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Test Set Implementation

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1   E XECUTIVE S UMMARY

This deliverable is the outcome of Task 4.2 "*Test set Implementation*" activities, which aim at **detailing the hardware demonstration platform**, *i.e.*, incumbent/cognitive systems and channels, channel emulator, cross and interference channels, interference detection, and network response, [1].

WP4 aims at validating and demonstrating the CoRaSat concept through testbed implementation of the selected scenario. Within this context, all of the cognitive techniques analysed in D3.3 [2] have been adapted to the CoRaSat system in D3.4 [3] and WP4 aims at providing an **end-to-end demonstration**. In D4.1, storyboard test cases representative of the developed scenarios, use cases, and technologies have been provided together with the test procedure. Based on these studies, the **feasibility** of the proposed cognitive techniques **is demonstrated** within the use cases defined in D4.1, [4].

In this document, the context of the hardware demonstration platform is described in details, which serves as basis for the formal test and demonstration that will conclude CoRaSat activities. This demonstration platform responds to the required laboratory setup for the execution of the storyboard cases as defined in the D4.1 context. From these storyboard test cases, a list of requirements that need to be setup in the demonstration context is defined, as well as what shall be implemented. The different implementation development work items are defined and explained in the context of this document. Furthermore, **the overall demonstration context is outlined** and the required test cases are explained in details.

All of the development tasks that were specifically made for the setup of the CoRaSat demonstrator are thoroughly described in this deliverable. The demonstration setup is described from a **top level architecture** perspective and the different storyboard scenarios are presented, together with the approach for their demonstration on the platform.

The used test platform is an **IF loop (L-band) based test setup** that emulates the forward and return links of a two-way satellite system based on representative "product grade" hardware for the user segment and the hub segment side. The used hardware and setup is therefore **"close to product implementation"** and demonstrates the feasibility of the proposed techniques in a test laboratory environment.

It shall be noticed that this deliverable is to be considered together with D4.2 "*Test Plan Document,*" which defines the overall test-plan, as derived from the storyboard cases.

2   SCOPE AND STRUCTURE OF THE DOCUMENT

This document describes and details the test set implementation, which is the work performed in the context of Task 4.2 "*Test set Implementation*" of the CoRaSat project. This document outlines the detailed test setup of the demonstration context for the CoRaSat demonstrator. The use cases for the demonstrator have been defined in the context of Task 4.1 in D4.1 and the test plan is outlined in D4.2. The test set implementation is then described in the context of these requirements for the test parameters and conditions.

This document describes the test set implementation and the detailed testplan is defined in the document D4.2, both of which are based on the considered scenarios and techniques from D3.4 and the related storyboard context defined in D4.1. Figure 2.1 shows the work plan for WP4, highlighting the link among the deliverables and the input to the defined documents for this phase of the project.
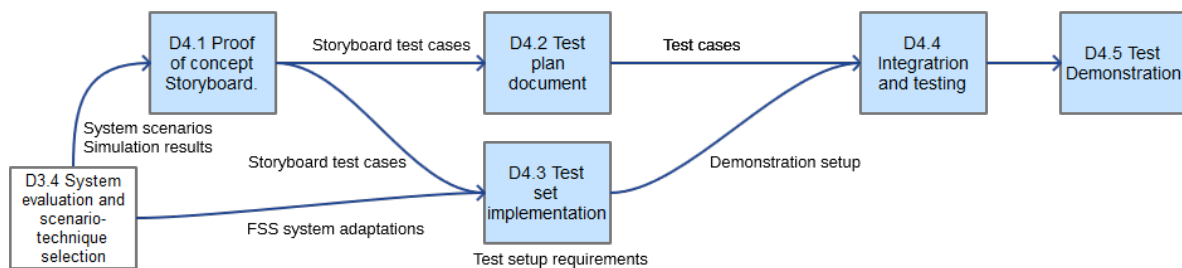
Figure 2.1 - WP4 study plan overview.

The equipment needed for the test set implementation is identified and the implementation of novel equipment features is described and outlined. The implementation plan foresees the lab setup of the test equipment and the development plan of new test features and capabilities that are implemented in the context of this project.

This description includes the following aspects that are covered by this document:

- Incumbent system representation.
- Cognitive system representation.
- Channel emulator.
    - o Incumbent channel (emulation).
    - o Cognitive channel (emulation).
    - o Cross or Interference channels (emulation).
    - o Interference detection by the secondary channel and network response.

This document is organized as follows.

In Chapter 3, the test use cases are summarized and the requirements of the test setup are derived from the detailed test plan described in D4.2 and the use cases defined in D4.1.

In Chapter 4, the development tasks are outlined. These include the elements that require development on top of existing equipment and technologies.

Chapter 5 details the implementation of the lab environment and the equipment used in the context of the setup in the lab.

In Chapter 6, the overall test cases from D4.2 are reviewed and the expected configuration of the lab equipment is elaborated. The subsequent work of test set integration is detailed and elaborated in this section.

Finally, Chapter 7 concludes this deliverable.

3 OBJECTIVES OF THE DEMONSTRATION PHASE

The objectives of the end-to-end FSS satellite system demonstration under scenario A [17.3-17.7] GHz and scenario B [17.7-19.7] GHz forward links and scenario C [27.5-29.5] GHz return link capacity utilization is to: i) verify and demonstrate the feasibility of the proposed cognitive techniques to mitigate the impact of the terrestrial interference in scenario A and B contexts; and ii) to demonstrate the possible compliance to a defined interference threshold defined in power spectral density [dBm/Hz] at the input of an FS receiver under scenario C context for the return link.

Therefore, the test set aims at emulating in L-band IF the end-to-end FSS satellite system (cognitive system) and the impact of the incumbent system so as to verify and demonstrate the feasibility of the proposed cognitive techniques. The key performance indicators (KPI) shall be measured on the system, including the achieved spectrum efficiency as well as the quality of service (QoS) of an end-to-end application under spectrum sharing conditions.

Another aspect that is considered in the definition of the test setup is the interference generated towards the incumbent user, which corresponds to the scenario C [27.5-29.5] GHz use case.

From these defined demonstration objectives a lab setup is defined and the demonstration of the identified cognitive techniques as outlined in D3.4 is performed. This is done under the definition of the presented requirements for the demonstrator.

3.1 Demonstrator setup requirements and scaling

The demonstration setup requirements are derived from the defined storyboard cases in D4.1 as outlined in Table 1.

Table 1 - Storyboard test cases defined according to D4.1.

Storyboard cases	Description
1	Installation/deployment of a network of terminals within a cognitive zone close to a FS link or BSS uplink with database support
2	Change network configuration of FSS terminal when incumbent user link interference is present (in cognitive zone)
3	Measure Network Efficiency with and without RA technique usage
4	Detect interference present from the incumbent user on the forward link
5	Change the forward link carrier capacity allocation (frequency) according to incumbent user interference presence
6	Measure interference levels from configured FSS system on the return link at the FS receiver
7	Change the return link carrier frequency, power and rates according to incumbent user environment
8	ESOMP movement through the coverage area

From the defined demonstration objectives, as outlined in the previous section and the storyboard test cases, we can derive the requirements for the lab setup, as shown in Table 2.

Table 2 - Demonstrator test platform requirements.

Requirement	Description	Related scenario	Related storyboard [as defined in D4.1 chapter 7]
1	The FSS end-to-end satellite link should be emulated (forward and return link)	A, B, C	All
2	The FS terrestrial incumbent link (or BSS feeder link) interference should be emulated	A, B	All
3	The FS receiver should be emulated	C	7
4	A fix and mobile (ESOMP) terminal can be emulated.	A, B, C	1-7 8 for ESOMP
5	Interference detection The FSS system shall be capable of identifying the presence of incumbent interference per terminal on the forward link.	A, B	4
6	Interference management The FSS system shall be capable of managing the return link transmission parameters such that the interference at the incumbent FS link receiver is within defined limited power spectral density.	C	7
7	Centralized NCC control requirement (CC) The FSS system NCC shall be capable of controlling the forward link allocation and return link transmission parameters of all terminals in the network.	A, B, C	All
8	Database interfacing requirement (DB) The FSS NCC shall interface with an external database emulator server.	A, B, C	1, 2, 6
9	NCC (SS-SNIR) Spectrum sensing based on system parameters The FSS NCC shall be capable of identifying omissions or errors in the NCC database by using interference detection methods (spectrum sensing) based on available system parameters per forward link.	A, B	4

10	Forward link re-configurability (DCA-FWD) The FSS terminal forward link shall be reconfigurable between different (at least 2) forward link carriers.	A, B	5, 8
11	Return link transmission configuration (DCA-RTN) The return link parameters (transmit power, frequency, modulation and coding, bandwidth used) can be reconfigured from the centralized NCC control to adapt to the required transmit conditions per terminal	C	7, 8
12	Resource Allocation (FWD and RTN link) The allocation of the forward and return link capacity to achieve a target overall average network efficiency shall be possible.	A, B, C	3

In addition to the demonstrator platform requirements, the D4.1 storyboard also requires the setup and development of the test equipment to measure and record the key performance indicators (KPIs).

Table 3 summarizes the required measurement metrics for the demonstration setup.

Table 3 - Measurement requirements of the demonstration platform..

Metric defined [according to D4.1]	Measurement point
System capacity metric #1	Measure the efficiency in terms of overall bps/Hz on average over the used capacity for forward and return link
Service throughput and availability metric #2	Measure the defined service availability for terminals in terms of throughput / terminal on the forward and return link according to the defined requirements in terms of service capacity
Impact on incumbent system metric #3	Measure power density at FS receiver input in terms of dBm/Hz. This is performed at the emulated FS receiver input with a measurement instrument after an emulated interference link

4   DEMONSTRATION TEST CASES

This chapter summarizes the top level layout and configuration of the different setups implemented on the test cases, establishing the different setup values for test-cases. Based on the defined storyboard in the document D4.1 and the derived demonstration platform goals and requirements of the preceding section, we define here the different components to be used for the test platform.

These are lab equipments that are as far as possible based on existing products and equipment. Some components and functionality is implemented in addition to existing products and lab components. These are clearly highlighted in the defined project context and outlined in accordance with the additional CoRaSat demonstration platform specific developments that have been performed.

