# Specification

Draft ANTARES Communication Standard Technical Specification

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# ANTARES

## *Communication Standard Technical* Specification

## DRAFT VERSION

**(DRL N°: D018B)**

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| Draft01 | 20/03/2012 | First draft | Indra Team |

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# 1. INTRODUCTION

This document, named Communication Standard Technical Specification, has been issued in the scope of WP2 of the ANTARES project and integrates the work performed by the ANTARES WP2 partners.

The main objective of the ANTARES project is the definition of a new Air Traffic Services (ATS) and Airline Operational Control (AOC) satellite Communications Standard and an associated system implementation that allows seamless operation with terrestrial standards.

The new satellite-based Communication Standard, covered by this document, specifies the physical and link layers of the protocol stack, including the mechanisms for signalling between physical entities using the Communication Standard. The Communication Standard specification addresses the user, control and management planes of the standardised interfaces.

**NOTE**

The current version of this document is a **DRAFT version** that reflects work done so far within the ANTARES project. However, as a consequence of future CS consolidation and refinement activities, relevant revisions and updates can be expected, especially in the following areas:

- System architecture
- Network layer functions
- Control layer functions, as logon, handover, ACM.
- Multiple Access
- Management functions
- Signalling functions
- Multicast control procedures

In this sense, a notice **To be revised in B2** has been added throughout the document to those sections or requirements where major updates are likely during ANTARES B2 phase.

## 1.1 Scope

The present document reports the Communication Standard Technical Specification for the provision of ATS and AOC services through satellite-based communications. The present Technical Specification specifies the physical and link layer for the user, control and management planes.

## 1.2 Structure of the document

This document is structured as follows:

- Section 1 presents the introduction to the document
- Section 2 compiles the definition, symbols, acronyms and conventions used in the document

- Section 3 reports the applicable and reference documents
- Section 4 reports the satellite communication system overview, identifying the entities involved in the communication.
- Section 5 provides an overview of the user, control and management planes
- Section 6 provides the technical specifications for user, control and management plane external interfaces
- Section 7 addresses the technical specification for the frequency band, multiple access and system carriers definition, channels and other general requirements
- Section 8 reports the technical specification for the user plane
- Section 9 reports the technical specification for the control plane
- Section 10 provides the technical specification for the management plane
- Section 11 identifies the technical specifications for the physical layer countermeasures against propagation channel impairments and RF interferences, applicable to user and control planes
- Section 12 provides the descriptions of the signalling structures

  In addition to these sections, the communication standard technical specification also contains the following annexes:

- Annex A provides the reference performances of PER figures
- Annex B provides the parity bit accumulators for IRA LDPC codes and the LDPC encoding procedure
- Annex C provides the forward link bit interleaving matrix (empty annex)
- Annex D provides the internal turbo code interleaving algorithm
- Annex E provides the return link bit interleaving matrix (empty annex)
- Annex F provide the HO procedures
- Annex G provides the G2G signalling specification.
- Annex H presents ACM mechanism implementation guidelines.

# 2. DEFINITIONS, SYMBOLS, ABBREVIATIONS AND CONVENTIONS

## 2.1 Definitions

### *2.1.1 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)
  - **Fixed link:** communication link between satellite and Ground Earth Station (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: CNLP (ATN/OSI), 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 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 they 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. It includes functions as MAC address resolution, IP header compression and support for mobility related events (as required for ATN/OSI).

- The following definitions are also applicable to the present document (see also Figure 2-1):
  - **NSDU** (Network Service data Unit) **or Segment**: A NSDU is the data unit posted by the transport layer to L3. It is also named Segment.
  - **NPDU** (Network Protocol Data Unit) **or Packet:** A 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). In some cases (for ATN/OSI or when ATN/IPS header compression is disabled), it is equivalent to a NPDU. 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:** A LSDU is the data unit posted by the network adaptation layer (L2.5) to L2 at the LSAP.
  - **LPDU** (Link Protocol Data Unit): A LPDU is the data unit forwarded to L1. Its payload contains fragments of one or several LSDUs. From a L1 point of view, it is equivalent to a PSDU.
  - **PSAP** (Physical Service Access Point): The PSAP is 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 also referred to as frame throughout the document.
- **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.

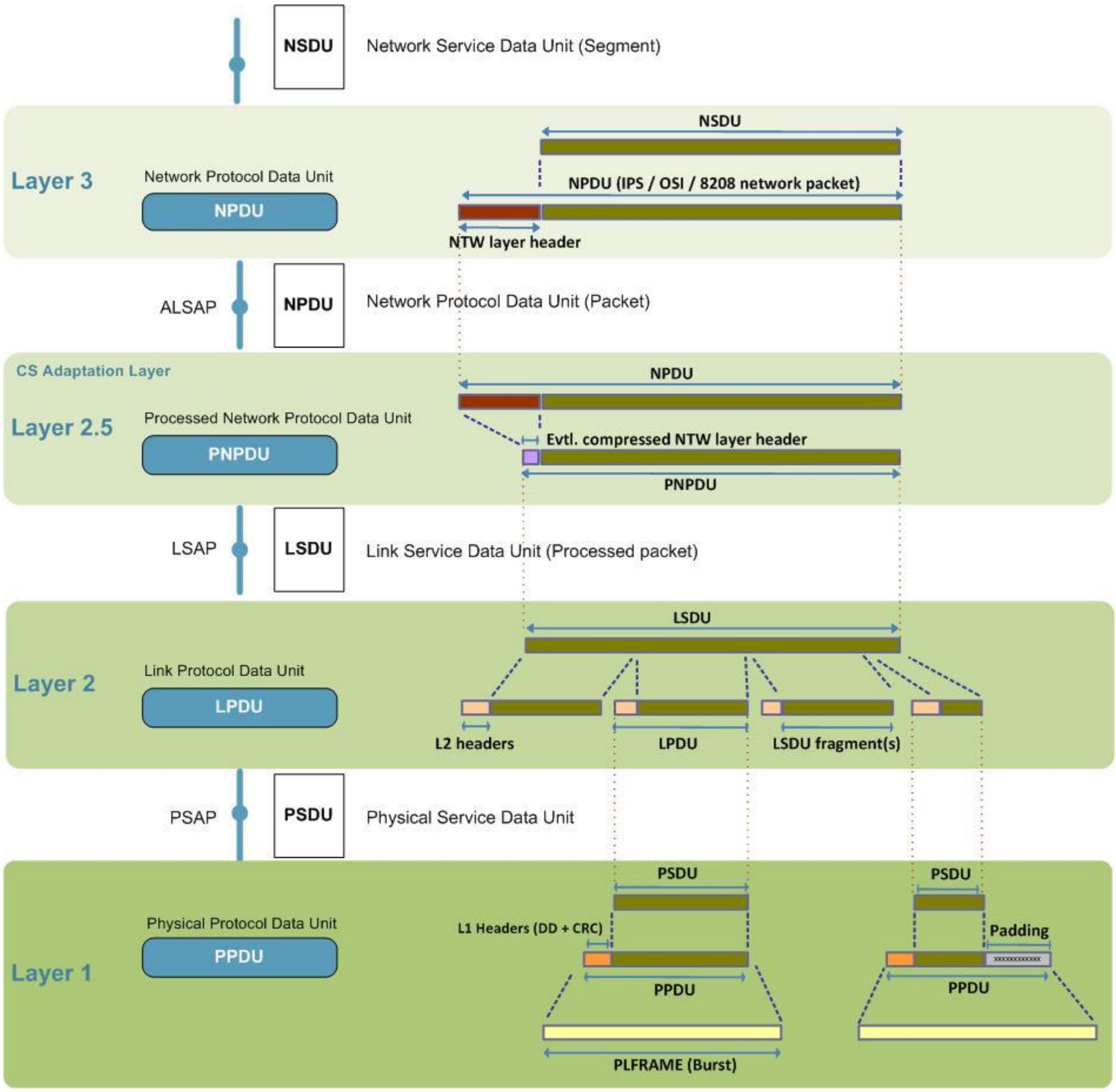



**Figure 2-1: Introducing layer model terminology[1]**

[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.

- **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.

### *2.1.2 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. A GES will typically user resources within a single beam of a single satellite, but this is not mandatory. A physical site may accommodate several logical GESs, and GESs may share Earth station infrastructure.
- **Network Control Centre (NCC):** The network entity that performs the control of the system resources and elements. It is expected that this entity covers neither the Satellite Control Centre nor the Satellite Operation Centre, but it includes the CSMa (Communication Spectrum Monitoring agent).
- **Network Management Centre (NMC):** The network entity that performs the management of the system resources and elements. It is expected that this entity covers neither the Satellite Control Centre nor the Satellite Operation Centre.
- **User Terminal (also called Airborne Earth Station - AES):** The avionics onboard the aircraft that implements the communication protocol and provides the interface to other on-board elements via an on-board network.

### *2.1.3 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 between updates beyond which a service interruption is declared.
- **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 to improve the link availability and thus the overall system availability by providing (at least) two links thanks to redundant elements and allowing to switch from one link to the other one (or combine the two) by choosing the best configuration/link available at a certain time. This solution is mainly used as 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.

## 2.2 Symbols

| Symbol | Definition |
|---|---|
| $f_N$ | Nyquist frequency |
| I | In-phase component |
| $K_{ldpc}$ | Uncoded LDPC block Size / Number of bits of FWD_BB_FRAME |
| $N_{ldpc}$ | Coded LDPC block Size / Number of bits of FWD_FECFRAME |
| $N_{FWD\_DD}$ | Number of bytes of FWD_DD (FWD Data Descriptor) header |
| $N_{FWD\_PSDU}$ | Number of bytes of the incoming FWD_PSDU |
| $N_{FWD\_BB\_DFL}$ | Number of bytes of FWD_BB_DATAFIELD |
| $N_{FWD\_CRC}$ | Number of bits FWD_CRC_32 field |
| $N_{FWD\_PPDU}$ | Number of bits of FWD_PPDU |
| $N_{FWD\_S\_PPDU}$ | Number of bits of Scrambled PPDU |
| $N_{FWD\_XFECFRAME}$ | Number of symbols (complex values) per FWD_XFECFRAME |
| $N_{FWD\_I\_XFRAME}$ | Number of symbols per FWD_I_XFRAME |
| $N_{FWD\_PR}$ | Number of FWD Preamble symbols |
| $N_{FWD\_PO}$ | Number of FWD Postamble symbols |
| $N_{FWD\_H}$ | Number of symbols of PLHEADER |
| $N_{FWD\_S}$ | Number of pilot symbols in a Pilot Block (PB) |

| Symbol | Definition |
|---|---|
| $N_{PB}$ | Number of Pilot Blocks per FWD_PLFRAME |
| $N_{FWD\_FRAG}$ | Number of Fragments per FWD:PLFRAME |
| $h_0, h_1, \ldots, h_{15}$ | FWD_DD Header bits |
| $i_0, i_1, \ldots, i_{Kldpc-1}$ | LDPC code information bits |
| $p_0, p_1, \ldots, p_{Nldpc-Kldpc-1}$ | LDPC code parity bits |
| $s_0, s_1, s_2$ | MODCOD_ID bits |
| $N_{FWD}$ | Number of rows of FWD Bit Interleaver |
| $M_{FWD}$ | Number of columns of FWD Bit Interleaver |
| $D_{FWD}$ | Number of rows of FWD Symbol Interleaver |
| $P_{FWD}$ | Number of columns of FWD Symbol Interleaver |
| Q | Quadrature component |
| R | Code rate |
| $R_1$ | First (inner) ring Radius of APSK modulation |
| $R_2$ | Second ring Radius of APSK modulation |
| $T_s$ | Symbol period |
| $\alpha$ | Roll-off factor |
| $\gamma$ | Constellation radius ratio |
| $\eta_{MOD}$ | Number of transmitted bits per constellation symbol |
| $N_{RTN\_DD}$ | Number of bytes of RTN_DD (RTN Data Descriptor) header |
| $N_{RTN\_PSDU}$ | Number of bytes of the incoming RTN_PSDU |
| $N_{RTN\_BB\_DFL}$ | Number of bytes of RTN_BB_DATAFIELD |
| $N_{RTN\_CRC}$ | Number of bits FWD_CRC_32 field |
| $N_{RTN\_BBFRAME}$ | Number of bits of RTN_BBFRAME |
| $N_{RTN\_S\_BBFRAME}$ | Number of bits of Scrambled BBFRAME / Uncoded TCC block size |
| $N_{RTN\_FECFRAME}$ | Number of bits of FECFRAME / Coded TCC block size (including tail bits) |
| $N_{RTN\_PS}$ | Number of Pilot bits transmitted through the Auxiliary channel |
| $N_{RTN\_DCH}$ | Number of symbols of Data Channel (BPSK mapped) |
| $N_{RTN\_ACH}$ | Number of symbols of Auciliary Channel (BPSK mapped) |
| $C_{ch,d}$ | Channelization code of Data Channel (RTN_DCH) |
| $C_{ch,c}$ | Channelization code of Auxiliary Channel (RTN_ACH) |
| $C_{ch,SF,k}$ | Channelization code identifier |
| $C_{Scram}$ | Complex Scrambling code |
| $\beta_2$ | Auxiliary Channel Gain Factor |
| $N_{RTN}$ | Number of rows of FWD Bit Interleaver |
| $M_{RTN}$ | Number of columns of FWD Bit Interleaver |
| G(D) | Transfer function of the 16-state constituent code for PCCC |
| $n_0(D)$ | First Forward Recursive Systematic Convolutional Generator polynomial |
| $n_1(D)$ | Second Forward Recursive Systematic Convolutional Generator polynomial |
| $n_2(D)$ | Third Forward Recursive Systematic Convolutional Generator polynomial |
| d(D) | Backward Recursive Systematic Convolutional Generator |

| Symbol | Definition |
|---|---|
| | polynomial |
| $x(0), x(1), \ldots, x(N_{RTN\_S\_BBFRAME}-1)$ | TCC (PCCC) code information bits |
| $y_1(0), y_1(1), \ldots, y_1(N_{RTN\_S\_BBFRAME}-1)$ | TCC (PCCC) parity bits of the first encoder (without tail bits) |
| $y'_1(0), y'_1(1), \ldots, y'_1(N_{RTN\_S\_BBFRAME}-1)$ | TCC (PCCC) parity bits of the second encoder (without tail bits) |
| $l_0, l_1, \ldots, l_{15}$ | RTN_DD Header bits |

**Table 2-1: Symbols**

## 2.3 Acronym list

| Acronym | Definition |
|---|---|
| 16-APSK | 16 Amplitude Phase Shift Keying |
| 3GPP | 3rd Generation Partnership Project |
| 3GPP2 | 3rd Generation Partnership Project 2 |
| 8-PSK | 8 Phase Shift Keying |
| A-CDMA | Asynchronous Code Division Multiple Access |
| ACK | Acknowledgement |
| ACM | Adaptive Coding and Modulation |
| ACQCH | Acquisition Channel |
| AD | Applicable Document |
| AES | Aeronautical Earth Station / Advanced Encryption Standard |
| AF | Assured Forwarding / Address Format |
| AFDX | Avionics Full-Duplex Switched Ethernet |
| AMS(R)S | Aeronautical Mobile Satellite (en Route) Service |
| AOC | Airline Operational Control |
| APSK | Amplitude and Phase-Shift Keying |
| A-R | Airborne Router |
| ARQ | Automatic Repeat reQuest |
| ARS | Administrative Region Selector |
| AS | Autonomous System |
| ATM | Air Traffic Management, Asynchronous Transfer Mode |
| ATN | Aeronautical Telecommunication Network |
| ATN/IPS | ATN/ Internet Protocol Suite |
| ATN/OSI | ATN/ Open Systems Interconnection |
| ATS | Air Traffic Services |
| AWGN | Additive White Gaussian Noise |
| BB | Base Band |
| BCCH | Broadcast Control Channel |

| Acronym | Definition |
|---|---|
| BE | Back-End |
| BER | Bit Error Rate |
| BGP | Border Gateway Protocol |
| BPSK | Binary Phase Shift Keying |
| BTCH | Broadcast/Multicast Traffic Channel |
| CBR | Constant Bit Rate |
| CC | Congestion Control |
| CCSDS | Consultative Committee for Space Data Systems |
| CDMA | Code Division Multiple Access |
| CLNP | Connectionless Network Protocol |
| COCR | Communications Operation Concept and Requirements |
| CoS | Class of Service |
| CRC | Cyclic Redundancy Checksum |
| CS | Communication Standard |
| CSMa | Communications Spectrum Monitoring agents |
| DA | Data Aided |
| DAMA | Demand Assigned Multiple Access |
| DD | Decision Directed |
| DDF | Design Definition File |
| DJF | Design Justification File |
| DiffServ | Differentiated Services |
| DSCP | DiffServ Code Point |
| DS-SS | Direct Sequence Spread Spectrum |
| UTCH | Unicast Traffic Channel |
| EATMN | European Air Traffic Management Network |
| EATMS | European Air Traffic Management System |
| ECAC | European Civil Aviation Conference |
| EIRP | Equivalent Isotropic Radiated Power |
| ESP | Encapsulating Security Payload |
| E-SSA | Enhanced Spread Spectrum ALOHA |
| ET | Expiration Time |
| FC | Fragment Counter |
| FCAPS | Fault, Configuration, Accounting, Performance and Security |
| FCH | Forward Channel |
| FCI | Future Communications Infrastructure |
| FUCCH | Forward Unicast Control Channel |
| FEC | Forward Error Correction |
| FID | Flow ID |
| FIFO | First In First Out |

| Acronym | Definition |
|---|---|
| FL | Forward Link |
| FLC | Forward Link Carrier |
| FRS | Future Radio System |
| FSS | Fixed Satellite Service |
| FW | Forward |
| FWD | Forward |
| G/G-R | Ground-Ground Router |
| GEO | Geostationary Orbit |
| GES | Ground Earth Station |
| GMP | Group Management Protocol |
| GS | Ground Segment |
| GSE | Generic Stream Encapsulation |
| GW | Gateway |
| HA | Home Agent |
| HO | Handover |
| HoA | Home Address |
| HPA | High-Power Amplifier |
| IBO | Input Back-Off |
| ICAO | International Civil Aviation Organization |
| ID | Identifier |
| IDRP | Inter-Domain Routing Protocol |
| IF | Interface |
| IFR | Instrument Flying Rules |
| IGMP | Internet Group Management Protocol |
| IP | Internet Protocol |
| IPS | Internet Protocol Suite |
| IRA | Irregular Repeat and Accumulate |
| ISH | Intermediate System Hello |
| ITU | International Telecommunication Union |
| L1 | Layer 1 – Physical layer |
| L2 | Layer 2 – Link Layer |
| L3 | Layer 3 – Network Layer |
| L4 | Layer 4 – Transport Layer |
| LAN | Local Area Network |
| LDP | Link Data Protocol |
| LDPC | Low Density Parity Check |
| LDPU | Link Protocol Data Unit |
| LGA | Low-Gain Antenna |
| LHCP | Left Hand Circular Polarisation |

| Acronym | Definition |
|---|---|
| LIR | Local Internet Registry |
| LREF | Local Reference |
| LPDU | Link Protocol Data Unit |
| LSDU | Link Service Data Unit |
| MA | Multiple Access |
| MAC | Medium Access Control |
| MCDU | Multi-Function Control and Display Unit |
| MEO | Medium Earth Orbit |
| MF-TDMA | Multi Frequency Time Division Multiple Access |
| MIB | Management Information Base |
| MN | Mobile Node |
| MODCOD | MODulation and CODification |
| MSB | Most Significant Bit |
| MSP | Mobile Service Provider |
| MTU | Maximum Transmission Unit |
| NACH | Network Access Channel |
| NACK | Negative Acknowledgement |
| NCC | Network Control Centre |
| NCR | Network Clock Reference |
| NMC | Network Management Centre |
| NMS | Network Management System |
| NSAP | Network Service Access Point |
| NTW | Network |
| OBO | Output Back-Off |
| OBP | On-board Processor |
| OSI | Open Systems Interconnection |
| OVSF | Orthogonal Variable Spreading Factor |
| PC | Packet Counter |
| PCCC | Parallel Concatenated Convolutional Code |
| PDU | Protocol Data Unit |
| PER | Packet Error Rate |
| PHB | Per-Hop-Behaviour |
| PIAC | Peak Instantaneous Aircraft Count |
| PID | Packet ID |
| PKI | Public Key Infrastructure |
| PL | Physical Layer |
| PPDU | Physical Protocol Data Unit |
| PRACH | Physical Random Access CHannel |
| PSAP | Physical Service Access Point |

| Acronym | Definition |
|---|---|
| PSDU | Physical Service Data Unit |
| PSK | Phase-Shift Keying |
| PT | Payload Type |
| QoS | Quality of Service |
| QPSK | Quadrature Phase Shift Keying |
| RA | Random Access |
| RACCH | Random Access Control Channel |
| RACH | Random Access Channel |
| RAMS | Reliability, Availability, Maintainability and Safety |
| RD | Reference Document |
| RUCCH | Return Unicast Control Channel |
| RF | Radio Frequency |
| RFU | Reserved for Future Use |
| RHCP | Right-Hand Circular Polarisation |
| RIR | Regional Internet Registry |
| RL | Return Link |
| RLC | Return Link Carrier |
| ROHC | RObust Header Compression |
| RRAC | Return Random Access Carrier |
| RRM | Radio Resource Management |
| RSC | Recursive Systematic Convolutional |
| RTC | Return Link Carrier |
| RT | Return |
| RTN | Return |
| RTP | Real-Time Transport Protocol |
| RTT | Round-Trip Time |
| SACK | Selective Acknowledgement |
| SCC | Satellite Control Centre |
| SCCH | Synchronisation Control Channel |
| SDU | Service Data Unit |
| SF | Spreading Factor |
| SNDCF | Sub-Network Dependent Convergence Functions |
| SNDU | Sub-Network Data Unit |
| SNIR | Signal to Noise plus Interference Ratio |
| SNMP | Simple Network Management Protocol |
| SNR | Signal to Noise Ratio |
| SOC | Satellite Operation Centre |
| SPS | Space Segment |
| SRD | System Requirements Document |

| Acronym | Definition |
|---|---|
| SREJ | Selective Reject |
| 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 Code |
| TCP | Transmission Control Protocol |
| TD95 | Transit Delay 95-th percentile |
| TDMA | Time Division Multiple Access |
| TS | Transport Stream / Timeslot |
| T-WAN | Terrestrial Wide Area Network |
| TX | Transmission |
| UDP | User Datagram Protocol |
| ULPC | Up-Link Power Control |
| UT | User Terminal |
| UW | Unique Word |
| WAN | Wide Area Network |

## 2.4 Specification numbering

The communication standard specifications are identified by a unique alphanumeric code with the following format:

CSREQ-NNNN

where:

- CSREQ is common for all the specifications
- NNNN stands for the specification number

## 2.5 Verb tense

In the present document, the following definitions apply:

- “Shall”: the specifications formulated as “shall” are mandatory specifications and must be implemented.
- “May”: The requirements formulated as “may” express a permissible practise or action.
- “Will”: The requirements formulated as “will” denotes a provision or an intention in connection with this requirement.

