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(DRL N°:D020)

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ANTARES

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(DRL N°:D020)

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TABLE OF CONTENTS

INDEX OF FIGURES

INDEX OF TABLES

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to provide a high-level and comprehensive description of the CS proposed within the scope of the ANTARES project and specified in detail in [RD-01].

1.2 Structure of the document

The document is structured as follows:

- Section 1 provides the introduction to the document.
- Section 2 provides the reference and applicable documents.
- Section 3 reports the Communication Standard context, identifying the CS mission, the system reference architecture, the interfaces covered by the CS, the traffic profile characteristics, the used aeronautical channel model, and considerations regarding support of non-nominal conditions by the CS.
- Section 4 provides an introduction to the CS, highlighting the key features.
- Section 5 provides reference user, control, and management plane protocol stacks from an end-to-end point of view.
- Section 6 introduces the logical and physical channels defined by the CS and the system carriers. It also provides an overview of the CS link-layer addressing concept.
- Section 7 provides the high level CS functional architecture.
- Section 8 provides the CS functional description, emphasising how the mechanisms defined by the CS interact.
- Section 9 addresses the interactions of the CS with other systems.

1.3 Definitions, abbreviations and conventions

1.3.1 Definitions

1.3.1.1 Communication

- **Communication protocol:** A set of rules defining how network entities interact with each other, including both syntactic and semantic definitions.
- **Communication links:**
  - **Mobile link (or ATM link):** communication link between satellite and aircraft (uplink and downlink).
  - **Feeder link:**fixed communication link between satellite and a GSE (Ground Segment Element) for uplink and downlink.
  - **Forward link:** communication link from the Ground Earth Station to aircraft, where:
    - **Uplink** is the communication link from ground to the satellite
    - **Downlink** is the communication link from satellite to aircraft

- **Return link**: communication link from aircraft to Ground Earth Station where:
  - **Uplink** is the communication link from aircraft to the satellite
  - **Downlink** is the communication link from satellite to ground

- **Protocol stack**: a specific instance of a layered protocol that defines the communication protocol. The present communication standard supports several protocols in parallel, each one using its own terminology. The ISO-OSI reference protocol stack terminology is used for describing these protocols. In the following, the description of the layers tailored for the present communication standard is provided:

  - **Physical layer (L1)**: The physical layer defines the Satellite Communication System waveform, including modulation and coding.

  - **Link layer (L2)**: The link layer defines the media access method (often referred to as MAC – Media Access Control) as well as framing, formatting and error control (often referred to as LLC – Link Layer Control).

  - **Network layer (L3)**: The network layer defines the format of end-to-end data packets, as well as routing of packets within the network. The following network layer protocols are supported: ISO 8208 packets (ATN/OSI) and IP (ATN/IPS).

  - **Transport layer (L4)**: The transport layer defines end-to-end functionalities such as reliable/unreliable data transport, flow, and congestion control. The transport layer operates end-to-end, and is implemented only in the end systems. Therefore, it has no direct impact on the Satellite Communication system. However, the mechanisms of the transport layer have to be carried, in form of overhead on network layer packets and additional packets.

    The following transport protocols are current or anticipated within the EATM environment:

    - TP4 (ATN-OSI reliable transport protocol)
    - TCP (ATN-IPS reliable transport protocol)
    - UDP (ATN-IPS unreliable transport protocol)

    TP4 and TCP generate significant numbers of transport layer acknowledgements.

  - **Session layer (L5)**: Not applicable for this standard. Defined by SESARJU.

  - **Presentation layer (L6)**: Not applicable for this standard. Defined by SESARJU.

  - **Application layer (L7)**: The application layer defines additional mechanisms used by end user applications. It handles user data units in the form of application messages.

  Additionally, definition of an additional layer located between layer 3 and layer 2 is useful:

  - **Network adaptation layer (L2.5)**: This layer has been specifically defined for the CS and provides functions that are needed to properly adapt the network layer to the generic (i.e., network layer agnostic) CS link and control layer functions. While L2.5 functions require interpretation / knowledge of the specific network layer of the data unit to be transmitted (interpretation of headers, etc.), they do not cover traditional network layer functions as described for layer 3. The L2.5 layer includes functions as IP header compression and support for mobility related events.

- The following definitions are also applicable to the present document (see also [RD-01]):
  - **NSDU** (Network Service data Unit) **or Segment**: An NSDU is the data unit posted by the transport layer to L3. It is also named Segment.
  - **NPDU** (Network Protocol Data Unit) **or Packet:** An NPDU is the data unit resulting from adding network layer headers to the NSDU provided by L4. It is the basic data unit handled by the network layer and exchanged among L3 peers. It is also the data unit forwarded to the network adaptation layer.
  - **ALSAP** (Adaptation Layer Access point): The ALSAP is the point where L2.5 provides its services to L3.
  - **PNPDU** (Processed Network Protocol Data Unit): A PNPDU is the resulting data unit after the incoming NPDU data unit is processed by the L2.5 layer of the CS (in particular, by applying header compression protocols). From a L2 point of view, it is equivalent to a LSDU.
  - **LSAP** (Link Service Access Point): The LSAP is the point where L2 provides the service to L2.5.
  - **LSDU** (Link Service Data Unit) **or Processed Packet:** An LSDU is the data unit posted by the network adaptation layer (L2.5) to L2 at the LSAP.
  - **LPDU** (Link Protocol Data Unit): An LPDU is the data unit resulting from adding L2 headers to LSDU or LSDU fragments (when fragmented).
  - **PSAP** (Physical Service Access Point): The PSAP is the point where L1 provides the service to L2.
  - **PSDU** (Physical Service Data Unit): A PSDU is the data unit posted by L2 to L1 at the PSAP. It is composed of 1 or more LPDUs.
  - **PPDU** (Physical Protocol Data Unit): A PPDU is a PSDU data unit which includes also L1 signalling headers (data descriptor), a CRC, and, eventually, padding (in case the PSDU size is smaller than the PPDU payload). One PPDU always contains at most one PSDU.
  - **PLFRAME** (Physical layer frame) **or Burst**: This is the data unit resulting from physical layer processes (coding, modulation, etc) as applied to one PPDU. It is also referred to as burst throughout the document.

Note: These terms have been adapted from the OSI layered model terminology.

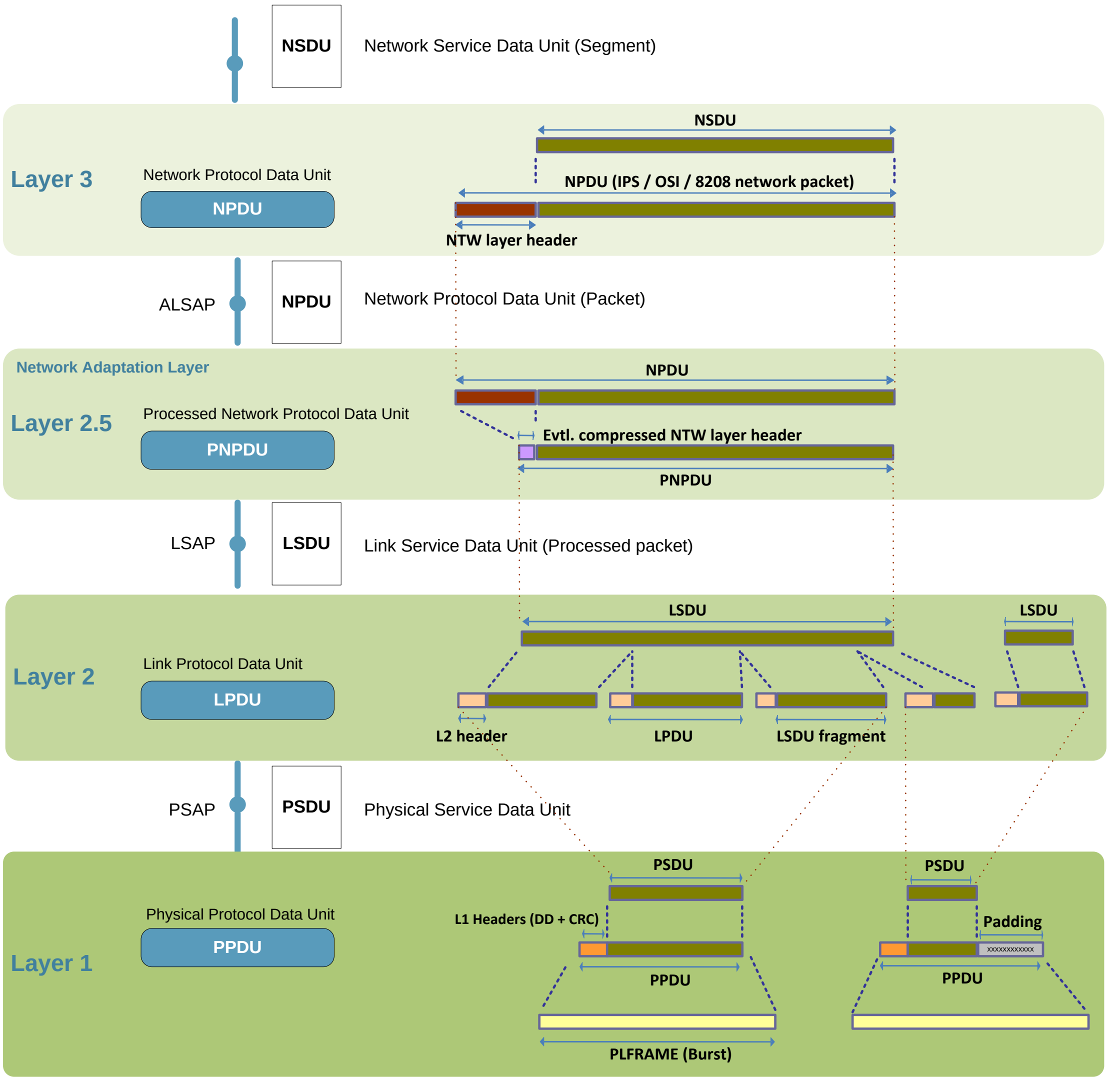

Figure 1-1: Introducing layer model terminology[1]

- **Addressing Terminology**

In order to clarify the description of message contents regarding addresses, here is a summary of the different addresses specified at layer 2 and its other names used during the CS specification process:

 - **ICAO ID:** 24 bit address fixed per aircraft by ICAO
 - **UT ID:** 16 bit address, as defined at ANTARES Layer 2 encapsulation custom scheme, also referred to as UT L2 address
 - **GES ID:** 8 bit address, as defined at ANTARES Layer 2 encapsulation custom scheme, also referred to as GES L2 address. The terms GES ID or NCC ID may be

[1] Depicted headers are for illustration only. They refer to headers and trailers and may not be always located at the start of the data unit as shown in the figure. Please refer to the specific data format definitions included in the CS specification for the exact description of the data units.

used, depending on the applicable GSE. The more generic term is GSE ID, referring either to GES ID or NCC ID.

- **GES satellite MAC address:** GES 6 bytes address, used for network layer address resolution protocols support in ATN/IPS.
- **UT satellite MAC address:** UT 6 bytes address, used for network layer address resolution protocols support in ATN/IPS.

- **QoS (Quality of Service):**
  - **Flow:** set of LPDUs belonging to a group of consecutive NPDUs, identified by consecutive sequence numbers/packet counters. The NPDUs transmission of a flow is performed in order of increasing sequence number/packet counter.
  - **CoS (Class of Service):** set of applications sharing similar QoS parameters, i.e., continuity (expired NSDUs rate), ET (expiration time), and TD95 (percentile 95 of transit delay) as defined in SYS-CSY-0080 at [AD-01].
- **Pt-to-pt**(point to point): A point to point channel is transmitted by one source and received by one destination.
- **Pt-to-mp** (point to multipoint): A point to multipoint channel is transmitted by one source and received by several receivers.
- **Mp-to-pt** (multipoint to point): A multipoint to point channel is transmitted by several source and received by one receiver.
- **Unicast**: the one-to-one transmission of data packets to one specified destination.
- **Multicast**: the one-to-many transmission of data packets to interested destinations.
- **Broadcast**: the one-to-all transmission of data packets to all possible destinations.
- **Physical layer link quality:**
  - **PER (Packet Error Rate):** In the Communication Standard, the term PER refers to the probability that a PPDU is received with errors. Therefore, the PER is computed as the number of erroneous PPDUs divided by the total number of received PPDUs.

1.3.1.2 Entities

- **Ground Earth Station (GES):** The network entity that provides the feeder link to the Space Segment. In the context of this document, a GES is defined as a logical entity that makes use of communication resources assigned to it in order to communicate with aircraft associated with it, providing voice and data traffic services. A GES will typically use resources within a single beam of a single satellite, but this is not mandatory. A physical site, referred as Ground Segment Element (GSE), may accommodate several logical GESs, and GESs may share Earth station infrastructure, providing interface with the terrestrial ATM networks.
- **Network Control Centre (NCC):** The network entity that performs the control of the satellite network system resources and elements. It is expected that this entity covers neither the Satellite Control Centre nor the Satellite Operation Centre. In the system reference

architecture, one backup NCC located at a different site for satellite link availability purposes for each active NCC can be foreseen.

- **Network Management Centre (NMC):** The network entity that performs the management of the overall satellite communication network (system resources and elements) in a centralised way. It is expected that this entity covers neither the Satellite Control Centre nor the Satellite Operation Centre. Management functions performed by the NMC are considered to be not critical since the system is designed for surviving to a failure of the management sub-system during a limited time.
- **User Terminal (UT) (also called Airborne Earth Station - AES):** The avionics equipment on-board the aircraft that implements the communication protocol and provides the interface to other on-board elements via an on-board network.

1.3.1.3 RAMS

- **Continuity**: Probability that a transaction will be completed having met specified performance. Possible anomalous behaviours include late transactions, lost messages or transactions that cannot be recovered within the expiration time, duplicate messages, and uncorrected detected message errors.
- **Instantaneous availability:** It is the probability that a service (or system) will be operational (up and running) at any random time, t. This is very similar to the reliability function in that it gives a probability that a system will function at the given time, t. Unlike reliability, the instantaneous availability measure incorporates maintainability information.
- **Average Uptime Availability (or Mean Availability):** The mean availability is the proportion of time during a mission or time period that the system (or service) is available for use. It represents the mean value of the instantaneous availability function over the period (0, T].
- **Integrity:** Integrity is the acceptable rate of transactions that are completed with an undetected error. Undetected errors include undetected corruption of one or more messages within the transaction.
- **Expiration Time:** Maximum time beyond which an NPDU data unit is considered lost.
- **TD95:** 95-th percentile of the transit delay one-way latency.
- **Diversity**: The simultaneous use of two or more mutually independent and different systems to increase service availability. Diversity allows improvement of the link availability and thus of the overall system availability by providing (at least) two links thanks to redundant elements and by allowing to switch from one link to the other one (or combine the two), choosing the best configuration/link available at a certain time. This solution is mainly used as a fade countermeasure technique and compensation of the channel, i.e., for events happening outside of the system. The overall availability for the two links (or paths) is better than the one for a single link (or path).
- **Redundancy**: Duplication of one element (of GES, NCC, satellite, or UT) or equipment within an element (e.g., RF sub-system) or sub-equipment (e.g., modem) to provide back-up in case of failure. Typical cases to be considered are intended unavailability of equipment due to maintenance operations as well as failures due to design or lifetime of equipment. The objective is to compensate for unavailability of elements due to the system itself.

1.3.2 Acronyms and abbreviations

Acronym	Definition
16-APSK	16-Amplitude Phase Shift Keying
8-PSK	8-Phase Shift Keying
AAL	ATM Adaptation Layer
A-CDMA	Asynchronous CDMA
ACH	Auxiliary Channel
ACK	Acknowledgement
ACM	Adaptive Coding and Modulation
AES	Aeronautical Earth Station
AGR	Air-Ground Router (in the GES)
ALSAP	Adaptation Layer Service Access Point
AMS	Audio Management System
AMS(R)S	Aeronautical Mobile Satellite (en Route) Service
ANSP	Air Navigation Service Provider
AOC	Airline Operational Centre
ARQ	Automatic Repeat request
ATC	Air Traffic Centre
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
ATN/IPS	ATN/ Internet Protocol Suite
ATN/OSI	ATN/ Open Systems Interconnection
AR	Airborne Router (at the aircraft)
BA	Binding Acknowledgement
BB	Baseband
BBFRAME	Baseband Frame
BCCH	Broadcast Control Channel
BD	Burst Descriptor
BE	Back-end
BER	Bit Error Rate
BGP	Border Gateway Protocol
BTCH	Broadcast/Multicast Traffic Channel
BU	Binding Update

CDMA	Code Division Multiple Access
CFMU	Central Flow Management Unit
CLNP	Connection Less Network Protocol
CoA	Care-of-Address
COCR	Communication Operation Concept and Requirements
CoS	Class of Service
CRC	Cyclic Redundancy Checksum
CS	Communication Standard
CW	Code Word
DAD	Duplicate Address Detection
DCE	Data Communication Equipment
DCH	Data Channel
DSCP	DiffServ Code Point
DTE	Data Terminal Equipment
DVB	Digital Video Broadcast
UTCH	Unicast Traffic Channel
EATMN	European Air Traffic Management Network
EATMS	European Air Traffic Management System
ECAC	European Civil Aviation Conference
ENR	En Route
ES	End System
E-SSA	Enhanced Spread Spectrum Aloha
ET	Expiration Time
FCAPS	Fault, Configuration, Accounting, Performance and Security
FCH	Forward Channel
FCI	Future Communications Infrastructure
FE	Front End
FEC	Forward Error Correction
FL	Forward Link
FLC	Forward Link Carrier
FRS	Future Radio System
FSS	Fixed Satellite Service
FWD	Forward
G/G-R	Ground-Ground Router
GEO	Geostationary

GES	Ground Earth Station
GISM	Global IonosphericScintillation Model
GPS	Global Positioning System
GS	Ground Segment
GSE	Ground Segment Element
GSE	Generic Stream Encapsulation
GW	Gateway
HA	Home Agent
HO	Handover
HEO	Highly Elliptical Orbit
HPA	High Power Amplifier
IC	Interference Cancellation
ICAO	International Civil Aviation Organisation
ICS	Internet Communication Services
ID	Identifier
IDRP	Intra-Domain Routing Protocol
IF	Interface
IF	Intermediate Frequency
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPS	IP Suite
IRA	Irregular Repeat Accumulate
IRS	Inertial Reference System
IS	Intermediate System
ISH	Intermediate System Hello
L1	Layer 1 – Physical Layer
L2	Layer 2 – Link Layer
L3	Layer 3 – Network Layer
LDACS	L-band Digital Aeronautical Communication System
LDPC	Low Density Parity Check
LDPU	Link Protocol Data Unit
LLC	Link Layer Control
LOS	Line of Sight
LSDU	Link Service Data Unit
LPDU	Link Protocol Data Unit

LREF	Local Reference
LS	Local Scattering
LSAP	Link Layer Service Access Point
M&C	Monitoring and Control
MA	Multiple Access
MAC	Medium Access Control
MAI	Multiple Access Interference
MCDU	Multi-Function Control and Display Unit
MF-TDMA	Multi Frequency Time Division Multiple Access
MIB	Management Information Base
MIPv6	Mobile IPv6
MLD	Multicast Listener Discovery
MN	Mobile Node
MODCOD	Modulation and Coding
MSP	Mobility Service Provider
MTU	Maximum Transmission Unit
NACK	Negative Acknowledgment
NCC	Network Control Centre
NCR	Network Clock Reference
NMC	Network Management Centre
NSAP	Network Service Access Point
NSDU	Network Service Data Unit
NTW	Network
OBP	On-Board Processing
ORP	Oceanic, Remote, Polar
OSI	Open Systems Interconnection
OVSF	Orthogonal Variable Spreading Factor
O-QPSK	Offset-Quadrature Phase Shift Keying
PB	Pilot Symbol Blocks
PCCC	Parallel Concatenated Convolutional Codes
PER	Packet Error Rate
PHY	Physical
PIAC	Peak Instantaneous Aircraft Count
PL	Physical Layer
PNPDU	Processed NPDU

PPDU	Physical Protocol Data Unit
PSAP	Physical Service Access Point
PSDU	Physical Service Data Unit
PSK	Phase Shift Keying
PTT	Push To Talk
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RA	Random Access
RACH	Random Access Channel
RAMS	Reliability, Availability, Maintainability, and Safety
RDCH	Return Data Channel
RF	Radio Frequency
RFC	Request for Comments
RFU	Reserved for Future Use
RL	Return Link
RLC	Return Link Carrier
ROHC	Robust Header Compression
RRM	Radio Resource Management
RTN	Return
RTP	Real-time Transport Protocol
Rx	Receiver
SARP	Standards and Recommended Practices
SCC	Satellite Control Centre
SCCH	Synchronisation Control Channel
SESAR	Single European Sky ATM Research
SF	Spreading Factor
SIC	Successive Interference Cancellation
SICF	Subnetwork Independent Control Function
SIP	Session Initiation Protocol
SME	System Management Entity
SNAcP	Subnetwork Access Control Protocol
SNDCF	Subnetwork Dependent Convergence Function
SNIR	Signal to Noise and Interference Ratio
SNMP	Simple Network Management Protocol
SOC	Satellite Operational Centre

SPS	Space Segment
SQU	Squelch Indicator
SRRC	Square Root Raised Cosine
SSA	Spread Spectrum Aloha
SSP	Satellite Service Provider
S-WAN	Satellite Wide Area Network
TBC	To Be Confirmed
TBD	To Be Defined
TCC	Turbo Convolutional Codes
TCP	Transport Control Protocol
TD95	Transient Delay 95%
TDMA	Time Division Multiple Access
TL	Transport Layer
TMA	Terminal Manoeuvring Area
TS	Time Slot
T-WAN	Terrestrial Wide Area Network
Tx	Transmitter
UCCH	Unicast Control Channel
UDP	User Datagram Protocol
UT	User Terminal
UTCH	Unicast Traffic Channel
VCS	Voice Communication System
VDL2	VHF Digital Mode 2
VHF	Very High Frequency
WAN	Wide Area Network
WG	Work Group

2. APPLICABLE AND REFERENCE DOCUMENT

2.1 Applicable documents

ID	Document Number	Title	Issue	Date
[AD-01]	Iris-B-OS-RSD-0002-ESA	Iris Phase 2.1 System Requirements Document	2.1	23.10.2012

Table 2-1: Applicable documents

2.2 Reference documents

ID	Document Number	Title	Issue	Date
[RD-01]	ANTAR-B1-CP-TNO-2006-IND	Communication Standard Technical Specifications (D018)	1.1	16.09.2013
[RD-02]	ANTAR-B1-CP-TNO-2005-IE	Communication Standard Implementation Guidelines Document (D023)	4.6	16.09.2013
[RD-03]	COCRv2	Communications Operating Concept and Requirement for the Future Radio System	2.0	
[RD-04]	TS 102 606 V1.1.1	Digital Video Broadcasting (DVB); Generic Stream Encapsulation (GSE) Protocol	1.0	2007
[RD-05]		O. del Río Herrero, R. de Gaudenzi, “A High Efficiency Scheme for Large-Scale Satellite Mobile Messaging Systems”, ICSSC 2009.		June 2009
[RD-06]	ICAO Doc 9880-AN/466	ATN SARPS Manual of Technical Provisions for the ATN	1.0	2010
[RD-07]	ICAO Doc 9776	Manual on VHF Digital Link (VDL) Mode 2 Ed 1		

Table 2-2: Reference documents

3. COMMUNICATION STANDARD CONTEXT

3.1 System reference architecture

Refer to [RD-01] for a description of the system reference model used for design activities.

3.2 Interfaces covered by the Communication Standard

Refer to [RD-01] for a description of the interfaces covered by the CS.

3.3 Reference traffic profile

Refer to [RD-02] for a description of the traffic profile used as reference for the design.

3.4 Aeronautical propagation channel

Refer to [RD-02] for a description of the aeronautical propagation channel model used for the design.

3.5 Robustness in front of non-nominal conditions

Procedures and mechanisms defined by the CS have to be robust in front of non-nominal conditions, including:

- Lost, corrupted, unexpected, duplicated, or re-ordered signalling messages, both of broadcast and of dedicated type.
- Negative response to request messages.
- Temporary loss of synchronization for a specific UT or group of UTs.
- Temporary total or partial GS system failures, as a consequence of failures not handled adequately by existing redundancy mechanisms.
- Traffic overload conditions, possibly associated with partial system failures or certain contingency situations.
- Failures in L3 protocols.
- Switch off or failures in UT system that produce the loss of communication capabilities, which will not result in a blockage of the UT status when the UT is recovered.

In this sense, the CS includes adequate protection mechanisms. For example:

- Protocols include retransmissions, consider adequate timeout values, and include specific fields that increase robustness (counters, identifiers, etc.).
- Protocols and processes are designed to avoid overload conditions, including back-off mechanisms when necessary.
- Specific mechanisms to handle concurrent triggers from different sources.
- Timeouts to detect non-nominal conditions that may cause excessive blockage times of some resource.

Protocols and processes are designed to detect anomalous conditions and reset state if necessary (for example, if maximum retrials are exceeded).

4. COMMUNICATION STANDARD OVERVIEW

This section provides a short overview of the main features of the communication standard.

4.1 Multiple Access Scheme

On the FWD link, the CS supports an MF-TDMA access scheme that allows efficient support of a distributed ground segment with a potentially high number of GES stations. MF-TDMA carriers over the forward link can have two different rates: 160 kbaud and 16kbaud(low rate waveform). Low rate waveform has been conceived to cope with constrained Link Budget environments and take into account data rates required by the transported applications. Resources on the FWD link are distributed among GES by the NCC according to the number of GES and the specific capacity needs. The design of the mechanisms for FWD link resource assignment is system dependent.

Over the return link, an A-CDMA scheme is proposed in which the traffic from active aircraft is transmitted by means of asynchronous packets using channel data rates from around 3 Kbps to 14 Kbps that share the same frequency channel. This scheme is based on an enhanced spread ALOHA access scheme (E-SSA) using interference cancellation techniques at the GS [RD-05].

Indicated carrier rates have been selected considering CoS requirements and preliminary link budgets based on state-of-the-art satellite segment implementations providing coverage to the European Civil Aviation Conference (ECAC) and surrounding areas. Values are set according to the specific satellite segment implementation characteristics.

4.2 Physical Layer

The physical layer must be able to counteract the aeronautical channel impairments such as multipath propagation phenomena and Doppler effects (Doppler shift and Doppler rate of change) and, at the same time, be spectral and energy efficient, allowing the system to operate at low SNIR conditions and even in degraded scenarios.

The adoption of adaptive waveforms on the forward link for carriers modulated at 160 kbaud allows the system to optimize the spectral efficiency while it adapts to the propagation channel characteristics. On the forward link, linear modulations (QPSK, 8-PSK and 16-APSK) are combined with certain code rates (1/4, 1/3, 1/2 and 2/3) to provide such flexibility, being the coding family selected the IRA LDPC, already used in DVB-S2 standard. On the other hand, forward link low rate carriers (16 kbaud) use constant channel coding and modulation (QPSK 1/4). Concerning the return link, the adoption of A-CDMA & Dual-BPSK as an access and modulation scheme allows the UT to counteract the effect of the multipath caused by the aeronautical mobile channel, and operate close to the HPA saturation point without losing performances. The data payload is encoded with 1/3 code rate using 16-states binary Parallel Turbo Codes, which provides a high degree of flexibility in terms of data payload size.

It should be noted that the physical layer also has been designed to accommodate the needs of rotary-wing aircraft.

4.3 Network synchronization

The adopted A-CDMA MA scheme in the return link does not require that UTs implement elaborate synchronisation procedures before transmitting. Absolute time synchronisation is not required, but a pre-compensation process is needed to limit carrier and chip frequency errors in order to minimise the return link guard bands and the time shift experienced during a random access channel burst, and facilitate the burst detection in the GS.

The pre-compensation process starts with the estimation of the frequency error from the Forward reception that allows the compensation of the return transmission.

Regarding the forward link, the different forward TDMA carriers are also kept synchronous with respect to the network reference to ensure that all forward carriers, regardless of the transmitting GS station, are received in the UT with the correct timing and frequency.

Network synchronization design has also taken into account requirements from non-GEO constellations, as MEO or HEO, which are also supported by the CS.

4.4 MAC and Link Layer

The transmission over the return link follows an A-CDMA scheme based on an Enhanced Spread Spectrum ALOHA (E-SSA) random access approach adapted to the traffic profile described in section 3.3. The A-CDMA random access scheme can efficiently support delay-sensitive short and long messages at the same time by defining adapted burst formats guaranteeing to fulfil the delay requirements.