Figure 4.1 illustrates the foreseen setup of the emulator.
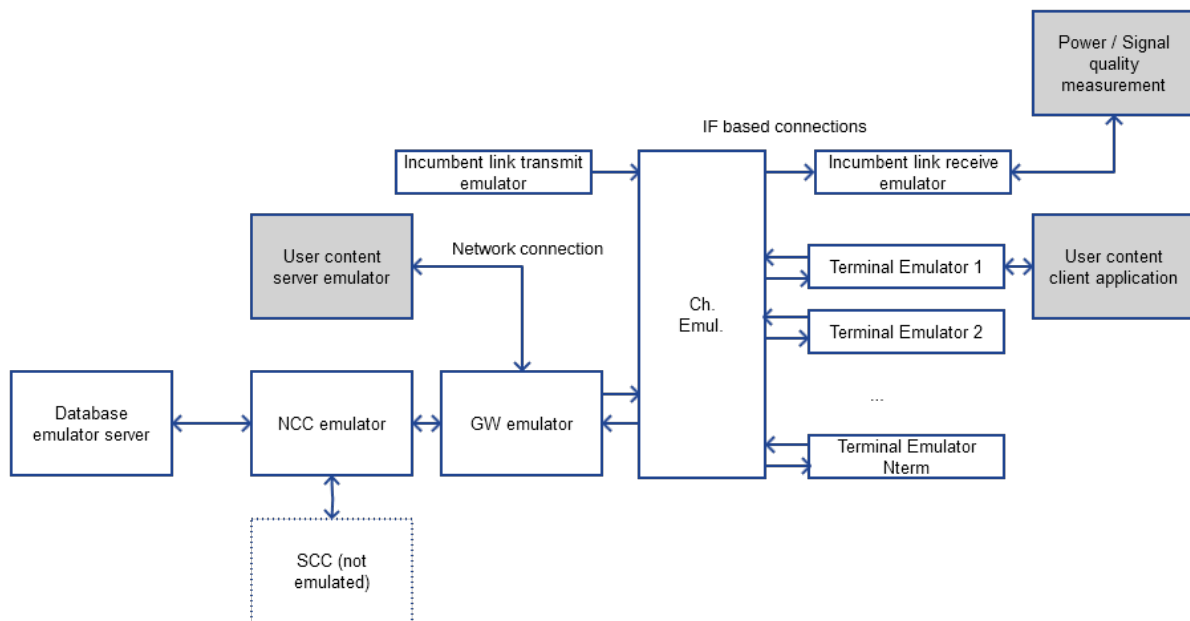
Figure 4.1 - CoRaSat Test and Demonstration Platform setup for the end-to-end link emulation.

The defined demonstration platform components are the following and the required additional development on CoRaSat is defined in Table 4.

Table 4 - Identified test equipment and required development tasks for the demonstration setup in WP4.

Demonstrator component	Available hardware	Required additional development or setup
1./ Database emulator (DBe)	None.	A database server is setup and implemented specifically for CoRaSat WP4 database emulation.
2./ Gateway emulator (GWe)	Available components from commercial equipment	None.

3./ Network Control Center (NCC)	Partially available based on commercial equipment	To be developed controller software for the NCC: Dynamic Capacity Allocation (DCA) for forward link Dynamic Capacity Allocation (DCA) for the return link Resource allocation (RA) algorithm Interference detection mechanism (SS-SNIR) Database Interface Interference context controller
4./ User terminal emulator (UTe)	Commercial user terminal is used	None.
5./ Channel emulator (CHe)	Not yet available	Developed in the context of the CoRaSat WP4 (as entire new stand-alone channel emulator equipment)
6./ Incumbent user receiver (IURe)	Available receiver and measurement equipment is used for emulation	None.
7./ Incumbent user transmitter (IUTe)	Available transmitter is used for the emulation	None.
8./ Content server and client (CS, CC)	Available traffic emulation devices are used	Specific configuration required for the CoRaSat WP4 setup
9./ Test Control PC	None	User Interface for the WP4 storyboard control and monitoring as required for the entire test management and control interface

4.1 Common configurations

All of the setups will share the following common configuration modules. After this, modules with different setup per scenario will be explained.

The overall system foresees the implementation of a basic setup of a two-way satellite system platform, which is available for the demonstration and is based on a HUB6000/Dialog Newtec platform [5].

The end-to-end system can operate a two way access terminal and provision, install, and operate the end-to-end system.

The additional components that are implemented are defined in Table 4 and summarized in their main aspects in the following:

- Channel emulator with specific interference input and variable link settings (#5 in Table 4).

- NCC emulator for the control of all of the terminal parameters, which implements the cognitive DB and RA mechanisms as well.

- Database emulator to emulate the regulatory database.

- Generic measurement instruments are used, such as a power meter to verify the interference levels at the incumbent user reception and a spectrum analyzer, IP traffic sources, and meters.

The KPI parameters listed in Table 5 are measured by the platform.

Table 5 - Key performance indicators measured on the test setup and the measurement devices.

KPI	Measurement point in demo setup
Overall efficiency / system	Aggregated in NCC
Efficiency average / terminal	Per terminal measurement at NCC
C/I estimates per terminal	Per terminal measurement at NCC
Throughput and BER / terminal	GWe for return link and Terminal for FWD link Measurements are collected at NCC

4.1.1   Database Emulator Server

The database will set the different test values in terms of interference levels. On every test-case different table values will be used, taking into account that expect for the test-case #8, the rest of the tests will use the database entries to simulate the tests.

Test-case #8 will imply several database values to simulate the movement path covered by the ESOMP terminal from one point to another inside of the satellite beam.

4.1.2   NCC Emulator

The network control and configuration (NCC) emulator has the task to control and monitor all terminal parameters and to manage the access of the terminals to the network. All required configuration, provisioning, monitoring, and control functions are implemented on the NCC for the service definition.

The tasks of the NCC controller include the following:

1. Configure, record, and provision all terminal services.

2. Keep track of the terminal states and the configuration of the terminal setup installations.

3. Measure and monitor the terminal link parameters and indicators and keep track of the parameters over time:

   a. Signal power (PWR).

   b. Signal to noise ratio (Es/N0).

   c. MODCOD.

   d. Error rate (BER).

4. Control terminal transmission and reception parameters, including:

   a. Forward link selection (FWD_1 and FWD_2).

   b. Return link power, frequency, modulation and coding, bandwidth allocation.

The NCC emulator on the basis of these functions will implement the set of CoRaSat cognitive techniques that we intend to demonstrate in the context of this project. These include a set of techniques as described in D3.3 [2] and adapted in D3.4 [3] context, as shown in Table 6.

Table 6 – Cognitive techniques implemented on the demonstration platform.

Cognitive technique	Technique reference
DB	Database interaction (DB)
SS	Interference detection on the forward link (SS-SNIR based interference detection, as described and adapted in document D3.4)
RA	Resource allocation on the return link Interference control and transmission management on the return link (JCPA / RA, as described and adapted in document D3.4)
DCA (FWD)	Dynamic Capacity Allocation – Forward link The possibility of the NCC to redirect capacity from one subnet (FWD1) to another subnet (FWD2) is implemented. The dynamic reallocation of the capacity is managed by the NCC.
DCA (RTN)	Dynamic Capacity Allocation – Return link The allocation of capacity on a specific return link carrier group is demonstrated. The NCC redirects the capacity from one carrier group to another, depending on the decision process of the interference detection process.

The NCC is also responsible to keep track of the interference levels detected on forward and return links per terminal and carrier. This implies that the NCC keeps track of the forward link carrier interference levels measured per terminal.

4.1.3   Channel Emulator (CHe)

The channel emulator implements the possibility to add signal, noise, and interference levels according to the computed levels from the simulated link budgets and as required for the emulation step. This implies the variable configuration of the interference levels according to the defined combination of signal-to-noise and signal-to-interference ratios.

A variable attenuation is used as basis. The stepless or continuous reconfiguration of the variable attenuator allows emulating the continuous ESOMP movements through an interference context as well.

4.1.4   Incumbent link transmit emulator (IUTe)

The incumbent link transmission is performed using a DVB-S2 [6] forward link emulation including the possibility to subsequently (measure at reception) the link quality in terms of SNR (Es/N0), efficiency (MODCOD used per frame), and the resulting Frame Error Rate (FER) and Bit Error Rate (BER).

This terrestrial FS link transmission is emulated using a DVB-S2 modulator. The used bandwidth and related signal-to-noise ratio is configured to the required adequate levels for the link emulation. One FS link is emulated in the context of this demonstration lab setup. An alternative for this transmitter is the usage of a specific test equipment capable of transmitting and generating multiple parallel DVB-S2 carriers in a single device.

The FS link transmission standard used in practice varies depending on the link and equipment vendor of the FS link. We do not assume any specific knowledge of the FS link transmission parameters other than the bandwidth, power, and the required signal-to-noise ratio for the target link quality.

4.1.5   Incumbent link receiver emulator (IURe)

The requirement on the emulator for the incumbent link reception is the capability to measure and verify the aggregate interference level as received at an emulated link combined form all the terminals reception.

The purpose is therefore to be able to measure the interference power density levels and identify the aggregate interference power at the input of the incumbent user terminal as well as measure the overall impact of the FSS terminal transmissions emulated on an incumbent emulated link.

The incumbent link is emulated on the basis of a DVB-S2 link, which is configured to a defined target SNR ratio to be emulated for the incumbent link. It is expected that the incumbent link experiences no signal loss or measurable degradation on the data transmission link.

4.1.6   User Content Server Emulator (CS)

For the traffic generation, the following available equipment can be used:

- Specific traffic test equipment for UDP traffic testing (*i.e.*, a "SPIRENT" for example is available for this project).

- Traffic server with specific traffic test software for TCP/UDP traffic flows.

Traffic for different Quality of Service or different priority levels can be applied to emulate and verify the applicability of different classes of traffic such as real time, critical data, and best effort.

Several types of traffic can be tested. For example, file transfer or streaming of video can be tested. These can be marked using DSCP values and services and classification profiles configured on the Gateway.

4.1.7 GW Emulator (GWe)

As it is explained in more details in Chapter 5, the GW Emulator is built as a lab test platform based on the Newtec DIALOG© "4IF Platform" using high resolution cording (HRC) in combination with multi-dimensional dynamic medium access (MxDMA), [7]. This equipment can be configured differently depending on the different test scenarios.

Additional developments and test equipment are foreseen op top of the standard components, which are the basis of the test setup.

This additional development is a specific cognitive carrier controller in the gateway emulator to change the forward link SatNet assignment of the terminals as well as the return link carrier group assignment. This is the dynamic capacity allocation (DCA) required to enable flexible assignment of the terminals to the available capacity.

4.2 Common GW configuration for the setup

The gateway is configured to include at least 2 satellite network configurations, SatNets. This is required to be able to map the capacity to different forward link configurations and demonstrate and test the terminal reassignment and reconfiguration possibility to a second SatNet.
The defined service profiles are configured such that the impact on an end-to-end real time traffic can be monitored.

4.2.1 Service Profiles

The Service profile will set the maximum peak information rate and committed information rate on the return path and also on the forward path. The services profiles used on this test setup are configured as class-based, for example:

- Real Time traffic (Video / voice).

