal for the general structure of the KPI file, which is likely to be enhanced once the simulation module has been set up.

Information regarding the type and configuration of the system being simulated is stored with the top-level key simulation_configuration. Currently, the following keys are anticipated:

- link_type: Possible values are cellular, satellite, hybrid.
- UAV_beams: Number of cellular beams available on each UAV. A value of 1 corresponds to an omni-directional antenna.
- ICIC_configuration: Indicator for the use of Inter-Cell Interference Coordination (ICIC). Possible values are off or the number of cells to use.

For each time step there is a dict with the following KPI information for each UAV.

- PHY: performance on physical layer
  - DL_SINR_dB, UL_SINR_dB: wideband SINR
  - DL_throughput_kbps, UL_throughput_kbps: downlink and uplink packet transmission throughput
  - UL_power_dBm: uplink transmit power (for cellular link)
  - DL_packet_error, UL_packet_error: downlink and uplink packet error rate
- MAC: performance on medium access layer
  - DL_delay_ms, UL_delay_ms: downlink and uplink packet radio transmission delay (latency). This includes delays due to potential radio handovers.
  - RAF_status: zero-one value indicating a Radio Access Failure (RAF) in the time slot, i.e. whether the radio connection was lost
- system: radio access system status
  - radio access: Hybrid access status, i.e. access link in uses. Possible values are cellular, satellite, hybrid-switched, hybrid-simultaneous. The performance data corresponds to the active access mode.
  - RLF_status: zero-one value indicating 3GPP Radio Link Failure, i.e. whether the connection was lost for at least 1 second (cellular network)
  - UAV_active_beam_id: Index/ID of UAV beam used to establish the connection.

Example:

```
{"simulation_configuration": {"link_type": "hybrid",
                              "UAV_beams": 4,
                              "ICIC_configuration": "off"
                             },
 "00:00:00.000": {
   "drone1": {"PHY": {"DL_SINR_dB": 0.0, "UL_SINR_dB": 0.0,
                      "UL_power_dBm": 20.0,
                      "DL_throughput_kbps": 150.0,
                      "UL_throughput_kbps": 45.0,
                      "DL_packet_error": 0.05,
                      "UL_packet_error": 0.0,
                     },
              "MAC": {"DL_delay_ms": 0.0,
                      "UL_delay_ms": 0.0,
                      "RAF_status": 0,
                     },
              "system": {"link_type": "hybrid-switched",
                         "UAV_active_beam_id": 3,
                        },
   },
   // data for remaining UAVs
 },
 // data for remaining simulation instances
}
```

4 Conclusions and outlook

This document describes the reference scenario, the models and data used to generate the scenario data, and the data formats used to represent scenarios in the DroC2om project.

The next steps within WP3 are to implement the GUI for viewing and analyzing the scenario data and simulation results provided by WP4. The parameters of the cellular path loss prediction and shadow fading models use to generate the cellular connectivity data will be calibrated based on outcomes of WP5. The reference scenario data will be refined in cooperation with WP4. Thales and Nokia will set up and implement their respective simulations according to the models described in deliverable D3.1 [1].

5 References

[1] DROC2OM project, „D3.1 - Models for combined cellular-satellite UAS communication," SESAR 2020-763601 DROC2OM deliverable, 2018.

[2] DROC2OM project, „D2.1 - Scenarios and requirements," SESAR 2020-763601 DROC2OM deliverable, 2018.

[3] DROC2OM project, „D4.2 - Satellite system concepts solutions for high reliability UAS data links," SESAR 2020-763601 DROC2OM deliverable, forthcoming.