# 3. APPLICABLE AND REFERENCE DOCUMENTS

## 3.1 Applicable documents

| ID | Document Number | Title | Issue | Date |
|---|---|---|---|---|
| [AD-01] | Iris-B-OS-RSD-0002-ESA | Iris Phase 2.1 System Requirements Document | 1.4 | 06/09/2010 |

**Table 3-1: Applicable documents**

## 3.2 Reference documents

| ID | Document Number | Title | Issue | Date |
|---|---|---|---|---|
| [RD-01] | RFC 2578 | Structure of Management Information Version 2 (SMIv2) | | 04/1999 |
| [RD-02] | RFC 3418 | Management Information Base (MIB) for the Simple Network Management Protocol (SNMP) | | 12/2002 |
| [RD-03] | RFC 2863 | The Interfaces Group MIB | | 06/2000 |
| [RD-04] | RFC 3877 | Alarm Management Information Base (MIB) | | 09/2004 |
| [RD-05] | Doc 9896-AN/469 | Manual for the ATN using IPS Standards and Protocols<br>1st edition | | |
| [RD-06] | RFC 1981 | Path MTU Discovery for IP version 6 | | 08/1996 |
| [RD-07] | RFC 4291 | IP Version 6 Addressing Architecture | | 02/2006 |
| [RD-08] | RFC 4271 | A Border Gateway Protocol 4 (BGP-4) | | 01/2006 |
| [RD-09] | RFC 2858 | Multiprotocol Extensions for BGP-4 | | 06/2000 |
| [RD-10] | RFC 4443 | Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification | | 03/2006 |
| [RD-11] | RFC 2475 | An architecture for Differentiated Services | | 12/1998 |
| [RD-12] | RFC 2597 | Assured Forwarding PHB Group | | 06/1999 |
| [RD-13] | RFC 5795 | The RObust Header Compression (ROHC) Framework | | 03/2010 |
| [RD-14] | RFC 4995 | RObust Header Compression (ROHC) : A profile for TCP/IP (ROHC-TCP) | | 07/2007 |
| [RD-15] | RFC 3095 | RObust Header Compression (ROHC) : Framework and four profiles : RTP, UDP, ESP, and uncompressed | | 07/2001 |
| [RD-16] | RFC 3843 | RObust Header Compression (ROHC): A Compression Profile for IP | | 06/2004 |
| [RD-17] | ITU-R P.618-9 | Propagation data and prediction methods required for the design of Earth-space telecommunication systems | | 08/2007 |

| ID | Document Number | Title | Issue | Date |
|---|---|---|---|---|
| [RD-18] | RFC 3411 | An Architecture for Describing Simple Network Management Protocol (SNMP) Management Frameworks | | 10/2002 |
| [RD-19] | RFC4862 | IPv6 Stateless Address Autoconfiguration | | 9/2007 |
| [RD-20] | ICAO Doc 9705/AN956 | ATN Standards and Recommended Practices (SARPs). Manual of Technical Provisions for the ATN. | 3.0 | |
| [RD-21] | | ITU Radio Regulations, Edition 2008 | | 2008 |

**Table 3-2: Reference documents**

# 4. COMMUNICATION STANDARD OVERVIEW

## 4.1 System reference model

The following figure illustrates the system reference model.

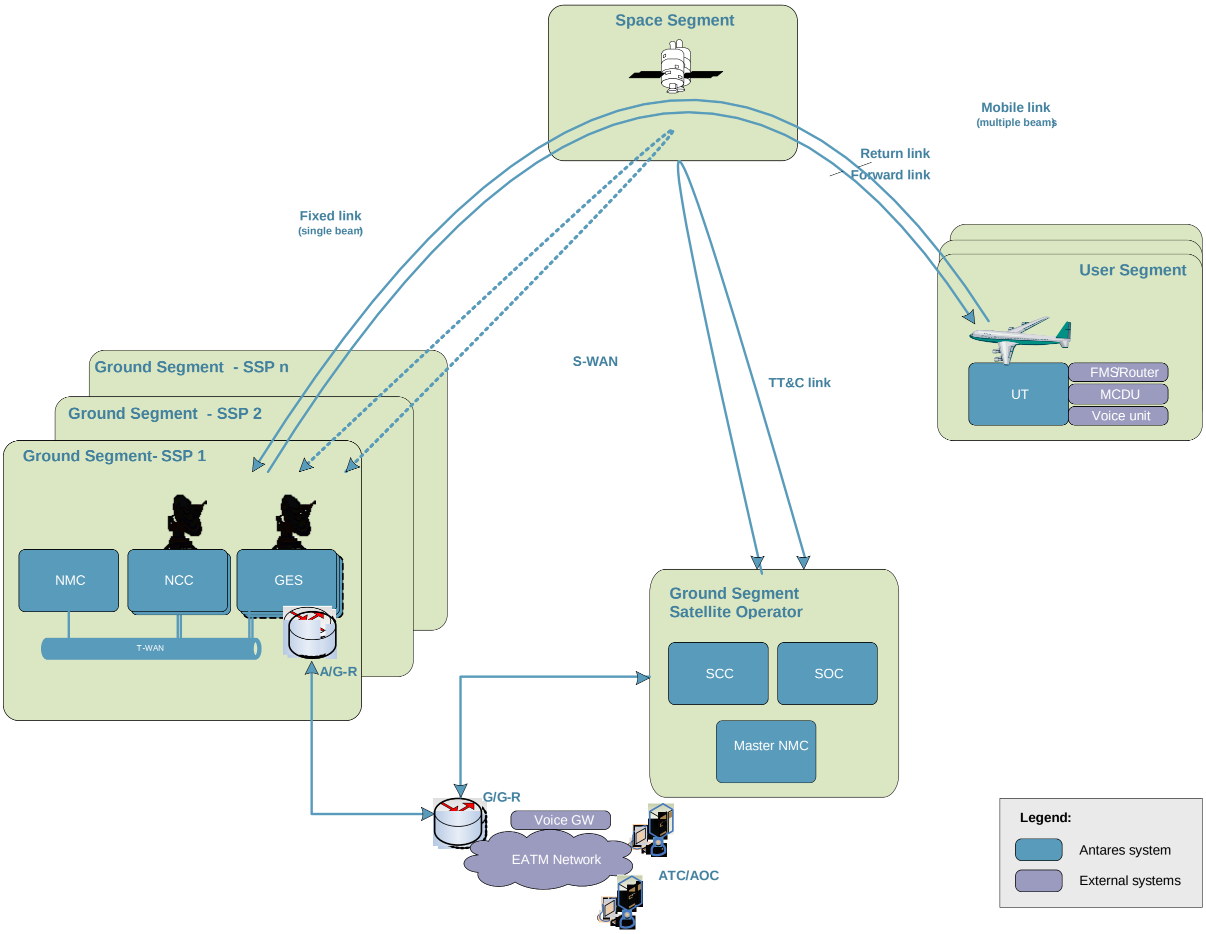



**Figure 4-1: System reference model**

This figure identifies the physical system components of the satellite communication network as well as the interfaces with the ATM network and the end users (ATC and AOC). The system reference architecture represents the most general system scenario where different Satellite Service Providers (SSPs) participate in the ATM service provision. In this general system configuration each SSP accesses the satellite communication resources by means of multiple stations providing the Tx/Rx communication capabilities. Depending on the particular operational requirements coming from the service providers, a simplified ground segment topology could be envisaged which is characterised by only one SSP accessing the satellite link via a single station. This scenario may be considered as sub-case of the most general one described above.

The satellite communication system reference architecture used for the development of the communication standard is composed of the three following segments:

- **The Space Segment (SPS)**. The SPS is composed of several satellites carrying dedicated ATM payloads operating in the AMS(R)S frequency band (portion of L-band spectrum reserved for aeronautical safety services) in the mobile link, whilst C, Ku or Ka frequency band is mainly used for the fixed link, being Ku band the most likely one.

The on-board ATM payloads are transparent, which means that they are not equipped with On-Board Processing (OBP) capabilities. In the mobile link, the SPS is a multi-beam system, while for the fixed link, a single beam is considered as reference architecture. For the system reference architecture, hot redundant GEO satellites are considered which may be either co-located in the same orbital position or orbitally separated.

- **The Ground Segment (GS)**. The GS is mainly composed of three types of network entities:
    - **Network Control Centre (NCC)**: the NCC is the network entity responsible for controlling the satellite network. In the system reference architecture, one backup NCC located at a different site for satellite link availability purposes for each active NCC is foreseen.
    - **Ground Earth Station (GES)**: The GES is the network entity that provides the feeder link to the Space segment. The GES makes use of the communication resources assigned to it in order to communicate with the aircraft associated with it, providing voice and data traffic services. The GES also provides an interface with the terrestrial ATM networks.
    - **Network Management Centre (NMC)**: the NMC is the network entity in charge of managing the overall satellite communication network (system resources, system elements, etc) in a centralised way. 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.

  Two possible alternatives applies to control functions in terms of location within Ground Segment elements:
    - Alternative1: control functions that can be Centralized in the NCC.
    - Alternative 2: control functions that can be distributed and collocated with GES.

  In both alternatives the GES is in charge of supporting the transmitting/receiving functionality. In the system reference architecture, multiple GESs are envisaged to adapt the satellite communication system to an operation concept where different administrative and political entities (communication service providers, etc) want to own and operate their facilities with a certain degree of autonomy. In the system reference architecture it is considered that any GES has connectivity to any mobile beam; that is, a GES can manage UTs located in any mobile beam.

  In case of multiple Satellite Service Providers (SSPs) envisaged in the most general system architecture configuration, there can be an additional entity, the **Master NMC**, in charge of allocating resources among the different SSP in a rather static way.

- **The User Segment**. The User Segment is composed of the mobile User Terminals (UTs) (or Aeronautical Earth Stations (AES)), which are the avionics equipment in charge of implementing the communication protocol and providing interface to the other on-board elements via the on-board network. The dimensioning and design of the UT is carried out taking into account several constraints impacting on the final achievable performance. In this respect, constraints on installation (e.g. possible configurations and location of the UT antenna, no need for external active cooling), on regulation, on cost etc. are considered which influence the final UT performance (e.g. HPA power, antenna radiation pattern etc.).

Although not considered for CS aspects, the GS will include the **SCC/SOC** stations in charge of controlling and monitoring the satellites. Communication Spectrum Monitoring agents (CSMa) are in charge of monitoring the forward link (all forward carriers, if needed) and uploading the status of the satellite to the SOC/SCC in order to minimize the processing of satellite events an quickly manage GS switchovers. It shall be deployed in every spot beam.

The GS Elements (NMC, NCC and GES) are interconnected through a Wide Area Network (WAN) supporting the Ground-to-Ground signalling communications, as depicted in the figure. Two different WAN typologies are considered in the system reference architecture:

- **Terrestrial-WAN (T-WAN)**: T-WAN is a terrestrial network used to transport the signalling among the GS Elements.
- **Satellite-WAN (S-WAN)**: S-WAN, also called Feeder-to-Feeder link, is based on interconnecting the GS Elements through satellite links operating in the FSS (Fixed Satellite Service). The S-WAN is used to support the signalling information exchange between the GS Elements.

The WANs are intended to transport control and management signalling among distant GS elements. The management signalling is expected to be carried over the Terrestrial WAN (T-WAN), as the NMS is not expected to be equipped with a satellite station.

For the control signalling exchanged among GS elements, several solutions are identified:

i. No control signalling is exchanged between GS elements and specific mechanism based on AES – GS extra signalling is envisaged.

ii. A highly available WAN (T-WAN + S-WAN) is deployed to connect the GS elements that rely on such WAN for critical information.

iii. A T-WAN or a S-WAN without any special availability requirements is deployed. Then the GS – AES protocol implements extra signalling as in the first solution.

The selection of the most appropriate solution from the above ones is a decision left to the SSP, as it depends on its operational strategy and constraints.

## 4.2 Interfaces covered by the Communication Standard

In the following figure, the basic architecture of an ANTARES system implementation is shown, including interfacing external elements. Internal elements (or a specific layer of an element, in the case of the airborne router Adaptation Layer) which would be part of an ANTARES system implementation are represented in orange, whereas elements (and layers of elements) outside this implementation are represented in blue[2]. The numbered circles represent the interfaces to be specified (partially or fully) by the CS.

This CS does not define a particular communication between potential GS elements like NCC and GES as this is a system-specific implementation aspect. Like some management functions which are not proposed for standardisation in the CS but in other standards, the Antares European System GS specification could also follow the same approach.

The CS also avoids over-specifying the GS entity responsible for interacting with the UT whenever this could be performed in different elements in different system implementations. In the case of the Antares European System implementation, this is covered in GS documentation (including GS DJF, GS functional allocation, GS DDF, etc.). Nevertheless, it may be necessary to specify in the CS certain performance requirements related to the GS that would indirectly imply requirements on the G2G link (if this link exists in a particular system implementation). (See section 19 Annex G: Ground to Ground signalling specification).

[2] The Voice GW may be part of an ANTARES system implementation if CS functionality has to be finally supported by this element (revision pending after MAC decision).

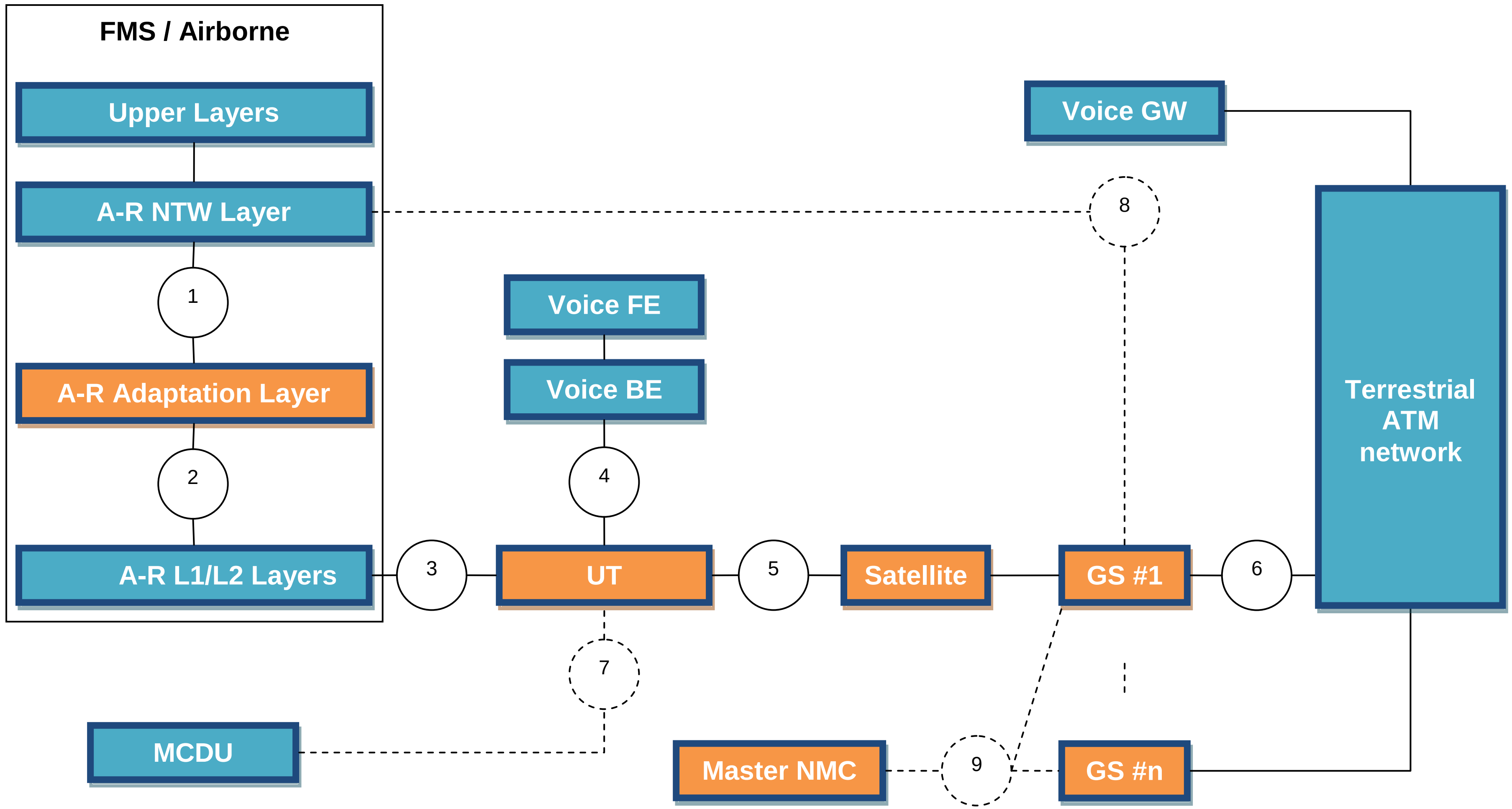



**Figure 4-2: Identification of interfaces specified by the CS**

Two types of interfaces are envisaged:

- Physical interfaces: Interfaces 1 – 6 of the previous figure. These interfaces are represented with solid-lined circles. This implies that the interface is implemented over a direct physical or software interface between the elements/layers.

  The list of physical interfaces is included hereafter:

  (1) **Airborne router Upper Adaptation Interface**: This interface is present only in the case of aircraft supporting the ATN/OSI protocol stack. Although being an ANTARES external interface, it is an airborne router internal interface between the airborne router Adaptation Layer (which belongs to the ANTARES system implementation) and the airborne router Upper Layers (L3 layers and above).

  (2) **Airborne router Lower Adaptation Interface**: Like the airborne router Upper Adaptation Interface, this interface is present only in the case of aircraft supporting the ATN/OSI protocol. It is an ANTARES external interface but a airborne router internal interface, in this case between the airborne router Adaptation Layer and the airborne router L1/L2 Layers.

  (3) **UT Avionics Interface**: This is a physical ANTARES external interface between the UT and the airborne local network. It connects, in principle, with the airborne router.

  (4) **UT Voice Interface**: It is a physical ANTARES external interface between the Voice Back-End (Voice BE) and the UT.

  (5) **UT Satellite Interface**: This is a physical ANTARES internal interface, as it is located between two ANTARES system elements: the UT and the Satellite, which in turn provides connectivity towards the GS.

  (6) **GS Ground Interface**: The GS Ground Interface is a physical ANTARES external interface which represents the interface between the ANTARES GS and the terrestrial ATM network. Via this interface, the ANTARES system will be able to communicate to ground end users (e.g. ATC and AOC centres, etc) and Voice GWs.

- Logical interfaces: Interfaces 7 – 9 of the previous figure. These interfaces are represented as dashed-lined circles. This represents that the interface is implemented as a logical connection/relationship between the elements/layers, although possibly not adjacent or with a direct/physically implemented interface one to each other.

  The list of logical interfaces is presented hereafter:

  (7) **UT Airborne Management Interface**: This is a logical ANTARES external interface between the UT and the MCDU. It is an airborne management interface, providing to the airborne user some management functionalities via its MCDU.

  (8) **GS Airborne Network Layer Interface**: It is a logical ANTARES external interface between the airborne router Network Layer and the GS, for network layer protocols related procedures such as next hop address determination.

  (9) **Master NMC Management Interface**: It is a logical ANTARES internal interface between the Master NMC and different ANTARES GS implementations, which is

in charge of distributing some management information such as general system information or general resource configuration.

# 5. USER, CONTROL AND MANAGEMENT PLANE PROTOCOL STACK OVERVIEW

The following sections present the user, control and management plane protocol stacks.

## 5.1 User plane protocol stack overview

The following diagram shows the user plane protocol stack for the ATN/IPS case.

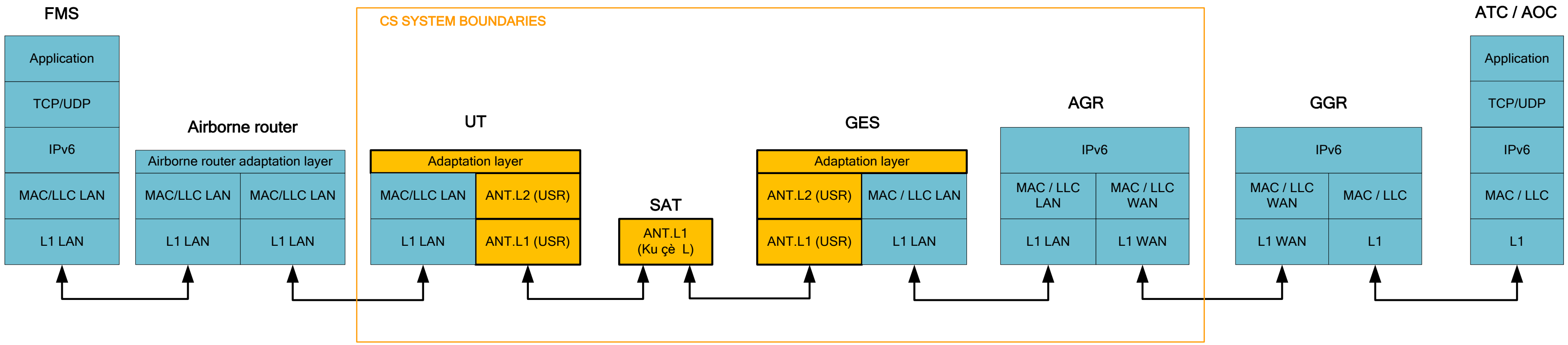



**Figure 5-1: Communication standard user plane protocol stack (end-to-end) – ATN/IPS**

The following diagram shows the user plane protocol stack for the ATN/OSI case in the Legacy mode implementation.