- Best Effort traffic (web browsing and data transmissions).

Traffic can be tagged differently depending on ports, IP addresses, and/or DSCP values.

As the traffic generator module will send traffic correctly tagged, this option will not be used for the tests scenarios and setups.

The service profiles are of relevance for the test cases where the links have to be throttled based on interference from or to incumbent users. This should be done according to the defined traffic classification in this case.

4.3 Setup configuration 1 (forward link emulation)

As mentioned earlier, the cognitive downlink FSS satellite terminals are pre-configured to a defined SatNet (forward link) according to the principle that the network aims at achieving the highest overall efficiency.

The provisioned terminals are receiving an emulated L-band signal of the desired forward link with the satellite channel impairments as well as interferences and additional noise as emulated by the Channel Emulator. These are reconfigured to emulate different geographical positions of the FSS

satellite terminals with respect to the terrestrial interference and within the satellite coverage area. The NCC controller (including the DB, SS-SNIR, and RA cognitive techniques implemented) decides which terminal will receive information on SatNet 1 (located on shared frequency band) and SatNet 2 (located on FSS exclusive frequency band).

The test cases executed on this setup are defined in D4.1 and detailed in the D4.2 test plan and procedures:

- **Test-case #1**: Installation/deployment of a network of terminals within a cognitive zone close to a FS link or BSS uplink with database support.

- **Test-case #2**: Change network configuration of FSS terminal in incumbent user link interference of presence (in cognitive zone).

- **Test-case #3**: Measure Network Efficiency with and without considered cognitive techniques DB, SS-SNIR and RA technique usage.

- **Test-case #4**: Detect interference present from the incumbent user on the forward link.

- **Test-case #5**: Change the forward link carrier capacity allocation (frequency) according to incumbent user interference presence.

- **Test-case #8**: ESOMP movement through the coverage area.

4.4   Setup configuration 2 (return link emulation)

The second setup is directly related to scenario C transmit emulation, in which the return link is tested.

In this scenario, the terminal will receive information on one SatNet established on the forward exclusive band, from 19.7 to 20.2 GHz. On the other hand, two return capacity groups will be defined on the GW return resources, as downlink tests, one on the [27.5-29.5] GHz shared band and one on the [29.5-30.0 GHz] exclusive band. An alternative shared band is defined in the project corresponding to 28.4465-28.9465 GHz.

The cognitive controller will change the terminals configuration depending on the interferences caused to the incumbents FS's. The implemented dynamic capacity assignment (DCA) on the return link manages power, frequency, bandwidth, transmission modulation, and coding modes of each terminal from the network control center (NCC) and reconfigures the return link carrier group (RCG) to comply with the interference requirements at the FS receiver input.

This is performed in a centralized action at the NCC, from which all transmit FSS terminal parameters are monitored and controlled to enable the dynamic capacity allocation on the return link.

The test cases for this setup are as follows:

- **Test-case #6**: Measure interference levels from configured FSS system on the return link at the FS receiver (using measurement device emulating the reception input).

- **Test-case #7**: Change the return link carrier frequency, power and rates according to incumbent user environment.

- **Test-case #8**: ESOMP movement through the coverage area (to be verified if the return link can be emulated as a mobile terminal).

4.4.1 Terminal Emulators

The basis terminal model used for the demonstration platform is the adapted MDM3300 terminal hardware to emulate FSS end-user terminals. The total number of terminals used in this setup has been defined to be 8 for this setup. This is based on the tradeoff that the setup involves a significant configuration and cabling for each terminal and a reconfigurable satellite forward channel, return link channel, as well as interference link channel. On the other hand, several terminals are required in order to emulate the resource allocation (RA) mechanism and gain sufficient statistical data for the gain evaluation at system level. Therefore the required setup is a lab setup with more than one terminal and we are limited by practical constraints and budget and setup complexity in terms of terminals to be emulated.

Each channel (transmit and receive) for these terminals has to be setup and emulated as well as the interference reception (scenario A and B) and the interference transmission (scenario C).

This configuration requires a significant amount of setup and cabling for each link emulation. The number of channels for the channel emulator has been set to 8 and we therefore configure this test setup with 8 terminals as well. This leads to the tradeoff of used terminals in the lab test setup.

4.4.2 Satellite Network configurations

Different SatNets or "satellite networks" can be configured in the system, with each SatNet corresponding to one forward link. The mechanism to redirect and reallocate the terminals from one SatNet to another is implemented specifically in the context of this project as dynamic capacity allocation mechanism of the forward link.

One carrier allocation per terminal is foreseen for the non-exclusive frequency band (for scenario A [17.3-17.7] GHz and scenario B [17.7-19.7] GHz) and another one for the exclusive band part [19.7-20.2] GHz. In the demonstration setup parts of these bands are emulated, but the redirection principle is fully representative for the considered cases. The allocation of two different forward links per terminal configuration is already possible with the current MDM3300 terminal software and this is illustrated in Figure 4.2.

 Figure 4.2 - Example configuration of a dual forward link reception configuration in the terminal user interface.

The allocation of the capacity for the different terminals to the FWD_1 and FWD_2 capacity is based on the NCC allocation of the terminals to the network in the logon phase. The provisioning of the terminals foresees the SatNet / FWD link allocation. The NCC procedures allocate the terminal capacity to the different SatNet allocations based on the detected or announced interference levels from the database configuration.

The terminal redirection is performed in the NCC from SatNet1 to SatNet2 and back if required (in the figure below for the example for Terminal T_3) to mitigate interference from scenario A or B configurations.

This is further refined with the Resource Allocation (RA) mechanism that allows to allocate the terminals on the basis of their required capacity as well as the achieved efficiency to maximize the overall efficiency of the network. This additional setting at the NCC is performed in case the network is under forward link contention condition.

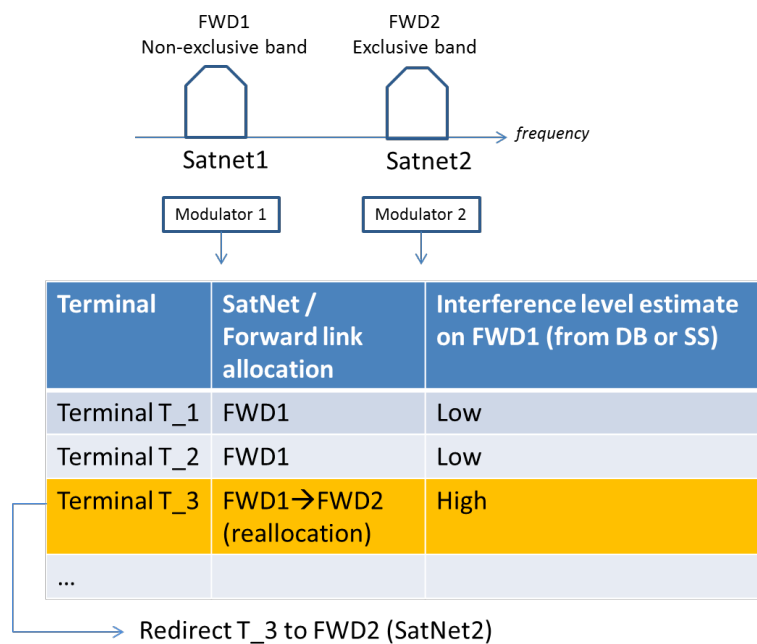| Terminal	SatNet / Forward link allocation	Interference level estimate on FWD1 (from DB or SS)
Terminal T_1	FWD1	Low
Terminal T_2	FWD1	Low
Terminal T_3	FWD1→FWD2 (reallocation)	High
…		

Redirect T_3 to FWD2 (SatNet2)

Figure 4.3 - Demonstration allocation of the forward link carriers with different forward link carriers on exclusive and non-exclusive frequency bands.

4.4.3   User Terminal - UTe

The user terminal is based on an existing hardware device for the consumer and professional market. The out-door-unit (ODU) is fully emulated during this test campaign. The end-to-end test is performed in an L-band loop manner with transmit and receive in L-band (emulating the RF front-end performance and the overall channel). Nevertheless, we assume different types of terminal categories for the ODU in order to compute the link budget and the terminal location accordingly so that the setup can emulate the end-to-end channel parameters as required.

Figure 4.4 - Demonstration user terminal equipment modem hardware used for the demo platform setup.

4.5 Test platform dimensioning

The defined storyboards to be tested in D4.1 as well as the derived requirements here above define the required equipment for the test setup.

We first note that the tests can be executed in L-band and no specific RF technique is defined to be tested within WP4 (for example it is not foreseen to test beamforming), therefore we can concentrate our testing on the L-band input/output setup.

Furthermore, we note that the resource allocation (RA) mechanism requires a certain amount of statistical data to compute an average efficiency for the forward and return link efficiency. This cannot be done with only one terminal emulated for the FSS network and therefore we require several.

Each of these terminals that is to be emulated in L-band requires a configurable link emulation for the satellite forward link, the satellite return link as well as the interference impact for all carriers. This multiplies the number of channel conditions that need to be emulated in L-band with the number of terminals used. A possible setup that allows delivering all required results requires therefore multiple terminal links.

Moreover, the setup of this demonstration and test platform is performed with hardware and software as close as possible to real commercial terminal products.

A setup with 8 terminals (MDM3300) with bi-directional L-band transmit and receive in a loopback configuration with a new developed channel emulator and a Newtec DIALOG© "4IF hub" is used in order to build on commercial products as much as possible. The definition, specification and development of the channel emulator is performed on the basis of an 8 interfaces port 1U device. This is a novel development for this project.

On this basis, an 8 terminals test setup is defined and configured as a lab test platform for the WP4 CoRaSat project to test and evaluate the cognitive techniques according to the defined requirements here above.

5 DEVELOPMENT TASKS

This Chapter provides a description of the different development tasks performed within WP4 activities, which include those outlined in WP4 workflow structure. This has been defined as the work that needs to be implemented to directly demonstrate the target CoRaSat techniques as defined in the WP3, as well as all related development tasks that are necessary to emulate the techniques in the laboratory as required in the WP4 context.

As outlined in Table 4, we define the following development tasks to implement the CoRaSat project in the lab context:

- **CE**: channel emulator with 8 inputs and variable configurable noise, external input interference, and signal power levels.

- **NCC** – Interface to DBe.

- **NCC** – Interference detection on the forward link (scenarios A and B).

- **NCC** – Interference mitigation on the return link (scenario C).

- **DBe**: database emulator (for scenarios A and B).

- **Control PC** to control and monitor the channel emulator and the configured test scenario.

A building block that is already implemented and used as a basis for the end-to-end testing:

- NEWTEC Hub6000/DIALOG© DVB-S2 / HRC/MxDMA platform for two way satellite communications and the usage of the MDM3300 terminals, [5].