The random access scheme supports congestion control mechanisms to ensure that the random access channel is not overloaded and that it operates under the most adequate conditions. The congestion control and retransmission mechanism is CoS-oriented, taking into account a relative packet priority depending on its delay requirements.

The A-CDMA scheme is basically based on the following definition:

- A number of frequency channels (or bands) are required to support the system traffic. A possible solution regarding the use of the frequency channels could be:
    - Use a full frequency reuse scheme. In general, this option allows reducing the overall required bandwidth.
    - If full frequency reuse is selected, burst formats with different spreading factors should not share the same band in order not to penalize the system capacity.
    - A terminal randomly selects the frequency channel to use for its transmission among the ones allocated to it. Congestion control can be applied prior to the frequency channel selection in order to balance the traffic among frequency channels.
- Gold codes are used as complex scrambling codes. The good auto-correlation properties of the complex scrambling codes allow distinguishing between different non-colliding UT transmissions. Discrimination of colliding bursts is possible if several scrambling codes are used in the same band, thanks to the good cross-correlation properties.
- Orthogonal codes (Walsh-Hadamard codes) are used as channelization codes to distinguish between data and control branches and the burst format. For each burst format, all the terminals can use the same set of channelization codes.

An ARQ scheme is supported both on the FWD linkand in the RTN link, where it is integrated with the overall random access scheme.

Encapsulation of data is based on customizations of the state-of-the-art GSE [RD-03] encapsulation scheme used in the DVB family of standards. The schemes have been adapted to efficiently integrate ARQ headers, used by the retransmission mechanisms defined by the CS.

4.5 Network layer

The CS supports two network layer stacks, ATN/IPS and ATN/OSI, allowing co-existence of both stacks in the same aircraft if needed. For legacy reasons, the CS supports the same OSI subnetwork dependent network layer functions as in current VDL2 networks (mobile SNDCF), so that required avionics adaptations are minimized. For IP, it provides a suitable link-layer interface for IPv6, and system implementers are mostly free to support any ATN/IPS compliant network layer mechanism of their preference.

As part of the functions associated with a specific protocol stack, the CS also supports adaptation to the underlying (network layer agnostic) link layer, especially in terms of mapping to the most adequate MAC CoS, and header compression capabilities. For IP, header compression is based on the state-of-the-art ROHC protocol, whereas for OSI the LREF method is used, inline with current ICAO SARPs.

4.6 Multicast

Satellites have inherent broadcast capabilities when compared to other terrestrial technologies and allow efficient distribution of multicast/broadcast information over broad geographical areas. The CS supports transmission of multicast flows from the ground toward the UTs.

4.7 Handovers

The ANTARES communication system shall support seamless handovers between GSE, between mobile link beams, and between different satellites and independent ANTARES system implementations. The use of an omni-directional antenna and two receiver modules at the UT facilitates this process.

The CS only relies on signal quality measurements to detect a need for handover, but location information provided by available IRS/GPS systems could allow more sophisticated handover policies (handover to a certain GES for administrative reasons over a certain region, etc.).

Upon a UT request, the responsible GS takes a handover decision based on multiple criteria (general system status, GES load, administrative preferences, etc.) and initiates handover execution. In order to support a seamless transfer of the communication, a make-before-break approach is followed, with the old and new connections being maintained in parallel during a certain time period until the L2 Tx buffers towards previous GES are emptied.

The CS has also been designed to allow support for bulk handovers (i.e., an instantaneous switch from one satellite to another for a potentially large group of UTs), which are needed if an MEO/HEO constellation implements the CS.

4.8 Security

No CS-specific security mechanisms are considered either in the user or in the control plane, as it is assumed that end-to-end security will be provided by upper layers, out of the scope of the CS.

4.9 Redundancy and diversity

An architecture avoiding single points of failure, with site diversity and with satellite / GS hot redundancy, is required to meet availability requirements imposed on ATM communication systems.

A redundancy concept is proposed which is based on the pre-synchronization of NCC/GES back-up elements with the active ones and on the sharing of context information (e.g., logged UTs). Under these conditions, a redundancy switch-over can be nearly transparent to UTs (which experience just a momentary signal loss) and thus only a minimal set of redundancy-related adaptationshave been included in the CS.

Activation of redundancy mechanisms as the switch-over described above is also an option to counteract fadings associated with rain.

5. REFERENCE USER, CONTROL AND MANAGEMENT PLANE PROTOCOL STACKS

Reference user, control and management plane protocol stacks associated with the CS can be found in [RD-01].

6. COMMUNICATION STANDARD CHANNELS AND CARRIERS DEFINITION

This section provides a description of the logical and physical channels defined by the Communication Standard as well as the system carriers. The distinction between logical and physical channels offers the system the flexibility to deal with different types of services.

It also describes the different link-layer addresses used by the CS.

6.1 Data and signalling channels

6.1.1 Logical channels

6.1.1.1 Description

Logical channels refer to the services offered by the MAC protocol layer between a UT and the GS. They define WHAT type of data is transferred, as opposed to the physical channels, which define the physical characteristics of the used channels (i.e., HOW data is transferred).

Two main groups of channels can be identified: control channels, which transfer control plane information, and traffic channels, for user plane information. They are briefly listed here and then described in more detail in the following sections:

- Broadcast/Multicast Traffic Channel (BTCH)
- Unicast Traffic Channel (UTCH)
- Broadcast Control Channel (BCCH)
- Unicast Control Channel (UCCH)

6.1.1.1.1 Traffic channels

- Broadcast/Multicast Traffic Channel (BTCH)

  The BTCH is a point-to-multipoint unidirectional logical channel used in the FWD link for the transmission of user plane data (LSDUs) to all or a sub-group of UTs within a mobile link beam. Only the GS may transmit on this channel.

- Unicast Traffic Channel (UTCH)

  The UTCH is a point-to-point bi-directional logical channel dedicated to the transmission of user plane data between the GS and a specific UT.

6.1.1.1.2 Control channels

- Broadcast/Multicast Control Channel (BCCH)

  The BCCH is a point-to-multipoint unidirectional logical channel of the FWD link used to forward general system control information that shall be announced to all or a sub-group of UTs within a mobile link beam, such as system tables for logon or congestion control parameters. Additionally, it may optionally broadcast the synchronization reference required to keep GS elements synchronized. Only the GS may transmit on this channel.

- Unicast Control Channel (UCCH)

  The UCCH is a point-to-point bi-directional logical channel used by the GS to exchange control messages with a specific UT.

6.1.1.2 Logical channel attributes

Each logical channelLSDU is further characterised by a set of attributes, as indicated below:

- L2 addresses (UT/GS). They identify the communicating endpoints. Destination link addresses may also be of multicast or broadcast type.
- LSDU types
  - Different LSDU types are defined for control and traffic channels according to transported data:
    - Control channel:
      - General signalling
    - Traffic channel:
      - IPv6 packet
      - Compressed IPv6 packet (ROHC packet)
      - v8208 packet (for ATN/OSI support)
- Class of service parameters
  - These parameters indicate how an LSDU belonging to a logical channel is tobe treated from a QoS point of view, and determines its scheduling priority and mapping to physical channels. They also support the correct setting of certain MAC/LLC parameters (number of retransmissions, timeout values).
  - CoS parameters considered for traffic and control channels are:
    - TD95: 95th percentile of the one-way transit delay latency of an LSDU.
    - Continuity: Probability that an LSDU will be successfully forwarded (without duplicates or undetected errors) before the expiration time defined below.
    - Expiration Time (ET): Maximum time beyond which an LSDU is considered lost. This time puts a limit also to recovery strategies applied when LSDU fragments are lost or received with errors.
    - Message size: needed just in the RTN link to perform the mapping to burst types.
  - A CoS category is also characterized by:
    - Support of retransmissions (yes/no ARQ).

6.1.2 Physical channels – burst types

The logical channels defined in the previous section are mapped into physical channels to be carried over the air. In this sense, the physical channels define how the information carried by the logical channels is transferred.

Physical channels are classified with consideration to their physical layer characteristics and functionalities. The physical channels specified by the Communication Standard refer to different burst types.

Physical channels have been classified on forward and return link physical channels. The reason for this classification is because of the different physical layer characteristics and associated functions of both links. The physical channels are listed here and briefly described in the subsequent sections:

- Forward link physical channels:
  - Forward Channel (FCH)
- Return link physical channels:
  - Random Access Channel (RACH)

6.1.2.1 Forward link physical channel

- Forward Channel (FCH)

  The FCH is the unique Forward Link physical channel and it is used for transmitting either user data and/or voice and/or signalling. The FCH can be transmitted indistinctly by the NCC and by the GES. The FCH channels are assigned individually to each GS Element upon request.

  The FCH can be modulated at 2 baud rates: 160 kbaud (normal rate waveform) and 16 kbaud (low rate waveform).

  - The FCH burst structure for the FWD Link carriers modulated at 160 kbaud is presented in Figure 6-1 (refer to [RD-01] for details regarding the FCH burst construction). The main characteristic of the FCH burst modulated at 160 kbaud is that it supports adaptive waveforms (ACM) in order to counteract channel impairments and optimise the system efficiency. This property is exploited in the bursts that carry dedicated traffic for a UT or a group of UTs, while the bursts that carry signalling are always modulated and coded with the most robust MODCOD, which is QPSK 1/4.

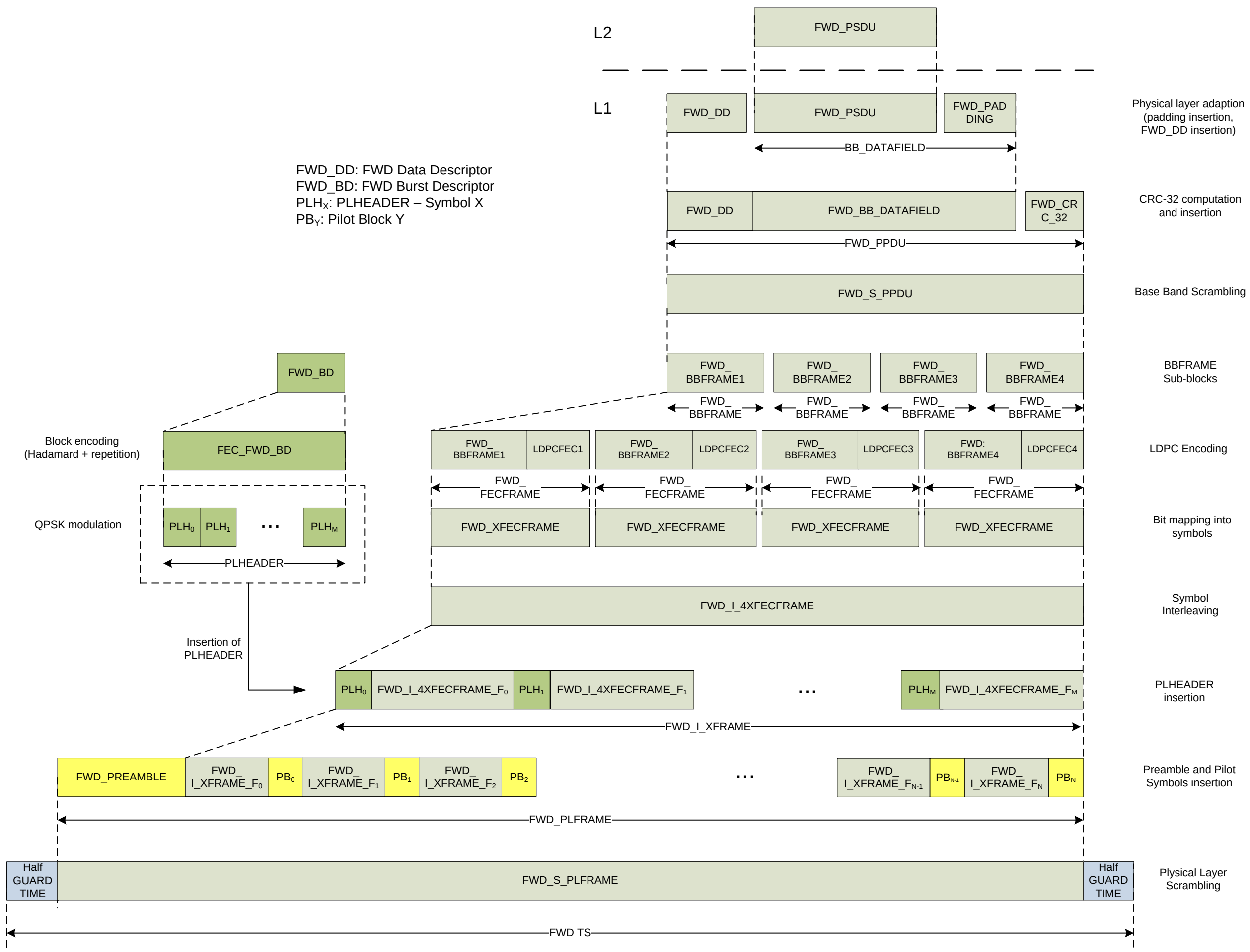

Figure 6-1: FCH burst format for carriers at 160 kbaud.

– The FCH burst structure for the FWD Link carriers modulated at 16 kbaud is presented in Figure 6-2 (refer to [RD-01] for details regarding the FCH burst construction). The main difference with respect to the FCH modulated at 160 kbaud is that ACM is not supported (Constant Coding and Modulation) and that a burst is only composed of 1 Data Word instead of 4.

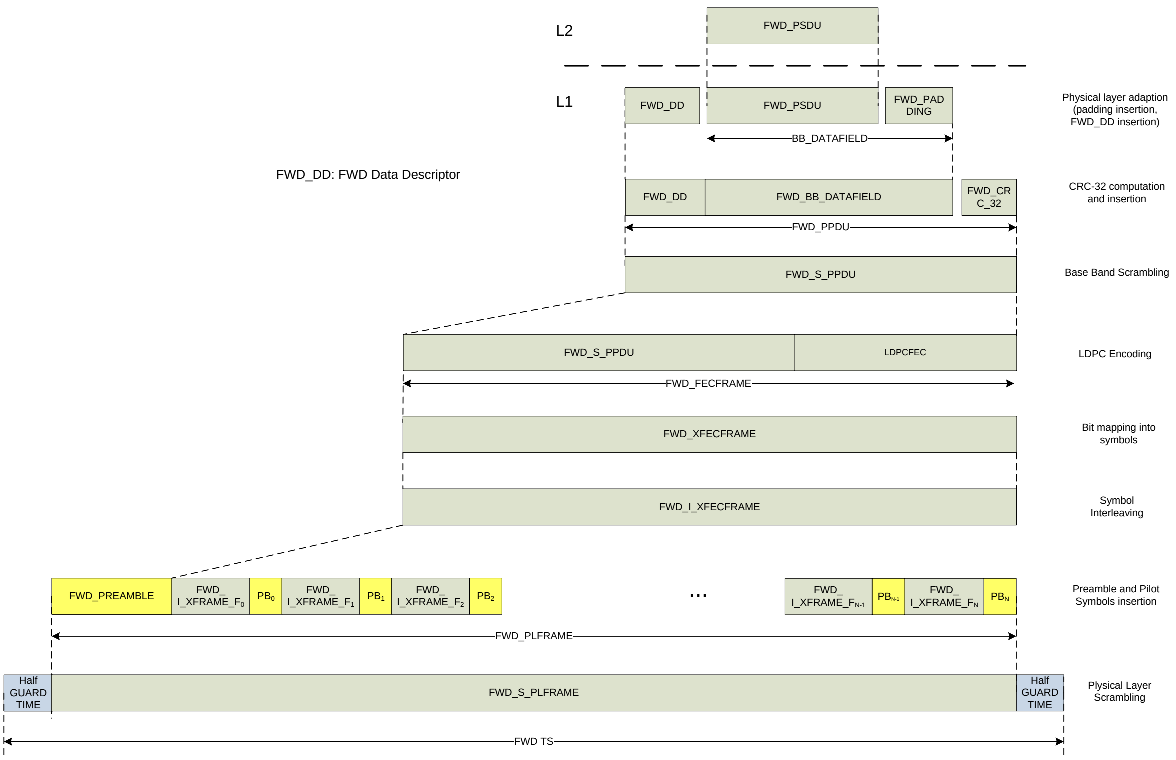

Figure 6-2: FCH burst format for carriers at 16 kbaud

6.1.2.2 Return link physical channels

- Return Access Channel (RACH)

  The RACH is the only physical channel defined on the RTN Link. It is a contention-based physical channel used by the UT to transfer both control (signalling) and user traffic information (data and voice).

  The generic RACH burst structure is illustrated in Figure 6-3 (refer to [RD-01] for details regarding the RACH burst construction).

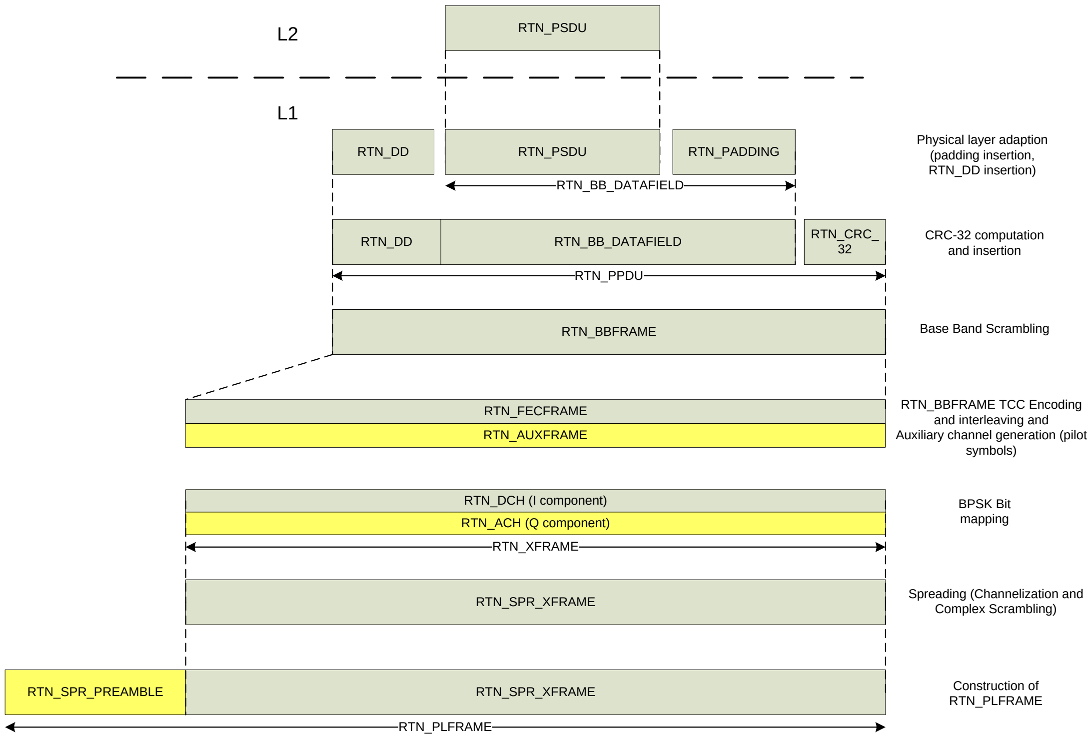

Figure 6-3: RACH burst format

The Communication Standard [RD-01] specifies 4 RACH Configurations, which are summarised in the following table.

RACH Configuration ID	Chip rate (kchip/s)	SF	Mod	Code rate	RTN_PPDU Size (bits)
RACH_CR$_{160}$_SF$_{16}$_DB$_{512}$	160	16	BPSK	1/3	512
RACH_CR$_{160}$_SF$_{4}$_DB$_{2048}$	160	4	BPSK	1/3	2048
RACH_CR$_{160}$_SF$_{16}$_DB$_{288}$	160	16	BPSK	1/3	288
RACH_CR$_{160}$_SF$_{4}$_DB$_{976}$	160	4	BPSK	1/3	976

Table 6-1: RACH configurations supported by the Communication Standard (Data channel)

Two spreading factors are defined for the RTN link A-CDMA access scheme, i.e., 4 and 16. The baseline proposal is to avoid SF mixing in a given frequency band. However, in case SF mixing is implemented, different preamble sequences must be used to identify, upon reception of a burst, the SF used in both RTN link Data and Control channels.

Data and Control channels are separated by using different OVSF codes (channelization codes). Besides, to distinguish different RACH configurations Id with the same SF, different Control channel codes must be used to determine the actual configuration.

All UT can use the same complex scrambling sequence for all RACH bursts tailored to the burst length. However, the coexistence of several complex scrambling sequences within the same carrier (i.e., bandwidth) is possible. The need for more than one scrambling sequence is determined by the probability of collision of two bursts with the same code phase.

The configuration parameters for the different RACH Id are distributed through the System tables (see [RD-01], section 11). In particular, the following parameters are distributed for each RACH Id:

- 1 OVSF code for Data Channel ($C_{ch,d}$)
- 1 OVSF code for Auxiliary Channel ($C_{ch,d}$)
- Up to 8 pairs of:
  - Preamble sequence index
  - Complex Scrambling index (C_{Scram})

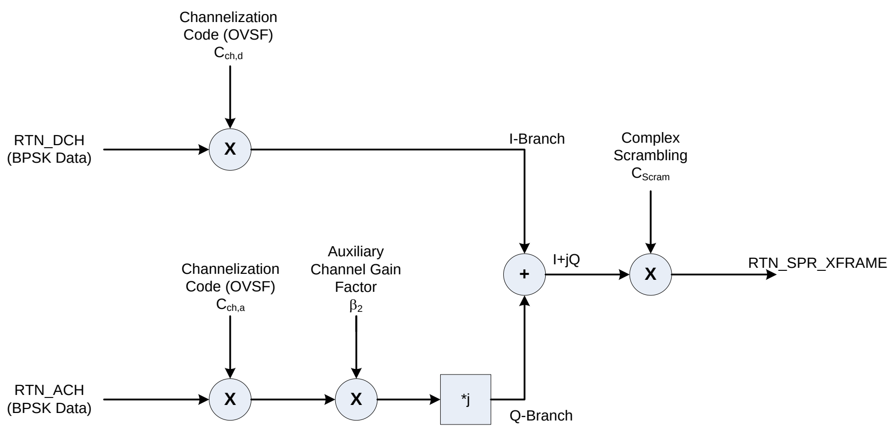

Figure 6-4: Spreading (channelization and scrambling) of RTN_DCH and RTN_ACH

Each RACH burst is designed to carry messages with different CoS requirements. The following table presents the mapping between RACH burst configurations and the messages, based on the service requirements.

RACH Configuration ID	Service	Splitting policy
$RACH\_CR_{160}\_SF_4\_DB_{976}$	Voice	Voice
$RACH\_CR_{160}\_SF_4\_DB_{2048}$	Data/Voice	Application message size ≥ 500 bytes Voice
$RACH\_CR_{160}\_SF_{16}\_DB_{288}$	Data/Signalling	Application messages or signalling that can be transmitted without fragmentation
$RACH\_CR_{160}\_SF_{16}\_DB_{512}$	Data/Signalling	Remain messages or signalling

Table 6-2: Mapping between services and RACH bursts Configuration

6.1.3 Mapping between logical and physical channels

The following figure shows the mapping between logical channels defined in section 6.1.1 and physical channels defined in section 6.1.2.

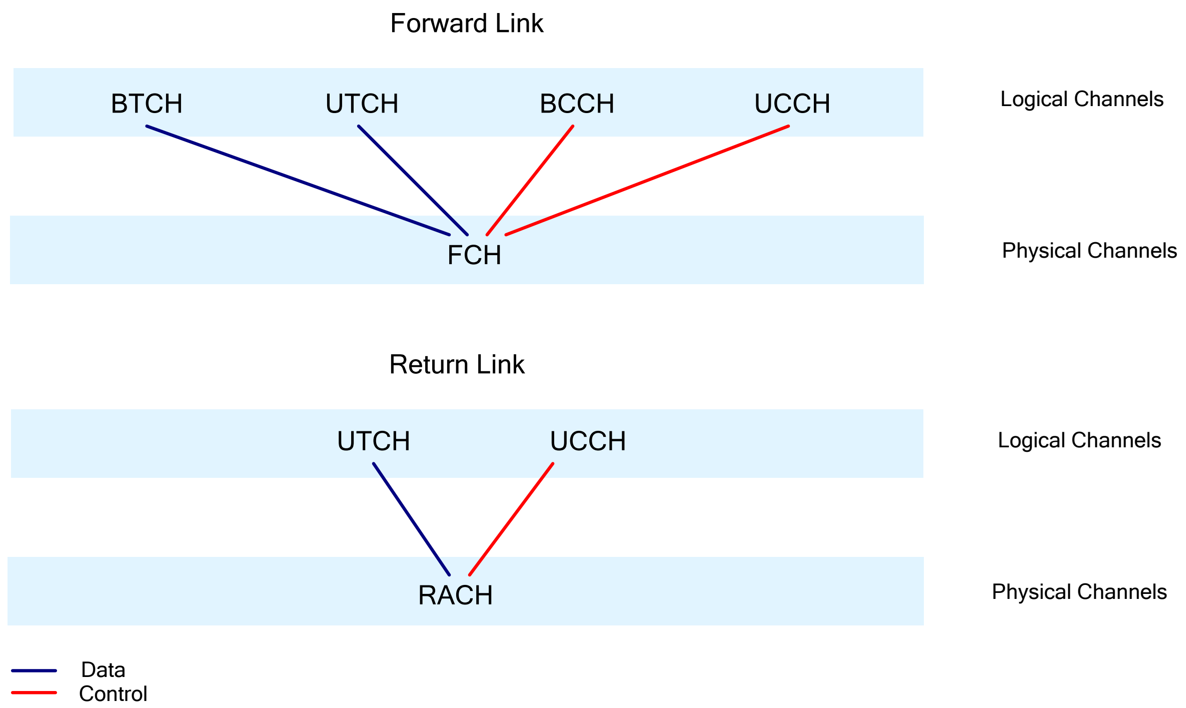

Figure 6-5: Mapping between logical and physical channels

6.2 System carriers

In the Communication Standard a System Carrier is defined as a fixed frequency bandwidth in L band.

The System will operate in the mobile link at frequencies identified by ITU for Aeronautical Mobile-Satellite (Route) Service (AMS(R)S), in agreement with Article 1, Section III, 1.33 of ITU Radio Regulations [RD-7] and allocated worldwide as follows:

- 1545 to 1555 MHz for the mobile downlink (from satellite to User Terminal).
- 1646.5 to 1656.5 MHz for the mobile uplink (from User Terminal to satellite).
- The mobile link polarisation specified is right hand circular (RHCP) for uplink and downlink.

Additional characteristics of the system carriers depend on the Multiple Access scheme.

6.2.1 Forward Link system carrier

On the FWD Link the Multiple Access scheme is MF-TDMA. Therefore, a FWD Link system carrier is defined as a fixed frequency bandwidth in a frequency band organised in time-slots to provide the mechanisms for conveying the signalling and user traffic. Within a carrier, the time-slots are organised in frames. The frame is the elementary period of time for the assignment of radio resources to the GS Elements. Each frame can be composed of different time-slots. The number of time-slots of a frame is not defined by the CS as it depends on an specific System as it only affects the sharing of resources by the GSE's. In addition, it is not necessary for the UT to be aware of the frame duration as it decodes all received time-slots.

Only one System carrier is defined:

– **Forward Link Carrier (FLC)**: The FLC is transmitted by the Ground Segment Elements (NCC and GES) to transfer the information to the UT. The FLC is shared between the GS Elements in TDMA mode. It is organised in frames of constant duration, and each frame is composed of forward link time-slots able to carry the physical channels. Each time-slot in a frame is individually assigned to a GS Element. On the forward link there is not a system carrier uniquely dedicated to distributing the network signalling but user traffic and network signalling (broadcast or dedicated) are multiplexed in the same system carrier. The FLC is able to multiplex FCH bursts with different configurations, as illustrated in the following figure.