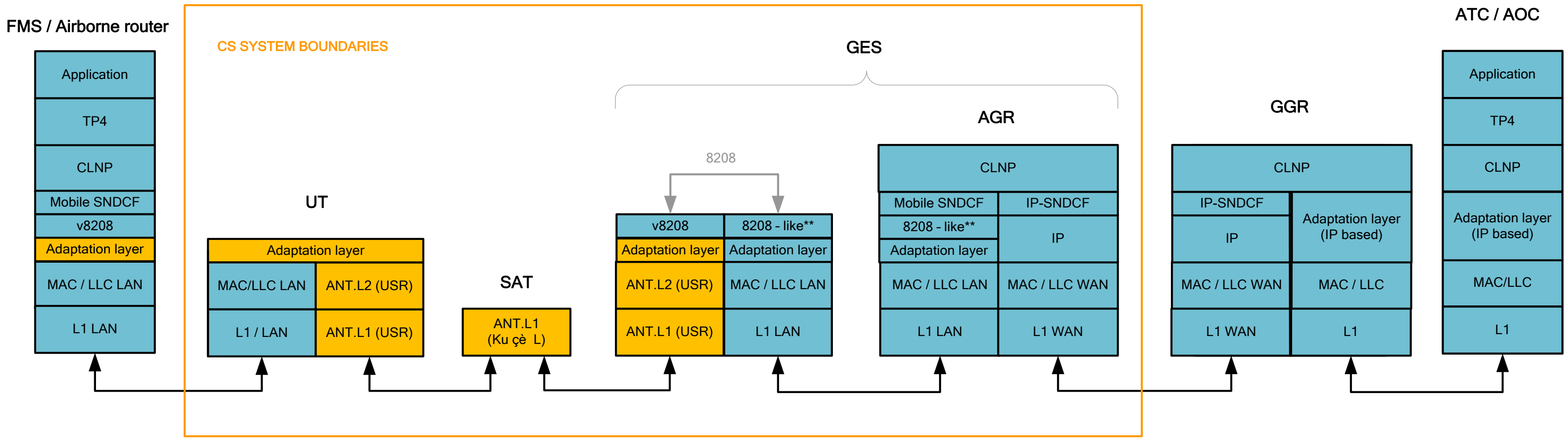



**Figure 5-2: Communication standard user plane protocol stack (end-to-end) – ATN/OSI (Legacy Mode)**

The following diagram shows the user plane protocol stack for the ATN/OSI case in the Iris mode implementation.

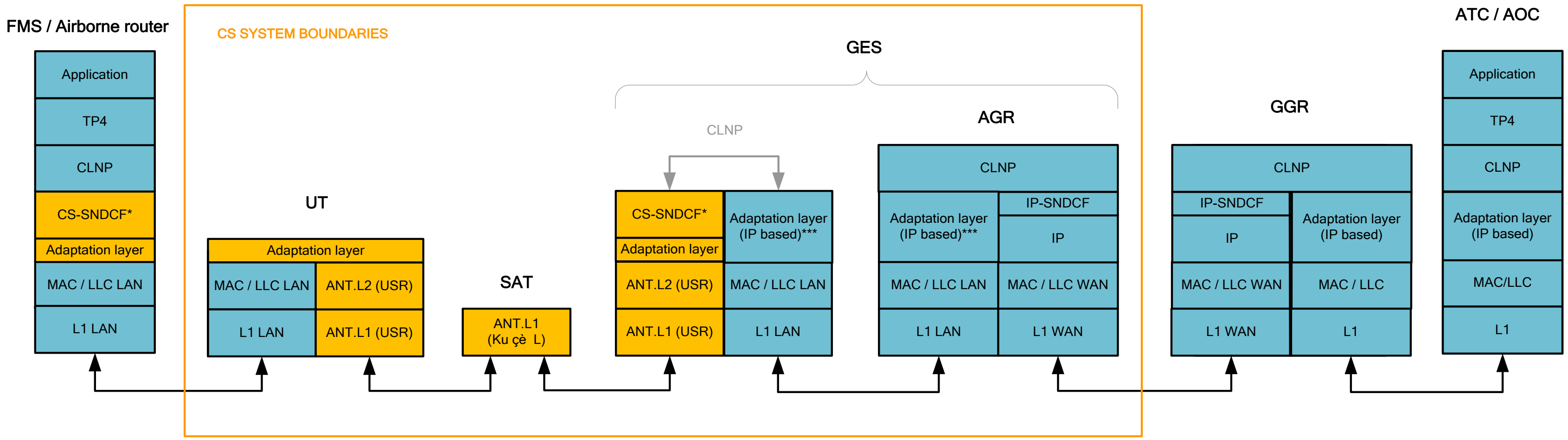



**Figure 5-3: Communication standard user plane protocol stack (end-to-end) – ATN/OSI (Iris Mode)**

The following diagram shows the user plane protocol stack for the ATN/OSI case in the Legacy conversion mode implementation.

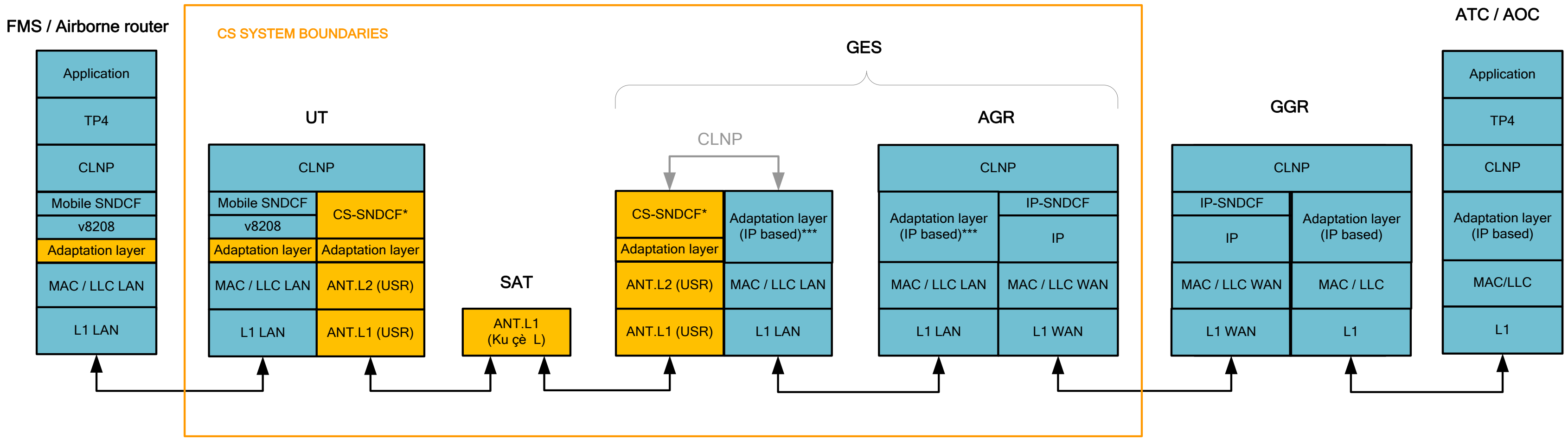



**Figure 5-4: Communication standard user plane protocol stack (end-to-end) – ATN/OSI (Legacy Conversion Mode)**

## 5.2 Control plane protocol stack overview

The following diagrams show the control plane protocol stack for ATN/IPS and for the different ATN/OSI modes (up to the network layer).

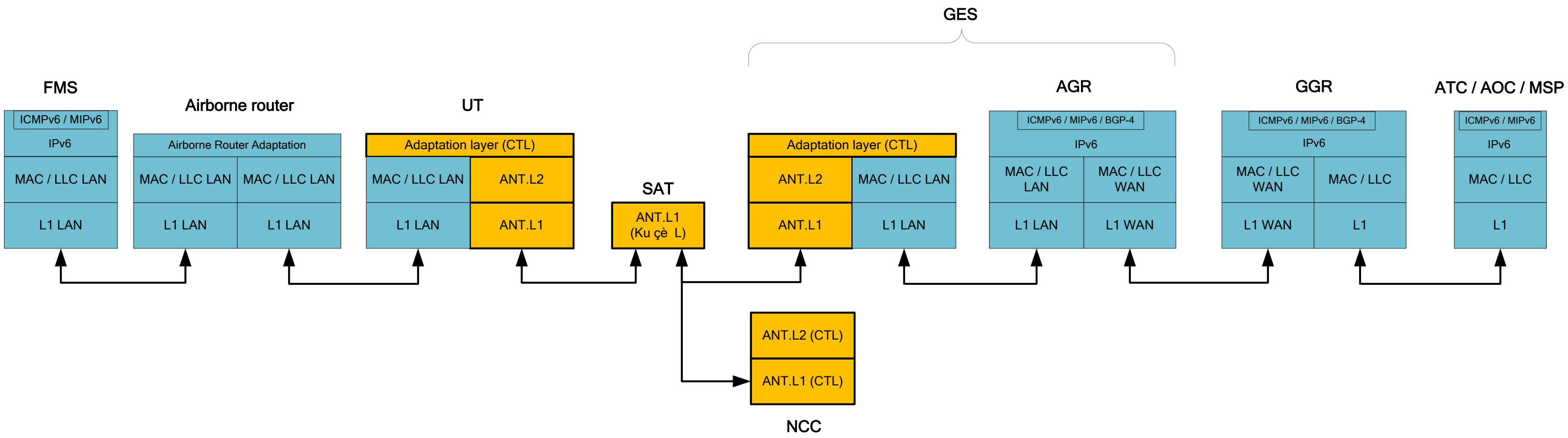



**Figure 5-5: Communication standard control plane protocol stack – ATN/IPS**

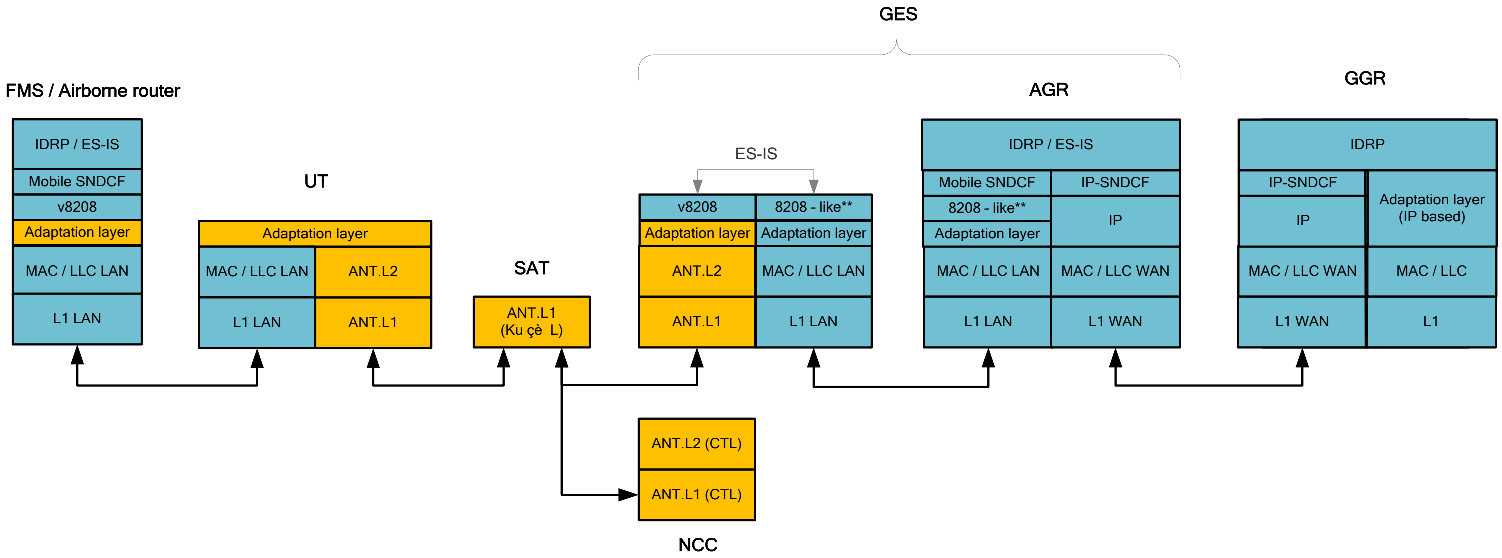



**Figure 5-6: Communication standard control plane protocol stack – ATN/OSI (Legacy Mode)**

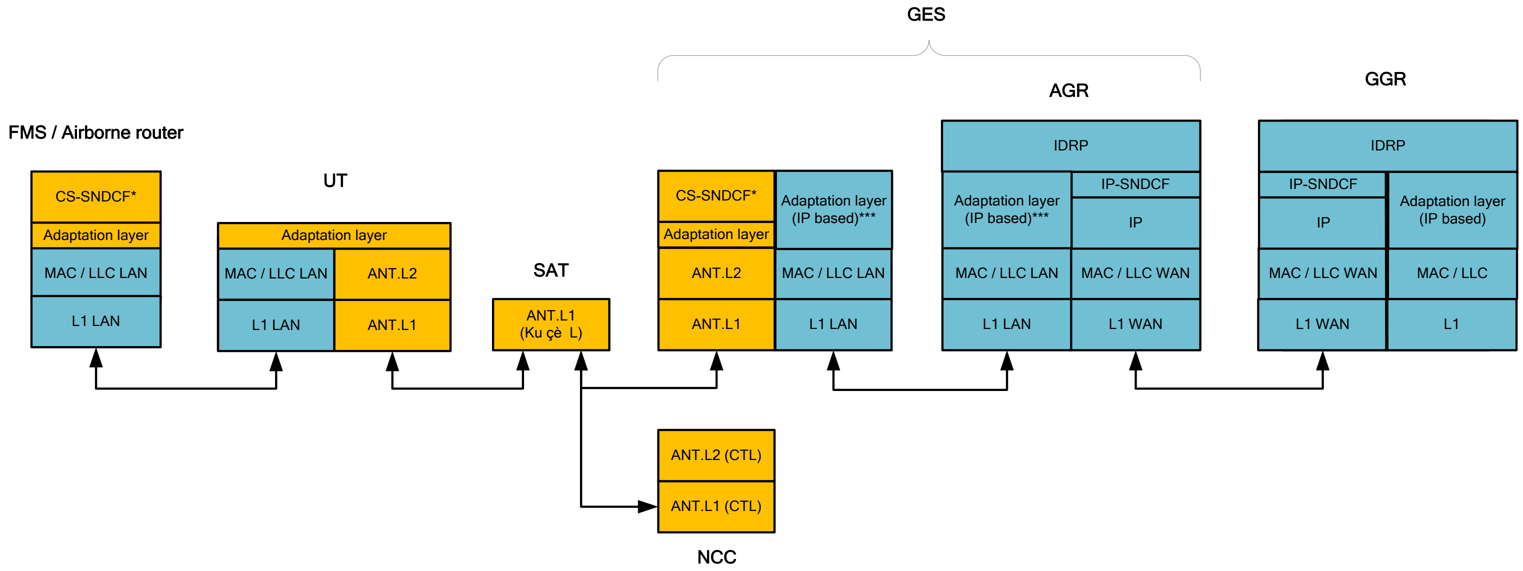



**Figure 5-7: Communication standard control plane protocol stack – ATN/OSI (Iris Mode)**

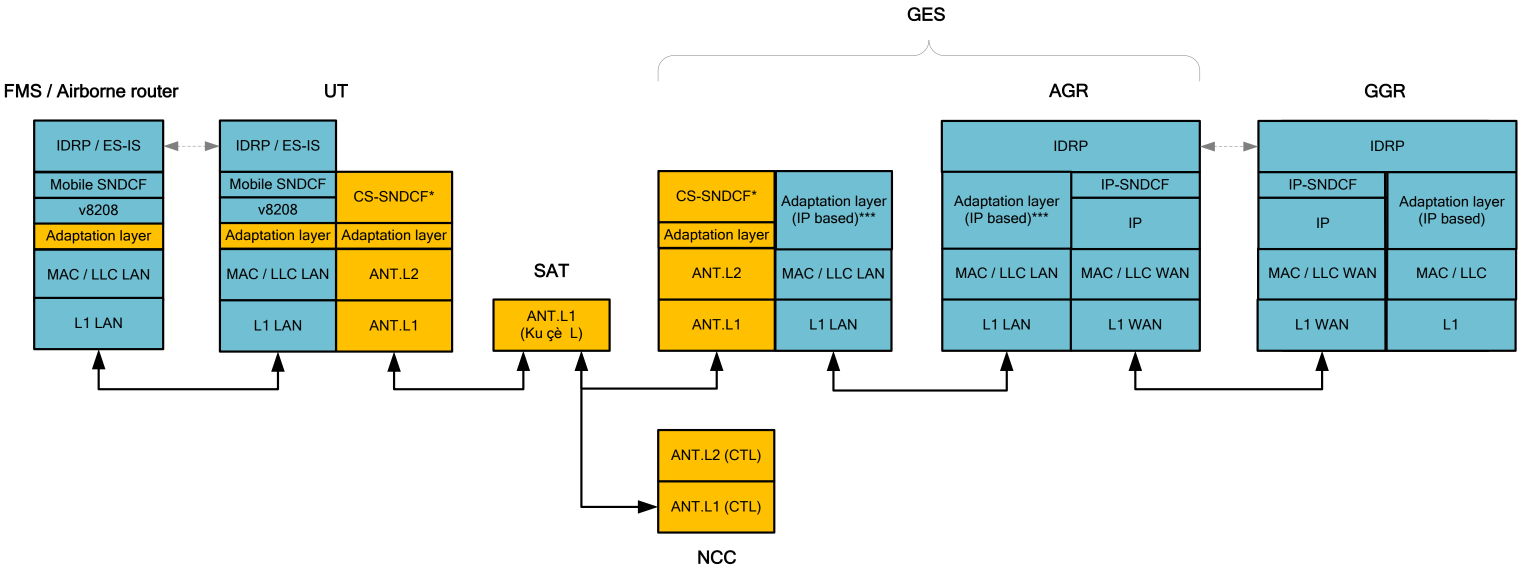



**Figure 5-8: Communication standard control plane protocol stack – ATN/OSI (Legacy Conversion Mode)**

## 5.3 Management plane protocol stack overview

The following diagram shows the management plane protocol stack.

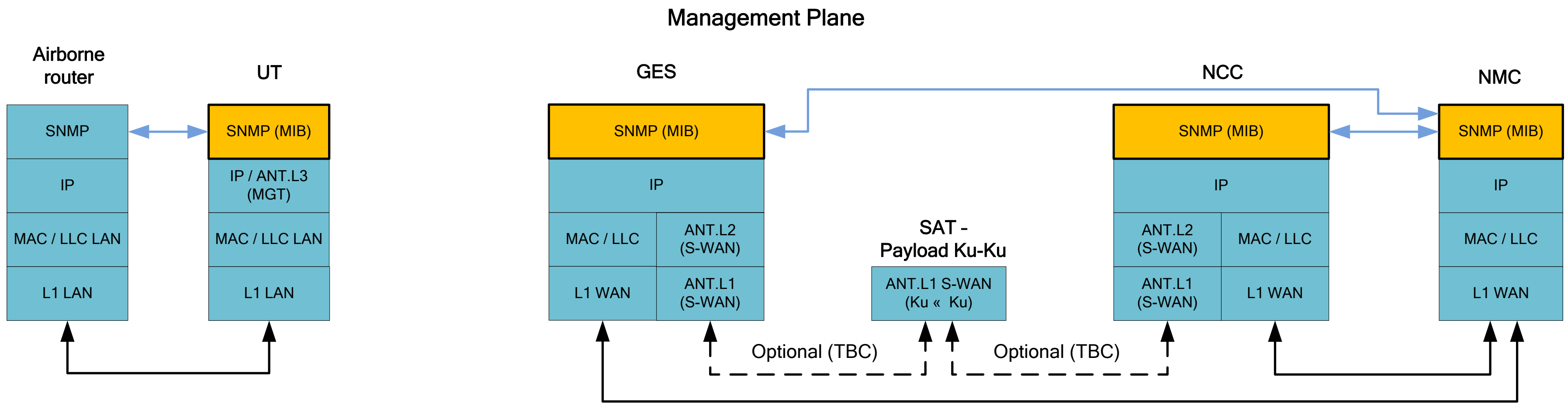



**Figure 5-9: Communication standard management plane protocol stack**

Critical control data could be exchanged also in the indicated Ku <-> Ku link (feeder to feeder link) in Figure 5-9 if the S-WAN option is selected.

# 6. USER, CONTROL AND MANAGEMENT PLANE EXTERNAL INTERFACES

In section 4.2, the interfaces of the ANTARES system are presented, and the specification of their type, external or internal, is also determined. In this section, the requirements placed by the CS on the external interfaces are defined. Two different protocol stacks are supported by an ANTARES system implementation: ATN/IPS and ATN/OSI.

## 6.1 ATN/IPS

In this section, the external interfaces requirements for the ATN/IPS architecture will be defined. It has to be noted that, as no airborne router Adaptation Layer is needed for the ATN/IPS architecture described in ATN/IPS protocol stacks in this document, the interfaces "Airborne router Upper Adaptation Interface" and "Airborne router Lower Adaptation Interface" are not envisaged in this section. As some requirements are shared between several interfaces, an initial "General Requirements" section is included, which will be referenced from the subsequent interface specification sections, if needed. For each interface, the requirements will be presented distributed into user, control and management planes.

### *6.1.1 General Interface Requirements*

#### *6.1.1.1 User Plane*

**CSREQ-0010**

The external interfaces to ATN/IPS network shall support the IPv6 network layer protocol as specified in [RD-05] for IPS nodes.

**CSREQ-0020**

The external interfaces to ATN/IPS network shall implement Maximum Transmission Unit (MTU) path discovery as specified in [RD-06].

**CSREQ-0030**

The external interfaces to ATN/IPS network shall set/maintain the Flow Label field of the IPv6 header to zero for outgoing packets.

**CSREQ-0040**

In the external interfaces to ATN/IPS networks, IPv6 addressing architecture using globally scoped IPv6 addresses when communicating, as specified in [RD-05], shall be implemented.

#### *6.1.1.2 Control Plane*

**CSREQ-0050**

ATN/IPS nodes shall implement Internet Control Message Protocol (ICMPv6) as specified in [RD-10].

#### *6.1.1.3 Management Plane*

**CSREQ-0060**

Care of IPv6 addresses (CoA) shall belong to the address prefix of the ATN/IPS FRS systems the aircraft is connected to. ATN/IPS FRS systems will be implemented as a set of ATN/IPS administrative domains. ATN/IPS administrative domains shall obtain IPv6 address prefix assignments from their Local Internet Registry (LIR) or Regional Internet Registry (RIR).

**CSREQ-0065**

Management protocol shall be based on SNMPv3 (RFC3410).

### *6.1.2 UT Avionics Interface*

#### *6.1.2.1 User Plane*

The user plane requirements for this interface are the ones included in section 6.1.1.1.

The CS does neither specify the physical nor the link layer of the avionics interface, which are left open to allow integration of the UT with aircraft avionics according to manufacturer preferences.

#### *6.1.2.2 Control Plane*

The control plane requirements for this interface are the ones included in section 6.1.1.2.

#### *6.1.2.3 Management Plane*

The management plane requirements for this interface are the ones included in section 6.1.1.3.