The building blocks for the demonstrator platform are thus existing two-way satellite platform components that are also used on the DIALOG © and MDM3300 © products of Newtec, and similar technology building blocks are used for the forward and return links emulation, DVB-S2 and HRC/MxDMA.

The existing components are the following:

- Satellite terminal for end user broadband access (based on the MDM3300 modem).

- Multi-carrier demodulator (part of the GWe) for the return link reception.

- Modulator (DVB-S2 modulator) for the forward link emulation (part of GWe).

- Controller and management system to control and monitor terminal behavior (part of NCC emulator).

- Access router for traffic (part of GWe).

- DVB-S2 ACM based forward link transmission emulation.

- HRC/Mx-DMA based return link transmission emulation.

The cognitive techniques adapted to the system context in D3.4 are then adapted to the existing demonstration platform servers. This includes the functionalities listed in Table 6, namely: i) the dynamic capacity allocation (DCA) on the forward and return link; ii) the resource allocation (RA) mechanism; iii) the spectrum sensing (SS-SNIR mechanism as adapted in the D3.4 document); and iv) the database access (DB) mechanism. All of these techniques require specific additional development on the network control server (NCC) emulator, specific to the CoRaSat WP4 context.

In addition, on the test control PC the storyboard test cases are implemented as defined in the storyboard document D4.1. This is performed as an integrated automated test case script that remotely controls the different components of the test setup and runs the storyboard cases as defined in D4.1.

In addition, specific channel emulator hardware is implemented specifically for this test setup under the CoRaSat WP4 context. This includes the channel emulator required for the demonstration setup.

The channel emulator is also developed as a stand-alone lab equipment with L-band input and output.

Components and equipment that are specifically developed during the course of the WP4 for this Corasat project are the following:

- Channel emulator (satellite channel emulator).

- Interference channel emulator.

- Cognitive techniques as defined in D3.4 system adaptation:

    o SS-SNIR technique (as adapted in the D3.4 document).

    o DB access from NCC emulator.

    o Dynamic Capacity Allocation (DCA) forward and return link.

    o Resource Allocation (RA) mechanism.

The CoRaSat demonstration platform is using existing components of an end-to-end VSAT network for consumer broadband and builds the additional defined functionality on top of the existing components to allow for an end-to-end service test platform that is representative of the link to be emulated.

In the following sub-sections we outline in more details the defined development tasks, which are executed specifically for the CoRaSat WP4 context.

5.1   Channel Emulator unit (CHe)

The channel emulator is implemented in a stand-alone unit to emulate a configurable set of channel impairments:

- Amplifier, TWTA (amplitude AMAM, phase AMPM).

- Channel filtering IMUX and OMUX filter configurations, (amplitude and group delay).

- Noise on the uplink and downlink channel.

- Delay of the satellite link signal.

- Interference input from an external interference source.

These impairments are configurable and programmable in the channel emulator setup.

Figure 5.1 shows the satellite part of the channel emulator implementation block diagram, including the delay emulation, TWTA AMAM and AMPM modelling, and IMUX and OMUX filter modelling.
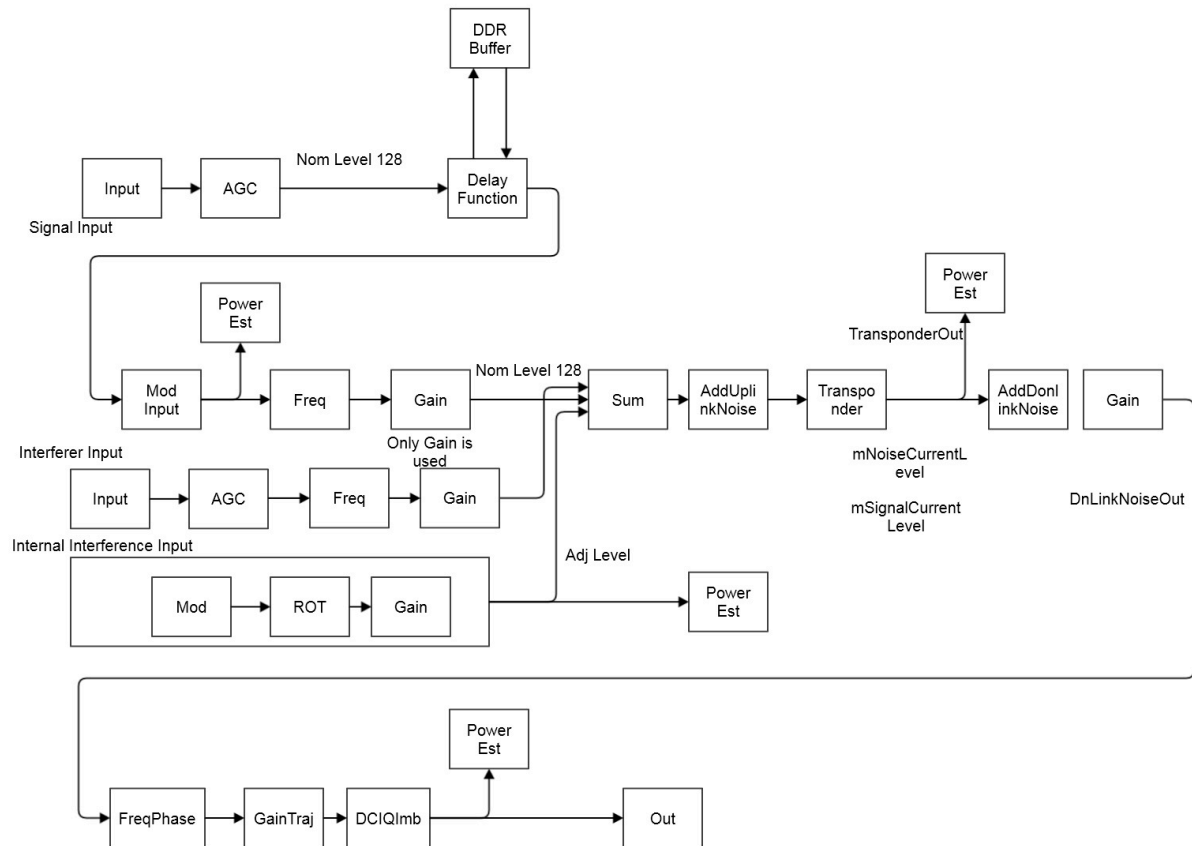
Figure 5.1 - Channel emulator satellite channel block diagram.

The channel emulator is shown in Figures 5.2 and 5.3 and is built as a stand-along 1U unit on the basis of existing MDM6000 hardware and with dedicated software development for the integration of the defined channel emulator blocks into the device firmware. Furthermore, a graphical user interface (GUI) is specifically developed to make the channel emulator a stand-alone unit that can be used in different configurations for the forward and return links emulation and with different channel impairments that are selectable and configurable in the device.

A second part of the channel emulation is the combined collection and configurable combination of the different paths from the interferers to the FSS terminal reception.

This part is implemented in a dedicated 1U device that implements a variable programmable attenuation step into a combined attenuation to emulate a configurable interference and noise level.

The downlink reception part of the channel emulator consists of 8 channels that are reconfigurable with programmable attenuators and reconfigurable interference levels for each channel.

The overall combination at the receiver inputs of the terminals is a signal that is a combination of the satellite repeater block impaired transmitted signal in combination with noise on the downlink and terrestrial interference emulation for the 8 terminals.

On the return link side, the emulated signal is combined form the 8 terminals after a variable reconfiguration of the transmit signals. This return link incumbent interference emulation makes it possible to emulate the interference receive power levels at the incumbent user input.

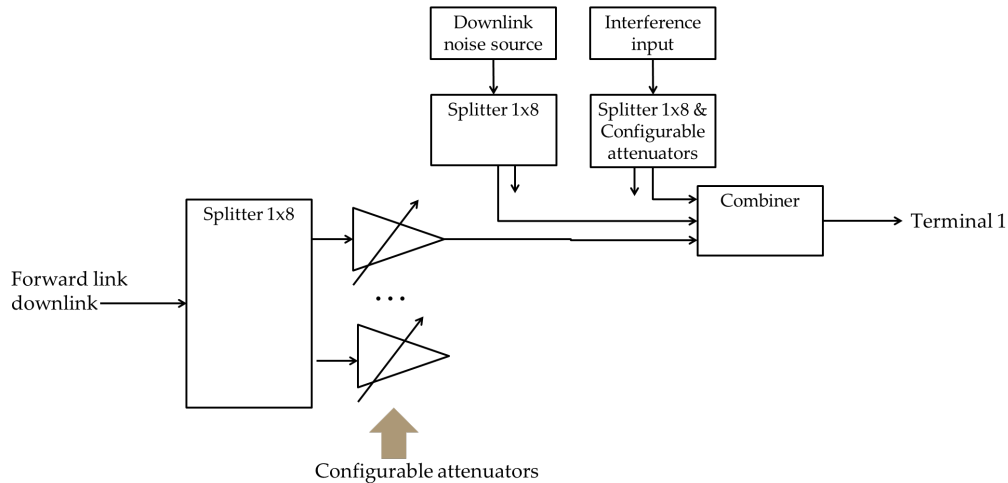The channel emulator is configurable with a dedicated user interface.

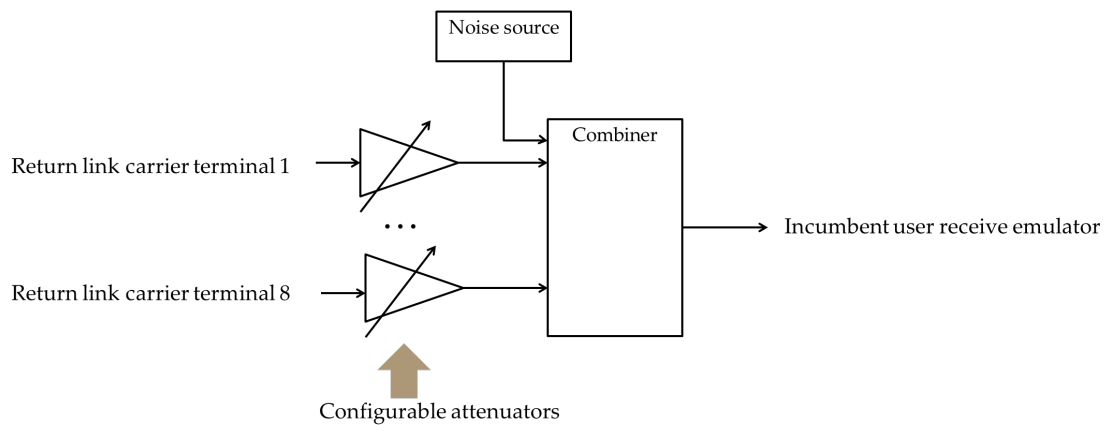Figure 5.2 - Channel emulator for 8 channels reception with configurable interference and noise levels.