  The characteristics of the FLC at 160 kbauds and at 16 kbauds are as follows:

	FLC at 160 kbaud	FLC at 16 kbaud
Carrier bandwidth (including Guard Bands)	192.6 kHz (GEO) 195.6 kHz (HEO) 192.5 kHz (MEO)	19.8 kHz (GEO)
Roll-off	0.2	0.2
Time-slot duration	86.35 ms	224.188 ms

Table 6-3: FLC characteristics (160 and 16 kbaud)

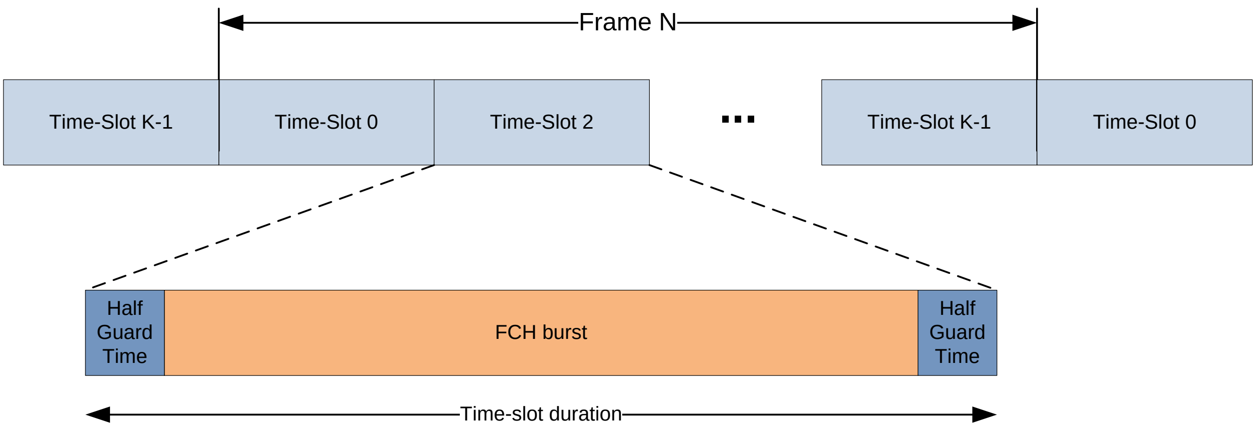

Figure 6-6: Example of FLC

6.2.2 Return Link system carrier

On the RTN Link the Multiple Access scheme is A-CDMA, which means that the transmissions from the UT are asynchronous. As a consequence, there is no need to organise the carrier in time-slots. Therefore, a RTN Link system carrier is defined as a fixed frequency band with the appropriate guard band to cope with all the synchronisation errors. In each carrier, the UT transmits only when necessary. In this type of access, the collisions between bursts are quite frequent, but, on the receiver side, the burst can be decoded thanks to the use of an Interference Cancellator.

Only one Return System carrier is defined:

- **Return Link Carrier (RLC)**: The RLC is a return link carrier shared by the UTs to transmit either signalling or user traffic information in an asynchronous manner.

  The characteristics of the RLC are as follows:

  - Carrier bandwidth: 200 kHz (including Guard Bands)
  - Carrier chip rate and roll-off: 160 kchips and roll-off = 0.2
  - Bursts duration:
    - RACH_CR$_{160}$_SF$_{16}$_DB$_{512}$: 167.6 ms (1676 symbols)
    - RACH_CR$_{160}$_SF$_{4}$_DB$_{2048}$: 157.1 ms (6284 symbols)
    - RACH_CR$_{160}$_SF$_{16}$_DB$_{288}$: 100.4 ms (1004 symbols)
    - RACH_CR$_{160}$_SF$_{4}$_DB$_{976}$: 76.7 ms (3068 symbols)

Full frequency re-use is supported on the RTN Link. Full frequency re-use allows optimization of the required system bandwidth. However, in order not to penalize the capacity provided by the access scheme, different RLCs could be used to transmit the different RACH configurations, at least one band per spreading factor. This means that there will be RLCs carrying RACH bursts with SF = 16 chips (RACH_CR$_{160}$_SF$_{16}$_DB$_{512}$ and RACH_CR$_{160}$_SF$_{16}$_DB$_{288}$) while other RLCs will carry RACH bursts with SF = 4 chips (RACH_CR$_{160}$_SF$_{4}$_DB$_{2048}$ and RACH_CR$_{160}$_SF$_{4}$_DB$_{976}$).

6.3 Link-layer addressing

The CS defines a set of link-layer addresses (i.e., sub-network specific identifiers) that are used to identify the elements of the satellite system (UTs and GSEs) and to ensure that data are exchanged between intended entities.

The UT uses the following link-layer addresses:

- **ICAO ID:** This is a 3-byte address that has been defined by ICAO and which is globally unique per aircraft (and thus per UT). It is a fixed UT identifier which does not change from logon to logon and which can also thus be used for management purposes (e.g., for accounting or monitoring purposes). It is used as UT L2 address in the encapsulation header during the logon process, until a (shorter) UT ID is assigned to the UT. At any moment, the GS knows the mapping from the ICAO ID to the (changing) UT ID defined below.
- **UT ID (or UT L2 address):** This is a 2-byte address, which is assigned to the UT as part of a logon or handover procedure and which shall be unique within a SSP network.

It may change from communication session to communication session and also during the communication session lifetime, as a consequence of handovers (with or without a change of SSP). Except during a logon procedure, this is the link-layer address used in the encapsulation headers included in each PSDU, as it is shorter than the ICAO ID and thus more efficient.

During a handover, the UT may handle up to two different UT ID identifiers, each associated with a different logical channel.

- **UT satellite MAC address:** This is a 6-byte address, which is a globally unique and fixed UT link layer interface identifier. As the ICAO ID, it does not change from logon to logon.

  It is used to generate a (unique) 8-byte link-layer interface identifier as required by the IPv6 protocol, by using the same procedure as Ethernet to convert a 6-byte identifier into an 8-byte identifier. It is the CS link-layer address from the IPv6 protocol point of view.

  At any moment, the GS knows the mapping from the UT satellite MAC address to the (changing) UT ID defined above.

  To a certain extent, the UT satellite MAC address and ICAO ID provide similar functionality in terms of addressing. However, the UT satelliteMAC address has been defined to provide a better support for the IPv6 protocol and to not limit airborne architecture implementation options: no specific format is imposed by the CS on this address, and several UT satellite MAC addresses (i.e., several link-layer interfaces) may be specified per UT.

The GS uses the following link-layer addresses:

- **GSE ID (or GSE L2 address):** This is a 1-byte address assigned to each GSE. Only the first most significant 6 bits actually identify the GSE, while the least significant two bits are used to support redundancy (i.e., a certain GSE may handle up to 4 different GSE ID values, in order to allow a more seamless switch-over from an active to a redundant element). These 6 bits shall have a fixed value per GSE and shall be unique within an SSP network.

  This is the Link-layer address used in the encapsulation headers included in each PSDU.

  Depending on the GSE role, the terms GES ID or NCC IDmay be used instead of GSE ID.

- **GES satellite MAC address:** This is a 6-byte address assigned to each GES and its globally unique and fixed satellite link layer interface identifier.

  It is used to generate a (unique) 8-byte link-layer interface identifier as required by the IPv6 protocol, by using the same procedure as Ethernet to convert a 6-byte identifier into an 8-byte identifier. It is the GES link-layer address from the IPv6 protocol point of view.

At any moment, the UT knows the mapping from the GES satellite MAC address to the GES ID defined above. This mapping is obtained during the logon/handover procedures.

To a certain level, the satellite GES MAC address and GES ID provide similar functionality in terms of addressing (together with the System ID and the SSP ID, the GSE ID also univocally identifies any GS element). For implementation reasons, however, it is convenient to allow use of any unique 6-byte identifier (e.g., as provided by an Ethernet interface), with no specific format imposed by the CS on this parameter.

Section 8.4.1.3 provides a description of how the mapping is made between the described UT/GES satellite MAC addresses and the corresponding IPv6 L3 addresses (address resolution functionality).

For ATN/OSI, address resolution is managed by associating a 8208 virtual channel to a specific link (established between a pair of satellite MAC addresses) using a JOIN event, as described in section 8.4.2.

It should be noted that, for both protocol stacks, address resolution is performed by the network layer functionality. This layer then provides the correct destination satellite MAC address to the underlying network adaptation layer. Satellite MAC addresses can then be directly mapped to the correct UT ID / GSE ID addresses, a mapping which is maintained and updated through the logon/HO procedures.

7. COMMUNICATION STANDARD FUNCTIONAL ARCHITECTURE

7.1 General functional architecture

The following figure presents the communication standard functional architecture, providing the separation between planes (user, control and management) and also between layers. Only functional blocks in blue are specified by the CS (either partially or totally).

The data flow of the information transmitted over the air is represented withgrey-shaded lines, whereas specific control information is represented withblack lines. Management plane flows (from the MGT function to all other functions) are not represented for the sake of clarity.

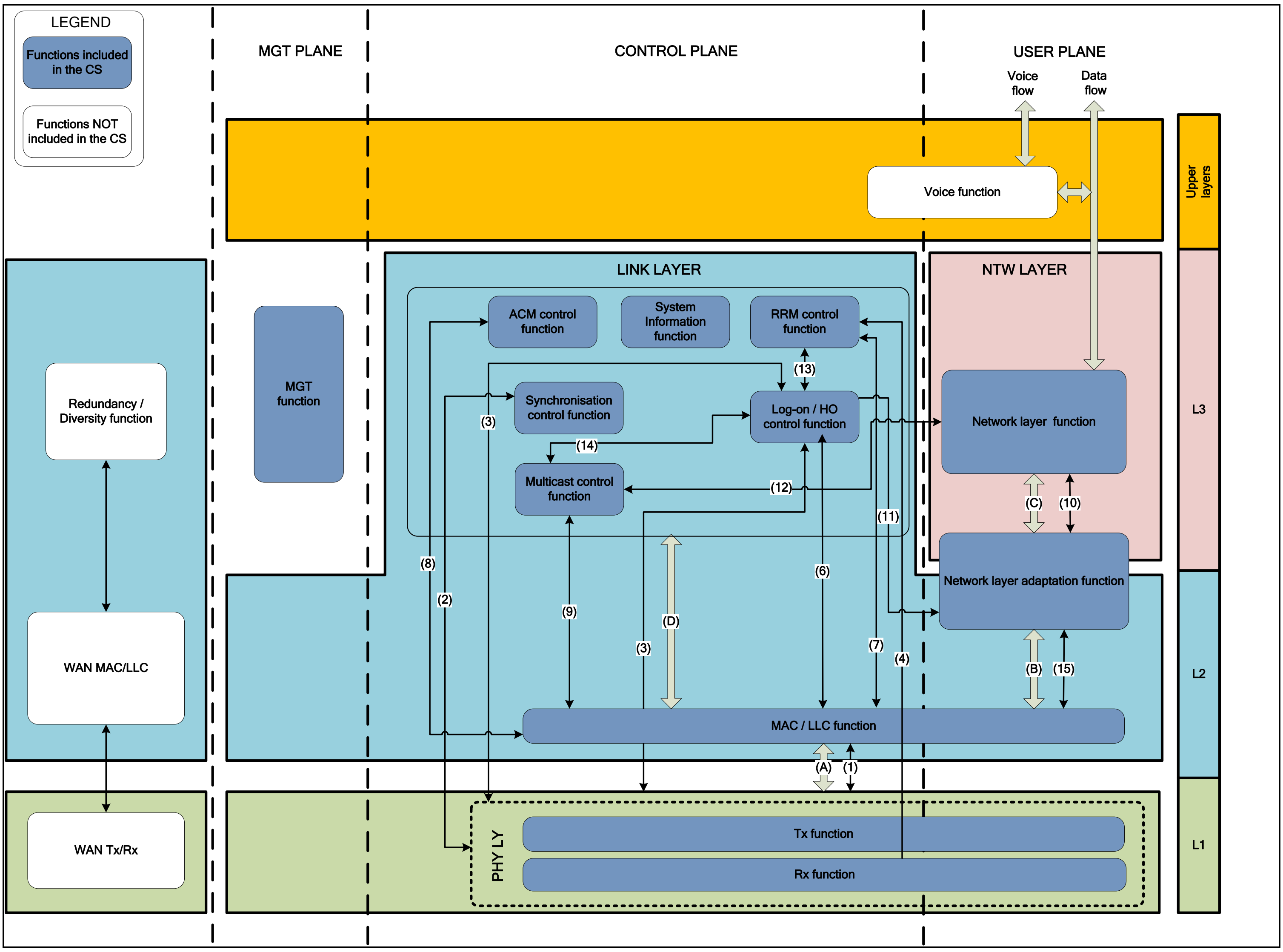

Figure 7-1: Communication Standard general functional architecture

Some functionalities represented in the figure are implemented on the ground, and others onboard. Some are implemented both on ground and on-board, even though the functionality could be different.

The Communication Standard functional architecture presented in the previous figure is composed of the following functions:

- User plane functions
  - Network layer adaptation functions
  - Network layer functions
- Common user and control plane functions
  - Tx function
  - Rx function
  - MAC/LLC functions
- Control plane functions
  - RRM function
  - ACM control function
  - Log-on / HO control function
  - Multicast / Broadcast control function
  - Synchronisation / Power control function
  - System information function
- Management plane functions
  - Management functions
- Other functions not included in the communication standard
  - Voice function
  - Redundancy and diversity
  - WAN MAC/LLC
  - WAN Tx/Rx function

7.2 Functional tree

The following table presents the Communication Standard functional tree, in which the hierarchical relations between the CS functionalities are provided. Five level 1 functions have been identified:

- A1: PHY layer function
- A2: LLC/MAC function
- A3: Network and Network adaptation layer function
- A4: Control function
- A5: Management function

COMMUNICATION STANDARD FUNCTIONAL TREE			
Level 1 function	**Level 2 function**	**Level 3 function**	**Comment**
A1- PHY layer function	**A1.1** – Tx function (FWD link)	**A1.1.1** – Physical layer adaption function	
		A1.1.2 – CRC insertion function	
		A1.1.3 – Base-band scrambling function	
		A1.1.4 – FEC Encoding function	It includes Channel Coding and bit interleaving (BICM).
		A1.1.5 – Bit mapping function	
		A1.1.6 – Symbol Interleaving	
		A1.1.7 – Physical Layer signalling insertion function	
		A1.1.8–Physical layer framing function	It includes Preamble and Pilot symbols insertion
		A1.1.9 – Physical layer scrambling function	
		A1.1.10– Shaping and quadrature modulation function	
	A1.2 – Rx function (FWD link)	**A1.2.1** – Physical layer adaption function	
		A1.2.2 – Integrity check function	
		A1.2.3 – Base-band de-scrambling function	
		A1.2.4 – FEC decoding function	It includes Channel Decoding and bit de-interleaving (BICM).
		A1.2.5 – Bit de-mapping function	
		A1.2.6 – Symbol De-interleaving	
		A1.2.7 – Physical layer de-framing and signalling extraction function	
		A1.2.8 – Physical layer de-scrambling	
		A1.2.9 – SNIR measurement function	
		A1.2.10– Physical Synchronization / Equalisation function	It includes the Matching function
		A1.2.11– Burst Detector	
	A1.3 – Tx function (RTN link)	**A1.3.1** – Physical layer adaption function	
		A1.3.2 – CRC insertion function	
		A1.3.3 – Base-band scrambling function	

COMMUNICATION STANDARD FUNCTIONAL TREE			
Level 1 function	**Level 2 function**	**Level 3 function**	**Comment**
		A1.3.4 – FEC Encoding function	It includes Channel Coding and bit interleaving.
		A1.3.5 – Bit mapping function	Bit mapping function is applicable to Data Channel and Auxiliary channel
		A1.3.6 – Auxiliary Channel generation function	
		A1.3.7 – Spreading function	It includes Channelization and Scrambling. Common to Data and Auxiliary channel.
		A1.3.8 – Preamble generation function	
		A1.3.9 – Preamble Spreading function	
		A1.3.10 – Physical layer framing function	
		A1.3.11– Shaping and quadrature modulation function	
	A1.4 – Rx function (RTN link)	**A1.4.1** – Physical layer adaption function	
		A1.4.2 – Integrity check function	
		A1.4.3 – Base-band de-scrambling function	
		A1.4.4 – FEC decoding function	It includes Channel Decoding and bit de-interleaving (BICM).
		A1.4.5 – Bit de-mapping function	
		A1.4.6 – Channel compensation function	It applies to the Data Channel
		A1.4.7 – Channel estimation function	It is based on the reception of Auxiliary channel
		A1.4.8 – De-spreading function	It includes the de-scrambling and de-channelisation
		A1.4.9 – Physical synchronization	It includes the matching filter
		A1.4.10 – Burst detector function	
		A1.4.11 – SNIR measurement function	

COMMUNICATION STANDARD FUNCTIONAL TREE			
Level 1 function	**Level 2 function**	**Level 3 function**	**Comment**
		A1.4.12 – Noise Rise estimation function	
A2- LLC/MAC layer function	**A2.1** – Encapsulation function		
	A2.2 – ARQ function		
	A2.3 – RRM/MAC function	**A2.3.1** – Scheduling and priority management function	
		A2.3.2 – Queuing and buffering functions	
A3 - Network and Network adaptation layer function	**A3.1** – Network layer function		
	A3.2 – Network layer adaptation function	**A.3.2.1** – Header compression function	
		A.3.2.2 – Support to mobility	
		A.3.2.3 – Logical channel adaptation function	
A4 - Control function	**A4.1** – System Information control function		
	A4.2 – Log-on control function		
	A4.3 – HO control function		
	A4.4 – RRM control function		
	A4.5 – Multicast control function		
	A4.6 – Synchronisation control function		
	A4.7 – ACM control function		
A5 - Management function			

Table 7-1: Communication Standard functional tree

7.3 Main relationship between functions

The table below indicates the main information exchanged between functional modules shown in Figure 7-1. Details regarding this information can be found in section 8.

Regarding the identifier (ID), a number indicates that control information is exchanged, whereas a letter indicates a connection which involves also the exchange of data units that are transmitted over the satellite link. These identifiers have been also included in Figure 7-1.

The last column (Dir) indicates whether the information is provided by the first function (→), the second one (←) or is bidirectional (↔).

ID	Interconnected functions		Exchanged information	Dir
A.1	PHY layer	MAC/LLC	PSDU unit	↔
			PSDU configuration for TX: RACH ID (RTN), MODCOD (FWD), FLC ID (FWD), PSDU size, Data Descriptor configuration, power randomization factor (RTN)	←
			PSDU error detection status (ok/nok)	→
			PSDU Data Descriptor (Rx)	→
			FLC PSDU reception performance (PSDU parity check status at Nnominal and Nreduced LDPC iterations – FWD Rx)	→
			FLC PSDU reception performance	→
2	PHY layer	Synchro	Network Time Reference	← NCC →Other
			Synchronization errors measurements (carrier & symbol/chip freqs and time)	→
			TX/RX sync corrections (carrier & symbol/chip freqs, time offset)	←
			SNIR measurements	→
			TX power corrections	←
3	PHY layer	Logon/HO ctrl	FLC(s) freqs to be tuned	←
4	PHY layer	RRM control	Load measurement (at PHY layer, for CC)	→
B	MAC/LLC	NTW Adapt LY	LSDU unit & attributes (src/dst L2 @,Type, CoS) - Traffic	↔
D.6	MAC/LLC	Logon/HO ctrl	LSDU unit & attributes (src/dst L2 @, Type, CoS) - Logon/HO signalling	↔
			TX/RX Buffer status	→
			Connection information: UT/GES ID, UT/GES L2 @, RLC/FLC, HO status.	←
			FLC reception performance (for HO detection)	→
D.7	MAC/LLC	RRM control	LSDU unit & attributes (src/dst L2 @, Type, CoS) - RRM signalling (CC)	←
			Load measurement (at MAC layer, for CC and FWD RRM)	→
			Random access CC parameters & status	→

D.8	MAC/LLC	ACM control	LSDU unit & attributes (src/dst L2 @, Type, CoS) - ACM signalling (CC)	↔
			FLC reception performance, for a certain GES ID (only UT)	→
			Preferred UT MODCOD (only GS)	←
			Need for additional MODCODs (dummy MODCODs)	←
C.10	NTW Adapt LY	NTW layer	Uncompressed L3 packet (IP/CLNP)	↔
			L2 logon/handover notification and associated UT satellite MAC address (IPS)	→
			Source satellite MAC address of the L3 packet (IP/CLNP) received over the satellite link	→
			L2 logon/handover OSI events (JOIN/LEAVE)	→
			Destination satellite MAC address of the L3 packet to be TX over the satellite link	←
11	Logon/HO ctrl	NTW Adapt LY	L2 logon/handover notification, including UT satellite MAC address	→
13	Logon/HO ctrl	RRM control	Load monitoring information (active data sessions)	→

Table 7-2: Information exchanged between functions

8. FUNCTIONAL DESCRIPTION

8.1 Physical layer functions

8.1.1 Key functions

The CS physical layer provides the mechanisms to allow the MAC/LLC layer to properly transfer the data flow over the satellite channel. Basically, the physical layer implements all the functions and mechanisms for the transmission and reception of the physical channels identified in section 6.1.2.

The physical layer functions can be grouped in two main categories:

- Tx function: Tx function is in charge of adapting the PSDUs received from L2 interface to the air interface (baseband processing functions) according to the specified physical channels, and transmitting the bursts at the right time and frequency (i.e., in the allocated time slots in dedicated channels in the forward link, or in the random access frequency bins following the RA protocol in the return link).
- Rx function: Rx function performs the reciprocal base-band signal processing operations performed by the Tx function.

The following table gives the physical layer configurations defined by the CS.

Link	Physical channel	Coding scheme	ModCods	Support of ACM
Forward	FCH @ 160 kbaud	IRA LDPC	QPSK 1/4,1/3, 1/2, 2/3 8-PSK 1/2, 2/3 16-APSK 2/3	Yes
	FLH @ 16 kbaud	IRA LDPC	QPSK 1/4	No
Return	RACH @ 160 kchips/s	16-states binary PCCC TCC	BPSK 1/3	No

Table 8-1: Physical channels configuration

8.1.2 Interfaces with other functions

The physical layer functions interfaces with:

- The RF IF & Antenna
- The MAC/LLC layer function
- Network synchronisation function
- RRM control function

8.1.2.1 Interfaces with RF front end

The physical layer provides the following inputs to the Tx RF IF & Antenna chain:

- The modulated FWD_S_PLFRAME / RTN_PLFRAME (I and Q samples at the output of the shaping and quadrature modulation).

On the Rx RF IF & Antenna chain, the physical layer receives:

- The received FLC / RLC (I and Q samples).

8.1.2.2 Interface to MAC/LLC

The interface between Physical layer and MAC/LLC is detailed in section 8.2.2.2.

8.1.2.3 Interface to Network Synchronisation function

The interface between Physical Layer function and Network Synchronisation function is detailed in section 8.7.2.

8.1.2.4 Interface to RRM control function

The interface between Physical Layer function and RRM control function is detailed in section 8.9.2.1.

8.1.3 Description

This section presents the functional block diagram for each of the physical layer functions identified in section 8.1.1 for both forward and return links. In addition, inputs, outputs, and the main configuration parameters are also identified.

It is noted that the purpose of the diagrams is to clarify the different functions, not to suggest a specific implementation.

8.1.3.1 Forward link

8.1.3.1.1 Tx function description

The Physical layer Tx function is composed of the following functional blocks:

- Physical layer adaptation function
    - This block provides the interface with the MAC/LLC layer. It receives the PSDU (FWD_PSDU) from the MAC/LLC layer and inserts the Data Descriptor Header (FWD_DD) based on the control information provided by the MAC/LLC (L2 Protocol). Each PSDU is mapped into one single burst. The Data Descriptor header for the Forward link is presented in section 6.1.2.
- CRC insertion function
    - The CRC block inserts 32 parity bits to the data block composed by the PSDU and the Data Descriptor for error detection and integrity verification. The resulting data block is called FWD_PPDU.
- Base-band scrambling function
    - The aim of the base-band scrambling is to randomise the incoming bits with the intention of removing long streams without transitions. Base-band scrambling can be seen as an algorithm for energy dispersal. The base-band scrambling is applied to the FWD_PPDU and generates the FWD_S_PPDU.
- FEC encoding function

  - The channel coding adds redundancy bits with the main objective of providing protection to the bits transferred through the satellite channel. The FWD_S_PPDU is encoded according the code rate provided by the PSDU configuration information (L2 control information). On the forward link, the coding family is IRA LDPC, supporting 1/4, 1/3, 1/2 and 2/3 code rates.
  - The encoder output is interleaved to break the error sequence introduced by propagation channel, especially due to the fades. The output of the interleaver is called 4_x_FWD_FECFRAME.
- Bit mapping function
  - This function maps a group of bits into a constellation point in order to increase the spectral efficiency. On the forward link, three constellations are supported: QPSK, 8-PSK and 16-APSK.
- Symbol interleaver function
  - This function implements a symbol block interleaver to assist the receiver in front of bursty errors.
- Physical layer signalling insertion function
  - This function inserts the burst descriptor indicating the MODCOD used for the rest of the burst. This field is encoded with a specific Block code.
- Physical layer framing(preamble and pilot symbols insertion) function
  - This function inserts the preamble to aid the burst detection and synchronisation / equalisation processes.
  - In addition, pilot symbols are inserted periodically into the payload to estimate the channel variability and to aid the data recovery.
- Physical layer scrambling function
  - this function applies a complex scrambling sequence to the symbols to be transmitted.
- Shaping and quadrature modulation function
  - This function conforms the baseband pulse to be transmitted using the Square Root Raised Cosine (SRRC).

Note that the description of the previous functional blocks corresponds to an FLC modulated at 160 kbaud. The same description is applicable to an FLC modulated at 16 kbaud, with the following exceptions:

- FCH bursts transmitted through an FLC at 16 kbaud are composed of only 1 DW. This means that the symbol interleaver block only interleaves 1 CW.
- ACM is not supported. This means that:
  - All the FCH bursts are encoded and modulated with QPSK 1/4.
  - It is not necessary to signal the MODCOD (no need of Physical Layer Signalling Insertion function).

– Preamble and pilot symbols distribution are different.

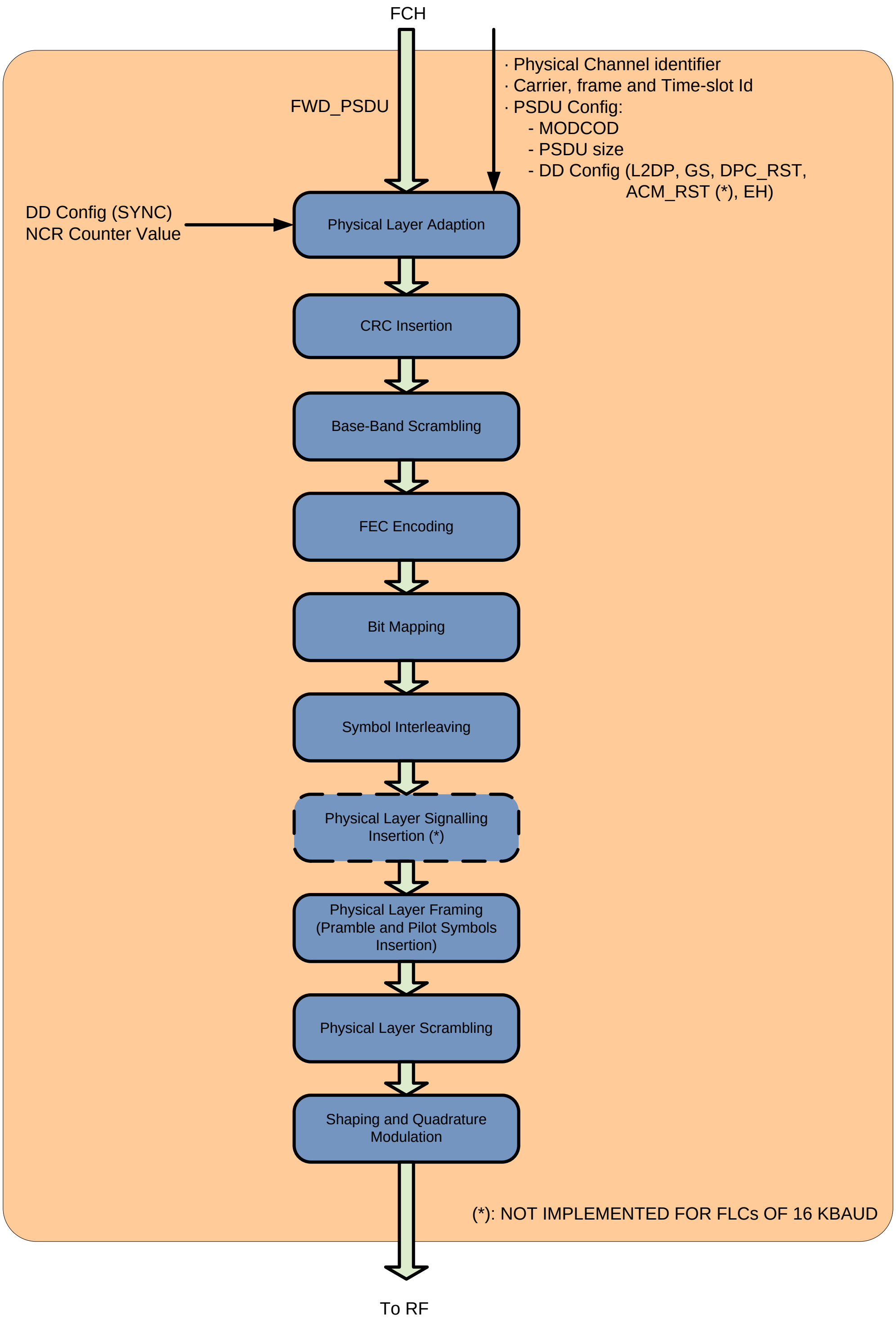

Figure 8-1: Physical layer functional block diagram – Forward link TX function (applicable to FLCs modulated at 160 and 16 kbaud)

It is noted that on the FWD link all the parameters required to generate the FCH burst (preamble size and contents, pilot symbols, complex scrambling, etc.) are fixed by the Communication

Standard (no dynamic configuration). The parameters configured from burst to burst (e.g., MODCOD) are regarded as inputs and are linked to a specific FWD_PSDU.