### *6.1.3 UT Voice Interface*

**(To be revised in B2)**

#### *6.1.3.1 User Plane*

The user plane requirements for this interface are the ones included in section 6.1.1.1.

The CS does neither specify the physical nor the link layer of the avionics interface, which are left open to allow integration of the UT with aircraft avionics according to manufacturer preferences.

#### *6.1.3.2 Control Plane*

The control plane requirements for this interface are the ones included in section 6.1.1.2. Additionally, the following requirements apply:

**CSREQ-0090**

The UT shall be able to notify to the Voice BE the opening of a return CBR channel by forwarding a “cbr on” control message.

**CSREQ-0100**

The UT shall be able to notify to the Voice BE the closure of a return CBR channel by forwarding a “cbr off” control message inside an IP packet.

**CSREQ-0110**

The Voice BE shall be able to request to the UT the opening of a return CBR channel by forwarding a “cbr req” control message inside an IP packet.

**CSREQ-0120**

The Voice BE shall be able to request to the UT the closure of a return CBR channel by forwarding a “cbr rel” control message inside an IP packet.

#### *6.1.3.3 Management Plane*

The management plane requirements for this interface are the ones included in section 6.1.1.3.

### *6.1.4 GS Ground Interface*

**(To be revised in B2, for voice service related aspects)**

#### *6.1.4.1 User Plane*

The user plane requirements for this interface are the ones included in section 6.1.1.1. Additionally, the following requirement applies:

**CSREQ-0130**

The GS shall provide a WAN interface towards the Terrestrial ATM Network.

#### *6.1.4.2 Control Plane*

The control plane requirements for this interface are the ones included in section 6.1.1.2. Additionally, the following requirements apply:

**CSREQ-0140**

Inter-domain routing protocol BGP-4 shall be implemented in this interface as defined in [RD-08].

**CSREQ-0150**

BGP-4 protocol extensions shall be implemented in this interface as defined in [RD-09].

**CSREQ-0160**

The GW shall be able to request to the GS the opening of a (forward, return or both) CBR channel towards an aircraft or group of aircraft by forwarding a "req cbr" control message inside an IP packet.

**CSREQ-0170**

Any CBR channel request from the Voice GW to the GS shall be acknowledged by forwarding an "ack" control message from the GS to the Voice GW inside an IP packet.

**CSREQ-0180**

The GES shall be able to notify to the Voice GW the opening of a forward CBR channel towards an aircraft or group of aircraft by forwarding a "cbr on" control message inside an IP packet.

**CSREQ-0190**

The Voice GW shall be able to notify to the GES the reception of a "cbr on" control message by forwarding an "ack" control message inside an IP packet.

**CSREQ-0200**

The Voice GW shall be able to request to the GS the closure of a (forward or return) CBR channel towards an aircraft or group of aircraft by forwarding a "rel cbr" control message with the identifier of the aircraft or group of aircraft inside an IP packet.

**CSREQ-0210**

Any CBR channel closure request from the Voice GW to the GS shall be acknowledged by forwarding an "ack" control message from the GS to the Voice GW inside an IP packet.

**CSREQ-0220**

The GES shall be able to notify to the Voice GW the closure of a forward CBR channel towards an aircraft or group of aircraft by forwarding a "cbr off" control message inside an IP packet.

**CSREQ-0230**

The Voice GW shall be able to notify to the GES the reception of a "cbr off" control message by forwarding an "ack" control message inside an IP packet.

#### 6.1.4.3 Management Plane

The management plane requirements for this interface are the ones included in section 6.1.1.3. Additionally, the following requirement applies:

**CSREQ-0240**

ATN/IPS administrative domains shall use AS numbers for ATN/IPS routers implementing inter-domain routing.

### 6.1.5 UT Airborne Management Interface

As the UT Airborne Management Interface is a management interface, this section only envisages the management plane.

#### 6.1.5.1 Management Plane

Refer to section 10.2.1 for general management requirements also applicable to this external interface.

**CSREQ-0260**

At least the following monitored parameters shall be accessible (read-only) by the MCDU from the User Terminal about its UT Satellite Interface:

| Parameter | Description | Type |
|---|---|---|
| Aircraft ICAO address | Allows access to the aircraft 24-bit ICAO address used in CS procedures. | Octet String |
| L2 addresses | Provides access to the layer 2 address(es) for the User Terminal. | Octet String |
| L3 addresses | Provides access to the layer 3 address(es) configured on the air interface. | Octet String |
| Traffic Log | Indicates the location of the traffic log files on the local file system for retrieval. | Octet String |
| Tx bytes | Provides the number of bytes transmitted on the interface since system startup. | Counter |
| Rx bytes | Provides the number of bytes received on the interface since system startup. | Counter |
| Rx Power | Indicates the received signal power level (0.1 dBm units). | Integer |
| SNIR | Indicates the received Signal-to-(Noise+Interference) Ratio (0.1 dB units). | Integer |
| BER | Indicates the current Bit Error rate on the air interface (1E-9 units). | Integer |
| PER | Indicates the current Packet Error rate on the air interface (1E-9 units). | Integer |
| ModCod evolution | Provides the history of the ModCod used by the user terminal. | Octet String |
| Status | Indicates the status of the communication link. This is a binary status and can either be “up” (1) or “down” (0). | Octet |
| Logon Status | Indicates the logon status of the user terminal. This can either be success in case the user terminal logon was successful or error otherwise. In case of error, an error code used to further diagnose the problem will be provided. | Octet String |
| Current GES Address | Indicates the address of the GES to which the User Terminal is currently assigned and to which data packets are to be addressed. | Octet String |

| Parameter | Description | Type |
|---|---|---|
| Current Tx carrier information | Provides access to the details on the current carrier(s) that is in use for transmitting traffic. | Octet String |
| Current Rx carrier information | Provides access to the details on the current carrier(s) that is in use for receiving traffic. | Octet String |
| Current SNIR | Indicates the currently published SNIR when ACM is in use (0.1 dB units). | Integer |
| Current ARQ retransmissions | Provides the total number of retransmissions performed by the ARQ mechanisms when it is in use. | Counter |
| Random Access collision rate | Indicates the current rate of collisions for the random access channel. | Integer |
| Current Random Access backoff | Provides access to the current transmission back-off parameter (tx_backoff) for the random access mechanism (10 ms units). | Integer |
| Current Random Access persistency | Provides access to the current persistency parameter for the random access mechanism (1E-2 units). | Integer |
| Current Random Access timeout | Provides access to the current retransmission timeout parameter for the random access mechanism (10 ms units). | Integer |
| Current Data Rate | Provides access to the data rate of the carrier(s) the User Terminal is currently using. | Octet String |
| Fault History | Lists the fault IDs of all the faults that have been recorded since system startup indicating for each fault, the timestamp at which it has occurred. | Octet String |
| Current Fault Status | Provides access to the current fault status for the User Terminal. Additionally, in presence of a failed state, information regarding the current fault is also provided. | Octet String |

**Table 6-1: UT monitored parameters**

**CSREQ-0270**

At least the following configurable parameters shall be accessible (read-write) by the MCDU from the User Terminal about its UT Satellite Interface:

| Parameter | Description | Type |
|---|---|---|
| Default system information | Provides the information about the system to which the User Terminal should try to logon by default. This includes the details necessary to acquire the initial System Information tables with signalling messages/carrier(s) for the system. | Octet String |
| ATN/OSI addresses and default routers | Allows access to the ATN/OSI configuration parameters such as addressing and routing information. | Octet String |
| System Logon credentials | Provides the credentials needed for logging on to the system. | Octet String |

**Table 6-2: UT configurable parameters**

### *6.1.6 GS Airborne Network Layer Interface*

#### *6.1.6.1 User Plane*

The user plane requirements for this interface are the ones included in section 6.1.1.1.

#### 6.1.6.2 Control Plane

The control plane requirements for this interface are the ones included in section 6.1.1.2.

**CSREQ-0275**

The CS shall support the stateless address autoconfiguration method as defined in RFC4862 [RD-19].

#### 6.1.6.3 Management Plane

The management plane requirements for this interface are the ones included in section 6.1.1.3.

### 6.1.7 Master NMC Management Interface

The Master NMC Management Interface provides the parameters necessary to support handover of UT to another inter-operable system complying with the CS.

As this interface is a management interface, this section only envisages the management plane.

#### 6.1.7.1 Management Plane

**CSREQ-0280**

In order to allow inter-system handover, at least the following parameters shall be available* for other inter-operable systems complying with the CS:

(*) Manual process by the network operator.

| Parameter | Description | Type |
|---|---|---|
| SSP identifier | Identifies the Satellite Service provider. | Octet String |
| Initial system details | Includes the details necessary to acquire the initial System Information tables with signalling messages/carrier(s) for the system. | Octet String |

**Table 6-3: External system parameters**

## 6.2 ATN/OSI

In this section, the external interfaces requirements for the ATN/OSI architecture will be defined. It should be noted that as voice services are not provided for ATN/OSI implementations, the interface "UT Voice Interface" is not envisaged in this specification. For each interface, the requirements will be presented distributed into user, control and management planes. Depending on the ATN/OSI mode (Legacy, Legacy Conversion or Iris mode) implemented, the interface requirements change, so the interfaces specification will be divided into three subsections.

### 6.2.1 Legacy Mode

#### 6.2.1.1 Airborne router Upper Adaptation Interface

##### 6.2.1.1.1 User Plane

**CSREQ-0290**

v8208 (ISO/IEC 8208 adaptation for VDL2) packet exchange shall be implemented in this interface.

##### 6.2.1.1.2 Control Plane

**CSREQ-0300**

UT logon shall be notified to the airborne router NTW Layer from the airborne router Adaptation Layer providing the A/G-R addresses.

**CSREQ-0310**

UT logoff shall be notified to the airborne router NTW Layer from the airborne router Adaptation Layer.

##### 6.2.1.1.3 Management Plane

No requirements are envisaged for the management plane of this interface.

#### 6.2.1.2 Airborne router Lower Adaptation Interface

##### 6.2.1.2.1 User Plane

**CSREQ-0320**

The airborne router Adaptation Layer shall be able to generate UNITDATA.request messages containing v8208 packets (ISO/IEC 8208 adaptation for VDL2) towards the UT.

##### 6.2.1.2.2 Control Plane

**CSREQ-0340**

The airborne router Adaptation Layer shall be able to generate PARAM.request messages towards the UT containing:

- Mode of operation (Iris or Legacy)
- Legacy Conversion Enabled flag
- Airborne router Address
- Preferred Service Provider Router Address (TBC)

**CSREQ-0350**

The airborne router Adaptation Layer shall be able to process PARAM.confirm to confirm PARAM.request parameter settings.

**CSREQ-0360**

The airborne router Adaptation Layer shall be able to process JOIN.indication messages from the UT when a UT logon occurs, containing the A/G-R addresses.

**CSREQ-0370**

The airborne router Adaptation Layer shall be able to process LEAVE.indication messages.

**CSREQ-0380**

The airborne router Adaptation Layer shall be able to process UNITDATA.confirm messages from the UT confirming the transmission or discarding of v8208 packets contained in UNITDATA.request messages sent.

##### *6.2.1.2.3 Management Plane*

No requirements are envisaged for the management plane of this interface.

#### *6.2.1.3 UT Avionics Interface*

##### *6.2.1.3.1 User Plane*

**CSREQ-0400**

The UT shall be able to process UNITDATA.request messages containing v8208 packets from the airborne router.

**CSREQ-0410**

The UT shall be able to generate UNITDATA.indication messages containing v8208 packets towards the airborne router.

##### *6.2.1.3.2 Control Plane*

**CSREQ-0420**

The UT shall be able to process PARAM.request messages from the airborne router containing:

- Mode of operation (Iris or Legacy)
- Legacy Conversion Enabled flag
- A-R Address

- Preferred Service Provider Router Address (TBC)

**CSREQ-0430**

The UT shall be able to generate PARAM.confirm messages towards the airborne router to confirm PARAM.request parameter settings.

**CSREQ-0440**

The UT shall generate JOIN.indication messages towards the airborne router when a UT logon occurs containing the A/G-R addresses.

**CSREQ-0450**

The UT shall generate LEAVE.indication messages towards the airborne router when a UT logoff or a L3 handover occurs.

**CSREQ-0460**

The UT shall be able to generate UNITDATA.confirm messages towards the airborne router confirming the transmission or discarding of v8208 packets contained in UNITDATA.request messages.

###### *6.2.1.3.3 Management Plane*

No requirements are envisaged for the management plane of this interface.

#### *6.2.1.4 GS Ground Interface*

###### *6.2.1.4.1 User Plane*

**CSREQ-0470**

The GS shall implement IPv6 encapsulation of CLNP packets by using IP-SNDCF.

###### *6.2.1.4.2 Control Plane*

**CSREQ-0480**

IDRP shall be implemented in this interface. (TBC)

###### *6.2.1.4.3 Management Plane*

No requirements are envisaged for the management plane of this interface.

#### *6.2.1.5 UT Airborne Management Interface*

As the UT Airborne Management Interface is a management interface, this section only envisages the management plane.

##### *6.2.1.5.1 Management Plane*

**CSREQ-0490**

The management plane requirements of this interface are the same as the ones in section 6.1.5.1 without the L2 protocol definition and including the following line in Table 6-2:

| Parameter | Description | Type |
|---|---|---|
| ATN/OSI addresses and default routers | Allows access to the ATN/OSI configuration parameters such as addressing and routing information. | Octet String |

**Table 6-4: Extra ATN/OSI UT configurable parameters**

#### *6.2.1.6 GS Airborne Network Layer Interface*

##### *6.2.1.6.1 User Plane*

**CSREQ-0500**

Mobile SNDCF shall be implemented in this interface.

**CSREQ-0510**

CLNP packet routing shall be implemented in this interface.

##### *6.2.1.6.2 Control Plane*

**CSREQ-0520**

The A/G-R and the airborne router shall implement Inter-Domain Routing Protocol (IDRP) functionality.

**CSREQ-0530**

The A/G-R shall implement Intermediate System Hello (ISH) functionality towards the GES.

**CSREQ-0540**

The GES shall implement Intermediate System Hello (ISH) functionality towards:

- The airborne router
- The A/G-R

**CSREQ-0550**

The airborne router shall implement Intermediate System Hello (ISH) functionality towards the GES.

##### 6.2.1.6.3 Management Plane

No requirements are envisaged for the management plane of this interface.

#### 6.2.1.7 Inter-system Management Interface

The requirements for this interface are the same as the ones included in section 6.1.7.

### 6.2.2 Legacy Conversion Mode

#### 6.2.2.1 Airborne router Upper Adaptation Interface

The requirements of this interface are the same as the ones presented in section 6.2.1.1.

#### 6.2.2.2 Airborne router Lower Adaptation Interface

The requirements of this interface are the same as the ones presented in section 6.2.1.2.

#### 6.2.2.3 UT Avionics Interface

##### 6.2.2.3.1 User Plane

The requirements of this interface are the same as the ones presented in section 6.2.1.3.1. Additionally, the following requirements apply:

**CSREQ-0560**

Mobile SNDCF shall be implemented in this interface.

**CSREQ-0570**

The UT shall be able to extract CLNP packets inside Mobile SNDCF.

##### 6.2.2.3.2 Control Plane

The requirements of this interface are the same as the ones presented in section 6.2.1.3.2. Additionally, the following requirements apply:

**CSREQ-0580**

IDRP shall be implemented in this interface.

**CSREQ-0590**

Intermediate System Hello (ISH) functionality shall be implemented in this interface.

##### 6.2.2.3.3 Management Plane

No requirements are envisaged for the management plane of this interface.

#### 6.2.2.4 GS Ground Interface

The requirements of this interface are the same as the ones presented in section 6.2.1.4.

#### 6.2.2.5 UT Airborne Management Interface

The requirements of this interface are the same as the ones presented in section 6.2.1.5.

#### 6.2.2.6 GS Airborne Network Layer Interface

In this mode, this interface does not apply, as the UT acts as a proxy between the airborne router and the A/G-R.

#### 6.2.2.7 Inter-system Management Interface

The requirements for this interface are the same as the ones included in section 6.1.7.

### 6.2.3 Iris Mode

#### 6.2.3.1 Airborne router Upper Adaptation Interface

##### 6.2.3.1.1 User Plane

**CSREQ-0600**

CLNP packet exchange shall be implemented in this interface.

##### 6.2.3.1.2 Control Plane

No requirements are envisaged for the control plane of this interface.

##### 6.2.3.1.3 Management Plane

No requirements are envisaged for the management plane of this interface.

#### 6.2.3.2 Airborne router Lower Adaptation Interface

##### 6.2.3.2.1 User Plane

**CSREQ-0620**

The airborne router Adaptation Layer shall be able to generate UNITDATA.request messages containing uncompressed CLNP PDUs towards the UT.

**CSREQ-0630**

The airborne router Adaptation Layer shall be able to process UNITDATA.indication messages containing uncompressed CLNP PDUs from the UT.

##### 6.2.3.2.2 Control Plane

**CSREQ-0640**

The airborne router Adaptation Layer shall be able to generate PARAM.request messages towards the UT containing:

- Mode of operation (Iris or Legacy)
- Legacy Conversion Enabled flag
- A-R Address
- Preferred Service Provider Router Address (TBC)
- LREF Compression Supported Flag
- Deflate Compression Supported Flag

**CSREQ-0650**

The airborne router Adaptation Layer shall be able to process PARAM.confirm from the UT to confirm PARAM.request parameter settings.

**CSREQ-0660**

The airborne router Adaptation Layer shall be able to process JOIN.indication messages from the UT when a UT logon occurs containing:

- A/G-R addresses.
- LREF Compression Supported Flag
- Deflate Compression Supported Flag
- Network prefixes for which the A/G-R has access

**CSREQ-0670**

The airborne router Adaptation Layer shall be able to process LEAVE.indication messages from the UT.

**CSREQ-0680**

The airborne router Adaptation Layer shall be able to process UNITDATA.confirm messages from the UT confirming the transmission or discarding of uncompressed CLNP PDUs contained in UNITDATA.request messages.

##### *6.2.3.2.3 Management Plane*

No requirements are envisaged for the management plane of this interface.

#### *6.2.3.3 UT Avionics Interface*

##### *6.2.3.3.1 User Plane*

**CSREQ-0700**

The UT shall be able to process UNITDATA.request messages containing uncompressed CLNP PDUs from the airborne router.

**CSREQ-0710**

The UT shall be able to generate UNITDATA.indication messages containing uncompressed CLNP PDUs towards the airborne router.

*6.2.3.3.2 Control Plane*

**CSREQ-0720**

The UT shall be able to process PARAM.request messages from the airborne router containing:

- Mode of operation (Iris or Legacy)
- Legacy Conversion Enabled flag
- A-R Address
- Preferred Service Provider Router Address (TBC)
- LREF Compression Supported Flag
- Deflate Compression Supported Flag

**CSREQ-0730**

The UT shall be able to generate PARAM.confirm from the airborne router to confirm PARAM.request parameter settings.

**CSREQ-0740**

The UT shall generate JOIN.indication messages towards the airborne router whenever it performs a logon, containing:

- A/G-R addresses
- LREF Compression Supported Flag
- Deflate Compression Supported Flag

**CSREQ-0750**

The UT shall generate LEAVE.indication messages towards the airborne router whenever it performs a logoff or a L3 handover occurs.

**CSREQ-0760**

The UT shall be able to generate UNITDATA.confirm messages towards the airborne router confirming the transmission or discarding of uncompressed CLNP PDUs contained in UNITDATA.request messages.

###### *6.2.3.3.3 Management Plane*

No requirements are envisaged for the management plane of this interface.

#### *6.2.3.4 GS Ground Interface*

The requirements of this interface are the same as the ones presented in section 6.2.1.4.

#### *6.2.3.5 UT Airborne Management Interface*

The requirements of this interface are the same as the ones presented in section 6.2.1.5.

#### *6.2.3.6 GS Airborne Network Layer Interface*

As no direct dialogs exist between the airborne router and the A/G-R for the Iris mode, this interface has no requirements.

#### *6.2.3.7 Inter-system Management Interface*

The requirements for this interface are the same as the ones included in section 6.1.7.

# 7. GENERAL REQUIREMENTS

## 7.1 Frequency band, multiple access and system carriers definition

### *7.1.1 Forward link*

#### *7.1.1.1 Mobile link frequency band specifications*

**CSREQ-0770**

The System shall operate the mobile link at frequencies identified by ITU for Aeronautical Mobile-Satellite (Route) Service (AMS(R)S), in agreement to in agreement to Article 1, Section III, 1.33 of ITU Radio Regulations [RD-21] and allocated worldwide:

- 1545 to 1555 MHz for the mobile downlink (from satellite to User Terminal)

**CSREQ-0790**

The mobile link polarisation shall be right hand circular (RHCP) for uplink and downlink (TBC).

#### *7.1.1.2 Forward link multiple access*

**CSREQ-0800**

The forward link access shall be based on a MF-TDMA scheme.

**CSREQ-0810**

The resource segmentation structure of the forward link shall be defined as follows:

- Time-slot: a time duration in which a burst is allocated. It is specified by duration, carrier frequency and carrier rate or bandwidth.
- Frame: defined as a sequence of time-slots at the same carrier rate.
- Super-frame: defined as a collection of frames at different carrier frequencies.

**CSREQ-6000**

The Forward Link frame shall be composed by TBD consecutive time slots.

**CSREQ-6005**

The Forward Link super-frame shall be a portion of time and frequency composed of frames from different carrier frequencies.

#### 7.1.1.3 Forward link system carriers definition and burst types

**CSREQ-0820**

The Forward Link shall be supported by one type of carrier: Forward Link Carrier (FLC).

**CSREQ-0830**

The Forward Link Carrier (FLC) shall provide the frequency and time reference of the system.

**CSREQ-0840**

The Forward Link Carrier shall be shared by the GS elements (NCC and GES) in MF-TDMA mode.

**CSREQ-0850**

The Forward Link Carrier shall transmit multiplexed both user traffic and network signalling (broadcast or unicast).

**CSREQ-0860**

The Forward Link Carrier shall transmit multiplexed the following physical channels or burst types (refer to section 7.2.2 for their definition):

- Forward Channel (FCH)

**CSREQ-5780**

The Forward Link Carrier shall support the following baud rates:

- 160 kbauds for the Spot beams (TBC)

**CSREQ-0870**

The guard band of the forward carriers shall be:

- 2 kHz for GEO and MEO constellations
- 5 kHz for HEO constellations

### 7.1.2 Return link

#### 7.1.2.1 Mobile link frequency band specifications

**CSREQ-0880**

The System shall operate the mobile link at frequencies identified by ITU for Aeronautical Mobile-Satellite (Route) Service (AMS(R)S), in agreement to in agreement to Article 1, Section III, 1.33 of ITU Radio Regulations [RD-21] and allocated worldwide:

- 1646.5 to 1656.5 MHz for the mobile uplink (from User Terminal to satellite).