Figure 5.3 - Channel Emulator for the demonstration setup with variable attenuators in combination with noise at reception emulation.

Interference and noise are configured according to the elaborated signal-to-interference ratio (C/I) from the link between the FS transmitter (scenario B) or BSS feeder link (scenario A) and the FSS terminal receiver input. This C/I figure is computed from the input of the database or measured via the spectrum sensing (SS-SNIR) mechanism on the FSS receiver link directly. Then, this input is configured in the channel emulator to control the C/I for each terminal as required by the emulated geographic position of the FSS terminals.

5.2   Interference detection on forward link (NCC controller)

The detection of the interference on the forward link is implemented in the NCC as a joint process that takes into account the long term observations of the reception parameters of each terminal on each carrier to make decisions on possible interference presence on the forward link.

This is performed using the trackers (signal power and signal to noise ratio) on the forward link and with the possibility to observe these trackers over the long-term to distinguish between different impairment effects:

- Fading on the forward link at the terminal side.

- Installation related impairments (de-pointing of the antenna).

- Interference related degradations.

The distinction between these different circumstances for the terminal operation is achieved with the observation of the power and signal-to-noise ratio parameters per terminal as following the decision principle here:

> The signal power and signal-to-noise ratio estimates (according to SS-SNIR) are measured continuously at the NCC side. This is performed in a manner that allows keeping track of the reference PWR and Es/N0 values for all terminals. In a continuous manner, the current measurements are compared to expected reference measurements and based on configured threshold values for the Es/N0 levels as well as for the power levels, the distinction between a fading event, an interference event, and a possible mis-pointed antenna is made. For this the signal power and signal-to-noise ratio levels are used to compare the measured values to the expected levels.

This is then used to process on short- and long-term average expected reference values the estimation of the distinction between fading events, interference events as well as potential mis-pointing of the terminal.
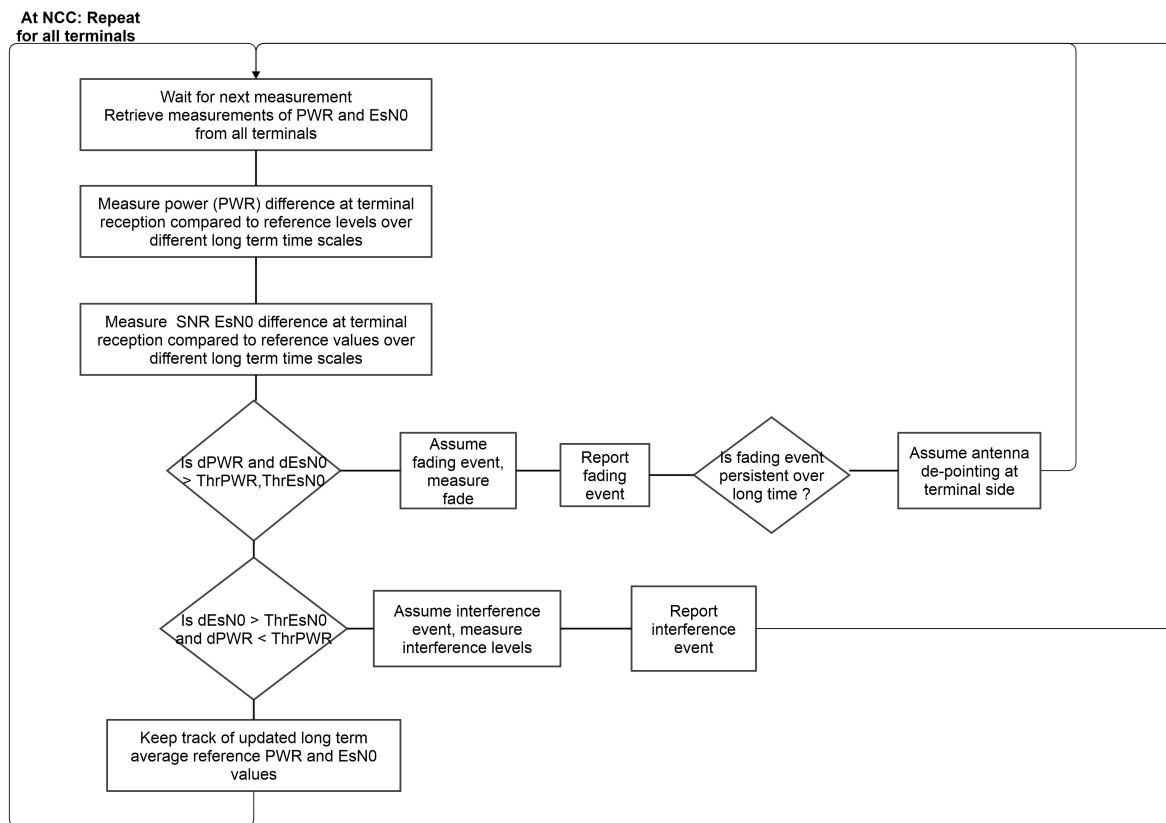
Figure 5.4 - Flow chart of the adapted interference detection from the SS-SNIR procedure.

This process runs on the NCC side with the loop over all terminals and the decision on potential fading events, antenna de-pointing and interference events are made by the NCC.

This is reported in the form of alarms to the operator to take appropriate actions. A possible automatic re-direction of the terminal to another forward link carrier can be performed. For this purpose, the interference mitigation procedure is used to evaluate the required actions as a response to this procedure. This procedure adapts the SS-SNIR procedure on the basis of the techniques described in WP3 documents.

5.3 Interference management on return link (NCC controller)

For the return link, interference management towards the incumbent user receivers in scenario C is performed on the NCC side as well. The NCC collects all data from the demodulators of the return link signal at the gateways and processes the measured signal performance parameters received.

Interference management on the return link is adapted to maintain the interference level within the limits of the required levels at the input of the incumbent user receivers.

The NCC uses the return link transmission parameter configurations to maintain the transmit power, frequency, and bandwidth at appropriate levels. This adjustment is performed by taking into account the transmit power and carrier frequency allocation constraints in the selection and allocation of the transmit mode configuration of each terminal transmit plan.

5.4 Dynamic Capacity Allocation (DCA) forward link (in NCC controller)

For the dynamic capacity allocation (DCA), the forward link DCA procedure foresees to redirect the terminals to the SatNet or forward link carrier that exhibits minimal or sufficiently small amount of interference from incumbent users on scenario A [17.3-17.7] GHz or scenario B carriers [17.7-19.7] GHz. The carrier redirection is performed on the basis of the information available on the incumbent user transmissions and the resulting expected interference levels at the receiver inputs of the FSS terminal receivers. The NCC allocates the assignment of the terminals to the SatNet (forward link) to avoid interference from incumbent users as possible.

The balance of the terminal assignments to the forward link carriers is performed on the basis of the information available from the database or from the detection of the interference levels. The usage of the resource allocation (RA) method can be used in the NCC to select the SatNet (forward link) assignment in case of contention on the forward link traffic.

5.5 Dynamic Capacity Allocation (DCA) return link (in NCC controller)

On the return link, the DCA acts on the transmission modes selected for each terminal in the network. The return link transmission is configured within a defined carrier group bandwidth. The DCA on the return link foresees to redirect terminal transmit capacity to the carrier group available and to avoid potential interference to the incumbent users.

Different flexibility options can be used to redirect the capacity on the return link.

- Change frequency of the terminals.
- Change bandwidth of the terminals. and MODCOD allocation

In addition, in the context of this project development, the carrier group reallocation is foreseen. This allows to redirect the terminal capacity to different frequency bands as required by the transmit plan the NCC allocates. Two approaches are considered in the DCA return link implementation, namely the RCG allocation change and the RCG bandwidth reconfiguration.

The dynamic carrier allocation on the return link follows the implemented DIALOG© HRC controller principles to automatically adjust the resource and the capacity, [5]. This resource allocation mechanism (already implemented and used) automatically manages the satellite power density constraints of all the transmitters, as well as the transmitter spectral regrowth specific second constraints.

The additional feature that is implemented in the context of CoRaSat is the scenario C specific additional constraint in the process of the return link resource allocation, which is the FS receiver

interference management limitation. This constitutes a third additional constraint on the return link transmissions.

For this additional resource management of the third constraint for the FS interference management, two different approaches are considered:

- **Return Carrier Group Allocation Change**: changing the transmitting terminals to another return link carrier group to manage the interference levels into the FS receiver.

- **Return Carrier Group Bandwidth Change**: changing the RCG bandwidth dynamically to adjust the required power spectral density to the maximal interference allowed for the FS receiver.

Return Carrier Group Allocation Change

The transmit bandwidth is selected on the bases of the allocated RCG range and transmit power limitations. Figure 5.5 illustrates the possibility to reallocate the capacity from one RCG carrier group to another when changing the SatNet configuration
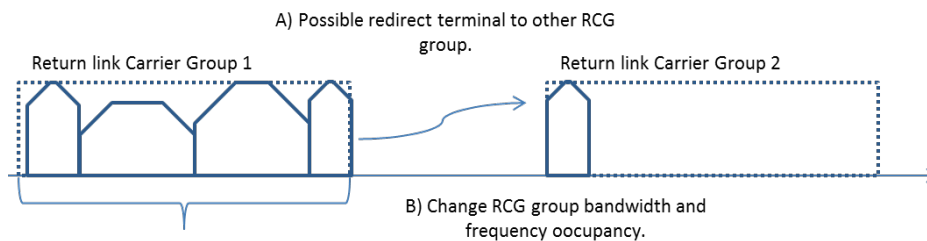
Figure 5.5 - Return link carrier group (RCG) reallocation and configuration according to interference limits applicable and required bandwidth constraints.

Return Carrier Group (RCG) Bandwidth Reconfiguration

Another dynamic capacity allocation (DCA) technique implemented on the return link is changing the RCG bandwidth used. This is performed by changing the allocated bandwidth while keeping the terminals operational on the carrier group and thereby allowing the usage of more bandwidth and consequently less required power to meet the target throughput requirements on the return link.

The following figure illustrates the principle of the return carrier group (RCG) with the 8 carriers occupying the RCG bandwidth spectrum. Under the assumed maximal spectral power density in combination with a configured MODCOD setting, the terminals need to occupy a certain bandwidth to satisfy the throughput requirement (according to the KPI). Under this condition, the terminals transmit power density is limited by the overall maximal power density allowed on the satellite, the maximal power the terminal can use (to satisfy its spectral regrowth limitations), as well as the the maximal total power allowed to satisfy the applicable ITU limit.