8.1.3.1.2 Rx function description

Most of the RX functionalities are the same as the ones described in the Tx function but are for the Rx chain. However, the RX function includes some additional functions, such as:

- Burst detector and physical synchronisation/equalisation
    - They are responsible for the correct reception of incoming bursts (detection and synchronisation/equalisation).
    - Equalisation compensates for aeronautical channel multipath effects. The equalisation mechanisms can take advantage of the preamble and pilot symbols inserted in the payload at regular intervals (known symbols).
- SNIR measurement:
    - it performs the SNIR estimation based on the received symbols.
    - SNIR measurements are used by GS elements to implement power control (in case that ATM links are used for forward link network synchronisation).

It is worth noting that the FEC Decoding outputs the Parity Check Status for each DW at $N_{reduced}$ LDPC decoder iterations. This status information is used by the ACM function.

The functional block diagram of the RX FWD link is shown in the following figure. This diagram corresponds to the reception of a FLC modulated at 160 kbaud. For FLC at 16 kbaud, some functions and outputs are not needed (see functions/outputs marked with (*) in the figure).

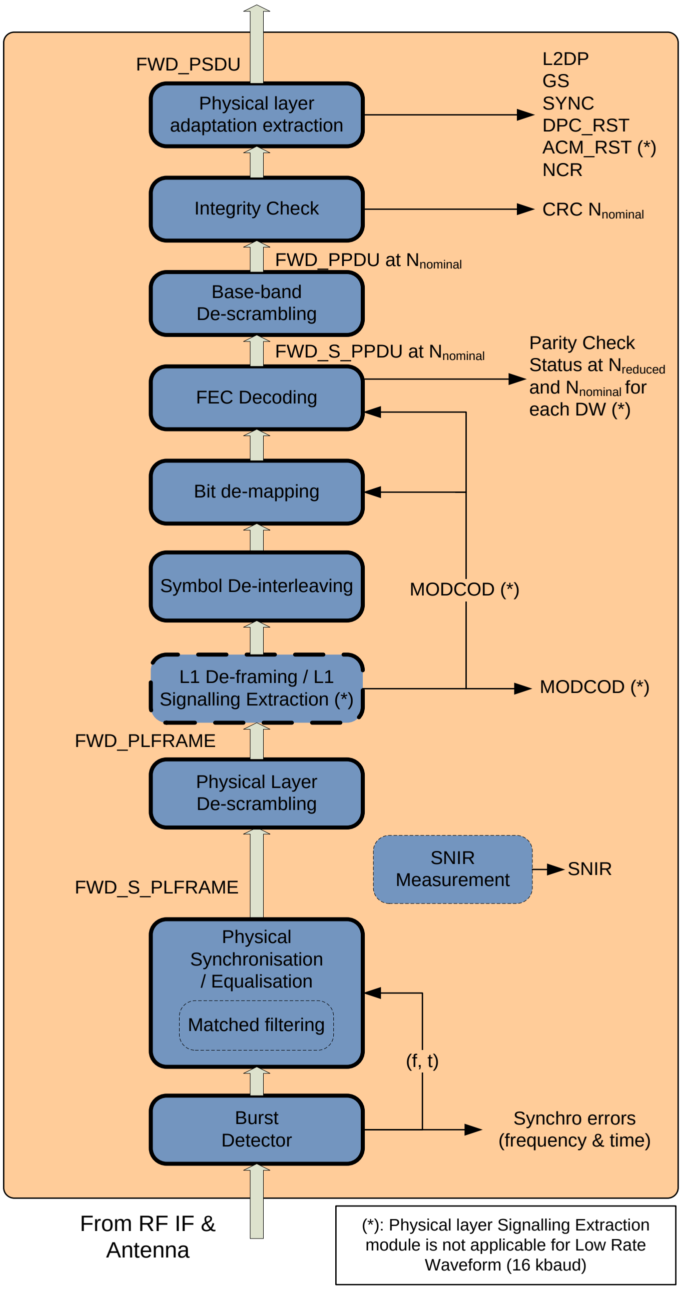

Figure 8-2: Physical layer functional block diagram – Forward link RX function

8.1.3.2 Return link

8.1.3.2.1 Tx function description

The Physical layer Tx function is composed of the following functional blocks:

- Physical layer adaptation insertion function
    - This block provides the interface with the MAC/LLC layer. It receives the PSDU (RTN_PSDU) from the MAC/LLC layer and inserts the Data Descriptor Header (RTN_DD) based on the control information provided by the MAC/LLC (L2

Protocol). Each PSDU is mapped into one single burst. The Data Descriptor header for the return link is presented in section 6.1.2.

- CRC insertion function
    - The CRC block inserts 32 parity bits into the data block composed by the RTN_PSDU and the Data Descriptor (RTN_DD) for error detection and integrity verification. The resulting data block is called RTN_PPDU.
- Base-band scrambling function
    - The aim of base-band scrambling is to randomise the incoming bits with the intention of removing long streams without transitions. Base-band scrambling can be seen as an algorithm for energy dispersal. Base-band scrambling is applied to the RTN_PPDU and generates the RTN_BBFRAME.
- FEC encoding function
    - The channel coding adds redundancy bits with the main objective of providing protection to the bits transferred through the satellite channel. The RTN_BBFRAME is encoded according to the code rate provided by the PDSU configuration information (L2 control information). On the return link, the coding family is 16-states binary TCC, supporting 1/3 code rate.
    - The encoder output is interleaved to break the error sequence introduced by the propagation channel, especially due to the fades. The output of the interleaver is called RTN_FECFRAME.
- Auxiliary channel generation
    - This module generates the pilot bits sequence (RTN_AUXFRAME) to be used in the Auxiliary Channel.
- Bit mapping function
    - This function maps coded bits (RTN_FECFRAME) into BPSK constellation points obtaining the I-Branch component (RTN_DCH).
    - The same function is applied to the pilot bits (RTN_AUXFRAME) of the Auxiliary Channel to map them into BPSK constellation points obtaining the Q-Branch component (RTN_ACH).
- Spreading (channelisation and scrambling) function
    - This block is responsible for implementing the spreading functionality, including both channelisation and complex scrambling, on the I and Q Branches. The output is RTN_SPR_XFRAME.
- Preamble generation function
    - This module generates a complex symbol preamble sequence (RTN_PREAMBLE).
- Preamble spreading function

- This block is responsible for implementing the spreading functionality on the preamble symbol sequence (RTN_PREAMBLE), including channelisation based on quaternary codes. The output is RTN_SPR_PREAMBLE.

– Physical layer framing function

- This function inserts the preamble (RTN_SPR_PREAMBLE) to aid the burst detection and synchronisation processes.

– Shaping and quadrature modulation function

- This function conforms the baseband pulse to be transmitted using the Square Root Raised Cosine (SRRC).

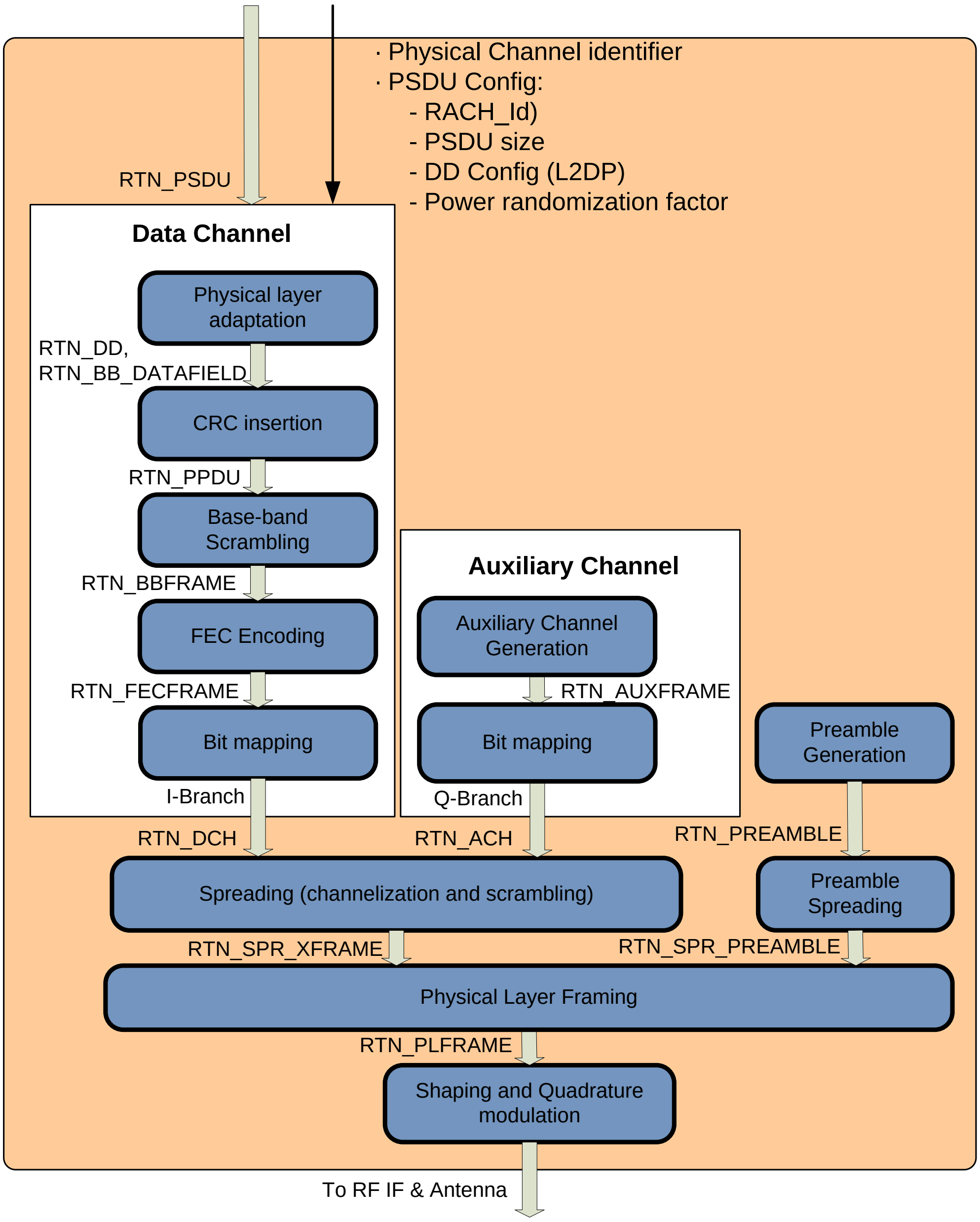

Figure 8-3: Physical layer functional block diagram – Return link TX function

It is worth noting that some relevant parameters for the RACH_Id configuration are distributed through system tables. For each RACH_Id, the following parameters are distributed:

- 1 OVSF code for the Data Channel
- 1 OVSF code for the Auxiliary channel
- Up to 8 pairs of:
    - Preamble sequence index
    - Complex Scrambling sequence index

8.1.3.2.2 Rx function description

Most of the Rx functionalities are the same as the ones described in the Tx function but for the Rx chain. However, the Rx function includes some additional functions such as:

- Burst detector and physical synchronisation
    - They are responsible for the correct reception of incoming bursts (detection and synchronisation).
- Channel estimation and compensation
    - This function performs the propagation channel estimation in order to compensate the multipath effects. Propagation channel estimation takes advantage of the preamble and the pilot symbols composing the Auxiliary Channel.
    - Compensation is then implemented on the Data Channel.
- SNIR measurement
    - It performs the SNIR estimation based on the received symbols.
    - Note: The SNIR measurements are only used for monitoring purposes.
- Noise Rise Estimator
    - It estimates the noise rise, i.e., increment in the noise floor caused by the return link multiple access interference, to assist the RRM control function in implementing return link congestion control.

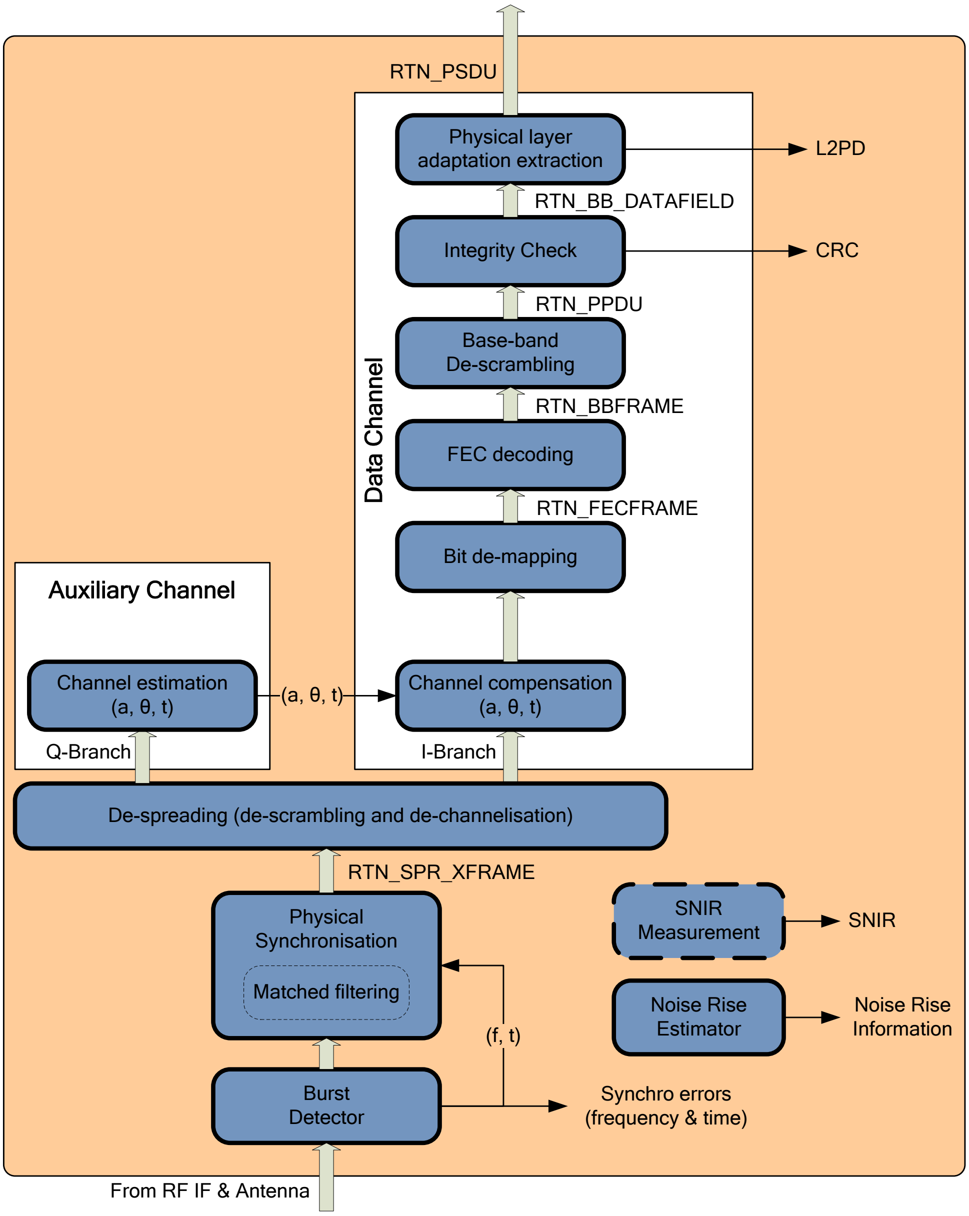

Figure 8-4: Physical layer functional block diagram – Return link RX function

The previous block diagram corresponds to a regular SSA receiver. However, it is still applicable to an E-SSA receiver in which an iterative IC process is implemented. Refer to [RD-02] for a detailed description of an E-SSA receiver (Successive Interference Canceller).

8.2 MAC/LLC function

8.2.1 Key functions and design concepts

The main functions provided by the MAC/LLC module are as follows:

– Encapsulation functions. Fragmentation/reassembly of the variable-length higher-layer LSDUs into/from PSDU units with a variable payload size, allowing the multiplexing/de-multiplexing of LSDUs associated with different logical channels (possibly associated with different UTs) over a single data stream.

- Error correction functions (ARQ), based on retransmissions of lost or corrupted data.
- MAC functions, such as mapping to physical channels, data buffering/queuing, and scheduling/priority handling between flows as required. This also includes functions specific to the random access functionality in the RTN link.

Following is a brief review of main design concepts supported by the CS for each of these functions.

- Encapsulation functions.
  - The CS specifies customized versions of the state-of-the-art encapsulation scheme used in the DVB framework (GSE [RD-04]). The proposed schemes provide efficient encapsulation of LSDU packets over variable-length PSDU frames and allow non-preemptive multiplexing of different flows over the same physical channel.
  - The aim of the customizations has been to reduce overheads and provide the flexibility required by the CS. They have consisted mainly of:
    - An addressing scheme that is more adapted to CS requirements and addressing plan.
    - Integration of ARQ headers with the encapsulation header. ARQ fields (those necessary for ARQ not already included in the standard encapsulation header) can be set on a per-LSDU basis and are signalled within the encapsulation header.
- Error correction functions.

  ARQ is applied at LSDU level, meaning that it ensures the correct reception of re-assembled LSDUs for each managed flow. As indicated above, there is a tight integration between encapsulation and ARQ functions. ARQ allows a correct re-assembly of received (variable-size) LSDU fragments or LPDUs by providing them in order and without gaps, and encapsulation headers carry information required for ARQ procedures.

  Error correction function design has been harmonized for both FWD and RTN link. These are the main features of the ARQ scheme:

  - The ARQ scheme is based on positive ACKs (no use of NACKs).
  - Retransmissions are because of retransmission timer expiration at transmitter end.
  - The ARQ scheme is based on a cumulative approach: The receiver only generates (positive) ACKs to a subset of the received LSDU fragments. The reception of an ACK associated with the fragment '*n*' automatically validates it and all previous fragments. This reduces the number of ACKs required in the RL.
  - The provision of ARQ support is signalled in the encapsulation header.
  - The need to send back an ACK for a given LPDU is signalled in the encapsulation header ARQ field P/F (Poll/Final) bit in case of multi-fragment LSDUs. In the case of single-fragment LSDUs, the receiver always generates an ACK.
  - The provision of ARQ support is associated with flow ID and signalled by the system.

- MAC functions.
  - The scheduling function has to ensure that QoS requirements associated with the flows are met, while complying with constraints imposed by the physical layer (MODCOD restrictions) or the access method (congestion control rules).
  - In the forward link, the functional model assumes a tight integration between MAC and ARQ/encapsulation functions (in line with GSE philosophy), meaning that LSDUs are not encapsulated when received by the MAC/LLC module from higher layers (as done, for example, if ATM/AAL encapsulation schemes are used), but when they are scheduled for transmission on a specific PSDU. This allows a higher scheduling flexibility and efficiency while ensuring adaptation to (variable) payload sizes resulting from the support of ACM.
    - The size of the LPDUs associated with LSDUs requiring ARQ support is determined by the payload size of the most robust MODCOD. This ensures that the LPDU fits into the PSDU even in case the ACM loop downgrades the MODCOD (e.g., to the most robust one) between the transmission and the re-transmission of the LPDU. This limitation on the size of the LPDUs is not applicable to LPDUs of LSDU not requiring ARQ support.
  - Over the RTN link, access is based on asynchronous spread ALOHA with SIC to mitigate the effects of the MAI (Multiple Access Interference). The scheme is based on a Congestion Control mechanism and EDF scheduler that is used for the provision of traffic QoS. The designed Congestion Control mechanism preserves the order in which the LPDUs of a LSDU are transmitted.
    - The UT provides a power randomization mechanism to enhance the power imbalance at the input of the SIC.

8.2.2 Interfaces to other functions

8.2.2.1 Interfaces to upper layer

The MAC/LLC functional block provides its services to:

- Network layer adaptation function. It is part of the user plane and requests logical traffic channels (BTCH, UTCH).
- Miscellaneous control functions which are part of the control plane. They request logical signalling channels (BCCH, UCCH) and also obtain control information associated with certain logical channels (measurements done by the physical layer functions).

For MAC/LLC transmission services, these functions provide the following input:

- An LSDU
- Its associated logical channel identifier, with attributes as defined in section 6.1.1.2.

For MAC/LLC reception services, these functions receive the following output:

- An LSDU
- Additional control information associated with the delivered LSDU, that allows selecting the appropriate destination functional block:

- LSDU type
- L2 address information (origin / destination)

8.2.2.2 Interfaces to lower layers

The MAC/LLC functional block interfaces with:

- Physical layer TX function.
- Physical layer RX function.

To the physical layer TX function, it provides the following inputs:

- A PSDU
- Additional control information associated with the delivered PSDU unit
  - Physical channel type (RACH / FCH)
  - Carrier, frame and time-slot identifier (FWD link)
  - PSDU configuration:
    - FCH bursts (FWD link):
      - MODCOD identifier (FWD link)
      - PSDU size for padding insertion
      - Data Descriptor configuration: L2DP (encapsulation protocol Id, GS flag, DPC_RST flag, ACM_RST flag, EH flag)
    - RACH burst (RTN link)
      - RACH_Id
      - PSDU size for padding insertion
      - Data descriptor configuration: L2DP (encapsulation protocol Id)
      - Power randomization factor

From the physical layer RX function, it receives the following outputs:

- A PSDU
- Additional control information associated with the delivered PSDU
  - FWD link
    - Error detection information (CRC)
    - MODCOD identifier (FWD)
    - PSDU size (after padding removal)
    - Data descriptor flags: L2DP, GS, ACM_RST
    - Parity check status at $N_{reduced}$ and $N_{nominal}$ LDPC decoder iterations
  - RTN Link:
    - Error detection information (CRC)

- PSDU size (after padding removal)
- Data Descriptor flags: L2DP

8.2.2.3 Interfaces with control plane functions

MAC/LLC interacts with the following functional blocks, which are part of the control plane:

- RRM control function
  - This module receives monitoring information about LSDUs processed by the MAC/LLC function, in order to trigger adequate RRM control functions (setting of congestion control parameters, etc.).
  - It provides the configuration and input parameters required by the scheduling and priority management and MAC functions within the MAC/LLC module (random access congestion control parameters, etc.).
  - Refer to section 8.9 for more details.
- ACM control function
  - For the GS, this function provides information about the MODCOD to be used by a UT over the forward link. This information is required by the FWD scheduling process.
  - In the UT, the MAC/LLC function provides control information associated with the received FCH bursts, regarding used MODCOD and reception performance (Parity Check Status at $N_{reduced}$ and $N_{nominal}$ LDPC decoder iterations).
  - Refer to section 8.8.2.1 for more details.
- Multicast control function
  - This module specifies which link layer multicast addresses are accepted by the filter functionality included in the MAC/LLC RX chain (only UT).
  - It also indicates on which physical channels (FLCs) a multicast flow has to be transmitted (only GS).
- Logon / HO control function
  - Tracking of unicast addresses of interest for a specific UT or GS element is done by the logon / HO control function, which establishes associations between UT and GS elements.This module specifies which link layer unicast addresses are accepted by the filter functionality included in the MAC/LLC RX chain.
  - This function also provides general data session information for a specific UT (currently assigned FLC, currently assigned RTN link frequency bands, UT identifier, etc.).

8.2.3 Description

The figure below shows the general functional blocks which are part of the MAC/LLC functionality, and their relationship to each other. It should be noted that the purpose of this diagram is to clarify the different functions, not to suggest a specific implementation.

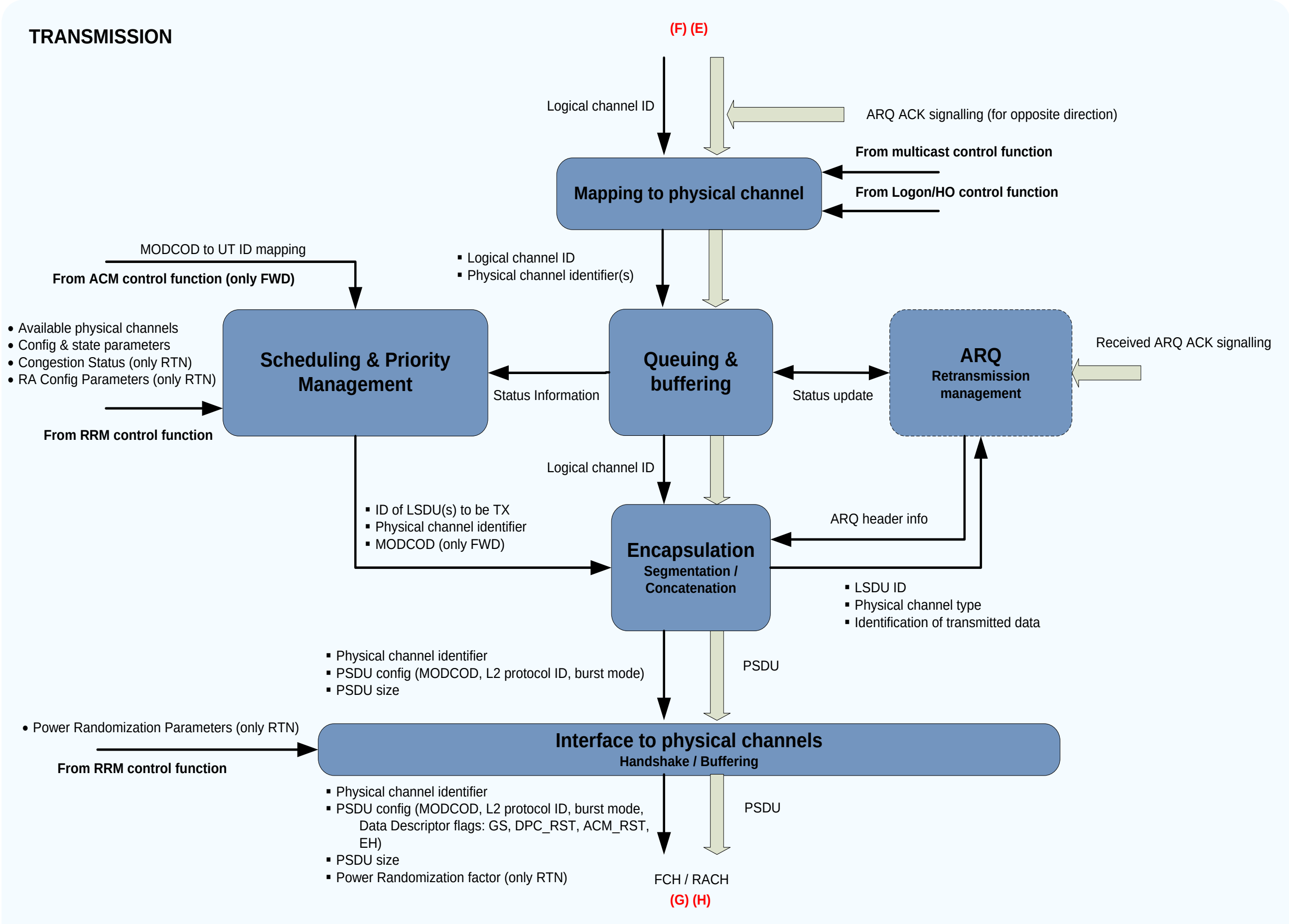

Figure 8-5: TX MAC/LLC function

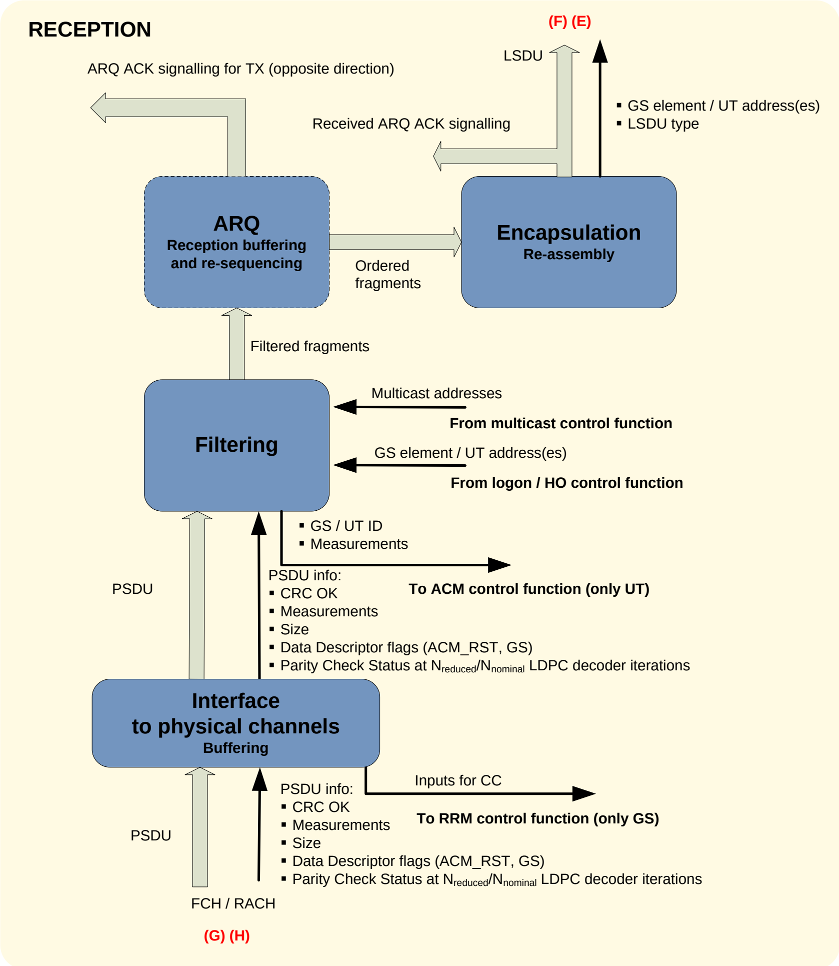

Figure 8-6: RX MAC/LLC functions

The following detailed functions are supported:

- Encapsulation (encapsulation / re-assembly) and filtering functions
  - Segmentation/re-assembly. This function performs the segmentation/reassembly of the variable-length higher-layer LSDUs into/from PSDU units with a variable payload size (according to the physical channel type, the supported MODCOD and the size of the LPDU(s) to transmit).
  - Re-sequencing and detection of duplicated ARQ of received LPDUs.
  - Concatenation. Several fragments of a LSDU may share the same PSDU.
  - Multiplexing/de-multiplexing of the different LSDU types and flows associated with different logical channels.
  - L2 addressing, i.e., identification of UT & GS elements.
  - Filtering of PSDUs according to L2 addresses included in the encapsulation headers. This function discards PSDUs or PSDU fragments that are of no interest to the receiving element.