#### 7.1.2.2 Return link multiple access

**CSREQ-0900**

The return link access shall be based on an A-CDMA (Asynchronous-CDMA) scheme.

#### 7.1.2.3 Return link system carriers definition and burst types

**CSREQ-0930**

The Return Link shall be supported by the following type of carriers:

- Return Link Carrier (RLC).

**CSREQ-0940**

The Return Link Carrier shall be shared by the UTs in Random Access mode to transmit either signalling or user traffic information.

**CSREQ-0960**

The Return Link Carrier shall transmit the following physical channels or bursts types (refer to section 7.2.2 for their definition):

- Random Access Channel (RACH).

**CSREQ-5790**

The Return Link Carrier shall support the following chip rates:

- 160 kchips/s (TBC)

**CSREQ-0980**

The guard band of the return carriers shall be:

- 8 kHz for GEO and MEO constellations
- 11.5 kHz for HEO constellations

The guard band shall account for return link frequency uncertainty:

- Due to UT clock instability and residual Doppler in the first access to the network (Log-on procedure).
- Due to residual errors on the UT Doppler pre-compensation.

## 7.2 Logical and physical channels

### *7.2.1 Definition of logical channels*

The following logical channels, covered in the requirements that follow, are defined:

| | FWD | RTN |
|---|---|---|
| **Traffic channels** | | |
| Broadcast/Multicast Traffic Channel (BTCH) | ✓ | - |
| Unicast Traffic Channel (UTCH) | ✓ | ✓ |
| **Control channels** | | |
| Broadcast Control Channel (BCCH) | ✓ | - |
| Forward Unicast Control Channel (FUCCH) | ✓ | - |
| Return Unicast Control Channel (RUCCH) | - | ✓ |

**Table 7-1: Logical channels**

**CSREQ-0990**

The BTCH shall be a point-to-multipoint logical channel for the transmission of user plane data to all or a sub-group of UTs within one or more beams.

**CSREQ-1000**

The BTCH shall be supported on the Forward Link only.

**CSREQ-1010**

The UTCH shall be a point-to-point bi-directional logical channel unicast to the transmission of user plane data (LSDUs) between the GS and a specific UT.

**CSREQ-1020**

The UTCH shall be supported on both the Forward Link and the Return Link.

**CSREQ-1030**

The BCCH shall be a point-to-multipoint logical channel used to forward general system control information that shall be announced to all or a sub-group of UTs within one or morebeams.

**CSREQ-1040**

The BCCH shall be supported on the Forward Link only.

**CSREQ-1050**

The FUCCH shall be a point-to-point logical channel used by the GS to exchange control messages with a specific UT.

**CSREQ-1060**

The FUCCH shall be supported on the Forward Link only.

**CSREQ-1070**

The RUCCH is a point-to-point or point-to-multipoint logical channel used by the UT to forward control messages to the GS.

**CSREQ-1080**

The RUCCH shall be supported on the Return Link only.

### *7.2.2 Definition of physical channels*

The following physical channels, covered in the requirements that follow, are defined:

| Channel | FWD | RTN |
|---|---|---|
| Forward Channel (FCH) | ✓ | - |
| Random Access Channel (RACH) | - | ✓ |

**Table 7-2: Physical channels**

**CSREQ-1110**

The FCH shall be used either for transmitting control or data information.

**CSREQ-1120**

The FCH shall be supported on the Forward Link only.

**CSREQ-1190**

The RACH shall be a used to transfer either control and/or user traffic information.

**CSREQ-1200**

The RACH shall be a contention-based physical channel whose transmission is based on a Spread Spectrum Aloha (SSA) approach.

**CSREQ-1210**

The RACH shall be supported on the Return Link only.

### *7.2.3 Mapping between logical and physical channels*

**CSREQ-1280**

The mapping between logical channels and physical channels shall be as defined in the following figure:

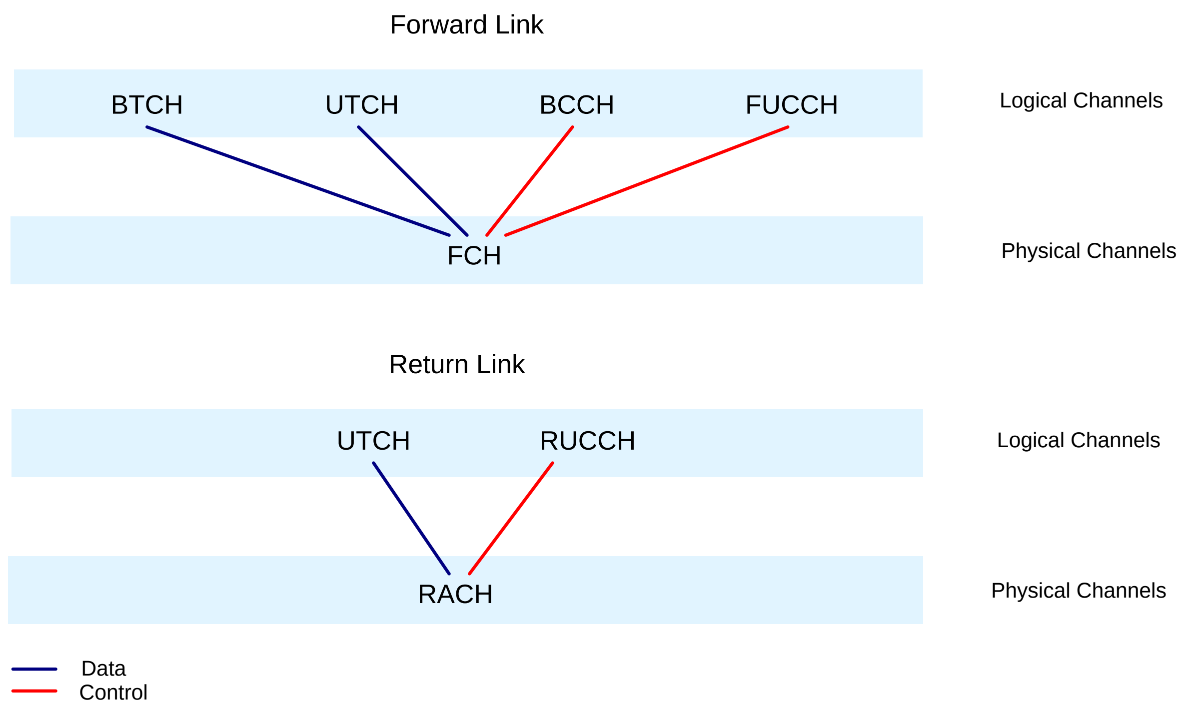



**Figure 7-1: Mapping between logical and physical channels**

### *7.2.4 Link layer process sequencing*

**CSREQ-1300**

The order of link layer transmission processes shall be as follows:

- Queuing / buffering, until the LSDU is scheduled for transmission
- Encapsulation, including associated functions:
  - ARQ header insertion (if applicable)
- MAC procedures associated to random access

**CSREQ-1310**

The order of link layer reception processes shall be as follows:

- Link layer filtering
- Reception buffering and re-sequencing, associated to ARQ (if applicable)
- Assembly of LSDU

## 7.3 Bit order

The following specifications are applicable to user, control and management plane.

### *7.3.1 Bit numbering*

**CSREQ-1320**

The interpretation of the bit numbering shall be the following:

- The term “bit 0” refers to the least significant bit of a multi-bit field.
- The most significant bit of a k-bit unsigned field shall be designated as “bit k-1”
- For signed fields, “bit k-1” shall refer to the sign bit and “bit k-2” to the most significant bit

### *7.3.2 Transmission order*

The following rules for the transmission order shall be considered in the implementation of the communication standard.

**CSREQ-1330**

Unsigned values shall be transmitted starting the most significant bit and ending with the less significant.

**CSREQ-1340**

Signed values shall be transmitted starting with the sign bit, followed by the most significant bit and ending with the least significant bit.

**CSREQ-1350**

Bytes shall be processed MSB first (big endian).

# 8. USER PLANE SPECIFICATION

## 8.1 User plane description

The User plane covers the aspects related to the transmission of user data. Refer to section 5.1 for details on the user plane.

## 8.2 Addressing scheme

**(To be revised in B2)**

### *8.2.1 Unicast addressing*

**CSREQ-1360**

The UT shall be identified by a 16-bit L2 address assigned during the logon process. This address should be associated to its 24-bit ICAO address in the ground segment element responsible for the logon procedure while the UT is logged on the system.

**CSREQ-1370**

The L2 ranges for UT addressing shall be (in hexadecimal notation):

- from 0x0000 to 0x007F: Multicast addresses
- from 0x0080 to 0x00FF: Reserved addresses
- from 0x0100 to 0xFFFE: Unicast addresses
- 0xFFFF: Broadcast address

**CSREQ-1380**

Each GS element shall be assigned a unique 8-bit L2 address used for all communications in which L2 addressing is required.

**CSREQ-1390**

The L2 ranges for GS element addressing shall be (in hexadecimal notation):

- from 0x00 to 0x7F: Reserved addresses
- from 0x80 to 0xFE: Unicast addresses
- 0xFF: Reserved address

### *8.2.2 Multicast addressing*

**CSREQ-1400**

The L2 broadcast address shall be 0xFFFF in hexadecimal notation.

**CSREQ-1410**

The L2 range for multicast addresses shall be from 0x0000 to 0x007F in hexadecimal notation. A mapping between L2 and L3 multicast groups shall be performed by the GS element responsible for multicast subscriptions management.

## 8.3 Security

**CSREQ-6020**

The CS shall not support any mechanism for user plane data encryption.

**CSREQ-6030**

The CS shall not support any mechanism for user plane data authentication.

**CSREQ-6040**

The CS shall allow transparent support of end-to-end security countermeasures applied to user plane data.

## 8.4 Network layer adaptation functions

### *8.4.1 ATN/IPS*

#### *8.4.1.1 Mapping between link layer and network layer addresses*

**(To be revised in B2)**

**CSREQ-1420**

The UT link layer address shall be derived from the aircraft network layer home address (or care-of-address, TBC), which contains the ICAO 24-bit aircraft address identifier.

*Note: The ICAO 24-bit Aircraft Address would be deduced from the ATN/IPS L3 Home address (HoA). This is TBC depending on whether this address is accessible from the inner ATN/IPS header in the HA-MN tunnel (depending on MSP security specifications). If not, the address could be deduced from the CoA (TBC depending on the CoA forming method proposed by the ICAO).*

**CSREQ-1425**

[Placeholder - Multicast address mapping]

#### *8.4.1.2 QoS*

**(To be revised in B2)**

**CSREQ-1430**

Every administrative domain shall make use of Differentiated Services (DiffServ) as specified in [RD-11] enabling DiffServ CoS.

**CSREQ-1440**

Administrative domains shall assign ATN/IPS application traffic to Assured Forwarding (AF) Per-Hop-Behaviour (PHB) as specified in [RD-12].

**CSREQ-1450**

Traffic in ATN/IPS addressed traffic shall be classified in the DiffServ Code Point (DSCP) header field by following the COCRv2 air-ground addressed CoS categories presented in Table 8-1 (TBC). It is allowed to reduce CoS number by aggregating both CoS into the higher category of both.

| COS | ET | $TD_{95\text{-}FRS}$ | $C_{UT\text{-}FRS}$ | $I_{UCT\text{-}FRS}$ | $A_{P\text{-}FRS}$ | $A_{U\text{-}FRS}$ | Service Type |
|---|---|---|---|---|---|---|---|
| DG-A | Reserved (rsvd) | 9.8 | rsvd | 5.0E-8 | rsvd | rsvd | NET Data |
| DG-C | 5.0 | 1.4 | 0.9996 | 5.0E-8 | 0.999995 | 0.9995 | ATS. A-G Data |
| DG-D | 7.8 | 2.4 | 0.9996 | 5.0E-8 | 0.999995 | 0.9995 | |
| DG-E | 8.0 | 3.8 | 0.996 | 5.0E-6 | 0.9995 | 0.9965 | |
| DG-F | 12.0 | 4.7 | 0.996 | 5.0E-8 | 0.9995 | 0.9965 | |
| DG-G | 24.0 | 9.2 | 0.996 | 5.0E-6 | 0.9995 | 0.9965 | |
| DG-H | 32.0 | 13.6 | 0.996 | 5.0E-6 | 0.9995 | 0.9965 | |
| DG-I | 57.6 | 26.5 | 0.996 | 5.0E-6 | 0.9995 | 0.9965 | |
| DG-J | Not available | 13.6 | Not available | 5.0E-8 | 0.9995 | 0.995 | AOC A-G Data |
| DG-K | | 26.5 | | 5.0E-10 | 0.9995 | 0.995 | |
| DG-L | | 51.7 | | 5.0E-10 | 0.9995 | 0.995 | |

**Table 8-1: Air-ground Addressed CoS categories**

**CSREQ-1460**

Mapping rules between services and DSCP field shall be as specified in TBD.

### *8.4.1.3 Compression*

#### *8.4.1.3.1 Header compression*

**CSREQ-1470**

For user traffic, the UT and GES may implement RObust Header Compression framework (ROHC) as specified in [RD-13]. If it is implemented, the following profiles shall be supported:

- UDP profile (defined in [RD-15]) and
- IP-Only profile (defined in [RD-16]).

Note: Benefits regarding the support of other profiles are under evaluation and still TBC.

##### *8.4.1.3.2 Data compression*

**CSREQ-1480**

Compression techniques for data should not be used.

Note: This is due to the small size of payload and in line with the fact that no data compression is used in practice with ATN/OSI.

### *8.4.2 ATN/OSI*

#### *8.4.2.1 Mapping between link layer and network layer addresses*

**CSREQ-1490**

The UT link layer address shall be derived from the ATN NSAP address, which contains the ICAO 24-bit aircraft address identifier (ARS field).

#### *8.4.2.2 QoS*

**CSREQ-1500**

QoS mapping for ATN/OSI shall be as specified in TBD.

#### *8.4.2.3 Compression*

##### *8.4.2.3.1 Header compression*

**CSREQ-1510**

LREF header compression shall be implemented between the airborne router and A/G-Rs, as specified in the ICAO ATN SARPS [RD-20].

**CSREQ-1520**

ATN/OSI routers implementing LREF header compression shall maintain local directories, with entries containing the following parameters:

- Source Address
- Destination Address
- Security Parameter
- CLNP Version Number

*8.4.2.3.2 Data compression*

**CSREQ-1530**

Deflate Data Stream Mode Compression should not be used between ATN/OSI routers.

## 8.5 User plane forward link specification

### *8.5.1 Link layer specification*

*8.5.1.1 ARQ protocol*

**(To be revised in B2)**

*8.5.1.1.1 ARQ header format*

**CSREQ-1540**

The ARQ header format shall include the following fields:

| Flow ID | Packet Count | Fragment Count |
|---|---|---|
| 0 | 1 | 2 |

where

| Field | Length | Description |
|---|---|---|
| **Flow identifier** field | 4 bits (forward)/3 bits (return) | This field differentiates between different flows/CoS. This field is optional for packets that are not fragmented by the encapsulation process, when ARQ is not used. It is however required by ARQ to handle retransmissions. For fragmented packets, this field is mandatory, ARQ being used or not; thus, it does not need to be added specifically for ARQ usage. |
| **Packet Count** field | 4 bits | This field is optional for packets that are not fragmented by the encapsulation process, when ARQ is not used. It is however required by ARQ to handle retransmissions, as it is a counter of packets that permit to determine losses. |
| **Fragment Count** field | 7 bits | This field is only used for packets that are fragmented by the encapsulation process. It is required by ARQ to number the different fragments of the same packet for handling retransmissions and for assembling the packet |

**Table 8-2: ARQ header fields encapsulation fields**

**CSREQ-1545**

[Placeholder for ARQ ACK format]

*8.5.1.1.2 ARQ procedure*

The main ARQ procedure characteristics are as follows:

- There is one ARQ management entity per each different flow (network layer message) to send at link layer.
- Only positive ACKs can be generated.

- Retransmissions can be triggered either because of retransmission timer expiration or because of the reception of other ACKs (next ACK or previous ACK duplicated).
- It is possible to piggyback ACKs to data if there is free room in the PDU.

**CSREQ-1550**

The ARQ procedure shall follow the SDL diagram shown below.

The following definitions apply:

- SDU (Service Data Unit), as the packet sent/received from upper layers
- PDU (Payload Data Unit), as the packet sent/received to lower layers
- Start_TX as the signal that indicates the instants to transmit to lower layers
- Close signal to finalise the ARQ entity

The ARQ Parameters present in this diagram are:

- "*Retx_Timer"* the time between retransmissions if no ACK received
- *"Max_Retx"* the maximum number of retransmissions allowed per PDU
- *"Disc_T"* the discarding timer.

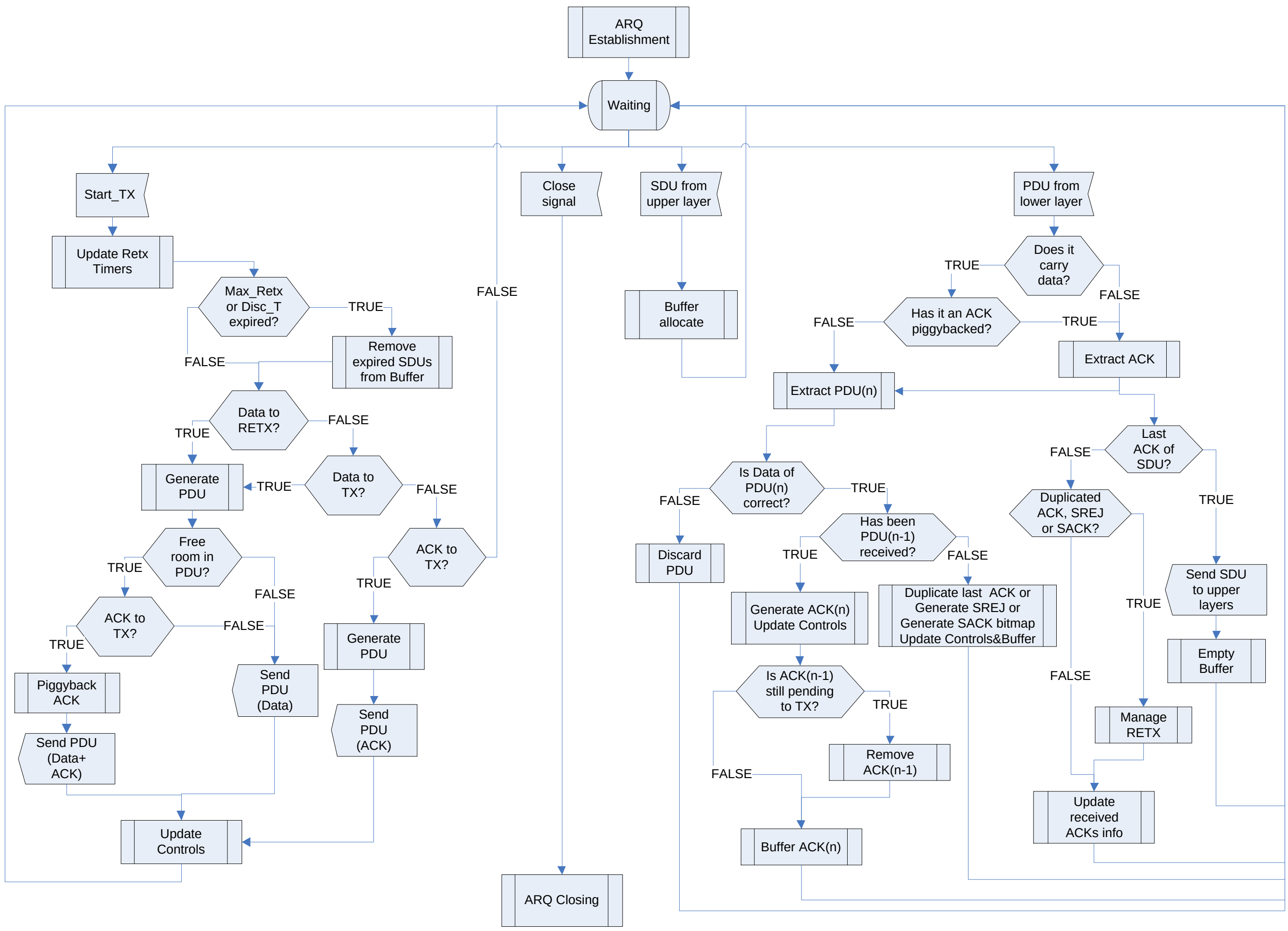



**Figure 8-1: SDL Diagram for ARQ protocol specification**

The diagram above is explained in the following paragraphs for informational purposes:

Once the ARQ entity has been established (i.e. initialised) at the time of setting up the different layers for the communication (e.g. at log-on), it moves to the *Waiting* state. It can leave this state when receiving an SDU from upper layers, a PDU from lower layers or a Start_TX signal. Similarly, when the communication is finished (e.g. at log-off) a control signal is assumed to close the ARQ entity.

When the ARQ entity receives an SDU from higher layers it checks if it carries data to transmit. If positive answer, it allocates the data in the transmission buffer. When the ARQ entity receives a PDU from lower layers it checks if it carries data or not. If not, it extracts the ACK. If yes, it checks if it carries any piggybacked ACK, and extracts it and also extracts the data (call it PDU(n)). Then, the ARQ entity checks the integrity of the data, and in case of error, no action is done, i.e. the PDU(n) is discarded. Otherwise, it checks if previous data (i.e. PDU(n-1)) has been received. If yes, the corresponding ACK(n) is generated and the ARQ control functions updated (i.e. to update record about which is the last cumulative ACK generated). Before placing it in the transmission buffer, it checks if ACK(n-1) is still pending to transmit. In that case, it removes ACK(n-1) from the transmission buffer and puts ACK(n) according to cumulative facility. In case the PDU(n-1) has not been received, depending on the selected type of acknowledgments option, it generates a duplicate of the last ACK, or one SREJ for each missing PDU, or a duplicate plus a SACK bitmap indicating the missing PDUs and the already received PDUs; it updates ARQ control functions (i.e. to update record about which PDUs have been correctly received) and puts the feedback information to the transmission buffer. If there is an ACK in the PDU, the ARQ entity checks if it is the last ACK of an SDU. If yes, it sends the SDU to the upper layers, and empties this SDU from the reception buffer. If it is not the last ACK pending to complete all the fragments of the SDU, it analyses if it is a duplicated ACK, an SREJ or an SACK bitmap, in order to manage the corresponding retransmissions, and it updates the information of the received ACK.