The two RCG resource allocation techniques are considered and evaluated and one is implemented in the CoRaSat WP4 demonstration context.
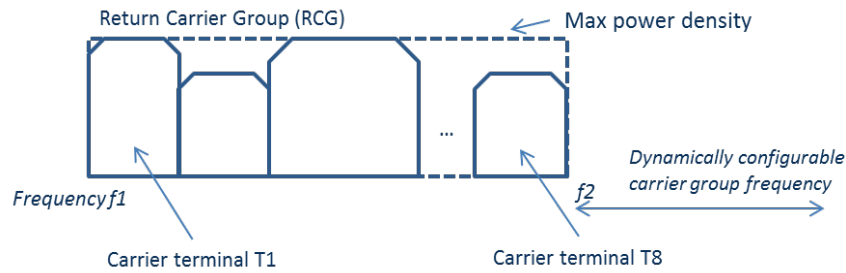
Figure 5.6 - Return Carrier Group (RCG) principle with reconfigurable bandwidth by changing the upper RCG edge frequency f2.

5.6   Database emulator (DBe)

A set context (geographic area) is defined for laboratory emulations. This has to be in the defined locations (*i.e.*, UK/France for scenario A and B and Slovenia/Finland for scenario C) for the emulated contexts (geographic areas). This is defined in the control PC on the user interface and fully defines the geographic locations of all FSS terminals and FS receiver and transmitter and BSS feeder link locations.

The database emulator is implemented as a stand-alone server (PC) running a common database with the defined incumbent links in the same data-format as available for the simulation of the noise floor contours (NFC) for the preceding tasks (see D3.3 and D3.4). The format includes all required information to compute the interference link budgets.

The additional task of computing the link attenuation between the incumbent user and the FSS terminal may be performed also on this database emulator or alternatively a pre-computed interference map is read out from the database. This dataset has already been computed in D3.4 in the context of different European countries, where database information has been made available for scenario B, *i.e.*, UK, France, Poland, Hungary, and Slovenia.

For scenario A, the available data for Luxembourg and UK can be used to emulate the specific contexts of BSS feeder link proximity to the FSS terminals.

For scenario C, the receiver location and attenuation between the satellite terminal FSS uplink and the terrestrial link FS receiver is computed based on a link budget evaluation between the emulated FSS transmitter location and the terrestrial FS receiver, also taking into account the antenna pattern data available. The scenario C data is available for Finland and Slovenia and through the BRIFIC database from ITU also for other European countries.

The ITU-R BRIFIC database that is available for this work can be used as well to emulate specific geographic contexts for the FSS terminal and FS link receiver locations.

The same example interference contexts have been used to obtain the results provided in D3.4 for the gain evaluation.

5.7   Test management and control unit (Control PC)

The management and control PC implements the interface to the test equipment and the used demonstration components.

The user interface allows to control the storyboard parameters and to run the tests in view of collecting the performance indicator data as defined here above.

The demonstration function of the control PC context follows the storyboards defined in D4.1 and allows demonstrating the related use cases.

In the following part, we describe the different functional blocks that are implemented in the CoRaSat platform in the context of the demonstration setup.

These include the specific demonstration platform components that need to be implemented to demonstrate the intended cognitive radio functionalities, as defined in D3.4 and the related storyboard cases as outlined in D4.1.

Therefore, the following functionalities are implemented in the test control PC connected to the demonstration setup:

1. Retrieve all measurement parameters from 8 terminals for the forward link.

2. Retrieve all measurement parameters from the spectrum analyzer (power measurement) and HRC controller for the return link.

3. Interface with the database and retrieve the interference at location.

4. Graphical User interface that outlies the 8 test cases and shows controls and measurement results for each case.

5. Control of the test data generation for the forward and return link and measurement of the throughput and error rates.

6. Control of the terminal allocation to a forward link (SatNet 1 or 2) by interaction with the DIALOG provisioning interface.

7. Control of the return link RCG (carrier group) bandwidth to change the total power density towards an FS receiver.

8. Control of the SatNet 1 and 2 forward link frequencies and possibility to set these frequencies to a defined value.

9. Implement the spectrum sensing as defined in D3.4 (SS-SNIR), [3].

10. Implement the database access (DB) technique as defined in D3.3,[2] .

11. Implement the resource allocation (RA) as defined in D3.3.

These functions are implemented on the dedicated CoRaSat test control server/PC to enable the full realization of the end-to-end testing of the CoRaSat test cases as defined in the storyboard document D4.1, [4].

6   DEMONSTRATION SETUP IMPLEMENTATION

This Chapter summarizes the lab setup for the demonstration work performed in WP4.

The requirements described in the preceding section are used to define the required setup in the laboratory so as to respond to them. A setup that is capable of emulating the requested channel contexts in forward and return links and of testing the end-to-end performance in terms of the considered KPIs is defined.

This describes one by one all the modules that will participate on the lab environment, showed in the following figure.
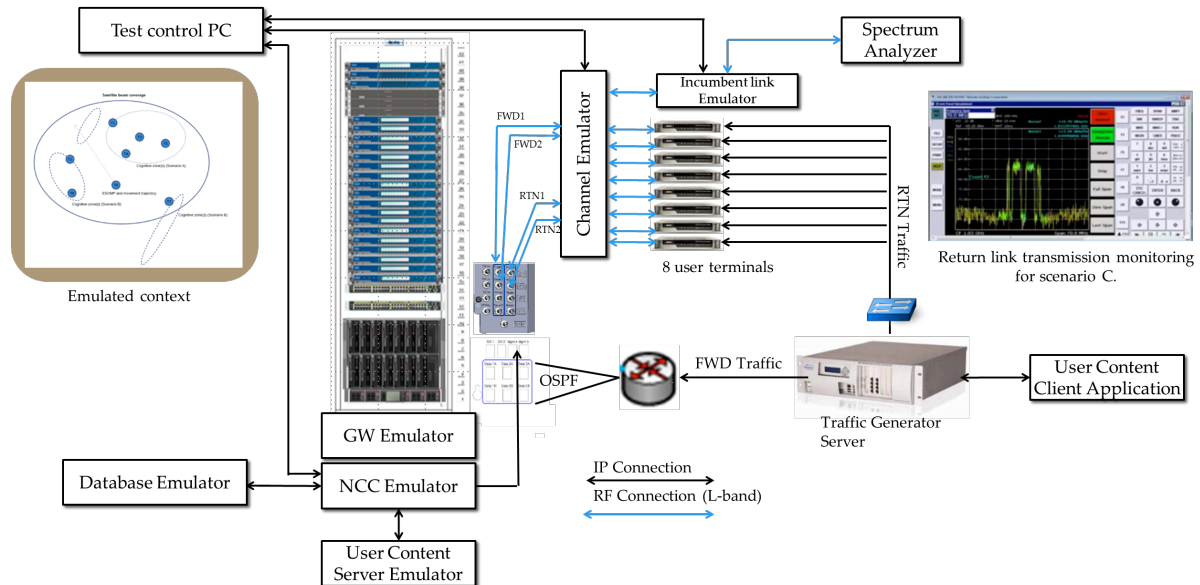
Figure 6.1 - Overall CoRaSat demonstrator setup overview with L-band Tx/Rx links.

The demonstration setup is combining the elements described in the following sections, in addition to the basis DIALOG platform with the MDM3300 terminals, specific developments are made to setup this platform. These additional development tasks specifically performed for CoRaSat are detailed in Chapter 5.

6.1   Database Emulator Server

The database emulator is built using dedicated server hardware and running commonly used and available database software suits to emulate the context of the incumbent user interference.

The database DBe emulator provides an interface to the external configuration possibility. The NCC interacts with the DBe emulator.

A specific scenario A and B interference environment can be emulated by the database content.

The information interactions with the NCC are based on common SQL database interaction protocols.

6.2   NCC + GW Emulator

In Satellite Communications, the DVB-RCS2 standard in [7],[8]-[9] defines roles as a logical grouping of responsibilities, with the intention of providing a generic framework for related functional entities with appropriate granularity.

The system configuration considered with 2 SatNet groups is illustrated in the following figure:

Figure 6.2 - Configuration logic of a SatNet and the configuration relationship between SATNET, forward links FWD_1 and FWD_2 and return link carrier groups (RCG).

Each SatNet is defined as a satellite network operator (SNO) configuration, as defined in the DVB-RCS2 higher layer specification (HLS) standard as well.

Network control center (NCC)

The Network Control Center (NCC) emulator is based on a dedicated server located on the demo gateway setup side. The demo setup for this CoRaSat system foresees to use 2 SatNet (Forward link configurations).

The NCC emulator interacts with the Gateway emulator and implements the following specific CoRaSat functions:

- Interaction with the CoRaSat database emulator (DBe).

- Interaction with the gateway emulator (GWe).

- Collect and record all forward and return link statistics of the terminal links.

- Implement the interference detection method as defined and adapted from the SS-SNIR mechanism.

- Implement the forward and return links capacity allocation of the terminals, including the Resource Allocation (RA) mechanism as defined in CoRaSat.

Gateway emulator (GWe)

The gateway emulator is based on existing components for the two-way demo setup. Here, the basis is provided by the hub control functions for the forward and return links as well as all traffic redirect functions in the normal gateway emulator.

6.2.1   SatNet and forward carrier allocations

For the CoRaSat setup, we foresee the configuration of at least 2 forward link carriers with DVB-S2 or S2X configuration and with the possibility to redirect capacity from one forward link configuration to the other (SatNet reconfiguration of the terminals).

The forward link carriers are configured as variable ACM links to the end user terminals.

The forward link metrics observed for CoRaSat are the received power levels as well as the signal-to-noise ratio at the terminal sites. These are collected and recorded by the network control center (NCC) over a management and control channel on the return link (the same used for the ACM messaging).

The observations of all forward link receptions are collected at the NCC to evaluate the reception conditions of all terminals and keep track of the short- and long-term reception performance. These "inline" signal data observations are used also by the (extended) SS-SNIR mechanism to analyze the reception conditions and to evaluate the possibility of reassigning the terminal to another forward link configuration.

Support of transmission parameter control

In addition to monitoring, channel parameter control is performed and emulated on the platform. This includes existing features such as the adaptive coding and modulation (ACM), as well as the automatic power control (AUPC) and the possibility to adapt dynamically the bandwidth of the return link carriers. These transmission parameter control features are part of the baseline technology set that is used within the simulation context. However, in addition to these existing features, the defined novel cognitive control features are implemented on top, in the context of the inline spectrum sensing mechanism, as defined and adapted to the system context in D3.4.