- ARQ functions
  - ARQ ensures that encapsulated PSDUs for a given LSDU are delivered to the re-assembly function complete, in order, without duplicates, and error-free (unless an undetected error has occurred). For this purpose, it generates and processes specific ARQ related signalling (ARQ ACK signalling).
- RRM / MAC functions
  - Buffering/queuing. This function stores the generated LSDUs fragments for the different flows and will keep them until they have been successfully received at the other side of the communication, or until their expiration time has been reached.
  - Scheduling and priority handling between flows. It specifies the order in which the buffered LSDUs or LSDU fragments of the different logical channels will be transmitted and/or retransmitted in order to ensure the quality of service requirements of the logical channel and a proper sharing of common radio link resources.
  - Mapping to and configuration of physical channels. This function decides which physical channel type (RTN link RA channel band or FWD link carrier and slot identifier) is used for transmission of a specific PSDU and required burst configuration in terms of MODCOD (FWD) or burst mode (RTN). It uses information provided by the logon/handover and multicast control functions.
  - Random access related functions (only for RTN link).
    - Support overall RTN link congestion control by applying restrictions on burst scheduling. These restrictions are derived following a specific congestion control algorithm, common to all UTs, that delays medium access according to channel status and puts limits to the burst transmission rate per UT. This function differentiates between different types of traffic.
  - MAC/LLC monitoring. This function provides monitoring information (amount of information waiting for transmission, etc.) if required by the RRM control function.
- Interfacing with physical channels
  - Information exchange with L1 TX/RX functions, regarding PSDU configuration (MODCOD selection, L2 protocol identification field, burst mode identifier, PSDU size) and characteristics of received PSDUs (error detection information, associated measurements).
  - In the RTN, computation of the power randomization factor derived from the selected physical channel and the power randomization parameters distributed by the GS.

8.2.4 Transmission sequence

To illustrate the MAC/LLC functions, a representative TX sequence is described in this section considering a UTCH logical traffic channel, with attributes as indicated in the table below. This example will focus on the TX functions within the UT.

It should be noted that variations in the presented sequence, driven by implementation preferences, may also be compatible with the CS.

Attribute	Value
L2 src / dst address	UT / GES_2
Packet type	ATN_IPS
Flow ID	2
Flow parameters	ARQ
QoS parameters	TD95 = 2.4 s ET = 7.8 s Cont = 0.9998
Priority	ATC
Stream ID	Beam 3

Table 8-2: Sample UTCH channel attributes

It is also assumed that the RRM control function has indicated to the MAC/LLC function that packets associated with flow ID #2 have to use a specific set of congestion control parameters (back_off time, persistency value), a certain physical layer channel (band XYZ) and a specific burst mode.

8.2.4.1 Description of a representative UT TX sequence

1. An incoming LSDU (LSDU_1) is queued, waiting for transmission. Let us assume that this LSDU requires the generation of 3 LPDUs that are grouped in a single ARQ block, so only the last LPDU shall be acknowledged by the receiver.
2. Applying the Congestion Control mechanism, a medium access delay is computed based on persistency and back-off delays parameters that are applicable to the current system load status.
3. Upon expiration of the medium access delay, all 3 LPDUs grant access to the medium and are forwarded to the scheduler that inserts them into the L1 queue.
4. In the meantime, a new LSDU (LSDU_2) arrives to the UT. Let us assume that this LSDU requires the generation of 1 LPDU. The UT applies the Congestion Control procedure and eventually delivers it to the scheduler. At the time the new LPDU is forwarded to the scheduler, only the first LPDU of LSDU_1 has been transmitted.
5. Let us assume that LSDU_2 has more demanding QoS constraints (less TD95 or ET margin). The scheduler identifies it, and schedules the transmission of the new LPDU before the not yet LSDU_1 transmitted LPDUs.
6. Eventually, the ARQ retransmission management function detects that one or more of the LPDUs associated with LSDU_1 have been lost because the acknowledgement associated with the ARQ block has not been received within the expected time. In

response, the UT applies the Congestion Control procedure to the whole ARQ block, all three LPDUs, and re-schedules them for transmission.

After all bursts have been acknowledged, the queuing/buffering function is instructed to delete all LSDU_1 fragments.

For every scheduled PSDU, the UT computes the random power factor that shall be applied by the physical layer at the moment of its transmission. Hence, the UT transmits at max power (*EIRP_dB*) plus a random power factor (which is obviously a negative contribution).

8.3 Network layer adaptation function

The network layer adaptation functionalityprovides functions that are needed to properly adapt the network layer to the generic (i.e., network layer agnostic) CS link layer functions. It requires interpretation/knowledge of the network layer of the data unit to be transmitted (interpretation of headers, etc.).

It supports two different ATN protocol stacks: ATN/IPS and ATN/OSI.

8.3.1 ATN/IPS

8.3.1.1 Key functions and design concepts

Key functions are listed hereafter:

- Classification of network layer data flows into a common set of logical channels used by the MAC/LLC function. This function supports setting associated logical channel attributes, including CoS parameters.
- Network layer header compression. IPv6 header overhead may be reduced overthe satellite link by applying a header compression protocol.
- Support to network mobility, by triggering network layer address configuration as soon as an L2 handover is detected. This function is only supported by the GS.

The main design concepts for each function listed are the following:

- Network layer header compression.
  - The overhead introduced by IPv6 headers (especially critical in MIPv6, as it implies an IPv6oIPv6 tunnel) can be reduced by supporting the Robust Header Compression framework (RFC5795, RFC3095). ROHC is characterized by:
    - Good header compression efficiency
    - Support of mechanisms to mitigate damage propagation (i.e., increase of NPDU residual error rate due to compression context damage)
    - Support of mechanisms to mitigate loss propagation (i.e., increase of NPDU loss rate due to compression context damage)
    - Minimal signalling overheads
  - The following compression profiles are supported:
    - IP-Only ROHC profile specified in RFC 3843
    - UDP profile specified in RFC 3095
    - TCP/IP profile, specified in RFC 4996
    - RTP/UDP/ESP profile specified in RFC 3095
- Classification of network layer data flows into logical channels (with their associated QoS) is based on network layer header fields.
- IPv6 address configuration required after a UT changes its network attachment point is accelerated by triggering the sending of a Router Advertisement message (with contents defined in RFC4861) just after L2 handover. This function is only supported by the GS.

8.3.1.2 Interfaces to other functions

8.3.1.2.1 Interfaces to upper layers

The network layer adaptation function interfaces the network layer function, for both user and control planes.

For this block, the network adaptation layer function provides and receives uncompressed IPv6 packets. Additionally, the network layer provides the destination UT/GES satellite MAC address 2 of the NPDU to be transmitted over the satellite link and the network adaptation layer provides the source UT/GES satellite MAC address of an NPDU received over the satellite link.

The network adaptation layer in the GS also interfaces the network layer in order to trigger the sending of a Router Advertisement message (with format as defined in RFC4861) just after an L2 handover which implies a change in the network attachment point of an UT.

8.3.1.2.2 Interfaces to lower layers

Please refer to section 8.2.2.1.

8.3.1.2.3 Interfaces with control plane functions (only GS)

The network layer adaptation function in the GS interacts with the following control function:

- Logon/HO control function:
  - The logon/HO control function indicates when a handover operation has been successfully completed at L2, so that required network layer procedures (CoA address update at the aircraft) are triggered as soon as possible.

8.3.1.3 Description

This section presents the general functional blocks which are part of the network layer adaptation functionality both for transmission (refer to Figure 8-7) and for reception (refer to Figure 8-8).

One instance of the indicated functions is required per system element, with the exception of the IPv6 header compression/decompression functions, which require several instances:

- One compressor/decompressor pair per each unicast logical channel (UTCH), both in the UT and the GS element.
- For a GS element, one compressor for each broadcast/multicast logical channel (BTCH). In the UT, there is one decompressor per received channel.

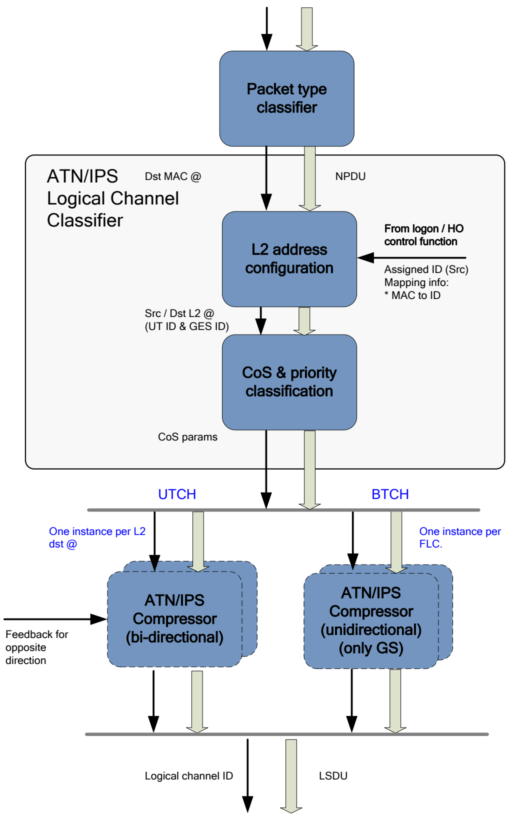

Figure 8-7: Network layer adaptation functions (TX)

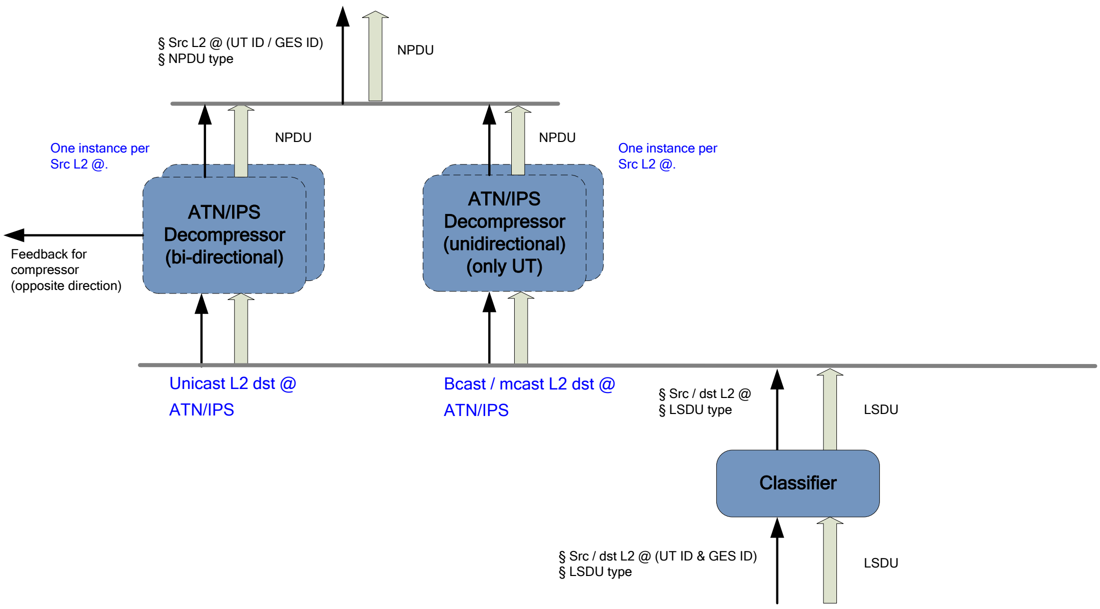

Figure 8-8: Network layer adaptation function (RX)

Each function is described in more depth hereafter:

- Packet type classification function. This module sets the packet type attribute of the logical channel, by identifying the applicable protocol stack (ATN/IPS or ATN/OSI). It is common to the ATN/IPS and ATN/OSI adaptation functions.
- Logical channel definition. This function identifies the logical channel to be associated with the data to be transmitted and defines its logical channel attributes per NPDU. Different functional instances are required depending on the protocol stack. It includes the following sub-functions:
  - Setting of L2 addresses.
    - This function sets the L2 addresses (UT ID / GES ID) that are required by the MAC/LLC module.
    - The destination satellite MAC address is provided by the network layer[2], while the origin satellite MAC address is fixed. There is a direct mapping between the satellite MAC address and the L2 address (UT ID, GES ID), established at logon/handover.
  - CoS and QoS parameters identification function.
    - Fields in the NPDU headers shall allow deriving the logical channel CoS and its associated configured QoS parameters (application type, application length in bytes, ARQ need (continuity), L2 CRC need (integrity), ET and TD95) that are a basic input for MAC/LLC and RRM control functions.
    - For ATN/IPS network layer packets, candidates for these fields are:
      - Traffic Class or Differentiated Services header field (1 byte), part of the IPv6 header. The six most significant bits of this field correspond to the Differentiated Services Code Point (DSCP), which allow specifying up to 64 different mappings.
      - A combination of IPv6 address / TCP / UDP header fields such as transport protocol type and port numbers.
      - Other mechanisms, e.g., deep packet inspection. This could be required in order to identify the specific application that the NPDU belongs to.

[2]Alternatively, in the GS, the network layer could provide also directly the UT L2 address instead of one of the valid satellite MAC addresses associated with the UT. This document illustrates just one possible interface.

    - The exact mapping between header fields and continuity/ET/TD95 parameters is a system aspect not included in the CS specifications, but it is key information to be updated and exchanged between systems to ensure adequate interoperability, using network management procedures. It should be in line with the end-to-end QoS concept applicable to all ATM communication networks (both radio and terrestrial networks) and it should be defined by the authority responsible for these more high-level design aspects (possibly SESAR or a work group within ICAO).
    - In case the QoS parameters of an incoming NPDU are not identified, it is treated on a best-effort basis, which is the lowest priority.

- ATN/IPS header compression/decompression function. Support of this functionality by the UTs and the GS is mandatory.
  - The compressor may be bi-directional or unidirectional.
    - If bi-directional, LSDUs carried in one direction may include feedback control information for the compressor in the opposite direction, as part of the header added by the compression protocol (refer to RFC 3095).
    - If unidirectional (broadcast or multicast data), the compressor works in a specific mode that does not require a feedback channel (U-mode).
  - The CS defines a set of fixed configuration parameters associated with the use of the header compression protocol (mainly related to context identifier length and format) and allows negotiation of others (e.g., the supported header compression profiles). In any case, it only specifies configuration of those parameters that are needed to ensure end-to-end compatibility between compressor and decompressor.

8.3.2 ATN/OSI

8.3.2.1 Key functions and design concepts

For ATN/OSI, the CS network adaptation layer function encompasses also all subnetwork dependent network layer functions (SNDCF and SNAcP functions), which are considered part of the network layer according to OSI terminology (intra-network sublayer).

Key functions of the network adaptation layer are listed hereafter:

- Classification of network layer data flows into a common set of logical channels used by the MAC/LLC function. This function includes setting associated logical channel attributes, including CoS parameters.
- Network layer header compression. ATN/OSI header overhead may be reduced for the satellite link by applying a header compression method.
- ATN/OSI support for mobility. By interfacing the logon/HO control function and based on logon/HO events at link layer, this function generates ATN/OSI control messages (join and leave events) processed by the network layer (or inter-network sublayer in OSI terminology).

- ATN/OSI support for redundancy. The CS supports a specific broadcast signalling message to allow an efficient reset of all active 8208 virtual circuits associated with a failed GSE.

Some functionality is provided for legacy reasons:

- Establishment of virtual circuits between subnetwork elements (i.e., elements internal to the satellite network), using a connection-oriented protocol (v8208 call set-up & clearing).
    - It should be noted that this functionality is actually not necessary considering the simple topology of the satellite system.

The main design concepts for this layer are the following:

- At the aircraft end, all NTW layer adaptation functions are traditionally implemented within the airborne router (or AR) (DTE), with the UT just acting as a modem (DCE). Thus the CS supports the same set of NTW layer adaptation protocols over the air/ground link as current VDL Mode 2 and AMSS networks, in order to ensure compatibility with legacy ATN/OSI Avionics and minimise required modifications to the AR:
    - SNDCF: Mobile SNDCF, as defined by ATN ICS SARPS [RD-06].
    - SNAcP: v8208 (ISO/IEC 8208 adaptation used with VDL2) [RD-07].
- Network layer header compression.
    - Header compression is performed as specified by the Mobile SNDCF (based on LREF method). Negotiation of header compression support and parameters is included in this specification.
- Only one class of service is supported, as in currently deployed VDL2 networks.
- ATN/OSI support for mobility.
    - Mobility related JOIN (notification of the establishment of a new satellite link) and LEAVE (notification of the release of a satellite link) events are provided to a systems management entity (IS-SME) within the network layer of the aircraft. They include information on available next-hop AGR 8208 address(es) and trigger a route initiation procedure.
- ATN/OSI support for redundancy.
    - In order to avoid signalling peaks over the satellite link, a specific broadcast signalling message is supported by the CS (OSI RESET) that instructs the UTs to locally reset the 8208 virtual circuits associated with a certain GSE. This is useful in case of switch-over to a redundant GSE (and AGR).
    - The UT can reset the 8208 virtual circuit locally by generating a (standard) 8208 RESET INDICATION message towards the AR and suppressing the associated acknowledgement.
    - This signalling message is transmitted several times, in order to ensure that all UTs have received it.

8.3.2.2 *Interfaces to other functions*

8.3.2.2.1 *Interfaces to upper layers*

The network layer adaptation function interfaces the network layer function, for both user and control planes.

For the user plane, the network adaptation layer function provides and receives uncompressed CLNP packets.

For the control plane, the network layer adaptation function receives the MAC destination address (or any equivalent link identifier) with each data unit to be transmitted and provides the MAC source address (or any equivalent link identifier) for each received unit.

Additionally, the network adaptation layer generates the following events, including the following information:

- JOIN event
  - Link identifier
  - AGR8208 address(es) and associated CSP
- LEAVE event
  - Link identifier

These messages are triggered upon:

- UT logon (JOIN)
- UT logoff (LEAVE)
- UT handovers which imply a change of network attachment point (change of AGR) (JOIN/LEAVE)

8.3.2.2.2 *Interfaces to lower layers*

Please refer to section 8.2.2.1.

8.3.2.2.3 *Interfaces with control plane functions*

The network layer adaptation function interacts with the logon/handover control function, in order to generate the JOIN/LEAVE events indicated above.

It may also interface redundancy control functionality (not part of the CS functional tree).

8.3.2.3 *Description*

For ATN/OSI, the CS network layer adaptation function includes the subnetwork dependent network layer functions, which are more detailed in the following:

- Sub-network Dependent Convergence Function (SNDCF).
  - A SNDCF provides certain defined subnetwork services required by the subnetwork independent network layer function. It thus represents an adaptation between subnetwork-specific functions and the generic primitives required basically by CLNP.

- ATN SARPS define a special purpose SNDCF, called the Mobile SNDCF, which is based on the SNDCF for ISO/IEC 8208, specified in ISO/IEC 8473-3, and includes the following functions:
    - Call setup/clearing (open, close and manage 8208 virtual circuits, indicating required parameters).
    - For each virtual circuit, negotiation and use of header compression procedures. Data compression is disabled by the CS.

  It is used by current VDL2 and AMSS subnetworks.

- Sub-network Access Protocol Function (SNAcP).
    - ISO 8208 (equivalent to IEEE X.25) is used as connection-oriented protocol immediately above the sub-network. It provides typical connection functionality, such as flow control and certain error detection capabilities, by means of virtual circuits.
    - ISO 8208 packets are numbered, so it can detect an out-of-sequence packet and attempt to recover a missing packet by performing a ”REJECT procedure.” The function is designed to detect and recover the odd missing packet, e.g., for negligible bit error rate situations.

Additionally, a CS specific function maps the v8208 packets generated by the SNAcP layer to the logical channels as handled by the CS link layer (refer to Figure 8-9).

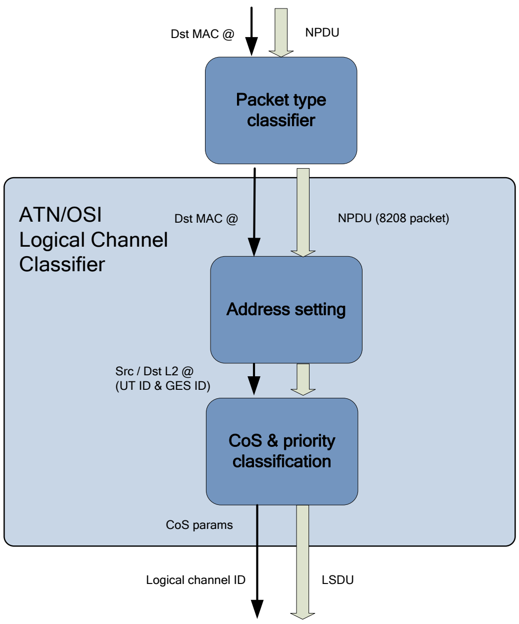

Figure 8-9: ATN/OSI logical channel classifier (TX)

This function is described in more depth hereafter:

- Packet type classification function. This module sets the packet type attribute of the logical channel, by identifying the applicable protocol stack (ATN/IPS or ATN/OSI).

- Logical channel definition. This function identifies the logical channel to be associated with the data to be transmitted and defines its logical channel attributes. It includes the following sub-functions:
  - Setting of L2 addresses.
    - This function sets the L2 addresses (UT ID / GES ID)that are required by the MAC/LLC module.
    - The destination satellite MAC addresses (or any equivalent identifier) are provided by the network layer, while the origin satellite MAC address is fixed. There is a direct mapping between the satellite MAC addresses and the L2 addresses (UT ID, GES ID), established at logon/handover.
  - CoS and priority classification function.
    - As baseline, a single priority (and thus a single virtual circuit) is foreseen, as this is the de-facto situation in legacy VDL2 networks. However, the CS allows support for multiple QoS classes, each one using a different virtual circuit (refer to [RD-02]).

8.4 Network layer function

8.4.1 ATN/IPS

8.4.1.1 Key functions and design concepts

The main functions provided by the ATN/IPS network layer function within the CS are the ones typically associated with the IP layer of the TCP/IP stack, also including address resolution. They are located in the GS and in the network layer elements on-board the aircraft (which may or may not be physically integrated with the UT) and are briefly listed hereafter:

- Routing. Network layer packets are forwarded through the most adequate interface. For this purpose, this function may interact with other routers. This function supports also multicast routing functionality (only at GS level).
- Dynamic network layer address configuration. This function is located in the GS and supports the network layer address configuration process of mobile nodes located in the aircraft. It supports also configuration of other network layer related parameters (e.g., MTU size) and performs duplicate address detection (DAD).
- Reporting of errors and informational conditions related to the network layer, and support of diagnostic functions. This functionality includes general control functions supported by ICMPv6 (RFC4443).
- Address resolution. This function supports setting the UT/GES MAC destination address, which is provided to the network adaptation layer together with the NPDU data unit.

The main design concepts are the following:

- The CS supports standard IPv6-based ATN/IPS protocols as specified by ICAO [RD-06]:
  - IPv6 (all functions)
  - ICMPv6 (address configuration/resolution, reporting and diagnostic functions)

- Satellite specific network layer parameters (MTUs, timers, etc.) are configured by using Router Advertisement messages (RFC4861) broadcasted by the GS.
- Address resolution:
    - The CS supports standard IPv6 address resolution mechanisms as described in RFC4861 (NS/NA messages). It should be noted that address resolution can also be performed without the need for additional signaling exchanges over the air interface (refer to [RD-02]).
    - The GS destination satelliteMAC address is provided to UTs by including a source-link layer address option in the Router Advertisement messages (RFC4861) sent by a GES.
    - In case of scenarios with multiple mobile nodes attached to the same UT (each one with a different link-layer interface), address resolution between these nodes (in the FWD link direction) shall be done locally by the UT (refer to [RD-02]).
- Recommended aircraft node IPv6 address configuration method is the stateless auto-configuration method, as it implies fewer satellite link message exchanges between the aircraft and the AGR compared to a stateful address configuration (e.g., using DHCPv6). However, the CS does not impose a specific configuration method.
- Duplicate address detection shall be performed at GS level, as NS/NA messages transmitted over the air interface are not necessarily received by all UTs.

Refer also to section 9.2, which illustrates the relationship between network layer functions supported by the CS and network layer mobility functions, based on MIPv6.

8.4.1.2 Interfaces to other functions

8.4.1.2.1 Interfaces to lower layers

Refer to section 8.3.1.2.1.

8.4.1.2.2 Interfaces with control functions

The network layer function within the CS interacts with the following functional blocks, which are part of the control plane:

– Interface to multicast control function:

- This functional module indicates which multicast groups the network layer function has to be registered to, so that they are finally forwarded to interested UTs.

8.4.1.3 Description

This section addresses only briefly address resolution, as other IPv6 functionality is already described extensively by standard IPv6 documents (RFCs) and ICAO ATN/IPS manual [RD-06].

The address resolution function is required to provide a mapping between the destination L3 addresses included in the NPDU and the link-layer addresses used in the satellite system. These link-layer addresses are the UT ID or GES ID used in the encapsulation headers and the satellite MAC addresses. The mapping between the satellite MAC address and the UT/GES ID is provided through logon/handover signalling, so implementations are free to use one address or the other in the address resolution functionality depending on their preferences, as long as the destination UT and GES entities are identified unequivocally.

In this document, the destination satellite MAC address is provided by the network layer to the network adaptation layer, but it would also be possible to provide the UT ID/GES ID directly.