When a Start_TX signal is received the ARQ entity updates the Retx_Timers (a timer for each fragment to count the time between retransmissions if no ACK received) and checks if the discarding timer (Disc_T) has expired or if the PDU to be transmitted exceeds the maximum number of retransmissions. If yes, if empties all the PDUs of the same SDU from the transmission buffer. Then, it checks if it has data to retransmit. If not, it checks if it has data to transmit for the first time. If not, it checks if it has ACKs (i.e. ACK, SREJ and SACK bitmap) to transmit. If yes, it generates and sends a PDU with the ACKs. In case it has data to retransmit or transmit for the first time, the ARQ entity generates the PDU and checks if there is free room in the PDU to piggyback an ACK. If not, it sends the PDU with only the data. If there is free room and it has ACK to send, it piggybacks the ACK and sends the PDU with data and ACK. Finally, it updates all the control information (i.e. buffer pointers, counters, fragments transmitted and waiting for the acknowledgment, retransmissions done and Retx_Timers blocked due to retransmissions of previous PDUs).

It should be noted that all the PSDUs from a single network layer packet can be transmitted before an ACK is received (window size depends on the number of fragments). Start Tx signal is generated by the access protocol to the physical medium.

#### *8.5.1.2 Encapsulation*

**(To be revised in B2)**

**CSREQ-1560**

The forward link encapsulation scheme shall support the integration, in the L2 header, of information optionally required for ARQ.

**CSREQ-1570**

The forward link encapsulation scheme shall support the flexibility required in terms of addressing capabilities: i.e. 0, 2, 3 or 4 bytes addressing field.

**CSREQ-1580**

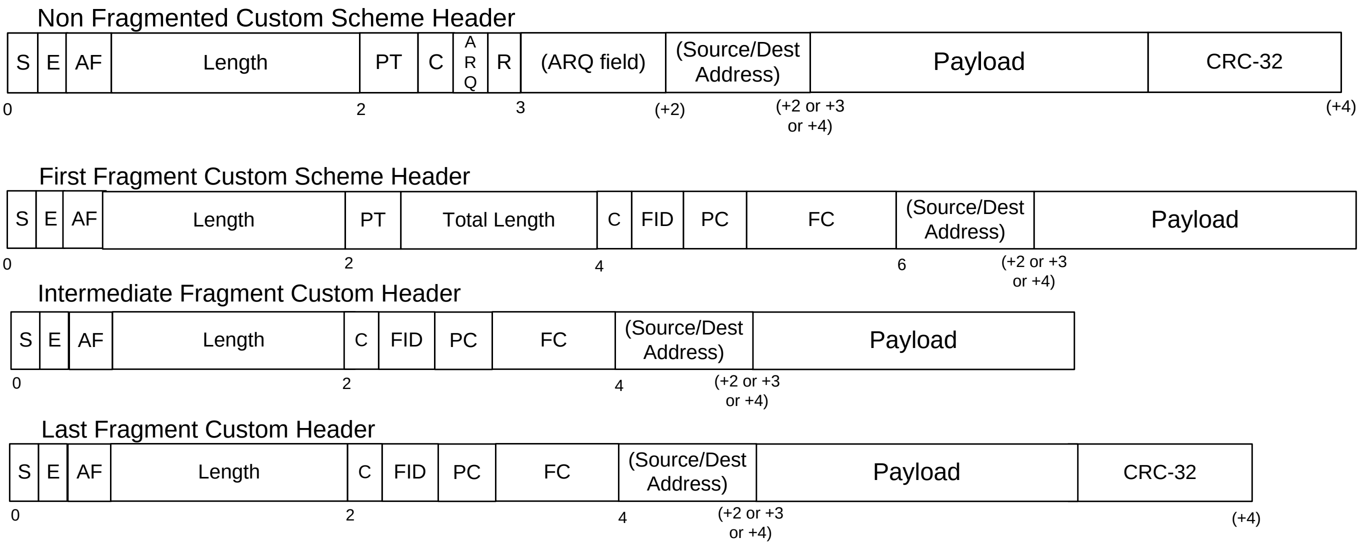
The UT shall support the de-encapsulation and re-assembly of L3 data units from L2 data units using the CS custom scheme for the forward link.

**CSREQ-1590**

GS elements shall support the encapsulation and fragmentation of L3 data units into L2 data units using the CS custom scheme for the forward link.

## CSREQ-1610

The forward link encapsulation scheme used shall comply with the following:




where

| Field | Length | Description |
|---|---|---|
| **S** and **E** flags:<br>Start and End bits | 1 bit each | These fields indicate if the packet is non-fragmented (11), if it is the first fragment (10), the last fragment (01) or an intermediate fragment (00) of a fragmented packet. |
| **AF** field:<br>Address Format | 2 bits | This field indicates the address format that will be contained in the encapsulation header. It can take the following values:<br>**00**: No address field/label re-use<br>**01**: 2 bytes address field: UT destination address<br>**10**: 3 bytes address field: 2 bytes destination UT address + 1 byte source GS element address<br>**11**: 4 bytes address field: 3 bytes destination UT ICAO address + 1 byte source GS element address |
| **Length** field | 12 bits | This field indicates the length of the L2 payload size for the current fragment (for fragmented packet) or the total length of the payload for non-fragmented packet. This length enables physical payload sizes up to 4099 bytes. |
| **Total Length** field | 13 bits | This field indicates the total length of the L3 payload when fragmented. This length enables L3 packet sizes up to 8192 bytes. |
| **PT** field:<br>Payload Type | 3 bits | This field indicates the type of the contained payload that can be ATN/IPS, ATN/OSI, Signalling, compressed data, etc. |
| **C** flag:<br>CRC Presence | 1 bits | This field indicates if a 4 bytes CRC field is present as a trailer in the current packet (when un-fragmented). |
| **ARQ** flag | 1 bits | This field indicates whether the ARQ process is used, implying an additional 2 bytes field for un-fragmented packet. When fragmented, all the required information for the ARQ process is already included in the encapsulation header. |
| **ARQ** field:<br>ARQ Information | 2 bytes | This field contains the information required for the ARQ process when the ARQ bit is set to 1. It shall comply with §8.5.1.1.1. |
| **R** field:<br>Reserved | 3 bits / 1 bit | This field is reserved for future use. 1 bit if fragmented. |

| Field | Length | Description |
|---|---|---|
| **Source/Dest Address** field | optional field of 2, 3 or 4 bytes | This field is optional and contains the source and destination addresses as indicated by the Address Format (AF) field. |
| **FID** field:<br>Flow ID | 4 bits | This field identifies the Class of Service (or the flow) of the current packet. This information is used by the ARQ process and by the re-assembly process when the packet is fragmented. |
| **PC** field:<br>Packet Count | 4 bits | This field identifies the packet currently sent, it is incremented for each packet sent toward a specific destination, using an independent counter for each flow ID. This field is used by ARQ process and by re-assembly process when the packet is fragmented. |
| **FC** field:<br>Fragment Count | 7 bits | This field is used as a counter for the fragments composing a packet. This field is used by ARQ process and by re-assembly process when the packet is fragmented. |
| **CRC-32** field | 4 bytes | When indicated by the C field or by system design, a 4 bytes trailer is added after the payload when un-fragmented or at the end of the last fragment when fragmented. |

**Table 8-3: Forward link encapsulation fields**

#### *8.5.1.3 Security*

Refer to 8.3.

### 8.5.2 Physical layer specification

The following section specifies the physical layer of the user plane FWD link.

#### 8.5.2.1 Burst types

**CSREQ-1711**

The User plane FWD link shall support the following burst types:

- FCH burst

**CSREQ-1720**

The FCH burst shall support adaptive coding and modulation (ACM). The following MODCODs shall be supported:

- QPSK 1/3, 1/2, 2/3
- 8-PSK 1/2, 2/3
- 16-APSK 2/3

#### 8.5.2.2 Burst waveform generation

**CSREQ-1712**

The burst waveform generation shall be applied to the PSDU and shall be composed of a sequence of functional modules as represented in Figure 8-2. The functional modules shall be:

- Physical Layer Adaption
- Error Detection
- Base Band scrambling
- FEC Encoding, which includes the inner encoding and the bit interleaver
- Bit Mapping into Constellation
- Symbol Interleaving
- Physical Layer Framing
- Base-band Pulse Shaping and Quadrature Modulation

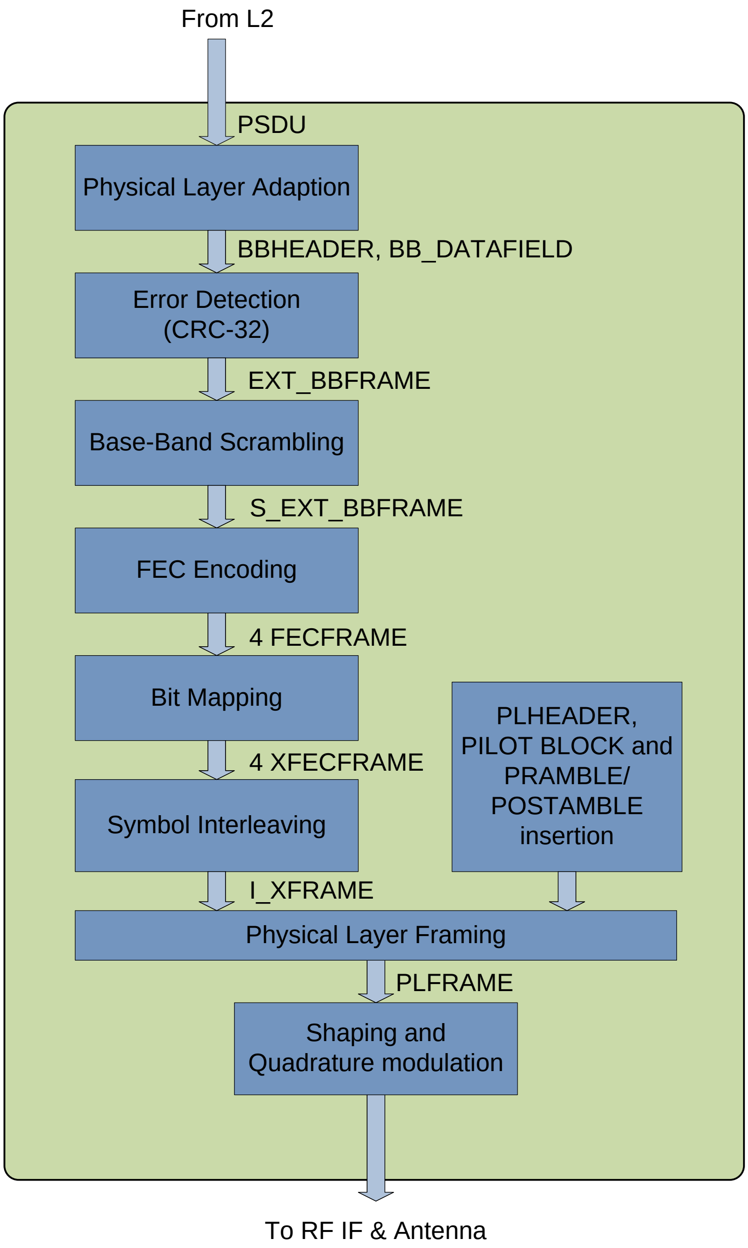



**Figure 8-2: Forward link burst waveform generation**

**CSREQ-1710**

The FWD Link bursts shall follow the frame format presented in Figure 8-3:

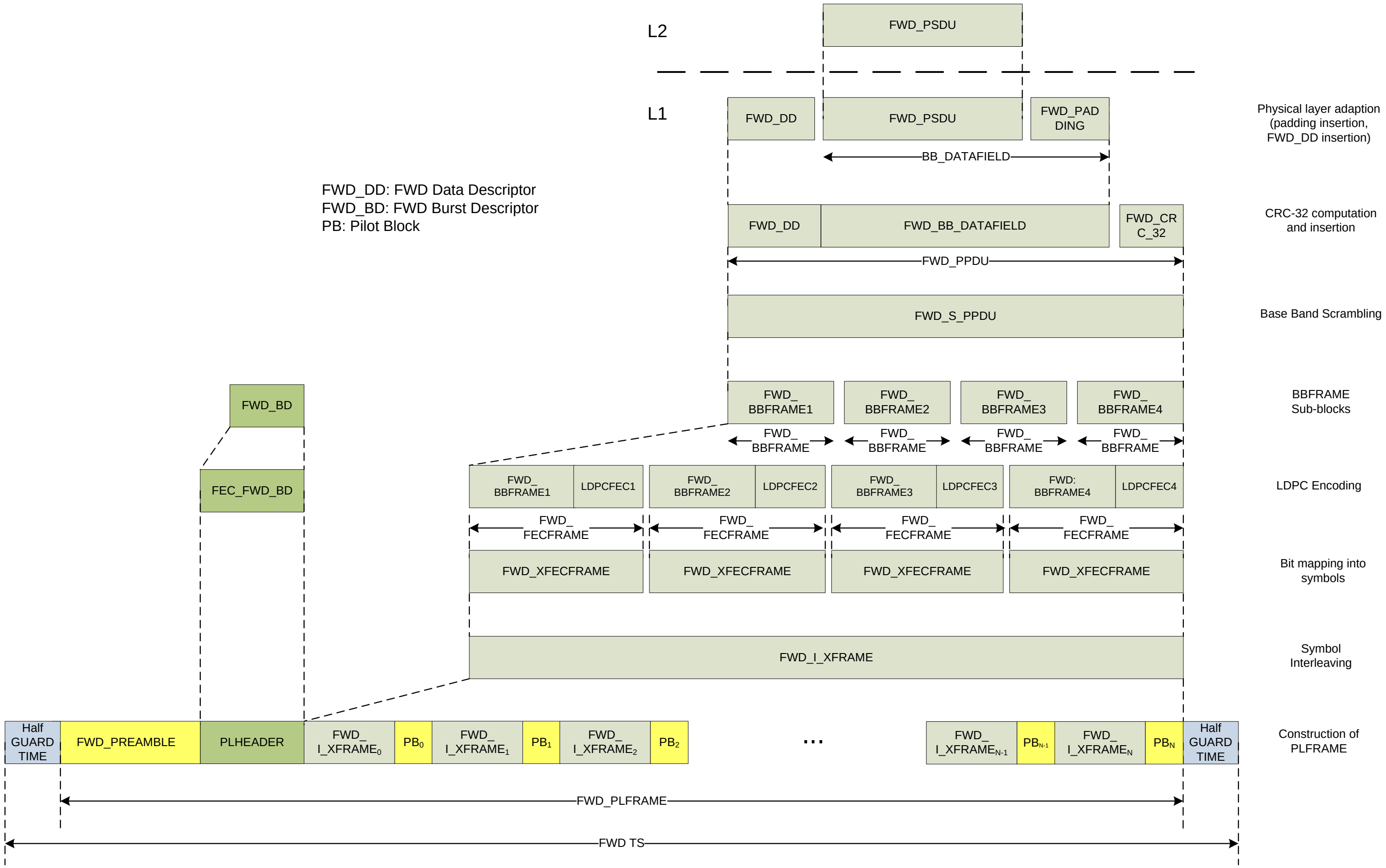



**Figure 8-3: FCH burst frame structure**

#### 8.5.2.3 Physical Layer Adaption

**CSREQ-1731**

The Physical Layer Adaption module shall perform:

- Interface with Layer 2
- Padding insertion
- FWD_DD (FWD Data Descriptor) insertion

**CSREQ-1732**

The input stream of the Physical Layer Adaption module shall be a FWD_PSDU and the output stream shall be a FWD_DD Header followed by a FWD_BB_DATAFIELD, as detailed in Figure 8-4 .

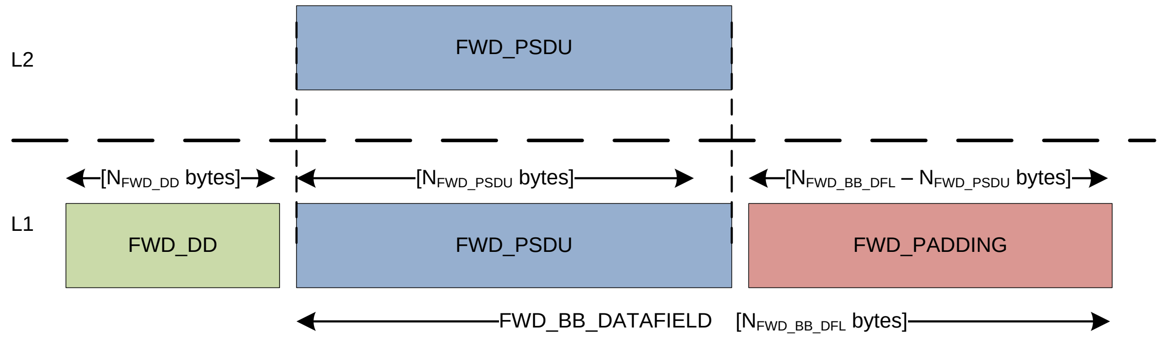



**Figure 8-4: Data format at the output of the Physical Layer Adaption module**

**CSREQ-1740**

A single PSDU shall be mapped onto a single FWD burst.

##### 8.5.2.3.1 Interface with Layer 2

**CSREQ-1730**

The Physical Layer Adaption module shall map FWD_PSDU of 3 types of layer 2 encapsulation protocols:

- GSE
- Protocol 1 (TBD)
- Protocol 2 (TBD)

**CSREQ-1760**

The FWD_PSDU size (in bytes) shall be variable in the range. The maximum PSDU size (Max. $N_{FWD\_PSDU}$) depending on the selected MODCOD shall be as detailed in Table 8-4:

| Mode | Max. $N_{FWD\_PSDU}$ [Maximum PSDU size (bytes)] |
|---|---|
| QPSK 1/3 | 1018 |
| QPSK 1/2 | 1530 |
| QPSK 2/3 | 2042 |
| 8-PSK 1/2 | 2298 |
| 8-PSK 2/3 | 3066 |
| 16-APSK 2/3 | 4090 |

**Table 8-4: Maximum PSDU size (bytes)**

#### *8.5.2.3.2 Padding insertion*

**CSREQ-1761**

($N_{FWD\_BB\_DFL}$ - $N_{FWD\_PSDU}$) bytes shall be appended after the FWD_PSDU according to Figure 8-4. The contents of the padding bytes shall be "0x00".

#### *8.5.2.3.3 FWD_DD (FWD Data Descriptor) insertion*

**CSREQ-1762**

A fixed length header (FWD_DD) of $N_{FWD\_DD}$= 2 bytes (bits $h_0$-$h_{15}$) shall be inserted in front of the BB_DATAFIELD according to Figure 8-4.

**CSREQ-1770**

The FWD_DD header shall contain the following fields:

| Bits | Field | Field size | Description |
|---|---|---|---|
| $h_0$ | PSDU Size Flag | 1 bit | It indicates if the PSDU Size is present in the FWD_DD header |
| $h_1$ | Alternate Descriptor Flag | 1 bit | It indicates if the Alternate Descriptor is present in the FWD_DD header |
| $h_2$-$h_3$ | L2 Protocol Type | 2 bits | It indicates the L2 protocol used in the FWD_PSDU |

| | | | |
|---|---|---|---|
| $h_4$-$h_{15}$ | Contents field | 12 bits | It contains the PSDU size or the Alternate Descriptor (see **CSREQ-6050**) |

**Table 8-5: FWD_DD header fields**

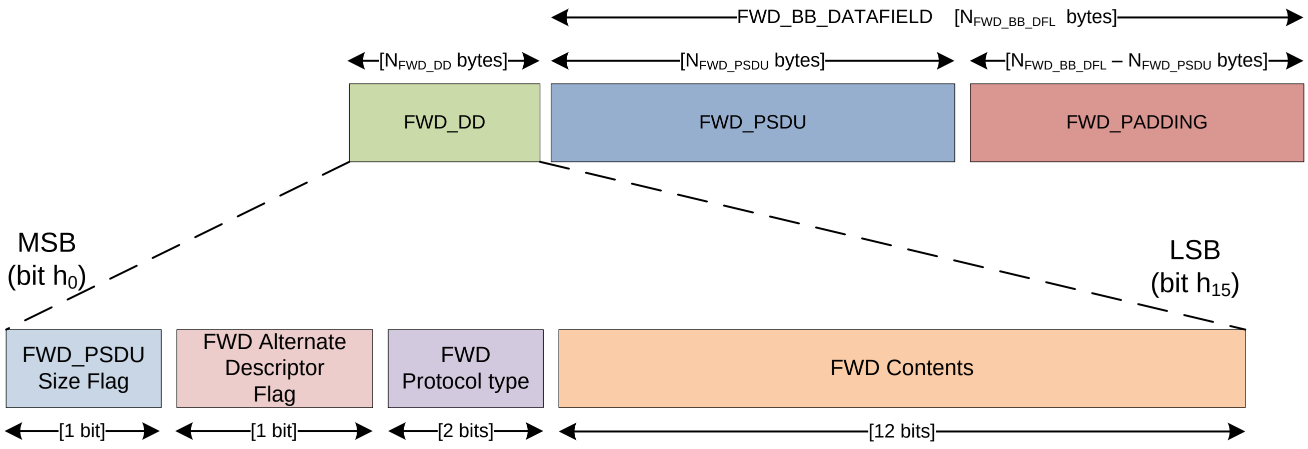



**Figure 8-5: FWD_DD Header fields**

**CSREQ-6050**

The mapping of the FWD_PSDU Size Flag, FWD Alternate Descriptor Flag and the FWD Contents field shall be as specified in Table 8-6.

| $h_0$ (FWD_PSDU Size Flag) | $h_1$ (FWD Alternate Descriptor Flag) | $h_4$-$h_{15}$ (FWD Contents Field) |
|---|---|---|
| 1 | 0 | "Contents" field is filled with the PSDU size, in bytes |
| 0 | 1 | "Contents" field is filled with the Alternate Descriptor<br>Note: Alternate Descriptor field is reserved for future use |
| 0 | 0 | N.A |
| 1 | 1 | N.A |

**Table 8-6: FWD Contents field mapping**

**CSREQ-1810**

The FWD Protocol Type field shall indicate which L2 entity (encapsulation protocol) is the client of the burst. It is a 2-bit field coded as detailed in Table 8-7.

| $h_2$ $h_3$ (FWD Protocol Type) | Description |
|---|---|
| 00 | Reserved |
| 01 | GSE |
| 10 | TBD |
| 11 | TBD |

**Table 8-7: RTN Link Protocol Type field mapping**

#### *8.5.2.4 Error Detection (CRC-32 encoder)*

**CSREQ-1811**

The FWD Error Detection module shall compute the CRC parity bits in order to detect erroneous packets in the receiver side and to provide a packet quality indicator.