The Demo platform supports ACM mode (Adaptive Coding and Modulation) based on the feedback from remote subscribers, a frame can be transmitted on a different MODCOD. Each combination of a specific modulation and coding has a certain spectral efficiency determining the data throughput, or the rate at which data can be transmitted. A higher MODCOD is linked to a higher data rate, but it requires a good signal-to-noise ratio at the receivers end. A lower MODCOD will work even with a lower signal-to-noise ratio, but at the cost of having a lower data rate.

ACM (adaptive coding and modulation) allows modification of the modulation parameters (*i.e.*, the MODCOD) of a satellite signal on the fly, without interrupting the transmission and without losing data. When combined with a measurement of the instantaneous link conditions every few seconds and a system that automatically adjusts the modulation parameters when needed, ACM allows using the highest possible modulation scheme and the lowest possible level of error correction at all times.

The MODCOD reference thresholds as defined in the DVB-S2 standard are stored in the user stations. Depending on the subscriber forward Es/N0, it will use one MODCOD or another.
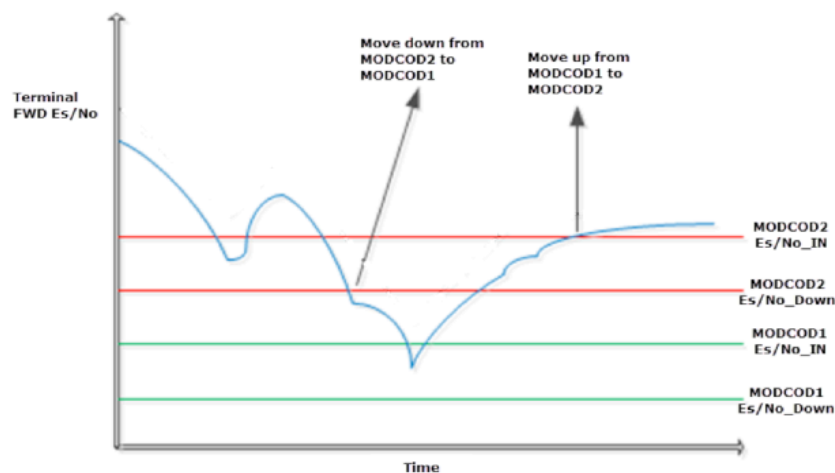
Figure 6.3 - Mechanism illustration of the ACM mechanism used on the forward link in combination with the signal power and Es/N0 detection.

Figure 6.3 shows a better explanation about ACM on the forward link.

The defined SS-SNIR technique requires an adaptation of the existing end-to-end ACM control mechanism. This includes the described functionality in D3.4 for the system adaptation of the SS-SNIR technique.

Both power and signal-to-noise ratio parameters are retrieved form the terminals and processed in the NCC to identify potential probable interference conditions.

6.2.2   Return carrier allocations

For the return link, the Demo system supports multiple types of coding and modulation technologies and the corresponding access schemes. An access technology is used to allocate return link resources to the subscribers, while a coding and modulation technology is used for the physical layer (transforming data into a satellite signal).

The main different available technologies are, [7]:

- MF-TDMA – 4CPM coding and modulation (not used in CoRaSat demo setup).

- Mx-DMA – HRC Coding and modulation (used in the CoRaSat demo setup).

The Demo platform allows subscribers to easily switch from one return link technology to another. This option could be used in combination with the required flexibility to change frequencies on the return link. In the context of this project, we concentrate on one technology option, namely HRC/MxDMA, and use the flexibility of this transmission mode to reallocate the carrier frequency, power and bandwidth without traffic impact.

While the HRC/MxDMA is a developed feature that is already available on the platform used for the testing, the control and measurement of the return link interference related power limitations has to be developed. The described mechanisms, the JCPA as defined in D3.4 has to be implemented in a basic manner.

This switch requires nothing more than a simple hub provisioning configuration changes of the corresponding subscriber. The traffic impact of a switch to a different return technology is limited to a couple of seconds of traffic loss.

Return traffic carriers in the Demo system are organized in 'Return Capacity Groups'. They are artificial frequency sections of the total return link spectrum of the beam. A beam is a geographical area that sends its return signal via a certain satellite transponder.

A Return Capacity Group (RCG) is segmented into Carrier Pools. Carrier pools are artificial frequency sections of the total spectrum of the RCG.

Each Carrier Pool consists of **traffic (TRF)** carriers with the same carrier spacing and associated modulation and coding (known as MODCOD) and is characterized by a minimum and maximum C/N0 (Carrier to Noise ratio). The RCSTs will be assigned dynamically to one or another Return Capacity Pools depending on their C/N0, the Gateway will receive feedback information from the subscribers about their C/N0, and will provision them on the respective Carrier Pool comparing that value with the maximum and minimum C/N0 thresholds or the pool.

It is worthwhile remarking that, as MF-TDMA basics explain, resources are shared among all the subscribers that want to transmit at that moment.

HRC MX-DMA

The definition of Return Capacity Groups and Return Capacity Pools remains equal in this access technology, but HRC return link carriers are dedicated to a subscriber and they are not shared dynamically by several subscribers. For that reason, previous technology is more appropriate when the number of receivers is high, and HRC Mx-DMA for a lower number, combining the flexibility and statistical multiplexing of MF-TDMA access technologies and the efficiency of SCPC technologies (an Mx-DMA carrier is assigned to just one terminal).

6.2.3　Frequency bands selection

The purpose of this project is to allow the FSS to use shared frequency bands and commute to exclusive bands when the interference technology detection determines it. The NCC process will interact with the Gateway configuration to swap the bands avoiding those interferences, with the minimum traffic outage. Forward bands will be also called SatNets and Return frequency bands will be called Return Capacity Groups.

From previous deliverables, the test frequency bands are emulated on the basis of the following frequency bands. The emulated frequency bands are L-band frequencies. The following frequency plan is considered as basis.

And the alternative for uplink tests:
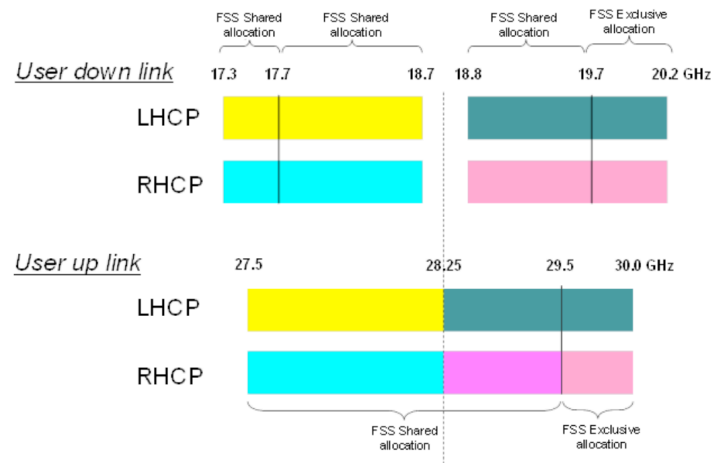
Figure 6.4 - Baseline frequency plan for the allocation of capacity on the forward and return link with exclusive frequency bands on forward and return link bands per beam.

With this frequency allocation per beam, we foresee a configuration of about 1450 MHz per beam on the forward link and 1500 MHz on the return link for the baseline configuration and 500 MHz for the alternative configuration.

In the demonstration setup, the emulation of the frequency plan is performed in the L-band available on the platform. The overall frequency plan then includes a subset of the band that emulates the non-exclusive part of the spectrum [17.3-19.7] GHz and [27.5-29.5] GHz and another part of the band that emulates the exclusive part of the spectrum [19.7-20.2] GHz and [29.5-30.0] GHz. Note that it is not foreseen in this demonstration to replicate the entire bandwidth of the non-exclusive or exclusive frequency bands in the available L-band emulation spectrum but rather parts of it, so that a bandwidth switching can be demonstrated.

6.2.4   Forward and return link resources

Deliverable 4.1 set the typical service parameters to be defined on the demo platform for the emulated service:

Table 7 - Service level agreement (SLA) example defined for the emulated end-to-end service.

Forward link peak rate	10 Mbps
Return link peak rate	4 Mbps
Service availability	99.5 % p.a.
Forward / Return link traffic ratio (average long-term)	8:1 (typically, other ratios possible as well)
Service classes	2 services classes Best Effort Traffic Priority (Voice, Specific priority services)
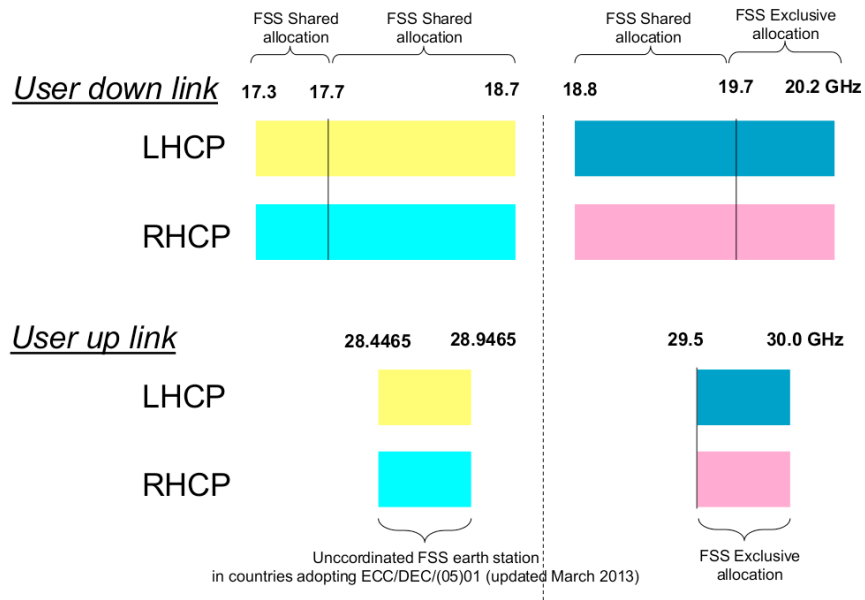
Figure 6.5 - Alternative emulated frequency plan with separate exclusive bands on the forward link and dedicated capacity on the return link allocation (HDFSS allocation).

Current technology set the maximum values that can be achieved on our test-cases. For this reason our lab values are:

Table 8 - Forward link parameters as defined in the considered scenario in D3.4.

Parameter	Unit	Value
Symbol Rate	Mbauds	52
Roll-off	%	20
Bandwidth	MHz	62.4

Each forward carrier will be configured in the center of the available band using previous values:

Table 9 - Defined transmission cases for scenarios A and B for the considered emulator dual forward link example.

Scenario	Forward Carrier 1	Forward Carrier 2
A	Center Frequency RF: 17.5 GHz	Center Frequency RF: 19.95 GHz
	Symbol Rate: 52 Mbauds	Symbol Rate: 52 Mbauds
B	Center Frequency RF: 18.7 GHz	Center Frequency RF: 19.95 GHz
	Symbol Rate: 52 Mbauds	Symbol Rate: 52 Mbauds

The NCC link control emulator demands a forward carrier change depending on the interference values on the different scenarios and test cases observed and/or depending on the database information retrieved.