Refer also to [RD-02] for additional address resolution clarifications.

8.4.2 ATN/OSI

8.4.2.1 Key functions and design concepts

The NTW layer function as defined by OSI is comprised of both subnetwork dependent and subnetwork independent sub-functions. This section addresses only the subnetwork independent sub-function, whereas the other functions are discussed in section 8.3.2.

The Subnetwork Independent Convergence Function (SICF) is equivalent to IP in IPS and provides the relaying of connectionless data units over multiple sub-networks selecting the best path. It compiles and maintains the routing data, apart from supporting network diagnostic functions.

In order to support mobility, specific local management procedures are required to manage changes in connectivity status and trigger routing procedures.

The main design concepts for this function are the following:

- The CS network layer conforms to ATN/OSI SARPS[RD-06] for air-ground (mobile) subnetworks and supports the following standard protocols:
    - CLNP (ISO/IEC 8473)
    - IDRP (ISO 10747)
    - ES-IS (ISO 9542)
- A JOIN event is received by the aircraft network layer upon UT logon and upon a UT handover implying a change in the network attachment point (change of AGR). This control message informs about the 8208 address of the next-hop router, so that a route initiation procedure can be initiated.
- LEAVE events are generated when a route towards the terrestrial network is closed (UT log-off or handover implying a change in the network attachment point).

8.4.2.2 Interfaces to other functions

8.4.2.2.1 Interface to lower layers

Refer to section 8.3.2.2.1.

8.4.2.3 Description

In ATN, the SICF is provided by the Connectionless Network Protocol or CLNP (ISO/IEC 8473), which is equivalent to the IP layer in ATN/IPS and provides the relaying of connectionless data units over multiple sub-networks selecting the best path.

CLNP supports the ISO global network addressing plan, quality of service specification, congestion control, and segmentation and reassembly of data packets. Additionally, provisions exist within CLNP for diagnostic actions such as end-to-end route recording and error reporting.

In addition, ATN/OSI employs a set of routing information protocols, which are required to compile and maintain the routing data that are needed by routers. The relevantprotocols from the CS point of view are:

- ES-IS (ISO 9542). This protocol is used between an end system and a router, to exchange L3 address data (in both directions). It is used to exchange the NET (Network Entity Title) or network address of the routers.
- IDRP (ISO 10747). The Inter-Domain Routing Protocol exchanges routing information between domains. It should be noted that in ATN/OSI the L3 address of the aircraft is always the same and that aircraft mobility is supported by the propagation of the new route by the AGR.

Once a link is established, the aircraft uses a combination of IDRP and the ISH PDU from the ES-IS (End-System to Intermediate System) protocol to exchange routing information between the AR and the AGR. The AGR then propagates routing information to the attached ATN/OSI ground/ground routers using IDRP.

In order to support mobility, specific local management procedures are required to manage changes in connectivity status, i.e., indicating availability of a new communication path (join event), and also loss of this availability (leave event) to the Intermediate System – Systems Management Entity (IS-SME) within the AR. These events also trigger air-initiated route initiation procedures, based on the establishment/release of 8208 virtual circuits and the exchange of routing information.

These functions are specified in detail in [RD-06], which adapts their functionality to the ATN.

8.5 System information function

The system, in order to allow the UT to operate and logon to the system, has to broadcast certain control information at regular intervals at least over one carrier in each beam of a certain system. This information, which is usually static (only changes from time to time, not from frame to frame), is organised and distributed in a table.

The logonsystem information table contains mainly:

- Administrative information (system identifiers, beam identifiers, SSP identifiers)
- RTN link access parameters (including congestion control information)

This information is typically mapped to a BCCH logical channel and transmitted using an FCH physical channel.

8.6 Log-on / HO control function

8.6.1 Key functions and design concepts

The main functions of the logon / handover control function are:

- To establish data and signalling sessions between a specific GS and a UT.

- To maintain in a seamless way data and signalling sessions when there is a change either in the GS element associated with a UT or in the system carriers/beams/satellites associated with this UT.

There are several scenarios in which the UT communication session needs to be transferred or handed over from one entity to another, which differ with respect to the level of required changes from satellite resources, the GS entities involved, and the associated complexity. The following table presents the all HO types. Additionally, bulk HO (a process which involves several UTs) shall be considered.

	GROUND SEGMENT							
	Same SSP						Different SSP	
	Same NCC				Different NCC		Different NCC	
	Same GES		Different GES		Different GES		Different GES	
SPACE SEGMENT	WAN/Collocated	No WAN	WAN	No WAN	WAN/Collocated	No WAN	WAN/Collocated	No WAN
Satellite Change								
Beam Change								
Channel Change								

Table 8-3: Handover scenarios

The HO types can be grouped in similar types, with unified resulting procedures that reduce the total number of cases. Four different procedures are defined:

- SSP handover and any other HO which involves a change of NCC elements will be executed accordingly to **SSP HO procedure.**
- **Direct LOGON HO** procedure will be used in case of an operation which is defined by taking the logon decision in the UT, as per manual HO request by aircraft (TBC).
- The rest of HO cases which do not change NCC element will be executed according to **GES HO procedure**.
- In case of single GES and L2 unified process implementation, **Fast HO** procedure can be used (simplification of GES HO procedure).
- All the cases can exploit the GS-WAN scenario (or if NCC/GES are collocated), to reduce the HO protocol not using some messages.

The key concepts in the design of logon/HO procedures are briefly reviewed:

- Logon and HO detection are supported by physical layer measurements at the UT, which support the decision process regarding the final GS element to be associated with the UT and the system carriers to be used.
- Logon can be performed without configuring any additional parametersin the UT, as long as the UT is able to detect the logon carrier (either by being configured with a list of possible logon carriers through local management or by scanning the CS frequency band for CS-compliant carriers).
- A Logon Table is broadcasted periodically over at least one FWD link carrier in a certain beam, including information on how to access the satellite system. The UT uses this information to access the system using a subset of RACH channel definition and mechanisms as the ones defined for traffic.

- Logon supports hybrid GS architectures, where the logon table is distributed by a single GSE in a SSP network, but the logon itself can be performed by the UT with different GSEs.
- Logon and HO decision regarding assigned GES and FWD/RTN link resources is handled by the GS.
- HO execution is based on a make-before-break approach, which requires that the UT is able to transmit in parallel (but never simultaneously) over the previous/new links and receive simultaneously through previous and new links, requiring the capability of reception of two FWD link carriers.
- Since the HO delay target currently taken as baseline (2/3 minutes[3]) is quite high, HO procedures will rely on emptying L2 buffers towards the previous GES, taking into account expiration times (ET) and TD95 values for all services (maximum are 57.6 s and 51.7 s respectively). Accelerating transmissions is an optional mechanism to accelerate the release of the old link.
- More complex procedures (based on re-routing data from the old connection to the new one) will not be used.
- From a signalling exchange point of view, the procedures follow the concept of HO orchestration by the UT. Required HO parameters and control messages are relayed by the UT to all GS elements involved in the HO execution process, so that there is no need for an additional communication medium between GS elements (e.g., a satellite or terrestrial-based WAN) in order to execute these procedures.
- HO decision is performed in the GS, even it may be triggered by UT detection algorithms based in measuring the signal of current beam vs. adjacent/neighbour beams. Nevertheless, there is one scenario in which the HO decision may be taken by the UT, triggered by APB or manually by air crew, resulting in a direct logon in the new SSP before notifying the current SSP.
- Both HO and logon/logoff procedures are generic to cope with different GS architectures (centralised/decentralised control/access to ATN networks), but allow some optimizations by means of optional messages that can be suppressed if not required.

8.6.2 Interfaces to other functions

8.6.2.1 Interface to MAC/LLC function

The logon/HO control functional block uses the services of the MAC/LLC function in order to establish logical signalling channels (UCCH) between the UT and the GS logon/HO control functions.

On the FWD link, it uses a logical signalling channel of type UCCH in order to forward the following signalling messages:

- Logon accept/Logoff request ground/Logoff accept

[3] Derived considering maximum aircraft speed and typical beam overlapping areas.

- HO command (to initiate HO execution and to provide HO configuration parameters)
- HO messages associated with multicast operations (join/leave)

This channel is mapped to a FCH physical channel.

On the RTN link, it uses a logical signalling channel of type UCCH, which is mapped to a RACH physical channel.

Exchanged signalling messages are:

- Logon request/Logoff request
- Logon accept ACK
- HO info request
- HO recommendation
- HO command
- HO validation &req
- Connection close
- HO finished
- For both FWD and RTN links, the respective ACK signalling messages.

The HO process in the UT shall use the capability to receive and process simultaneously a second FWD carrier for HO detection process and during the HO execution for reception of the new link while the first receiver is locked to the old link.

The HO function also interacts with MAC/LLC to check the status of the transmission buffer in order to release the old channel when the buffer is empty.

Additionally, the logon/HO control function provides to the MAC/LLC function:

- Unicast addresses of interest, for reception filtering.
- The physical resources assigned to a certain UT, both for the FWD and the RTN link

8.6.2.2 Interface with NTW layer adaptation function (only GS)

In case a handover implies a change in the network attachment point, the logon/handover control function informs the NTW layer adaptation function in the GS, so that the network layer update can be triggered as soon as possible.

8.6.2.3 Interface with other control plane functions

The logon/HO control function interacts with the following functional blocks, which are part of the control plane:

- RRM control function
  - For the GS HO decision, RRM shall provide input information to decide the target beam/channel for the HO.
- Network synchronisation control function

- For the bulk HO process, the GS shall be able to pre-synchronise to the new satellite before performing the satellite switch.

The logon/HO control function also provides UT session information (for example, the currently assigned UT ID or GES ID and the mapping towards the UT/GES satelliteMAC address) to any interested functional module.

8.6.2.4 Interface with management plane functions

Apart from extracting configuration parameters from the management plane, HO and logoff can be triggered for management purposes (e.g., flight crew decision, planned maintenance tasks).

8.6.2.5 Interface with external functions

Optionally, in the UT there may be an interface with an external aircraft location function (e.g., a GPS or an inertial reference system), which may support the decision of target in an HO with trajectory information.

In the GS, the bulk HO control process requires information concerning the overlapping period of incoming and outgoing satellites from SCC, in order to prepare the process and perform synchronisation during this overlapping period.

8.6.3 Description

In the figure below, functional modules associated with the logon/HO control function are presented, differentiating between blocks located in the UT and those located in the GS.

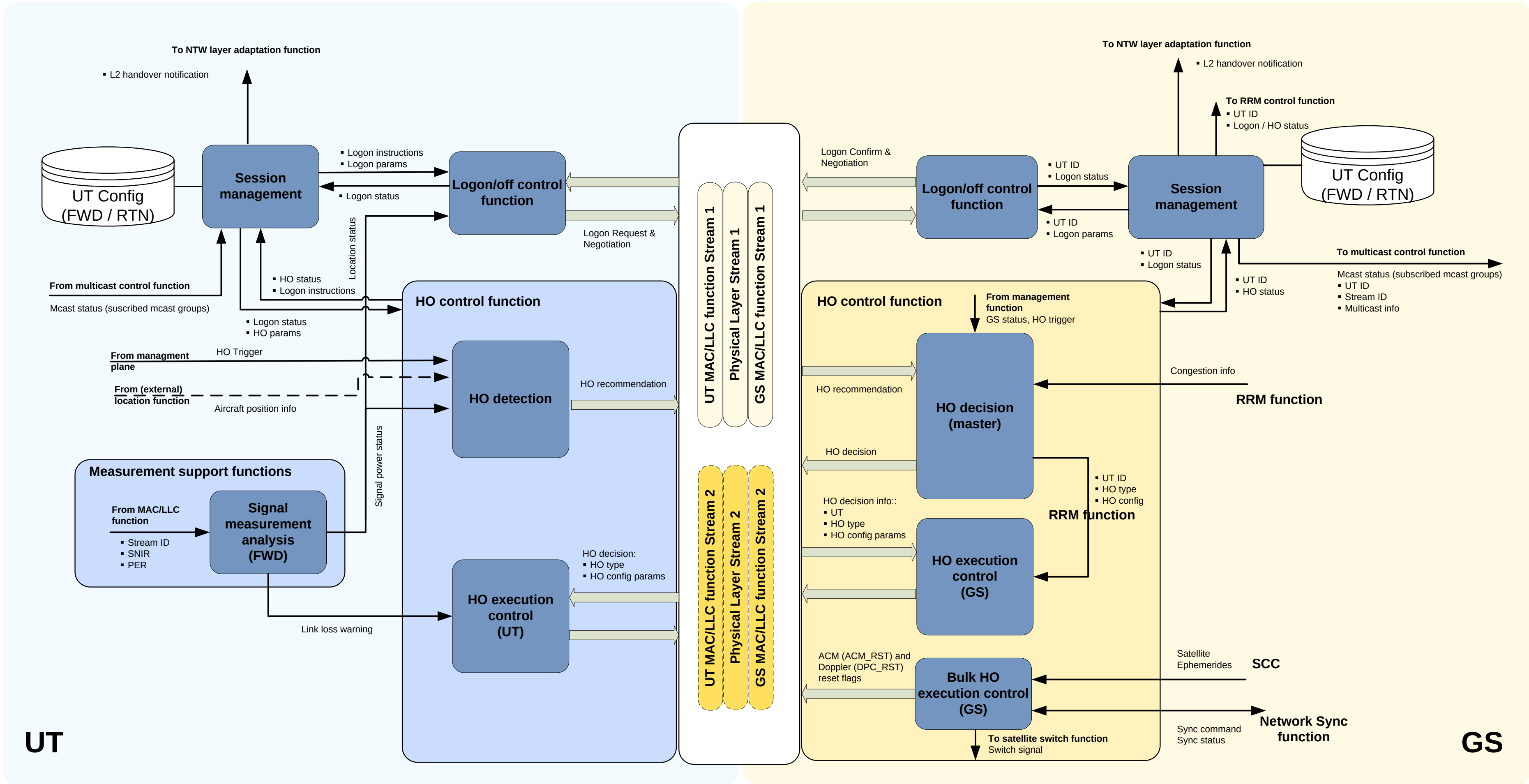

Figure 8-10: Logon/handover control functions in the UT and in the GS

They are described in more detail hereafter:

- Session management function
  - Session control. This function establishes and maintains data and signalling sessions between a specific GS element and a UT. This function uses the services provided by the logon/off and handover control functions and constantly tracks session status and associated parameters (e.g., active UT ID as used by the aircraft, beam where the UT is located, etc.).
  - Session information. It is necessary to provide required up-to-date session information to other CS functions so that they can perform their tasks (mapping of UTs to FWD carrier & RTN link frequency bands, etc.) and configure themselves appropriately (especially, regarding the number of required functional instances, e.g., number of MAC/LLC blocks).
- Logon/off control function (session establishment and release)
  - Logon control function
    - A specific logon procedure has to be followed so that a UT can use the traffic/signalling services provided by a CS system implementation.
    - It will be performed at UT start-up, but also during certain handover operations (inter-satellite handovers if there is no G2G communication between NCC from the same SSP or handovers between different SSPs).
    - Logon control function within the UT may use the services provided by the measurement support functions, in order to select the most adequate carrier for logon.
  - Logoff control function. This function is only triggered by the UT for management procedures.
- Handover control function (session maintenance)
  - The handover control function ensures that sessions are maintained without performance degradation even when there is a change either in the GS element associated with a UT or in the stream associated with this UT, so the handover process is performed seamlessly.

- This function can be further divided into three sub-functions:
  - HO detection. The need for an HO operation is detected by the UT with the support from measurement functions described below. The CS does not specify the specific HO detection algorithm to be used, but puts some constraints on the performance of this algorithm and specifies the detection parameters to be included in the HO recommendation signalling message finally sent to the GS.
  - HO decision. The HO decision function decides whether and when to initiate an HO execution and selects the new GS element and resources to be used by the UT. This function is located in the GS.
  - HO execution. This functionality coordinates the actual handover process, sending required signalling messages and executing the required process.

- Measurement support functions
  - Signal measurement analysis. This module supports logon and handover functions by monitoring the status and evolution of the signal quality of alternative and current carrier sets, in order to detect the best logon/HO candidates. Measurements shall provide reliable information, filtering out temporary effects, to the logon and HO processes.

8.6.4 Relationship with other functions

While a handover execution is in process, the UT manages up to two communication sessions in parallel, which may be established with the same or different GES (associated with the same or even different NCCs).

This section describes the instances of MAC/LLC, NTW adaptation layer, and Tx/Rx functional blocks, presented already in previous sections, which are required in the user plane, both in the UT and the GES(s).

The figure below presents the required blocks for the case when the UT has to maintain sessions in parallel through two different channels. Modules in yellow are active during the handover execution process and modules outlined in red will be removed after successful handover completion.

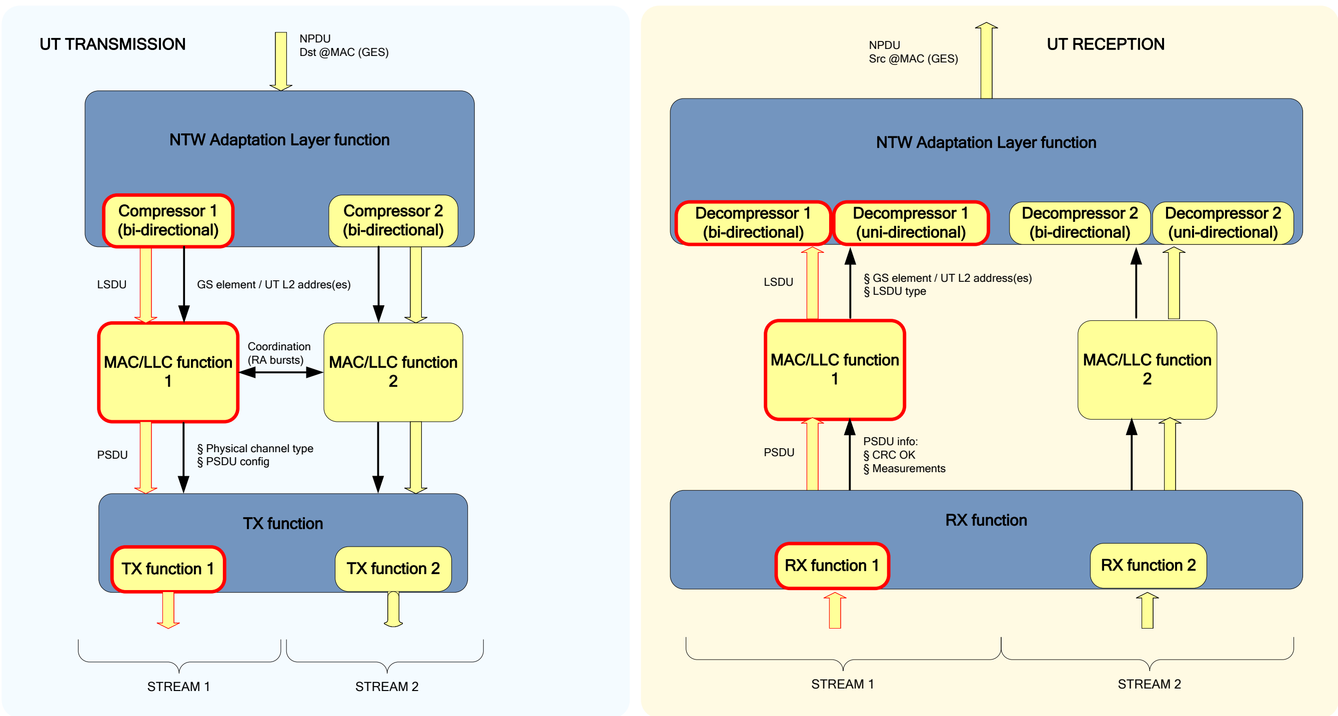

Figure 8-11: Functional blocks in the UT during a handover execution (different streams).

In yellow: modules which are active during an HO. Outlined in red: modules which will disappear after HO execution.

In the UT there is a single NTW adaptation layer block which has two (unicast) compressor modules; i.e., each session has its own compression context[4]. For each channel, MAC/LLC functions (encapsulation, ARQ and scheduling) are handled independently (although there is certain coordination in order to ensure that burst transmissions are not scheduled at the same

[4] It should be noted that the header compression protocol provides capabilities for context replication in case there is a single GES managing two different sessions, so that already established context may be reused in this particular case.

moment). Physical layer TX and RX functions are specific for each channel, as configuration parameters and Doppler pre-compensation corrections may be different.

8.6.5 Logon procedure sequence

The following interactions take place during a nominal logon procedure:

1) The UT detects possible candidate systems and beams for logon, based on signal quality measurements and, eventually, position information (not mandatory). It selects the most adequate system based on general signal quality criteria and user preferences (preferred SSP, etc.).
2) For the selected system, the UT obtains all necessary information to perform the logon by listening to a configuration table (logon table) periodically broadcasted by the system information function. It then accesses the system using a RACH physical channel, providing its ICAO 24-bit aircraft identifier.
3) The GS identifies the UT and performs an admission analysis based on the system status (congestion, partial failure, etc.). A specific GES is assigned to the UT and a logon response with configuration information is provided to the UT.
4) After this step, the UT also contacts its assigned GES, so that the communication session is established.
5) Optionally, the UT may also contact the NCC to confirm that the logon procedure with the GES has been successful. This step is only required in scenarios where NCC and GES do not coordinate using a terrestrial WAN.

8.6.6 Individual HO procedure

The following figure presents the overall handover procedure, which may involve several GS entities (GES and NCCs) depending on the HO type. The first step of the process is always HO detection, the second is HO decision, and the rest is the actual HO execution process.

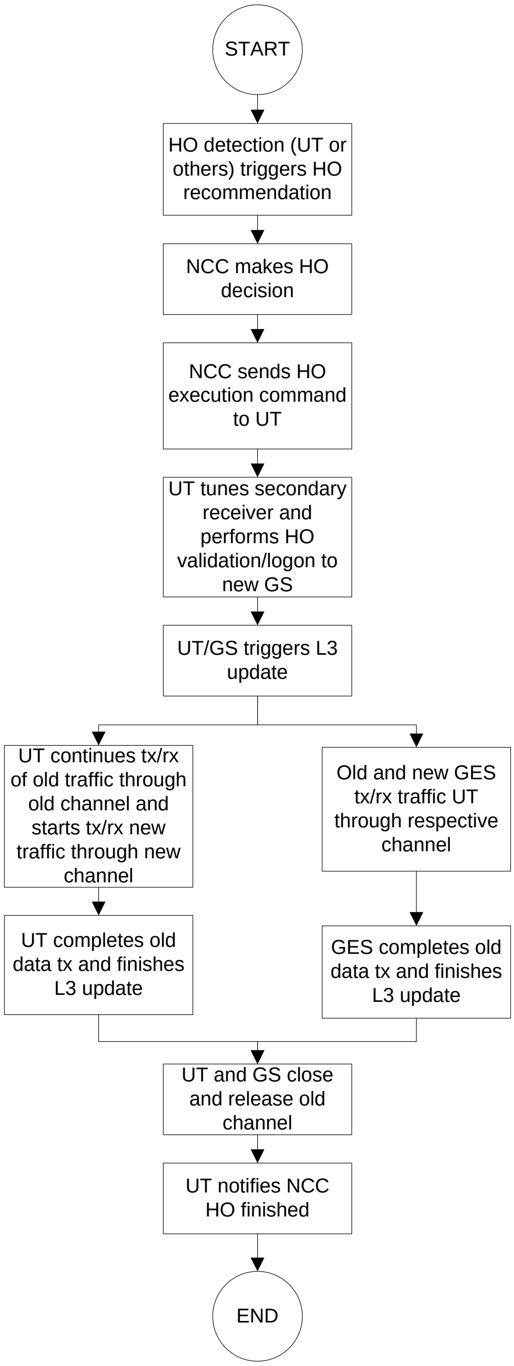

Figure 8-12: HO procedure

Depending on the HO type, some parts of the procedure can be avoided, thus simplifying the execution process.

8.6.7 Bulk HO procedure

The concept of "Bulk Handover" is defined as an HO in which all traffic in a beam or a complete satellite is handed over to another satellite in a single operation, with several UTs involved in this case.

This is mainly intended for the non-GEO satellite case (and especially for the HEO constellation) in which all traffic shall be switched from the descending (currently serving) satellite to an ascending satellite.

For the non-GEO satellite case, in which the coverage area is the North Polar region, the bulk HO should be triggered when both satellites are providing coverage over the same area (hereafter called overlapping period). In the following figure the scenario is presented.

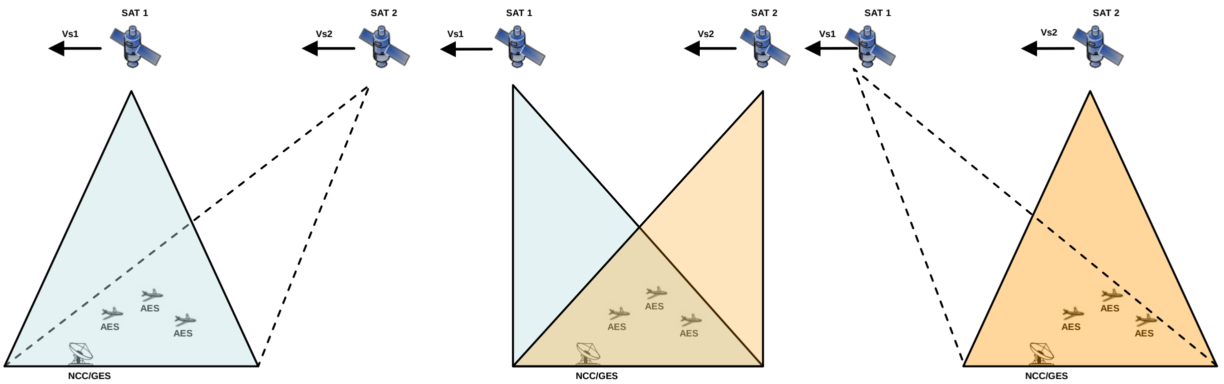

Figure 8-13: Bulk HO scenario

Based on satellite orbital information from SCC, the GS station (NCC/GES) will be able to predict in advance the loss of coverage to the whole Polar area of the serving satellite. During the overlap period of both satellites, the GS station shall devote one unit to the new satellite, performing network synchronization over the new satellite in advance. Once GS is synchronised to the new satellite, it performs a switch to all the carriers to the new satellite, keeping the same channels used in the old satellite.

Since the UT have non-directive antennas, they will be able to receive FLC carriers from the new satellite with no other effect appreciated than the switch in return link Doppler of the new satellite. The UT will be able to perform user link Doppler pre-compensation of their transmitter after receiving the first FCH timeslot.

The following figure presents the overall bulk HO procedure.

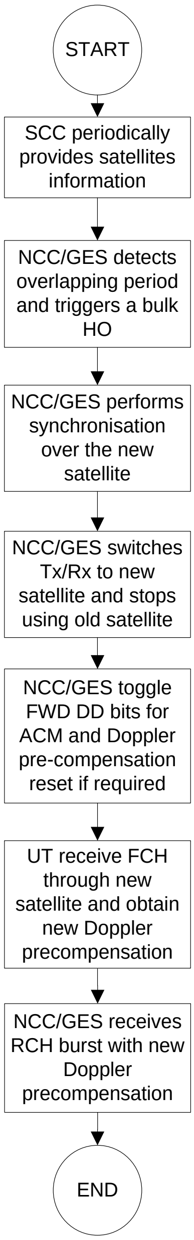

Figure 8-14: Satellite bulk handover procedure

8.7 Network synchronization function

8.7.1 Key functions and design concepts

Network synchronisation procedures are aimed at providing the mechanisms required to guarantee that transmissions in both forward and return links are properly synchronised.

In this section the following concepts are used as follows:

- Feeder-to-Feeder links: GS-Satellite-GS fixed links operating at Ku, Ka or C band.
- Satellite ATM transceiver: satellite transceivers from/to Ku, Ka or C band to/from L band.

Considering the MA scheme adopted for the forward link (MF-TDMA), accurate time and frequency synchronisation is required. Forward link network synchronisation can be implemented either through FLC carriers or Feeder-to-Feeder links.

The adopted MA scheme in the return link, i.e., A-CDMA, does not require that UTs implement elaborate synchronisation procedures before transmitting. Actually, no absolute time synchronisation is required at all and very simple processes are needed to limit carrier and chip frequency errors.

8.7.2 Interface to other functions

The network synchronisation function interfaces with other modules as depicted in Figure 8-15 and Figure 8-16.

In both NCC and GES, the network synchronisation function shall receive the satellite information from SCC and interface with PHY layer encapsulation to fill in some header information.