**CSREQ-1812**

The input stream of the Error Detection module shall be a FWD_DD header followed by a FWD_BB_DATAFIELD and the output stream shall be a FWD_PPDU, as illustrated in the Figure 8-6.

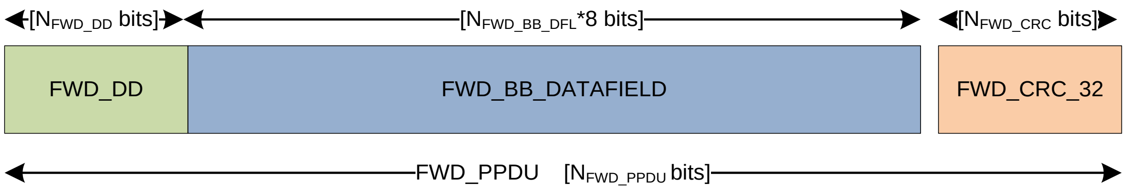



**Figure 8-6: Data format at the output of the FWD Error Detection module**

**CSREQ-1820**

The 32-bit CRC (CRC_32 field) shall be appended after the BB_DATAFIELD, as illustrated in Figure 8-6.

**CSREQ-1830**

The CRC_32 shall be computed over:

- the FWD_DD header
- the FWD_BB_DATAFIELD

**CSREQ-2030**

The CRC parity bits are computed using the following cyclic generator polynomial:

$$G(X) = X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^{8} + X^{7} + X^{5} + X^{4} + X^{2} + X + 1$$

**CSREQ-2040**

The CRC parity bits (FWD_CRC_32 field) shall be the remainder of the division of the input stream by the polynomial *G(X)*. (

$$CRC = remainder\ [X^{32}M(X) : G(X)]$$

where,

- all the arithmetic is in modulo 2
- *n* is the number of bits of the CRC encoded message
- *M(X)* is the input stream to be encoded expressed as a polynomial as a binary coefficients: $M(X) = M_0 X^{k-1} + M_1 X^{k-2} + ... + M_{k-2} X + M_{k-1}$

**CSREQ-2041**

The CRC parity bits shall be generated by the shift register structure shown in Figure 8-7. The CRC parity bits shall be computed according to the following procedure:

1. The shift register cells shall be initialized to 1.
2. All the switches shall be set in the A position.
3. The shift register is clocked a number of times equal to the number of input bits (FWD_DD + FWD_BB_DATAFIELD). The MSB of the FWD_DD shall be the first bit to be inserted in the shift register.
4. Once the last input bit has been inserted in the shift register (LSB of FWD_BB_DATAFIELD), the switches shall be set to position B, forcing that the inputs to the shift register are 0.
5. The shift register shall be clocked an additional number of times equal to the number of CRC parity bits (i.e. 32). The 32 additional bits shall be the CRC parity bits (FWD_CRC_32 field).
6. The CRC parity bits shall be transmitted in the order of generation (MSB first).

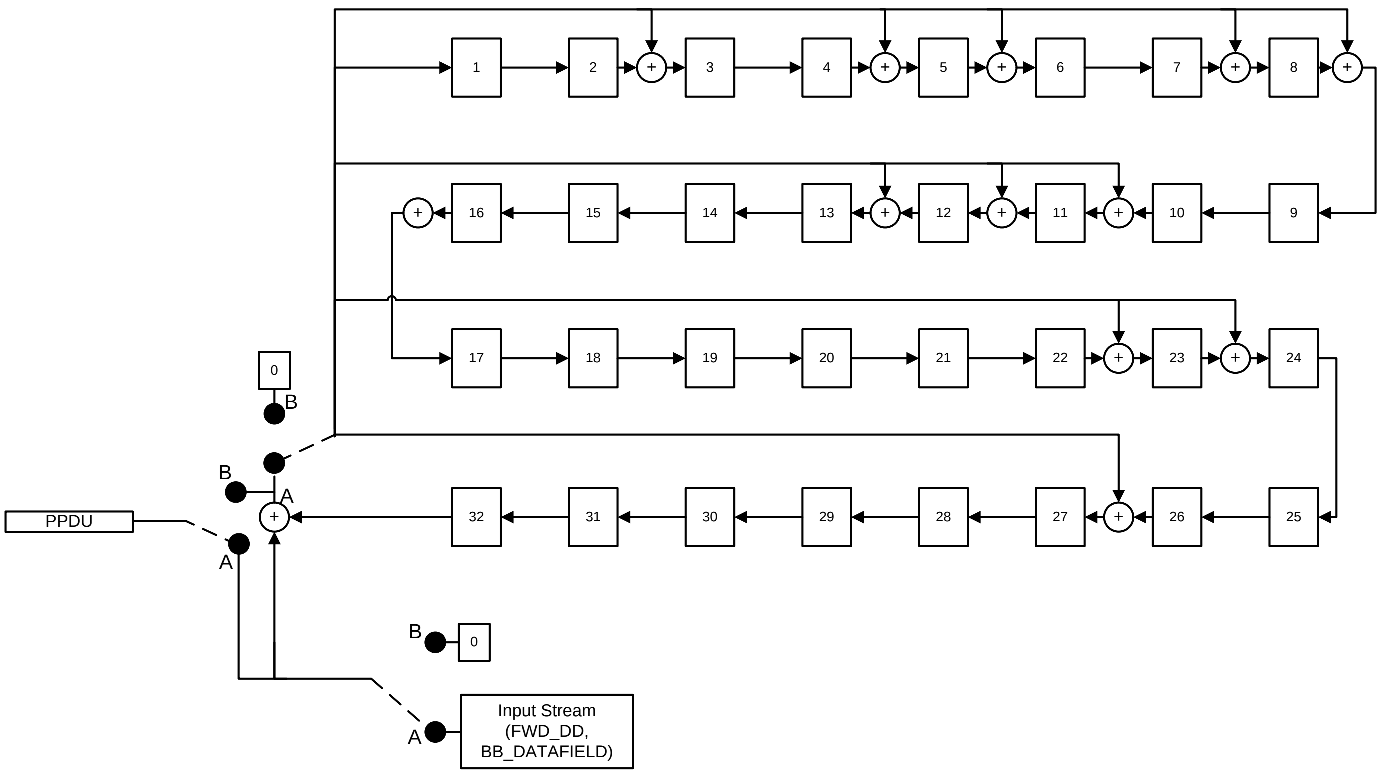



**Figure 8-7: CRC_32 computation**

### *8.5.2.5 Base-Band scrambling*

**CSREQ-2051**

The Base-band scrambling module shall perform data randomisation in order to ensure adequate binary transitions.

**CSREQ-2052**

The input stream of the Base-band scrambling module shall be a FWD_PPDU and the output stream shall be a FWD_S_PPDU (FWD Scrambled PPDU).

(Note: the length of the input and output data stream (FWD_PPDU and FWD_S_PPDU) is the same, as the Base-band scrambling does not add redundancy)

**CSREQ-2050**

The Base-band scrambling shall be synchronous with the FWD_PPDU.

**CSREQ-2060**

The scrambled frame (FWD_S_PPDU) shall be generated by the following feed-back shift register: TBD

### *8.5.2.6 FEC Encoding*

**CSREQ-6071**

The FEC Encoding module shall perform the following functions:

- Inner channel coding (IRA LDPC)
- Bit interleaving

**CSREQ-6072**

The input stream of the FEC encoding module shall be a FWD_S_PPDU and the output stream shall be 4 FWD_FECFRAME, as illustrated in the following figure.

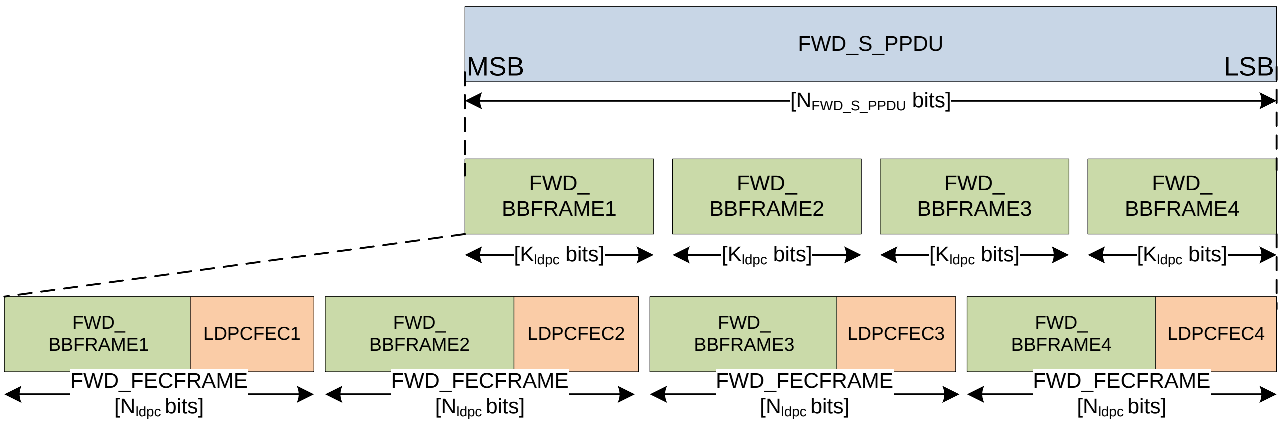



**Figure 8-8: Output stream of the FEC Encoding before the bit interleaving**

**CSREQ-6070**

The FWD_S_PPDU ($N_{FWD\_S\_PPDU}$ bits) shall be divided in 4 FWD_BBFRAME of $K_{ldpc}$ bits each starting from the MSB (i.e. FWD_BBFRAME1 contains the MSB of FWD_S_PPDU).

$K_{ldpc}$ depends on the supported MODCOD types (Mode). The coding parameters are provided in the following table.

| MODCOD Id | MODCOD | $N_{FWD\_S\_PPDU}$ (bits) | $K_{ldpc}$ (bits) | $N_{ldpc}$ (bits) |
|---|---|---|---|---|
| MODCOD1 | QPSK 1/3 | 8192 bits | 2048 bits | 6144 bits |
| MODCOD2 | QPSK 1/2 | 12288 bits | 3072 bits | 6144 bits |
| MODCOD3 | QPSK 2/3 | 16384 bits | 4096 bits | 6144 bits |
| MODCOD4 | 8-PSK 1/2 | 18432 bits | 4608 bits | 9216 bits |
| MODCOD5 | 8-PSK 2/3 | 24576 bits | 6144 bits | 9216 bits |
| MODCOD6 | 16-APSK 2/3 | 32768 bits | 8192 bits | 12288 bits |
| Note: QPSK 2/3 and 8-PSK 2/3 shall be punctured according to the puncturing patterns specified in CSREQ-2120. | | | | |

**Table 8-8: BBFRAME block size**

**CSREQ-6080**

The 4 FWD_BBFRAME belonging to the same FWD_S_PPDU shall be encoded with the same MODCOD.

*8.5.2.6.1 Inner encoding (LDPC)*

**CSREQ-2080**

Each FWD_BBFRAME$_i$ ($K_{ldpc}$ bits) shall be encoded using IRA LDPC codes to generate a FWD_FECFRAME$_i$ ($N_{ldpc}$ bits).

**CSREQ-2090**

LDPC parity bits shall be appended after the FWD_BBFRAME, as illustrated in Figure 8-9:

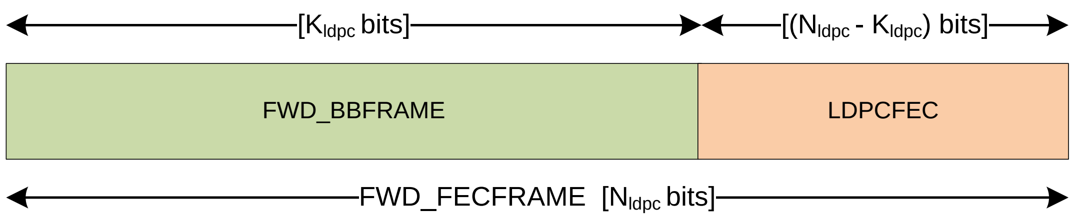



**Figure 8-9: Format of data after FEC encoder (LDPC)**

**CSREQ-2110**

The FWD_BBFRAME shall be encoded following the procedure specified in section 14.

**CSREQ-2120**

The output of the LDPC encoder shall be punctured according to the puncturing patterns detailed in the following table in order to obtain the desired code rate. The puncturing pattern shall only be applied over the parity bits (LDPCFEC field in Figure 8-9), systematic (FWD_BBFRAME field in Figure 8-9) bits are not affected by the puncturing.

| MODCOD Id | MODCOD | Original code | Puncturing pattern (p) $[p_{2k}\ p_{2k+1}]$ | Comments |
|---|---|---|---|---|
| MODCOD 1 | QPSK 1/3 | 1/3 | [1 1] | No puncturing |
| MODCOD 2 | QPSK 1/2 | 1/2 | [1 1] | No puncturing |
| MODCOD 3 | QPSK 2/3 | 1/2 | [1 0] | Puncturing pattern over the parity bits |
| MODCOD 4 | 8-PSK 1/2 | 1/2 | [1 1] | No puncturing |
| MODCOD 5 | 8-PSK 2/3 | 1/2 | [1 0] | Puncturing pattern over the parity bits |
| MODCOD 6 | 16-APSK 2/3 | 1/2 | [1 1] | No puncturing |

Notes:

- the punctured code is obtained by periodically-repeating over the parity bits the puncturing pattern p, starting for the MSB of the LDPCFEC field
- In the puncturing pattern, ‘1’ denotes the bit positions related to the transmitted and bits, and ‘0’ denotes the bit positions related to the punctured bits.
- $p_{2k}$, $p_{2k+1}$ represent the LDPC parity bits

**Table 8-9: LDPC puncturing patterns**

The transmitted sequence for code rates without puncturing (1/3 and 1/2) shall be:

$$i_0, i_1, i_2, i_3, \ldots\ldots., i_{kldpc-3}, i_{kldpc-2}, i_{kldpc-1}, p_0, p_1, p_2, p_3, \ldots\ldots., p_{nldpc-kldpc-3}, p_{nldpc-kldpc-2}, p_{nldpc-kldpc-1}$$

The transmitted sequence for code rates with puncturing (2/3) shall be:

$$i_0, i_1, i_2, i_3, \ldots\ldots., i_{kldpc-3}, i_{kldpc-2}, i_{kldpc-1}, p_0, p_2, \ldots\ldots.. p_{nldpc-kldpc-4}, p_{nldpc-kldpc-2}$$

where $i_k$ stands for the LPDC code information bits (FWD_BBFRAME bits) and $p_n$ stands for the LDPC code parity bits.

**CSREQ-7260**

The de-puncturing shall be performed by reconstructing the original code rate according to CSREQ-2120 by inserting “erasure” bits into the received data stream at the positions in which the original rate coded bits were deleted on the transmitting side.

The “erasure” bits shall be 0.

*8.5.2.6.2 Bit interleaving (for 8-PSK and 16-APSK only)*

**CSREQ-2130**

The output of the LDPC encoder and puncturing (FWD_FECFRAME) shall be bit interleaved using a block interleaver (row/column) with the parameters defined in the following table:

| Modcod Id | MODCOD | $N_{FWD}$ (Rows) | $M_{FWD}$ (Columns) |
|---|---|---|---|
| MODCOD 1 | QPSK 1/3 | N.A | N.A |
| MODCOD 2 | QPSK 1/2 | N.A | N.A |
| MODCOD 3 | QPSK 2/3 | N.A | N.A |
| MODCOD 4 | 8-PSK 1/2 | 3072 | 3 |
| MODCOD 5 | 8-PSK 2/3 | 3072 | 3 |
| MODCOD 6 | 16-APSK 2/3 | 3072 | 4 |
| Note:<br>– N stands for the number of rows<br>– M stands for the number of columns | | | |

**Table 8-10: Bit interleaver parameters**

**CSREQ-6160**

The bit interleaver depth shall be 1 FWD_FECFRAME (1 Code Word)

**CSREQ-6170**

On the transmitter side, the encoded bits shall be serially written into the interleaver column-wise and shall be serially read out row-wise according to Figure 8-10. MSB of FWD_FECFRAME shall be written and read out first.

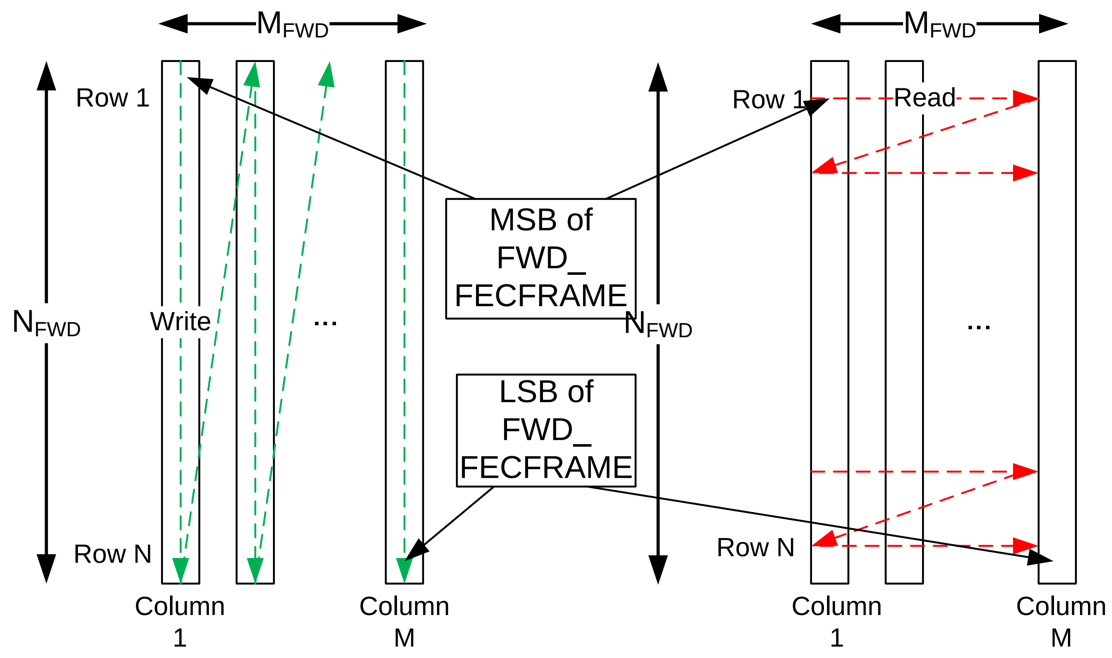



**Figure 8-10: Bit interleaving scheme (Tx side)**

**CSREQ-6180**

On the receiver side, the encoded bits shall be serially written in row-wise and shall be serially read in column-wise. MSB of FWD_FECFRAME shall be written and read out first.

*8.5.2.7 Bit mapping into constellation*

**CSREQ-2141**

The Bit Mapping module shall perform the mapping of the incoming bits into symbols (complex values) according to the specified constellation order.

**CSREQ-2142**

The input stream of the bit mapping module shall be a FWD_FECFRAME and the output stream shall be a FWD_XFECFRAME (FWD compleX FECFRAME)

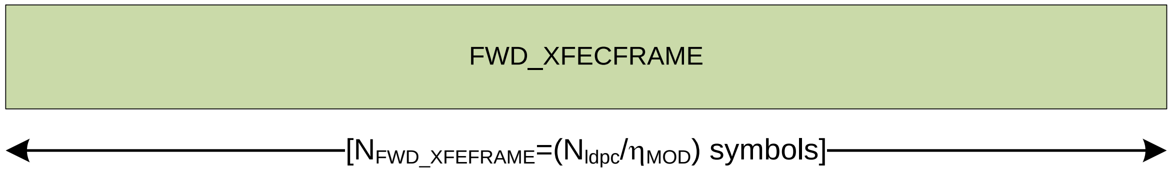



**Figure 8-11: Data format at the output of the Bit mapping module**

**CSREQ-2140**

Each FWD_FECFRAME shall be serial-to-parallel converted. Three parallelism levels shall be supported (parallelism level = $\eta_{MOD}$)

- $\eta_{MOD}$=2 for QPSK
- $\eta_{MOD}$=3 for 8-PSK
- $\eta_{MOD}$=4 for 16-APSK

Then, each parallel sequence shall be mapped into constellation, generating a complex (I,Q) sequence (FWD_XFECFRAME) according to the modulation efficiency ($\eta_{MOD}$) as described in section 8.5.2.7.1 for $\eta_{MOD}$=2, section 8.5.2.7.2 for $\eta_{MOD}$=3 and section 8.5.2.7.3 for $\eta_{MOD}$=4.

**CSREQ-6200**

The number of symbols after the bit mapping shall be constant, as detailed in the following table

| Modcod Id | MODCOD | $N_{ldpc}$ (bits) FWD_FECFRAME size | Mod. efficiency ($\eta_{MOD}$) | $N_{FWD\_XFECFRAME}$ (symbols) FWD_XFECFRAME size |
|---|---|---|---|---|
| MODCOD 1 | QPSK 1/3 | 6144 bits | 2 | 3072 symbols |
| MODCOD 2 | QPSK 1/2 | 6144 bits | 2 | 3072 symbols |
| MODCOD 3 | QPSK 2/3 | 6144 bits | 2 | 3072 symbols |
| MODCOD 4 | 8-PSK 1/2 | 9216 bits | 3 | 3072 symbols |
| MODCOD 5 | 8-PSK 2/3 | 9216 bits | 3 | 3072 symbols |
| MODCOD 6 | 16-APSK 2/3 | 12288 bits | 4 | 3072 symbols |

**Table 8-11: Bit mapping parameters**

**CSREQ-6100**

The FWD_FECFRAMEs belonging to the same FWD_S_PPDU (4 FWD_FECFRAME) shall be modulated (bit-mapped) using the same modulation format.

*8.5.2.7.1 Bit mapping into QPSK constellation*

**CSREQ-2150**

The bit mapping into QPSK constellation shall be compliant with Figure 8-12. Two FWD_FECFRAME bits shall be mapped to a QPSK symbol.

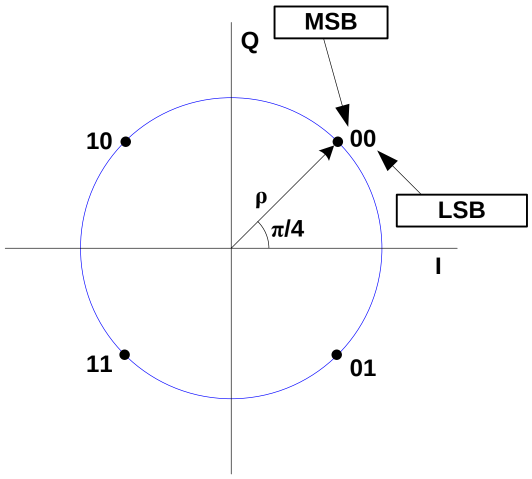



**Figure 8-12: Bit mapping into QPSK modulation**

**CSREQ-2160**

For the QPSK modulation, the normalised average energy per symbol shall be equal to $\rho^2 = 1$.