6.2.5 Return Resources

There are two different usages of the return frequency bands defined in the project context. The first one fully uses the available spectrum for scenario C [27.5-29.5] GHz and [29.5-30.0] GHz for FSS subscriber link application. Moreover, an alternative plan is proposed that uses the frequencies allocated to HDFSS in combination with [29.5-30.0] GHz.

The defined return link services are based on the service level agreement (SLA) defined throughput requirements per carrier. The transmission requirements are defined and configured according to the MxDMA controller mechanism to adapt the return link transmission modes to the required traffic requirements per terminal.

In this particular case of a possible FS link interference management, an additional rule is introduced in the configuration of the return link capacity, which limits the power density of each terminal transmission to a maximum value per terminal (see JCPA description in D3.4).

6.2.6 Service level definition

The end-to-end service level agreement (SLA) is defined as a committed and peak rate service. The Quality of Service (QoS) is a set of technologies for managing network traffic in a cost effective manner to enhance user experiences. These QoS technologies allow to measure bandwidth, detect changing network conditions (such as congestion or availability of bandwidth), and prioritize or throttle traffic. Following steps are applied in order to achieve QoS:

- Marking.
- Classification.
- Shaping.

Marking is done by making use of DSCP (Differentiated Services Code Point) bits. These bits reside in the IP header. The value assigned to an IP packet is then used as tag to mark a certain type of traffic. This action will be executed by the CS (Content Server), sending already marked traffic on the forward and the return link.

Based on DCSP values, traffic is mapped to one of the possible quality classes. This is known as **classification**. The Demo platform supports following classes:

- Real Time: Highest priority. Three sub-priorities. Two will be used to apply different priority to video and VoIP (Voice over IP) traffics, as is intended for traffic that requires very low jitter/delay.

- High Priority. Not used on our setups.

- Best Effort. Lower priority, for traffic that doesn't require prioritization or guarantees.

Within a Demo system, it is possible to distinguish two QoS models:

- **Class-Based**: In a class-based service offering, the service provider offers applications to customers. The applications are mapped to classes by marking them. Remote terminals are then linked to the traffic classes by using service profiles (service profiles shape and limit the user's traffic per traffic class). On an aggregate level where the applications contend for bandwidth (*i.e.*, in case of congestion), the network operator will want to prioritize the higher priority applications but also protect the lower priority applications from being starved. A part of the satellite resources needs to be reserved for such class-based services.

- **Transport-Based**: In a transport-based service, a customer rather buys a bandwidth pipe that has a committed rate, sometimes burstable to a higher rate. Prioritization of customer hosted applications is then managed within that bandwidth pipe by the B2B customer itself. This type of service is comparable with the concept of a leased line (except that unused bandwidth within a pipe can be distributed amongst other transport-based customers if necessary). In this case, the remote terminals are directly linked with their forward and return pools, and contention occurs between terminals and not between applications.

Seeing this, for our lab tests, the best option is to use class-based model as is more related with a B2C model, assuring a minimum peak rate to each type of traffic.

- **Services Profiles:** This QoS is directly connected with the Service Profiles as they refer to a set of parameters controlling bandwidth usage per traffic class. Based on the Service Profile, the user's traffic is shaped/controlled/limited/guaranteed by the System.

Each Service Profile can be assigned to one or more Forward Pools and one or more Return Pools.

Moreover, each VNO is linked to one or more forward and return pools. The combination defines which Service Profiles are available to the VNO.

For our setup scenario same Service Profile will be used, allowing only two types of traffic with the peak information ratio values specified in Chapter 3:

- Best Effort traffic.

- Real Time traffic.

6.3   Channel Emulator

The channel emulator parts consist of emulation of the satellite channel, the incumbent interference at the forward link reception at the 8 terminals input and the interference generated upon the incumbent user receiver. All these three parts are configurable to reflect different link budget conditions as a function of the different emulated terminal locations within the reception coverage.

The detailed channel emulator design is described in the section 4.1.3.

6.4   Subscriber Emulator

The different test cases of deliverable D4.1 define a total of 8 subscribers distributed among the satellite beam. The subscriber's position determines different values on power transmission and reception of the terminals thanks to the channel emulator. The output of the RCSTs will be looped-back to the Gateway through the Channel Emulator, and the NCC will use that information to check if the frequency band where the subscriber is provisioned needs to be changed.

The Channel Emulator will be positioned between the Gateway and the RCSTs

The Channel Emulator is connected to 8 subscribers Emulator on the diagram with both transmission and reception links. This subscribers will be Newtec MDM3300 IP Satellite Modem, connected each one by means of a IP switch to the User Content Client Application for traffic transmission and reception.

The terminal equipment used, the MDM3300, is capable of receive DVB-S2 in an optimal availability and efficiency based on specific ACM techniques and therefore the best practically possible MODCOD and efficiency is chosen in any case (with or without interference present). It can also transmit in different return technologies as MF-TDMA 4CPM and MX-DMA, again in modes that automatically adapt to channel impairments with ACM.

The end-to-end services adapt to the required end user subscription needs through prioritizing the traffic on both forward and return link. Subscribers receive and transmit different types of traffic:

- Data traffic, categorized as Best Effort.
- Video traffic, categorized as Real Time.

The different subscribers will inform the HUB about their received C/N0 thanks to the channel emulator, and they will be allocated on a specific Traffic carrier defined on the Return Resources of the HUB.

The different test cases will define the changes required on the interferences created by BSS (Scenario A), FS (Scenario B) or over FS (Scenario C): different values will make the NCC Emulator request a Forward and Return carrier change. Subscribers will need to change their configuration to receive and transmit on the new carriers, to avoid that interference.

6.5   User Content Server Emulator (CS)

The user content server emulates the IP layer applications using UDP streams of IP packets at different configurable packet sizes and throughputs.

6.6   User Content Client Application (CC)

The used client application in the context of these tests enable the possibility to receive the test streams and keep track of the key IP level performance indicators, such as IP packet throughput, jitter and loss rate.

6.7   Demonstration Outcome link to Exploitation plan

The exploitation of the techniques developed in the course of this project is well taken into account in the product roadmap of future product developments.

The following table summarizes how the developments are considered for next product updates.

Table 10 - Mapping of the techniques developed within the CoRaSat project for commercial product fits.

Technology developed within CoRaSat	**Fit to product feature**	**Target commercialization date**
Channel emulator	Internal tool to test different end-to-end transmission scenarios for fix and mobile SatCom applications ($\rightarrow$ CE6000 Internal product)	2015
Interference detection (SS-SNIR)	VSAT platform applications	2016
Interference mitigation (forward link) and management (return link)	End-to-end professional VSAT applications	2016 (as required by commercial demand)
Entire test platform setup for WP4 with traffic emulation	Internal test setup is used also in future user test case validations for commercial applications	2015
Interface to external database access (NCC$\leftarrow\rightarrow$DB)	End-to-end VSAT applications	Available when the proposed non-exclusive Ka-band frequencies are made available for usage

7   CONCLUSIONS AND NEXT STEPS

Within this document, the definition of the different components for the hardware demonstration setup for the CoRaSat demonstration platform have been described. All functional blocks of the hardware test setup have been described and the defined development work done in the context of the CoRaSat WP4 demonstration setup prototyping is described.

In particular, the hardware demonstration platform has been thoroughly described. This demonstration platform responds to the required laboratory setup for the execution of the storyboard cases as defined in the D4.1 context. The different implementation development work items have been defined and explained together with the overall demonstration context the required test cases. The demonstration setup has been described from a top level architecture perspective and the different storyboard scenarios have been presented, as well as the approach for their demonstration on the platform.

The used test platform is an IF loop (L-band) based test setup that emulates the forward and return links of a two-way satellite system based on representative "product grade" hardware for the user segment and the hub segment side. The used hardware and setup is therefore "close to product implementation" and demonstrates the feasibility of the proposed techniques in a test laboratory environment.

D4.2, which is being prepared in parallel to this document, defines the test cases to be played out during the WP4 demonstration setup.

The overall demonstration platform is implemented on the basis of specifications in line with the top level architecture descriptions defined in this document. The implementation work and steps are documented within internal workflows at Newtec.

The full outcome of the demonstration platform will be reported in subsequent documents, namely D4.4 and D4.5. In particular, the integration and testing with baseline results and the results for the different storyboard lines as outlined in D4.1 will be reported in D4.4, while the final demonstration of the cognitive techniques will be included in the formal test and demonstration report D4.5.

Outside the scope of this project, this technology demonstration test setup is subsequently foreseen to be used in further test and development work related to the specific product adaptation of the defined cognitive techniques. The basis for this product adaptation is outlined in the product roadmap in Chapter 7 as well as in the WP5 exploitation plan for the specific techniques developed within the course of this project.

8 DEFINITION, SYMBOLS AND ABBREVIATIONS

ACM	Adaptive Coding and Modulation
AUPC	Automated Uplink Power Control
ACI	Adjacent Channel Interference
CE	Channel Emulator
CQI	Channel Quality Information
CR	Cognitive Radio
CS	Compressive Sensing
CSI	Channel State Information
CENELEC	Centre for Electro Technical Standards
DB	Database (cognitive technique)
DCA	Dynamic Capacity Allocation
DVB	Digital Video Broadcasting
DVB-RCS	Digital Video Broadcasting with Return Channel via Satellite
DVB-S	Digital Video Broadcasting via Satellite
DVB-S2(X)	DVB via Satellite version 2 (extensions)
EBU	European Broadcasting Union
ETSI	European Telecommunications Standards Institute
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network (a.k.a LTE)
FC	Fusion Center
GPRS	General Packet Radio Service
HRC	High Resolution Coding
IA	Interference Alignment
IC	Interference Cartography
IDW	Inverse Distance Weighted
LRT	Likelihood-Ratio Test
LTE	Long Term Evolution
LTE-A	LTE Advanced
MAC	Medium Access Control
MIMO	Multiple Input Multiple Output
MODCOD	Modulation and (channel) Coding
MxDMA	Multi-dimensional dynamic medium access
NCC	Network Control Centre
RA	Resource Allocation (cognitive technique)
REM	Radio Environment Map
RCST	RCS subscriber
RF	Radio Frequency
RLC	Radio Link Control
RSS	Received Signal Strength
SS-SNIR	Spectrum Sensing (SNIR based cognitive technique)
SNIR	Signal to noise and interference ratio
SIN	Satellite Interactive Network

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10 Document History

Rel.	version	Date	Change Status	Author
0	0	05/12/2014	Document Creation	NTC
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