The specific network synchronisation function interfaces from/to PHY function are identified below for the following network elements: NCC, GES and UT.

On the NCC side, the network synchronisation function shall receive from the PHY functions:

- The carrier frequency offsets from the demodulator (to estimate the satellite clock error).
- The SNIR estimates from the demodulator (to implement forward link power control).

It shall also provide:

- The Network Time Reference.
- NCR value to be inserted in the FWD_DD header.
- Transmitter synchronisation corrections (from Feeder link compensation): carrier and symbol frequencies and time.
- Transmitter power corrections.
- Receiver synchronisation corrections (from Feeder link compensation): carrier and symbol/chip frequencies and time offset.
- SYNC flag value (field of the FWD_DD). For the NCC, SYNC flag is always set to “1”.

In addition, the NCC shall also broadcast the Satellite Clock Error to all the GS elements. This information can be distributed to the GS elements in different ways:

- As a signalling packet transmitted through the FLC carrier or through Feeder-to-Feeder link (depending on the solution adopted).
- By other means, e.g., terrestrial WAN.

On the GES side, the network synchronisation function shall receive from the PHY function:

- Received NCR values and the time estimates performed by the burst detector (to locally recover the Network Time Reference).
- The carrier frequency and time offsets from the demodulator (to adjust its own transmissions to those from the NCC).
- The SNIR estimates from the demodulator (to implement forward link power control to adjust its own transmission to those from the NCC).
- GS flag in order to distinguish the FCH bursts transmitted by the NCC and from the ones transmitted from other GESs (to implement FWD link synchronization mechanism).

It shall also provide:

- Locally recovered Network Time Reference (NCR).
- Transmitter synchronisation corrections (from Feeder link compensation and FWD link echo loop): carrier and symbol frequencies and time offset.
- Transmitter power corrections.
- Receiver synchronisation corrections (from Feeder link compensation): carrier and symbol/chip frequencies and time.
- SYNC flag status (to be inserted in the FWD_DD header) from the FWD link echo loop.

In addition, the GES shall also receive the Satellite Clock Error in order to compensate the satellite translation error.

The GS shall also interface with the HO function (Bulk HO). In particular,

- The NCC/GES shall receive from the HO function a Sync command, which is used in case of Bulk HO to indicate that the NCC should synchronize with the new satellite.
- The NCC/GES shall provide to HO function a Synch status, which is used to indicate that the NCC is synchronized with the new satellite.

On the UT side, the network synchronisation shall receive from the PHY function:

- For each received FCH burst:
  - The carrier frequency offsets from the demodulator.
  - SYNC flag (from the FWD_DD header).
  - CRC status.
  - DPC_RST bit (from FWD_DD header) to reset the Doppler Pre-compensation mechanism.

It shall also provide:

- Transmitter carrier and chip frequencies corrections (from the User Link Doppler pre-compensation responsible for compensating both Doppler offsets and drifts).
- Alarms:
  - Transmitter frequency reference not properly recovered.
  - FWD link carriers not being received after a certain amount of time.

  (Note: These alarms are also provided to L2 Control function.)

8.7.3 Description

Figure 8-15 presents the forward link network synchronisation functional block diagram for the NCC and GES.

The following functions have been identified, some common to NCC and GES and some specific in one of the GSE:

- Time Reference (NCR) distribution (NCC) and recovery (GES).
- Feeder link compensation (by all GSE):
  - Compensates the satellite clock error (in transmission) and the Feeder Link Doppler effect in both transmitter (uplink) and receiver (downlink).
  - This function is common both for Forward and Return link synchronisation.
- FWD link echo loop (GES):
  - GES estimates (and corrects) synchronisation and power errors computed from the reception of its own transmissions (and the ones from the NCC which are used as a reference).

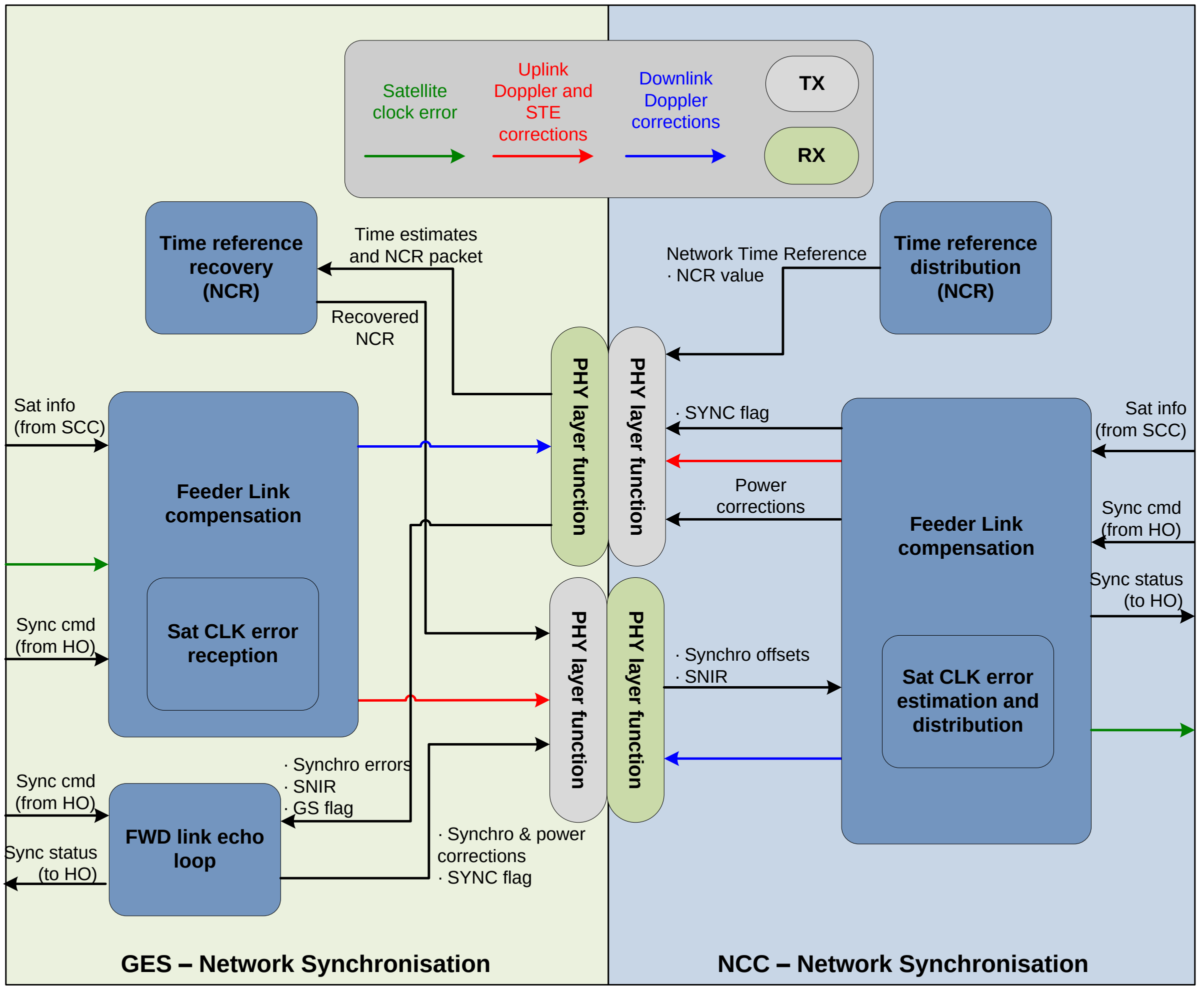

Figure 8-15: Forward link network synchronisation functional block diagram

Figure 8-16 presents the return link network synchronisation functional block diagram for the GS and for the UT.

Two main functions have been identified, one in the GS and the other one in the UT:

- Feeder link compensation (GS)
  - Compensates the satellite clock error in both forward (transmitter) and return (receiver) links, and the Feeder Link Doppler effect in both transmitter (uplink) and receiver (downlink).
- User Link (transmitter) Doppler pre-compensation (UT):
  - The UT estimates and compensates return up-link Doppler shift and drift from FLC (FCH bursts) reception. Only FCH bursts with SYNC flag set to “1” and without decoding errors (i.e., CRC ok) are used to estimate the up-link Doppler pre-compensation.
  - Doppler pre-compensation mechanism shall be reset if DPC_RST bit changes its value (DPC_RST is used in toggle mode).

- Two instances of this algorithm are put in place to support the HO process.

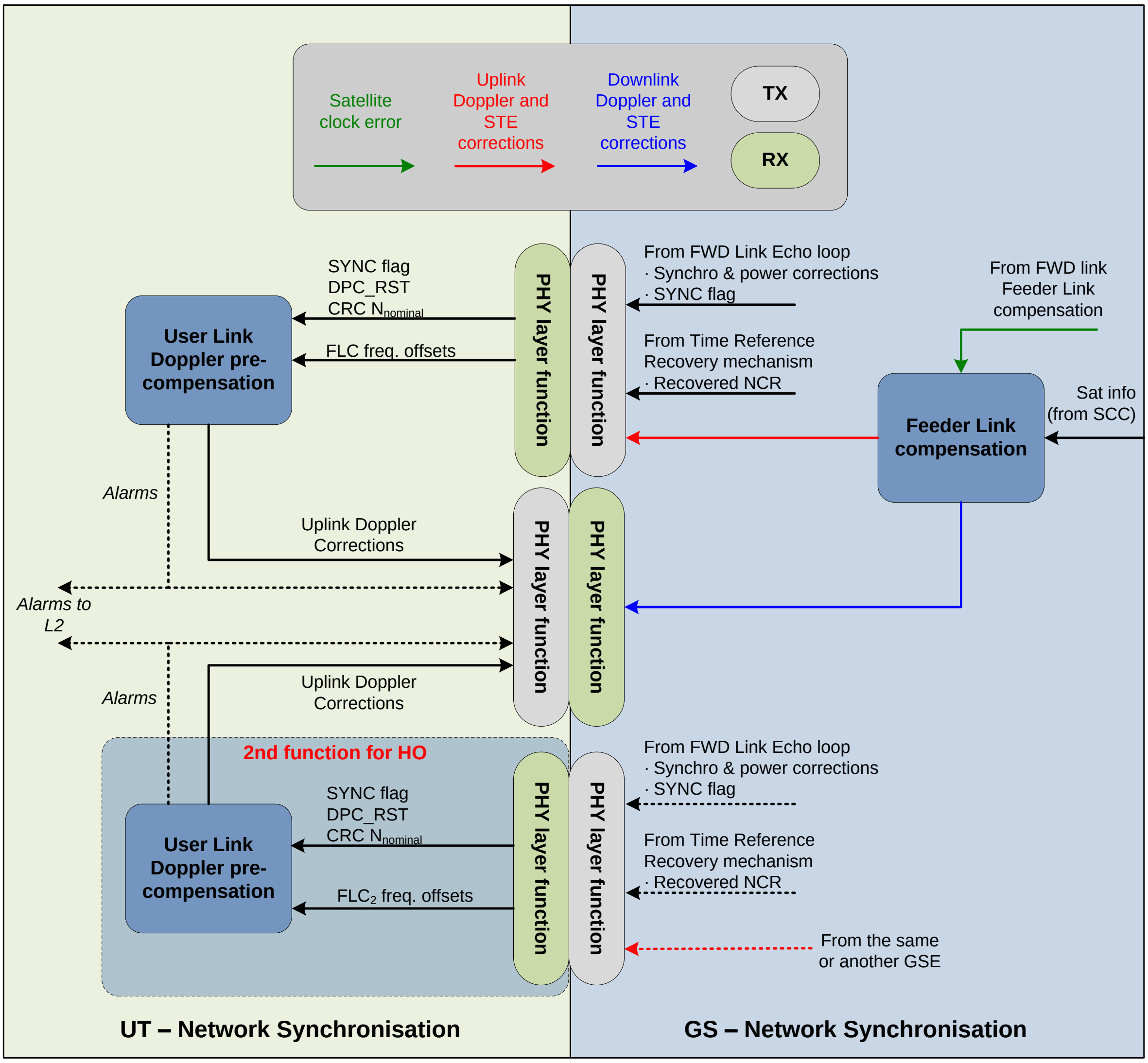

Figure 8-16: Return link network synchronisation functional block diagram

8.7.4 Network synchronisation procedures

This section describes the network synchronisation procedures for forward and return link.

Network synchronisation procedures are aimed at providing the mechanisms required to guarantee that transmissions in both forward and return links are properly synchronised, which implies that:

- Transmissions to a given frequency band (FLC carrier) do not overlap in time at the satellite front-end. This is only applicable to the forward link, which uses an MF-TDMA scheme.
- Simultaneous transmissions (to different FLC carriers) do not overlap in frequency at the satellite front-end.

To achieve the previous objectives, guard times (for the forward link only) and guard bands are defined to face time and frequency uncertainties.

To synchronise GS transmissions in the forward link and UT transmissions in the return link, the distribution of a common reference is required from a central element (NCC) to all the other GS elements and UTs. Absolute time reference is distributed by means of NCR messages from NCC to the rest of GS elements.

Thus, GS elements must recover the network reference before they can transmit to the satellite. Analogously, UTs must recover the frequency reference before they can start transmissions to the return link.

The following sections describe the procedures that must be carried out to synchronise the network and keep it synchronised.

8.7.4.1 Forward link network synchronisation procedures

An MF-TDMA access scheme is adopted for the forward link, being the synchronisation of the distributed GS transmitters essential for the network operation.

The forward link synchronisation is aimed at keeping GS transmitters synchronous in terms of carrier frequency and burst timing. It is especially critical for the functioning of the system because it may compromise the performances of the return link synchronisation procedures as well.

There are two alternatives to implement the forward link network synchronisation:

- through FLC carriers
- by means of Feeder-to-Feeder links.

The procedures presented below are valid for either of the previous options, which provide equivalent performances.

Actually, what is really important about forward link network synchronisation is not the final approach adopted, which is not imposed by the CS, but the fact that it should guarantee that GS transmissions are synchronous, i.e., the guard times and guard bands defined for forward links are fulfilled.

The forward link network synchronisation includes three main procedures:

- The NCC distributes time and frequency reference to all GS elements
    - Absolute time reference is distributed by means of NCR values.
    - Frequency reference is distributed implicitly through the bursts transmitted by the NCC.
- Feeder Link Compensation
    - It is actually part of both forward and return link network synchronisation and is fully implemented by GS elements.
    - It is aimed at (i) compensating the Feeder Link Doppler Effect, including both time and frequency and (ii) compensating the satellite translation error in both forward and return links.

- GS elements synchronisation
  - Time and frequency reference recovery by means of the reception of NCC bursts. Absolute time reference is recovered from the NCR values. This procedure shall be performed continuously.
  - GS elements compensate their transmitters by means of the recovered time reference (open loop) and start transmitting bursts. The round trip delay is estimated from the GSE and satellite positions and pre-compensated.
  - GS elements receive their own transmissions and compute frequency, time and power errors with respect to the received NCC bursts.
  - GS elements apply synchronisation (frequency and time) and power corrections (if required).
  - Synchronisation maintenance: last steps are performed while the GS elements are attached to the network.

8.7.4.2 Return link network synchronisation procedure

The adopted MA scheme in the return link, A-CDMA, does not require that UTs implement elaborate synchronisation procedures before transmitting. Actually, no absolute time synchronisation is required at all and quite simple processes are needed to limit carrier and chip frequency errors in order to minimise the return link guard bands, and the frequency drifts and the time shift experienced during a RACH burst.

Thus, the return link network synchronization shall guarantee that UTs are always ready to transmit with limited frequency (both carrier and chip) errors. Synchronisation is maintained by a User link Doppler pre-compensation mechanism.

The return link network synchronisation includes three main procedures:

- GS elements distribute a frequency reference to all UTs through the Forward Link Carrier
  - The frequency reference is distributed implicitly through all FLC carriers.
- Feeder Link Compensation
  - It is actually part of both forward and return link network synchronisation and is fully implemented by GS elements.
  - It is aimed at compensating the Feeder Link Doppler Effect, including both time and frequency, and compensating the satellite translation error in both forward and return links.
- UTs synchronisation
  - This procedure defines the steps that a UT should follow to synchronise its transmitter so that the maximum frequency offsets and drifts and time shifts experienced during a RACH bursts are respected.

8.7.4.2.1 UT synchronisation

The return link UT synchronisation procedure is composed of the following processes:

- Forward Link Carrier Reception[5]
- User Link (transmitter) Doppler pre-compensation

Forward Link Carrier Reception

This process involves the following steps:

- GS elements transmit the FLC carrier multiplexing network control and user data information in a MF-TDMA basis. There is not a system carrier specifically devoted to carry network control information.
- The UT knows beforehand the information required to receive one or more FLC carriers (carrier frequency, symbol rate, coding scheme, etc.) and starts to tune the different frequencies, looking for available carriers.
- Reception of FLC carriers involves the following steps (note that this process is performed permanently by the UT, until it logs out from the network.):
  - FLC physical synchronisation: the physical FLC synchronisation process entails the detection, synchronisation, and decoding of FCH burst.
  - Network frequency reference recovery: it is based on the carrier frequency offsets estimated by the UT demodulator, which are used to assist the User Link Doppler compensation mechanism in order to compensate the Doppler (shifts) and Doppler rate (drifts) affecting UT transmissions in the return up-link.
  - Extraction of MF-TDMA data, i.e., system information tables.

User Link(transmitter) Doppler pre-compensation

The User Link Doppler Pre-compensation mechanism is aimed at compensating the Doppler Effect in the return up-link. It is fully implemented by UTs and includes the following steps:

- Upon reception of FCH bursts, the UT performs the following process:
  - The UT computes transmitter carrier and chip frequencies corrections (both offsets and drifts), based on the FLC carrier frequency offsets estimated by the demodulator. Frequencies compensations shall be computed so that Doppler Effects are compensated at the expense of incrementing clock instability errors, which are lower even when operating in GEO constellations.
  - The UT must discard those FCH bursts received with errors for the process[6].
- The UTcontinuously applies the carrier and chip frequency corrections to its transmitter, even during RACH burst transmission, in order to minimise return link frequency drift.
- The UT shall interrupt its transmissions if any of the following abnormal events occur:

[5] Some steps of this procedure are actually part of the Physical Layer function instead of the Network Synchronisation function.

[6] FCH bursts identified (with the SYNC field of the FWD_DD descriptor) by the GS as inappropriate for User Link Doppler Pre-compensation must be discarded as well.

- The FLC is lost, i.e., no FCH bursts are received within *FLC_loss_timeout* seconds.
- The Doppler pre-compensation mechanism is not able to estimate return uplink Doppler shift and drift.

The UT shall resume transmissions once the nominal operation is reached.

8.8 Adaptive Coding and Modulation (ACM) control function and procedures

8.8.1 Key functions

Adaptive Coding and Modulation (ACM) is a fade countermeasure technique consisting of adapting the coding and modulation rate of the transmission in order to counteract the channel variations.

ACM allows avoiding a worst case system dimensioning by always using the MODCOD with the highest spectral efficiency and/or data rate, instead of a constant MODCOD with a low spectral efficiency.

Taking into account the nature of the FWD and RTN link Multiple Access, the CS supports ACM only on the FWD link. Besides, ACM is only envisaged for the physical channels (FCH) devoted to transferring user data information in unicast mode modulated at 160 kbaud. FLCs modulated at 16 kbaud do not support ACM.

Note that the FCH is also used for carrying signalling (broadcast and dedicated) and broadcast/multicast user traffic information. In this case, the most robust MODCOD is used.

The MODCOD configurations supported by this physical channel are:

Link	Physical channel	Coding scheme	MODCODs
Forward	FCH @ 160 kbaud	IRA LDPC	QPSK 1/4, 1/3, 1/2, 2/3 8-PSK 1/2, 2/3 16-APSK 2/3

Table 8-4: ModCod configurations for FCH physical channel at 160 kbaud

8.8.2 Interface with other functions

The ACM control function interfaces with the MAC/LLC function (see Figure 8-17).

8.8.2.1 Interfaces to MAC/LLC function

The interface of the ACM control function with the MAC/LLC function is slightly different if it is considered the GS or the UT.

On the GS, the ACM control function receives from the MAC/LLC function:

- A signalling LSDU containing:
  - The requested MODCOD (Note: the LSDU also contains the UT Id).

On the GS, the ACM control function provides to the MAC/LLC function:

  - Most efficient MODCOD a UT can use (associated with a certain UT Id).
  - Need for additional MODCODs (dummy packets to be inserted to allow MODCOD upgrade).

On the UT, the ACM control function receives from the MAC/LLC function:

- Control information associated with the received FCH bursts. This information shall be provided to the ACM Control function for all the bursts received by the UT[7] (even if the burst is not addressed to the UT) in the serving beam:
  - The MODCOD (MODCOD_ID) of the received FCH burst.
  - Parity Check Status at $N_{reduced}$ LDPC decoder iterations for each DW of a FCH burst.
  - Parity Check Status a $N_{nominal}$ LDPC decoder iterations for each DW of a FCH burst.
  - ACM_RST value (obtained from the FWD_DD header).
  - The GES (GES_ID) that has transmitted the burst.

On the UT, the ACM control function provides to the MAC/LLC function:

- A signalling LSDU containing:
  - The most efficient MODCOD that the UT is able to receive correctly (Note: the LSDU also contains the UT Id).

8.8.3 Description

Figure 8-17shows the functional block diagram regarding the ACM control function. For a better understanding, the functional diagram is not restricted only to the ACM control functions but also provides an idea of how the ACM control function interacts with the RRM and the LLC/MAC functions.

[7] In fact, the lower layers shall provide the requested information for all the bursts in which the UT is able to decode the PLHEADER.

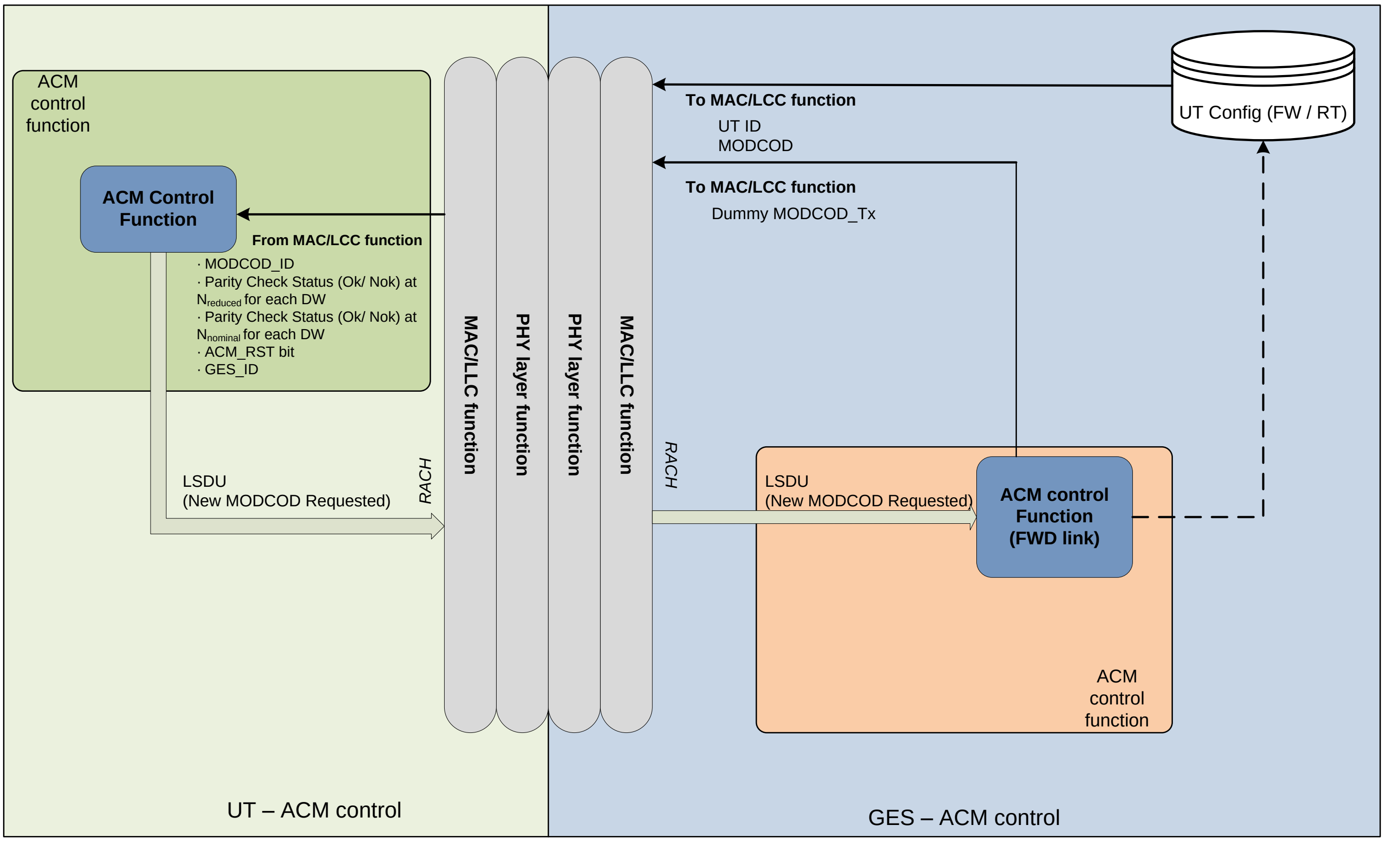

Figure 8-17: ACM control functional block diagram

The following functions are considered to be part of the ACM control function:

- ACM control function on the UT side:
  - Signalling LSDU generation. Based on the information provided by the lower layers, it generates the LSDU packet containing the maximum MODCOD which the UT can receive correctly. The MODCOD indicated by the UT must be mandatory for the GS in the sense that the GS cannot send any packet with a more efficient MODCOD than the MODCOD requested by the UT. On the contrary, the GS can send packets with a less efficient MODCOD (more robust) than the MODCOD requested by the UT.
- ACM control function on the GS side:
  - MODCOD decision.
    - Based on the signalling LSDU packet received from the UT, which carries the requested MODCOD for a UT, this function proposes to the MAC/LLC function the most efficient MODCOD that can be used on the FWD link to communicate with this UT.
  - Additional MODCODs

- Taking into account the MODCODs requested by the UTs and the requirements from the Slow ACM mechanism, this function requests that the MAC/LLC control includes dummy packets with a less robust MODCOD.

8.8.4 ACM mechanisms

This section presents how the FWD Link ACM shall operate in the system, based on the functionalities presented in the previous section.

The FWD link ACM procedure is based on two mechanisms. One is designed to react against slow variations of the propagation channel conditions while the other is designed to react against fast variations in the propagation channel.

For slow variations in the propagation channel, the mechanism allows the transmitter to adapt the MODCOD to the channel quality in a progressive way in order to prevent any packet loss. On the contrary, the fast mechanism forces a switch back to the most robust MODCOD.

It is worth noting that the ACM mechanism is initiated when the UT is logged in to the system and the GS has assigned a FLC carrier to it. During an HO, two instances of the ACM mechanism are running in parallel.

8.8.4.1 Slow ACM mechanism

The slow ACM mechanism is based on estimating the PER at $N_{reduced}$ LDPC decoder iterations for all the MODCODs present in the FLC carrier. The mechanism is as follows:

1. The GS transmits FCH bursts through the FLC carriers carrying either user information (data and/or voice) or signalling information or a mix of both. The FCH bursts can be transmitted either by the NCC or by the GESs.
2. The UT receives the FCH bursts transmitted by the GS and continuously monitors:
   - The Parity Check Status of each DW at $N_{reduced}$ LDPC decoder iterations, and for each MODCOD computes the PER $N_{reduced}$ LDPC decoder iterations (one PER statistics per MODCOD).

   Regarding the PER estimation at $N_{reduced}$ LDPC decoder iterations, the following considerations have to be taken into account:

   - In the event that on the FWD link an Uplink Power Control algorithm is put place, which ensures that all the FWD link carriers at the satellite level have the same power, the UT can monitor the PER at $N_{reduced}$ LDPC decoder iterations in all the FCH bursts (whatever the GES has transmitted the bursts).
   - In the event that Uplink Power Control is not put in place on the FWD link or it is not accurate enough, the UT can only use the slots transmitted by its assigned GES to estimate the PER.

   It is worth noting that if the UT can only use the bursts transmitted by its assigned GES, the number of GES sharing a carrier will have an impact on the reactivity of the ACM loop to a change of channel condition.

At power-up (after the logon), the GES shall use the most robust MODCOD to transmit data to the UT.

3. Based on the PER measurements at $N_{reduced}$ LDPC decoder iterations, the UT selects the most efficient MODCOD (in terms of spectral efficiency) that can be used.

   If the ACM_RST bit changes its value, the ACM mechanism shall be reset.

4. The UT indicates to the GES the most efficient MODCOD that can be used by the GES to communicate with the UT on the FWD Link. This control information is sent to the GS using a RACH burst. The UT only indicates the preferred MODCOD to the Ground Segment in case the preferred MODCOD changes.

5. Based on the UT recommendation and other aspects (RRM), the GS selects the MODCOD to be used to communicate with that UT. At the end, in terms of spectral efficiency, the selected MODCOD shall be such that: *Selected MODCOD ≤ MODCOD recommended by the UT*.

8.8.4.2 Fast ACM mechanism

The Fast ACM mechanism is envisaged as a safety mechanism in order to keep the communication even in challenging propagation conditions (e.g., aircraft banking, etc.). It is based on measuring the errors in the DW at $N_{nominal}$ LDPC decoder iterations for all the MODCODs present in the FLC carrier. The mechanism is as follows:

1. The UT receives the FCH bursts transmitted by the GS and continuously monitors the Parity Check Status of each DW at $N_{nominal}$ LDPC decoder iterations each MODCOD.

2. If a burst of errors occurs in the DW at $N_{nominal}$ LDPC decoder iterations (e.g., 2 consecutive DW in error) in any MODCOD with a spectral efficiency ≤ the preferred MODCOD, the UT triggers the Fast ACM mechanism and indicates to the GES that the preferred MODCOD is the most robust one (i.e., the less spectral efficient one).

It is worth noting that for the Fast ACM, the points described in the Slow mechanism related to the GS Uplink Power Control are also applicable for the Fast one.

8.9 Radio Resource Management (RRM)control function

8.9.1 Key functions and design concepts

The main function of this module is to complement the scheduling and priority management function within the MAC/LLC functional block by providing the necessary RRM control functions. In particular, it supports mainly control tasks associated with:

- Random access method:
  - Control of RA channel operation point (congestion control), by adaptively setting configuration parameters that govern UT channel access according to load status.
  - Selection of frequency band to be used (if several are possible).
  - Control of the power randomization range for each of the available bands.

Regarding the distribution of resources among GSEs (FWD link RRM), the CS does not impose a specific design solution. The semi-static forward link RRM managed policies shall observe the constraints shown below:

- Only one on-board receiver is used in nominal mode for the reception of both system signaling and traffic. The other is kept for back-up and handover detection and execution purposes.
- User terminals (UT) are not aware of frame structure. Hence, no frequency hopping can be envisaged in the radio resource assignment in forward link to UT.

8.9.2 Interface to other functions

8.9.2.1 Interfaces with physical layer functions

The RRM control function interacts with the following PHY functional blocks:

- Forward link physical layer RX function
    - The GS physical layer RX function provides monitoring information (noise rise) to be used as input for congestion control mechanisms associated with random access channels.

8.9.2.2 Interface to MAC/LLC function

The RRM control functional block uses the services of the MAC/LLC function in order to establish signalling channels between the GS RTN RRM control functions and the UT.

On the FWD link, it uses a logical signalling channel of type BCCH in order to forward the following signalling messages:

- Random access control parameters, associated with each RTN link random access channel:
    - Congestion status or traffic load condition. This information is used by the UT to select the appropriate transmission parameters (back-off, persistency, and re-transmission timeout) as indicated in Section 8.2.
    - Congestion control configuration parameters, includingpower randomization parameters.

This channel is mapped to a FCH physical channel.

Additionally, the MAC/LLC function:

- Receives configuration parameters required by the scheduling and priority management function within the MAC/LLC module (random access congestion control parameters, criteria for burst mode selection, etc.)
- Provides QoS monitoring by providing information about processed traffic delay histograms and packet losses per CoS/application.

8.9.2.3 Interfaces with control functions

The RRM control function interacts with the following functional blocks for control information exchanges:

- Logon/handover function
    - The logon/handover function may receive load monitoring information, to support the logon and HO decision process.

8.9.3 *Description*

Figure 8-18 shows the general functional blocks which are part of the RTN RRM control. All functions are required per mobile-link beam.

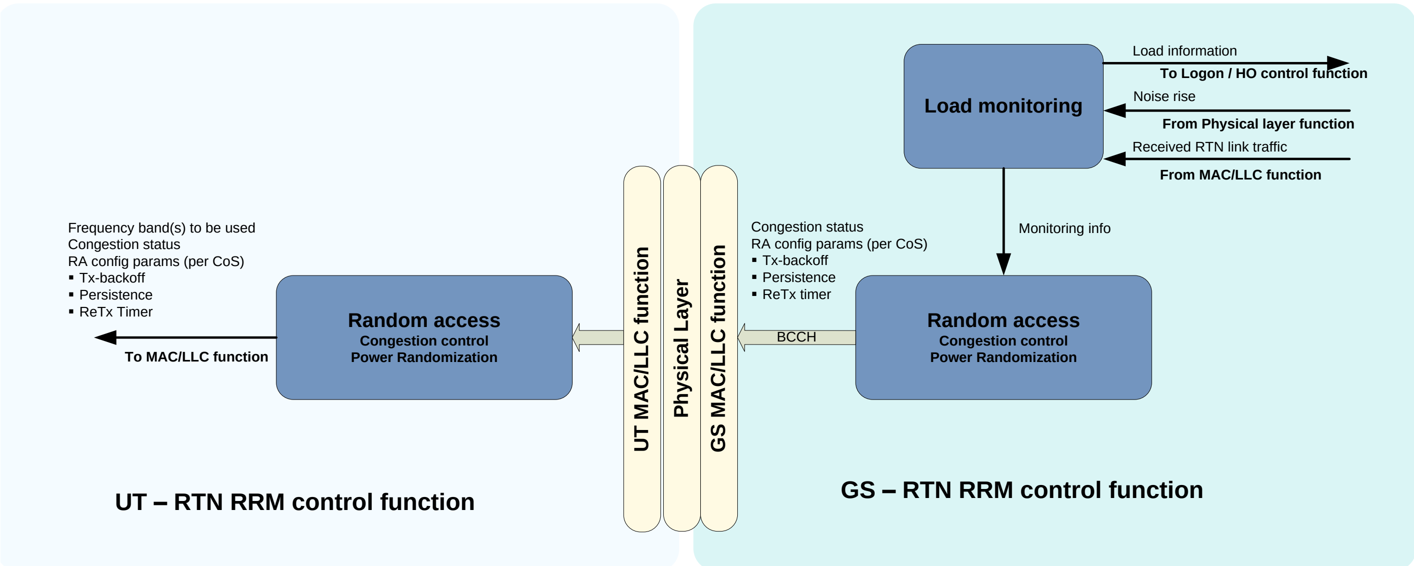

Figure 8-18: RTN RRM control functions

The following detailed RRM functions are supported:

- Random access congestion control (only RTN)
    - This function dictates certain rules to UTs for use of random access channels, so that it is ensured that these channels are not overloaded and that they work in the most suitable operation point. Refer to section 8.2 for the applicable algorithm.
    - Congestion control parameters are set adaptively by the GS according to measured channel load and then broadcast to all UTs each second over a broadcast logical signalling channel (BCCH). It is mandatory that the indicated rules are then enforced by the MAC/LLC function within the UT.
- Load monitoring
    - This function supports the rest of the functions by monitoring the load level and providing the corresponding load measurements to the other decision functions. It considers traffic load and possibly logon status information. For RTN RRM control, it also evaluates physical layer status (noise rise).

8.10 Multicast control function

8.10.1 Key functions and design concepts

It should be noted that there is currently no application defined by aviation that requires multicast, but provision for having multicast functionality has been included in the CS.

The following main functions have been identified for this module:

- Indicatewhich FWD link carriers shall transmit a certain multicast group. This information is used by the MAC/LLC function in order to forward multicast traffic to the correct FWD link carrier(s).
- Provide information needed by the NTW layer function in the GS, so that this element can interact with the terrestrial network (ATMN) in order to feed its attached nodes with the requested multicast traffic.

It should be noted that multicast services are only provided to UTs implementing ATN/IPS, as multicast concept is not supported by the ATN/OSI stack.

Regarding multicast service design, the CS supports a GES-based, static membership. GES (and not UTs) subscribe to multicast groups and act as multicast members. GES group membership is configured statically (or semi-statically), with no signalling required over the satellite link.

This scheme is adequate if multicast applications provide a basic service, which is part of the standard ATC/AOC procedures used by all aircraft (e.g., alerts or meteorological reports), or if there is a continuous demand for this service (e.g., multicast services linked to airports or to airlines), so that the probability is that there is always a nearby aircraft which is an active member of a multicast group in the target area.

Static forwarding can be done per FWD link carrier, so that the GES can forward multicast traffic more selectively (e.g., only to certain beams).

It should be noted that, as multicast flows generated by different GES may have overlapping multicast L3 addresses (as, for example, link-local multicast addresses used for signalling), it shall be ensured that the UT receives only one possible flow. This could be an issue when GES share a FWD link carrier: in this case, the MAC/LLC function shall distinguish the flows by adding a GSE ID in the encapsulation header.

8.10.2 Interface with other functions

The multicast control function interacts with the following functional blocks for control information exchanges:

- NTW layer function:
  - In the UT, this module (which, for ATN/IPS, is outside the scope of the CS) provides information on multicast group membership as provided by multicast applications running in hosts/routers connected to the UT.
  - In the GS, it receives membership information to be used by multicast routing protocols supported on the interface towards the terrestrial ATM network.
- MAC/LLC function:
  - The multicast control function provides information required by the MAC/LLC function to map a multicast logical channel to one or more destination FWD link carriers.
  - Additionally, it provides the configuration for the filtering functionality within this module (receiver end), so that only relevant multicast traffic is received.

8.11 Management functions

8.11.1 Key functions and design concepts

The management plane aims at supporting non-real time functions, such as FCAPS (Fault, Configuration, Accounting, Performance, and Security), and network resources operation planning (frequency allocation, network reconfiguration, maintenance phases planning, etc.), as well as user database management. It should be noted that not all these management functions require standardization by the CS, as many functions are internal to the UT/GS and can be provided according to the specific preferences of each CS-compliant implementer.

In this sense, only the following management functions, which require specification in order to avoid interoperability problems, are part of the CS functional architecture (refer to section 8.11.3 for details):

- Provision for Inter-System handover between compatible systems.
- System elements configuration.
- Collection of monitoring and accounting data.

Regarding the design of managementfunctions, the following key design aspects can be highlighted:

- UT management interface. Features such as UT remote monitoring and control could provide a way for operators on the ground to diagnose and possibly repair failures in the UT such as sub-optimal configurations or incorrect parameter settings while the system is in operation. However, this would be only possible at the cost of extra bandwidth usage on the satellite link. There would also be potential security issues and the need to certify those procedures, when possible. So, although it is technically feasible to perform them, it is not foreseen to have such features in the communication standard. Management of the UT is thus solely local to the aircraft and does not require any exchange of information over the air interface.

- GS element management interface. The CS also defines a common set of NCC/GES monitoring and configuration parameters.

8.11.2 Interfaces to other functions

The management functions provide/receive all kinds of configuration and monitoring information, as required by most CS functions which are part of the control and user planes and which have been described in detail in the previous sections. A detailed identification of all provided parameters is considered out of the scope of this high-level document.

8.11.3 Description

This section describes in more detail those management functions that have to be supported by the CS:

- Provision for inter-system handover between compatible systems
  - This function ensures that all configuration parameters required for inter-system handovers are exchanged correctly and unambiguously between the different management entities of these inter-operating systems.
  - For example, the logon carrier frequency of other neighbour or alternative systems as well as the coverage area delimitations provided at the NMC by the operator will be made available to the GES/NCC through the management plane, so that this information can be used for instructing UT to perform inter-system handover when required.
- System elements configuration
  - By system elements configuration function, it is understood that the network operator is able to set the value of a certain number of predefined configuration variables for each of the elements under its management.
  - Especially for the UT, a basic set of parameters to be configured, and their type and size, are to be included in the communication standard to ensure interoperability.
- Collection of monitoring and accounting data
  - This function provides the monitoring and accounting interface with the system elements. A minimum set of values to be made available through this interface and their exact meaning are to be standardized.

9. INTERACTIONS OF THE CS WITH OTHER SYSTEMS

9.1 Voice services

The voice service is conceived as a service providing access arbitration (floor control), voice compression/trans-coding, and translation/compression of signalling messages. All messages exchanged between entities (ground based or airborne) are defined as data sent and received at the application layer. So the voice service is conceived as an independent service from the CS, although the CS shall provide the required bearer service. This approach is represented in the following figure:

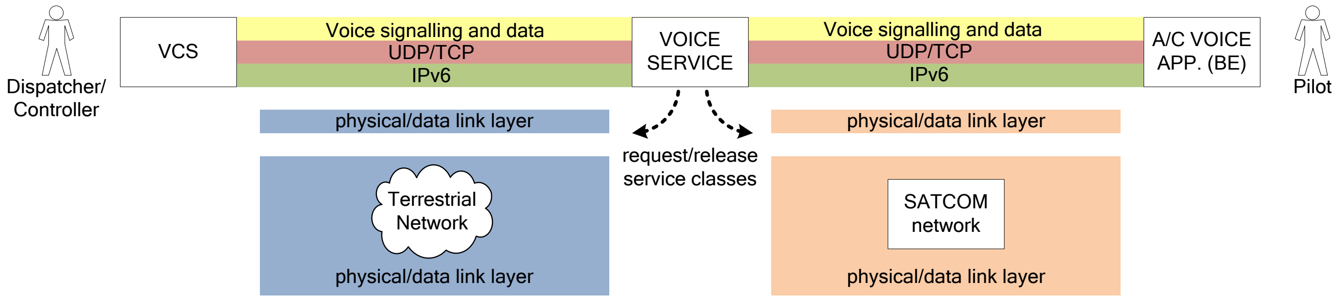

Figure 9-1: Layered design approach[8]

The proposed design allows changing the transport infrastructure (i.e., physical layer and data link layer) without the need to change the voice application, and therefore already considers a multi-link environment. It also assumes that services provided by layers below (transport, network, data-link and physical) are available and offer a certain quality (i.e., different classes of service).

It must be noted that voice services over the satellite communication system will be provided only using ATN/IPS protocol stack (VoIP).

The following sections are merely intended to illustrate how the aircraft voice application could work using the satellite system.They should not be understood as a mature design specification, which should be provided in any case by a specialized ICAO work group.

9.1.1 Reference architecture

The architecture envisaged for the voice service is what is presented in this section. The main specific elements in the architecture are listed hereafter:

- Voice front-end: The voice front-end, in conjunction with the voice back-end (see below) compound the Aircraft Voice Application. The voice front-end (radio tuning unit) manages different airborne radio systems (back-end) via a data bus (e.g., ARINC 429). The front-end as well as the headset and the PTT button connect to a number of different back-end. The Aircraft Voice Application architecture is exemplified in the figure hereafter.

[8]The green layer refers to the network layer, the red one refers to the transport layer and the yellow one is the application layer.

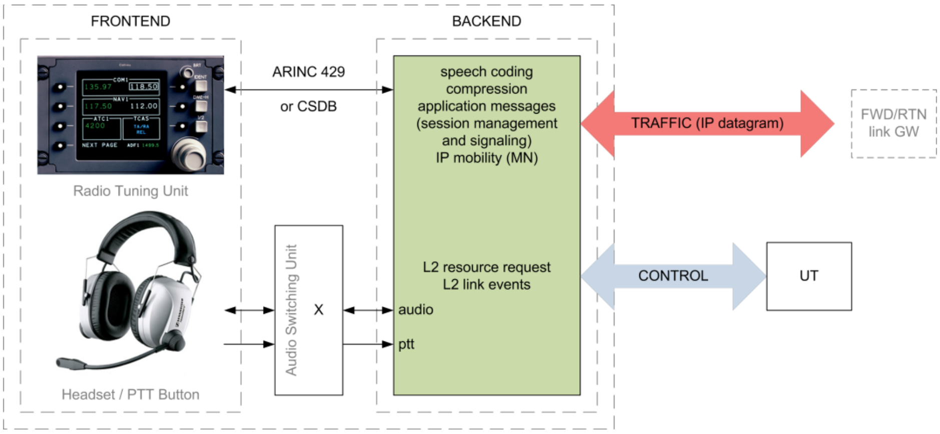

Figure 9-2: A/C voice application (exemplary)

- Voice back-end: The voice back-end serves as host for the application, receiving and sending IP datagrams as mobile node (MN) via the satellite communication system, and therefore connects directly to the UT. In addition, it maintains a management session opened for the UT for control purposes (link events). The voice back-end performs speech coding and compression. It can also exchange session management and signalling messages with the ground segment service entities that are part of the voice service, although this is not foreseen in the ANTARES CS and system.
- Voice GW: This is a voice service element that includes two entities, as shown in Figure 9-3:
  - FWD and RTN Link Voice Gateway is an element that translates between signalling and voice protocols defined in the ground segment (EUROCAE WG-67) and signalling and voice messages that are received from or sent to the a/c voice application back-end via IP datagrams.
  - The Sector Floor Control performs speaker arbitration and provides priority override mechanisms for all participants that have joined a sector.

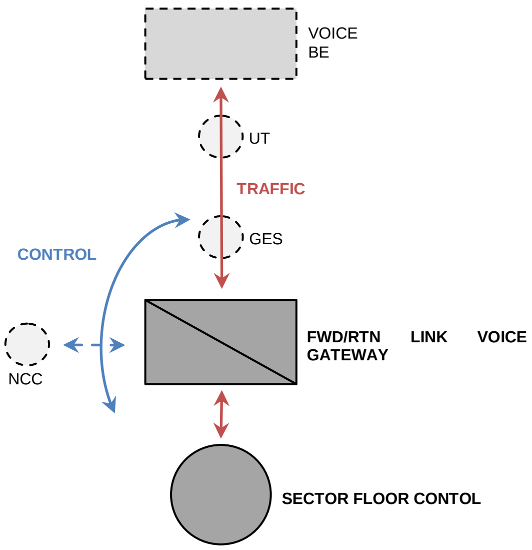

Figure 9-3: Voice GW architecture

9.1.2 Reference service model

In general, the voice service over the satellite system could be implemented as follows, in line with WG-67 specifications for the terrestrial voice service:

- The VCS voice application opens a SIP session to the voice service gateway. Then, audio together with PTT and SQU information is transmitted via RTP (according to the WG-67 definitions). The voice application within the aircraft opens a similar session (introduced as Control dialogue), but encodes messages in a different way in order to reduce the datagram size of exchanged messages. Audio together with PTT and SQU information is transmitted via e.g., RTP or other means of audio stream encapsulation. This is represented in the following figure.

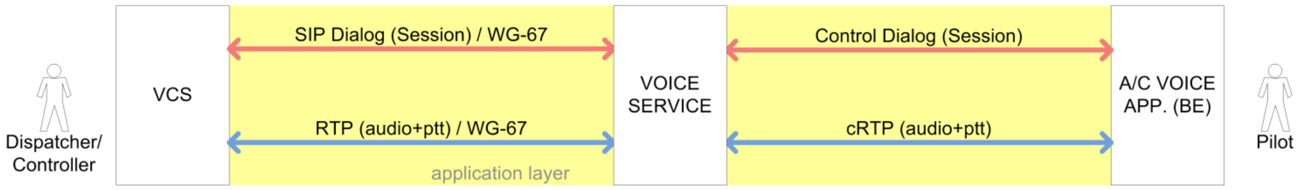

Figure 9-4: Application layer sessions

9.1.2.1 Service Access

Joining a sector from the airborne part requires human interaction via a control element (e.g., control display unit) by the pilot. Changing or 'tuning' to another sector generates a join message sent from the voice back-end to the ground voice service entities. The Sector Floor Control provides a unique PTT ID and the FWD Link Voice Gateway announces, in the event that multicast is used on the FWD link, the corresponding IP multicast address.

Service access from ground based entities is similar except messages being exchanged are SIP methods. Basically, a Sector Floor Control establishes sessions to each FWD/RTN Link

Voice Gateway that belongs to a sector. The number of voice gateways depends on how many different beams cover a certain sector. At the VCS, a controller typically selects the sector via the user interface at the controller working position, which triggers a SIP session setup towards the Sector Floor Control. Then, unique PTT ID will be provided by the Sector Floor Control, as part of the answer message. Further it may distribute all aircraft IDs to the VCS via SIP NOTIFY messages. Such IDs might be used by the VCS to address an aircraft directly.

9.1.2.2 Speaker Access and Arbitration

The Sector Floor Control connects VCSs with each aircraft that has joined this sector: It virtually represents a VHF radio channel of a single sector.

In case a party-line feature must be provided, the Sector Floor Control performs re-transmission of the received audio stream (RTN link) to all connected FWD Link Voice Gateways. Otherwise, only signalling (L3 datagram) messages are used in order to inform participants about actual speakers (ground based or airborne). Such full duplex capability allows, apart from the party-line service, the possibility of overriding a speaker, which can be seen as key new feature compared to legacy VHF communication.

Satellite communication adds additional propagation delay compared to ground-based communication systems. Therefore, the reaction of the system to a speaker’s request is different compared to VHF communication. To overcome this deficiency, additional features need to be implemented in the aircraft voice application and the FWD Link Voice Gateway which may comprise audio buffering or an acoustic feedback to the speaker,saying that the audio transmission is currently blocked.

9.1.2.3 Priority Interruption

Priority interruption at speaker level of normal radio communication is provided by the Sector Floor Control and may occur any time a priority PTT (ID together with a priority flag set) arrives at the Sector Floor Control. In the event that FWD link streaming resources have already been requested, the ongoing audio stream will be interrupted by the new one with higher priority. If new resources are required, the present one are released and the new one are requested in parallel.

9.1.2.4 Handover

During a handover, two cases (depending on the type of voice service) are envisaged:

- For multicast voice services (forward link), during HO execution the multicast flow must be transmitted simultaneously by both carriers/GS entities. The voice application shall be able to handle these duplicated flows.
- For unicast services, two approaches can be used:
    - Use generic IP mobility mechanisms (RFC3775).
    - Perform application based management of mobility, re-registering to the voice IP application server.

It should be noted that, during a handover, the voice application on-board the aircraft is always accessible either through the old or through the new link, as during a certain time both links are active in parallel. This can be exploited at application level to provide a seamless voice service, especially if standard IP mobility mechanisms do not provide enough performance.

In any case, the voice application should be able to handle (by using appropriate buffers) the differences in path delay associated with the different routes during the HO.

9.2 Integration with overall network layer mobility concept

9.2.1 ATN/IPS

The ATN/IPS protocol stack bases its mobility on Mobile IPv6 (MIPv6), described in RFC3775. The main mobility related elements and their functions are briefly described hereafter:

- MN (Mobile Node): It is an end node located onboard an aircraft implementing MIPv6 and attached to the UT.
- AGR (Air/Ground Router): It is a MIPv6 router acting as the gateway to the ground network for any MN. It is an element of the GES.
- HA (Home Agent): It is the entity in charge of controlling the end-to-end routing. It is managed by a Mobility Service Provider (MSP).
- GGR (Ground/Ground Router): It is an IPv6 ground router that provides interconnection between end networks (FRS networks, air controller networks, etc.)
- CN (Correspondent Node): It is an end node located at ground dependencies. It maintains application level conversations with the MN.

The MN is end-to-end accessible by the home address (HoA), which is an address belonging to the home network prefix allocated in the MSP and managed by the HA. This address is used by the CN to access the MN. On the other hand, the MN changes its Care-of Address (CoA, a global routable address but, in principle, not known by the CN) as it moves. Hence, the MN has to register its new CoA to the HA whenever it changes.

In an HO procedure, just the MN, the AGR, and the HA are involved. The idea behind the ATN/IPS mobility is as follows: Each AGR periodically advertises to the air interface its own network prefix. Once connected to an ANTARES system, aircraft receive these advertisements and configure its CoA addressing. Finally, the MN registers its new CoA with the HA and becomes reachable through this address. Hence, no routing exchanges are needed in the ground network.

The process is detailed in the following diagram, for the particular case of stateless address auto-configuration.

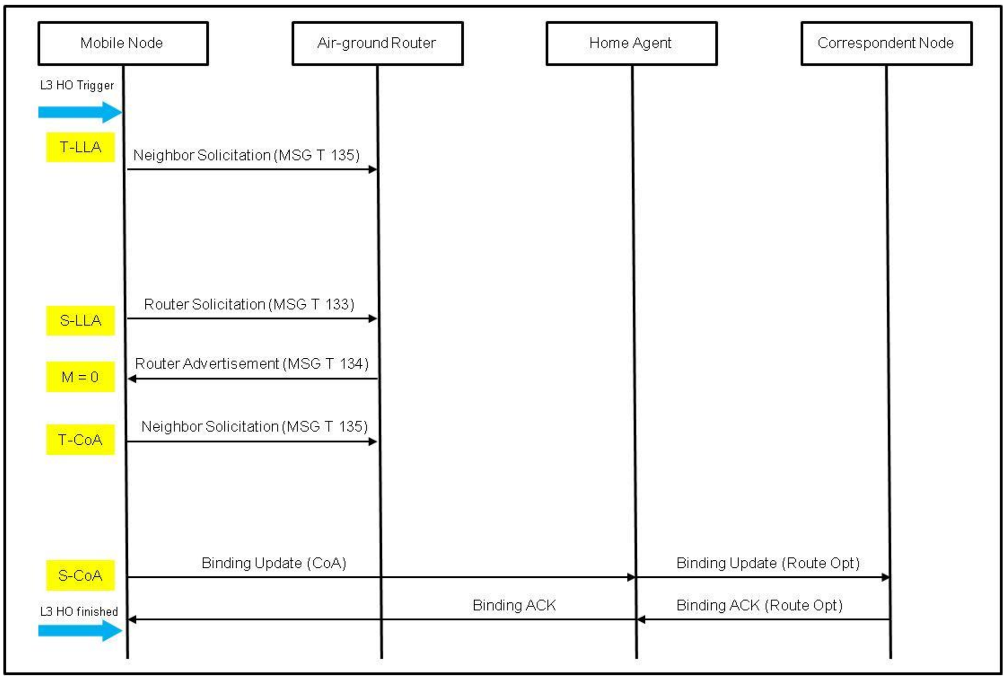

Figure 9-5: MIPv6 HO dialogue (stateless autoconfiguration)

In order to trigger the L3 handover, the AGR may transmit an RA which contains the new AGR network prefix upon L2 handover detection. After movement detection, the HO process from a network layer point of view is summarized hereafter:

- The MN generates its own link-local address (LLA) by appending an interface identifier to the link-local prefix. Generally before a Tentative LLA (T-LLA) can be assigned and used, the mobile node must verify that this address is not already in use by another mobile node. Therefore the aircraft MN must verify the uniqueness of its T-LLA by performing Duplicate Address Detection (by sending a NS message, which should receive no NA in response).
- The mobile node may perform a Router Discovery to discover the new AGR and prefixes on the new link by multicasting to all routers a Router Solicitation message with its selected LLA as the source address (S-LLA). The new AGR returns a Router Advertisement message back to the mobile node in response to the Router Solicitation message.
- The mobile node acquires its CoA through conventional IPv6 mechanisms, such as stateless or stateful autoconfiguration. In the event of stateful autoconfiguration (M bit set to zero in the RA message), the mobile node uses the prefix information included in the RA message to form a tentativeCoA (T-CoA).
- Again, the aircraft MN should verify the uniqueness of its CoA by performing a Duplicate Address Detection (by sending a NS message, which should receive no NA in response).
- Hence, the HA has to update its address translation table (known as the binding table). This is done by the MN, which registers its selected CoA (S-CoA) with the HA by forwarding a binding update packet (BU), acknowledged by the HA with a binding acknowledge (BA).

9.2.2 ATN/OSI

ATN/IPS bases its mobility procedure on changing the MN addressing and registering these changes with an MSP. On the contrary, ATN/OSI bases its mobility procedure on routing.

Each aircraft uses a certain fixed L3 address to address the airborne equipment. This addressing does not change as the MN moves. Instead, the MN registers the route to its airborne prefix with AGRs, and the AGRs advertise the end networks they have access to.

9.3 Security

The CS does not support specific security features mainly because,from a safety point of view,it is not acceptable for the satellite system to discard data even if it is suspected to be invalid or rogue.

Any security mechanisms should thus be implemented end-to-end by upper layers. In any case, the CS is designed in such a way that these mechanisms can be supported transparently.

END OF DOCUMENT

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