*8.5.2.7.2 Bit mapping into 8-PSK constellation*

**CSREQ-2170**

The bit mapping into the 8-PSK constellation shall be compliant with Figure 8-13. Three FWD_FECFRAME bits shall be mapped to a 8-PSK symbol.

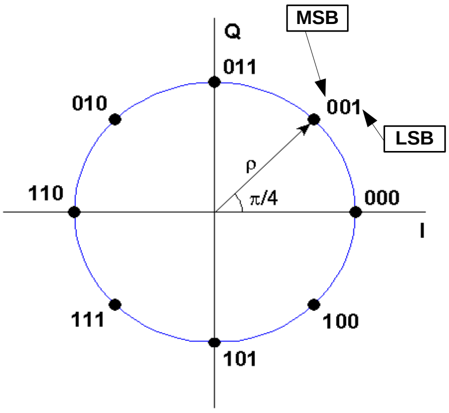



**Figure 8-13: Bit mapping into 8-PSK modulation**

### CSREQ-2180

For the 8-PSK modulation, the normalised average energy per symbol shall be equal to $\rho^2 = 1$.

*8.5.2.7.3 Bit mapping into 16-APSK constellation*

### CSREQ-2190

The 16-APSK modulation constellation shall be composed of two concentric rings of uniformly spaced 4 and 12-PSK points respectively in the inner ring of radius $R_1$ and the outer ring of radius $R_2$ (See Figure 8-14).

### CSREQ-2200

The bit mapping of the 16-PSK constellation shall be compliant with Figure 8-14. Four FWD_FECFRAME bits shall be mapped to a 16-APSK symbol.

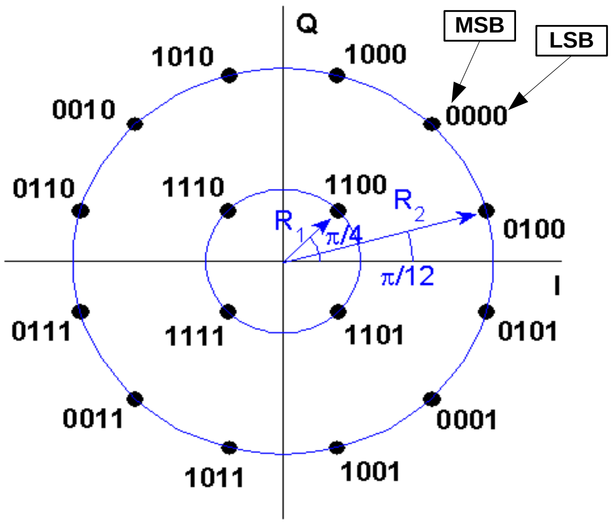



**Figure 8-14: Bit mapping into 16-APSK modulation**

**CSREQ-2210**

The ratio of the outer circle radius to the inner circle radius shall comply with Table 8-12: Optimum constellation radius ratio for 16-APSK:

| Code rate | Modulation/coding spectral efficiency | γ |
|---|---|---|
| 2/3 | 2.66 | 3.15 |

**Table 8-12: Optimum constellation radius ratio for 16-APSK**

*Note: the ratio between the outer and inner circle depends on the code rate.*

**CSREQ-2220**

For the 16-APSK modulation, the $R_1^2 + 3R_2^2 = 4$ equality shall be complied with, in order to ensure that the average energy per symbol shall be equal to $\rho^2 = 1$.

### *8.5.2.8 Symbol interleaving*

**CSREQ-6211**

The Symbol Interleaving module shall interleave the symbols of 4 FWD_XFECFRAMES in order to exploit the time diversity.

**CSREQ-6212**

The input stream of the Symbol Interleaving module shall be 4 FWD_XFECFRAME and the output shall be a FWD_I_XFRAME (FWD Interleaved complex FRAME)

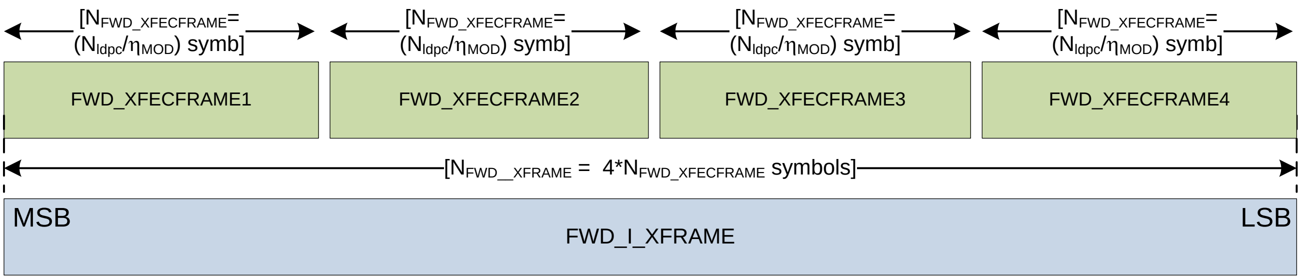



**Figure 8-15: Data format at the output of the Symbol Interleaving module**

**CSREQ-6210**

4 FWD_XFECFRAMES shall be symbol interleaved using a block interleaver (row/column) with the parameters defined in the following table:

| **Modcod Id** | **MODCOD** | **D (Number of rows)** | **P (Number of colums)** | **$N_{FWD\_I\_XFRAME}$ (symbols)** |
|---|---|---|---|---|
| MODCOD 1 | QPSK 1/3 | 192 | 64 | 12288 symbols |
| MODCOD 2 | QPSK 1/2 | 192 | 64 | 12288 symbols |
| MODCOD 3 | QPSK 2/3 | 192 | 64 | 12288 symbols |
| MODCOD 4 | 8-PSK 1/2 | 192 | 64 | 12288 symbols |
| MODCOD 5 | 8-PSK 2/3 | 192 | 64 | 12288 symbols |
| MODCOD 6 | 16-APSK 2/3 | 192 | 64 | 12288 symbols |
| Note:<br>– D stands for the number of rows<br>– P stands for the number of columns | | | | |

**Table 8-13: Symbol interleaver parameters**

**CSREQ-6230**

On the transmitter side, the symbols shall be serially written in column-wise (starting from the MSB of FWD_XFECFRAME1 and ending with the LSB of FWD_XFECFRAME4) and shall be serially read out row-wise according to the following figure.

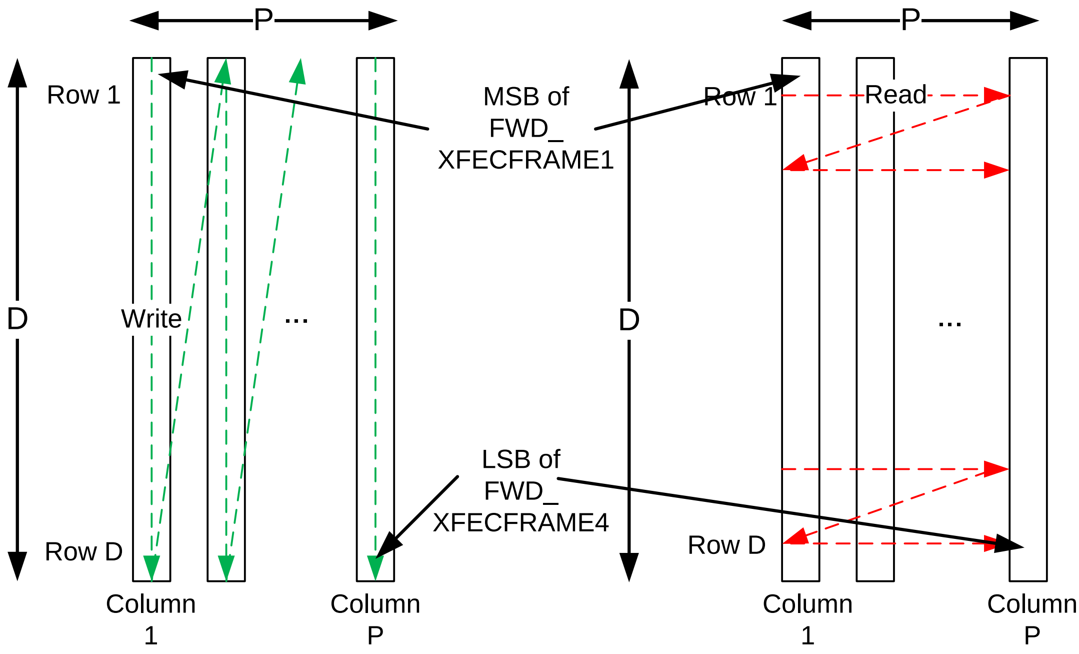



**Figure 8-16: Symbol interleaving scheme**

**CSREQ-6240**

On the receiver side, the symbols shall be serially written in row-wise and shall be serially read out column-wise.

### *8.5.2.9 Physical Layer Framing*

**CSREQ-2021**

The Physical Layer Framing module shall perform the following process:

- PLHEADER (Physical Layer Header) generation and insertion.
- PB (Pilot Block) insertion.
- FWD_PREAMBLE insertion.
- FWD_POSTAMBLE insertion.

**CSREQ-2022**

The input stream of the Physical Layer Framing sub-system shall be a FWD_I_XFRAME and the output a FWD_PLFRAME.

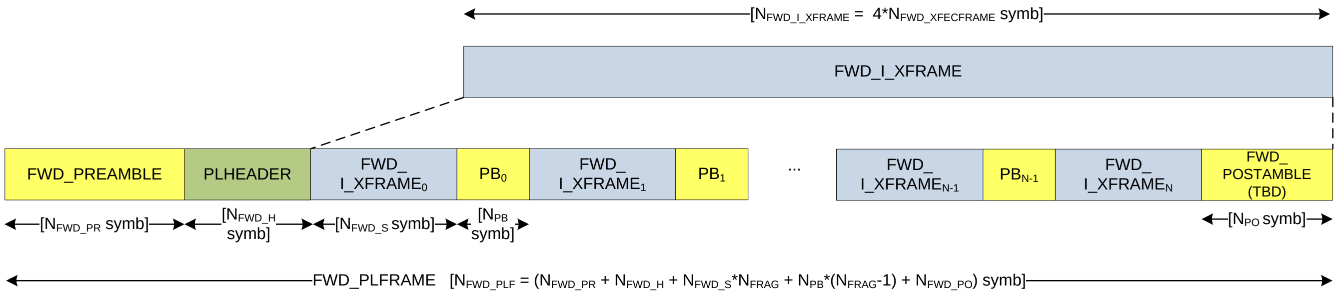



**Figure 8-17: Data format at the output of the Physical layer framing module**

**CSREQ-2020**

The FWD_PLFRAME shall be surrounded by guard time which allows for power switch-off transients and system timing errors. The guard time of the FCH shall be 12 symbols.

*8.5.2.9.1 PLHEADER generation and insertion*

**CSREQ-1940**

The FWD_BD (FWD Burst Descriptor) field shall break into:

- The MODCOD_ID field (3 bits) (TBC)

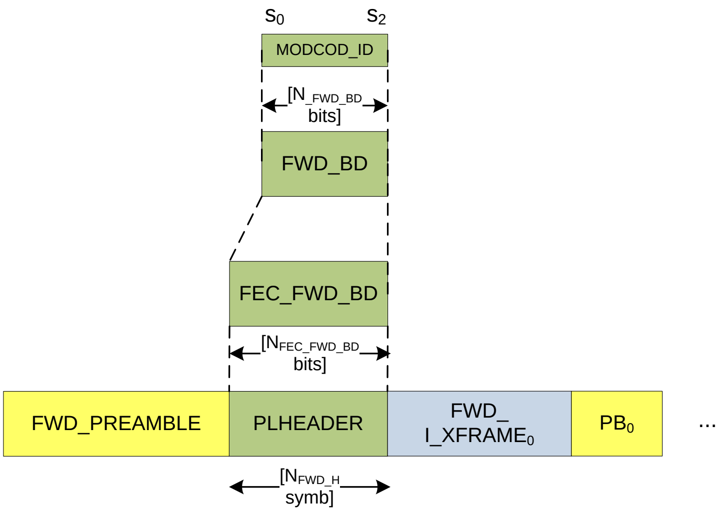



**Figure 8-18: Construction and insertion of FWD_BD header**

**CSREQ-1950**

The MODCOD_Id field shall indicate which MODCOD has been used for transmitting the FWD_I_XFRAME. The MODCOD_Id shall be coded on $N_{FWD\_BD}$ = 3 bits ($s_0$, $s_1$, $s_2$) according to the following table:

| Mode | MODCOD_Id | | |
|---|---|---|---|
| | bit $s_0$ | bit $s_1$ | bit $s_2$ |
| QPSK 1/3 | 0 | 0 | 1 |
| QPSK 1/2 | 0 | 1 | 0 |
| QPSK 2/3 | 0 | 1 | 1 |
| 8-PSK 1/2 | 1 | 0 | 0 |
| 8-PSK 2/3 | 1 | 0 | 1 |
| 16-APSK 2/3 | 1 | 1 | 0 |
| RFU | 0 | 0 | 0 |
| RFU | 1 | 1 | 1 |

**Table 8-14: Feasible forward link MODCODS for Traffic burst**

**CSREQ-1970**

The FWD_BD field shall be encoded with TBD block code, generating the FEC_FWD_BD field of $N_{FEC\_FWD\_BD}$ bits length.

**CSREQ-1971**

The FEC_FWD_BD field shall be modulated in QPSK, according to the specification in section 8.5.2.7.1, generating the PLHEADER of $N_{FWD\_H}$ symbols length.

**CSREQ-1972**

The PLHEADER shall be inserted before the FWD_I_XFRAME, as illustrated in Figure 8-17.

*8.5.2.9.2 PB (Pilot Blocks) insertion*

**CSREQ-1981**

The FWD_I_XFRAME shall be divided in constant-length fragments of $N_{FWD\_S}$ = 32 symbols each, called $FWD\_I\_XFRAME_i$ (See Figure 8-17).

The number of fragments per FWD_I_XFRAME shall be as detailed in the following table.

| MODCOD_Id | FWD_I_XFRAME length (symbols) | $N_{FWD\_FRAG}$ (Number of 32-symbols fragments) |
|---|---|---|
| From MODCOD1 to MODCOD6 | 12288 symbols | 384 fragments |
| Note: The I_XFRAME length does not depend on the MODCOD. | | |

**Table 8-15: Number of fragments ($N_{FWD\_FRAG}$) per FWD_I_XFRAME**

**CSREQ-1980**

A PB (Pilot Block) field of $N_{PB}$=3 symbols shall be inserted after each FWD_I_XFRAME$_i$ with the exception of the last fragment (FWD_I_XFRAME$_N$), as illustrated in Figure 8-17.

**CSREQ-1990**

The PB field shall be modulated in QPSK following the specification described in section 8.5.2.7.1.

**CSREQ-6150**

The contents of each PB field shall be the following: TBD

#### *8.5.2.9.3 PREAMBLE insertion*

**CSREQ-1901**

The FWD_PREAMBLE shall be inserted before the PLHEADER, as illustrated in Figure 8-17.

**CSREQ-1900**

The FWD_PREAMBLE shall consists of a $N_P$= 100 symbol (TBC) string modulated in QPSK format following the specification described in section 8.5.2.7.1

**CSREQ-1910**

The FWD_PREAMBLE sequence shall be: TBD

*8.5.2.9.4 POSTAMBLE insertion*

**CSREQ-1902**

The FWD_POSTAMBLE shall be inserted after the last FWD_I_XFRAME fragment (FWD_I_XFRAME$_{383}$), as illustrated in Figure 8-17.

**CSREQ-1903**

The FWD_POSTAMBLE shall consists of a $N_{FWD\_PO}$= TBD symbol string modulated in QPSK format following the specification described in section 8.5.2.7.1

**CSREQ-1904**

The FWD_POSTAMBLE sequence shall be: TBD

*8.5.2.10 Base-band pulse shaping and quadrature modulation*

**CSREQ-2010**

After the bit mapping, the FWD_PLFRAME shall be shaped and quadrature modulated.

**CSREQ-2230**

I and Q signals shall be shaped using a Square Root Raised Cosine with a roll-off factor $\alpha$=0.2.

**CSREQ-2240**

The baseband SRRC filter shall have a theoretical function defined by the following expression.

$$H(f) = 1 \qquad \text{for } |f| < f_N(1-\alpha)$$

$$H(f) = \left\{ \frac{1}{2} + \frac{1}{2}\sin\frac{\pi}{2f_N}\left[\frac{f_N - |f|}{\alpha}\right]\right\}^{1/2} \qquad \text{for } f_N(1-\alpha)$$

$$H(f) = 0 \text{ for } |f| > f_N(1+\alpha),$$

where $f_N = \frac{R_S}{2}$ is the Nyquist frequency and $\alpha$ is the roll-off factor.

**CSREQ-2250**

The quadrature modulation shall be performed by multiplying the In-phase component (I) by $\cos(2\pi f_0 t)$ and the Quadrature component (Q) by $-\sin(2\pi f_0 t)$. I and Q signals shall be added to conform the modulation output.

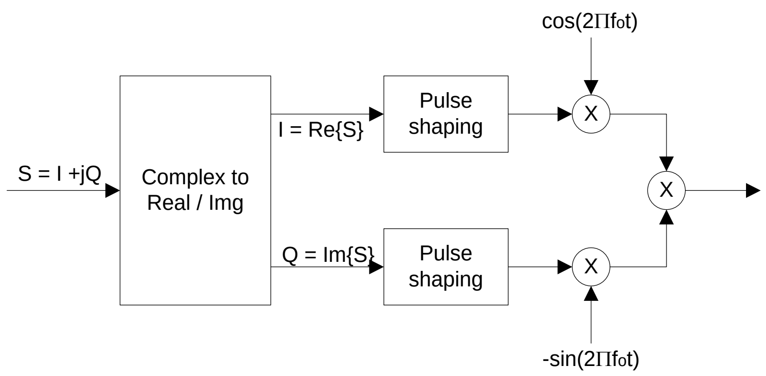



**Figure 8-19: Forward link modulation**

## 8.6 User plane return link specification

### *8.6.1 Link layer specification*

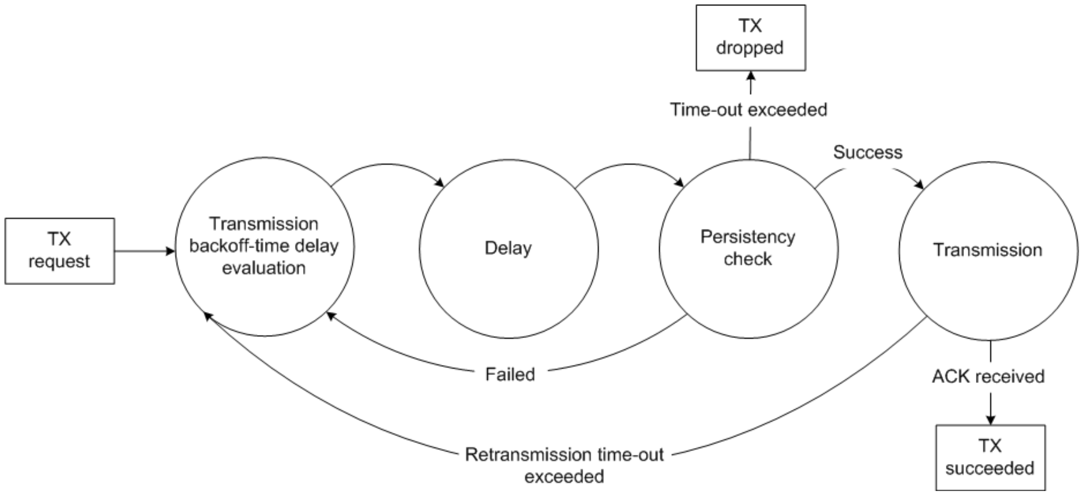
#### *8.6.1.1 Random access*

**CSREQ-6470**

The CS shall support the ALOHA state machine depicted below for RTN link random access.

It includes the following steps:

- Every time a transmission is going to happen, a random delay (back-off delay), following an exponential distribution (pdf = $\lambda e^{-\lambda x}$), is applied. The mean value of this delay, defined as $\frac{1}{\lambda}\lambda = 2^n \cdot tx\_backoff$, increases with the number of transmissions (n). *tx_backoff* is a configuration parameter associated to congestion control.
- After the application of the transmission back-off delay, a persistency check is performed. With a probability equal to the persistency parameter, the transmission is actually performed. Otherwise a new delay is applied, using the procedure described in the previous bullet. This operation is repeated until the PSDU is transmitted or a time-out is exceeded. In this latter case the PSDU is dropped without being transmitted.
- After every (effective) transmission a timer is started and if it exceeds the time-out, a retransmission is attempted.

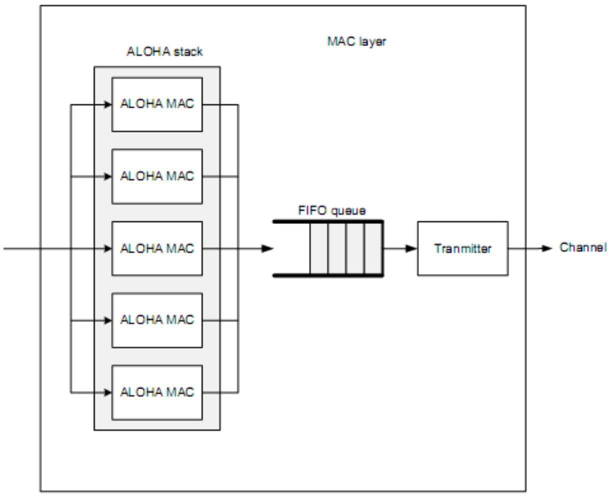



## CSREQ-6480

Several ALOHA state machines as defined in CSREQ-6470 shall run in parallel (ALOHA state machine bank). Each of them shall work independently, scheduling pending data for transmission once the state machine becomes idle (i.e., previous transmission has either succeeded or failed).

## CSREQ-6490

A PSDU scheduled according to the ALOHA state machine bank shall be put into a FIFO (TBC, to be revised in B2 considering CoS refinements) transmission buffer before actual (physical) transmission.




Note: There is a single physical transmitter.

## CSREQ-6492

[Placeholder for the strategy to be adopted with the remaining LSDU in case a LSDU fragment can not been transmitted by an ALOHA state machine (TX dropped)].

**CSREQ-6494**

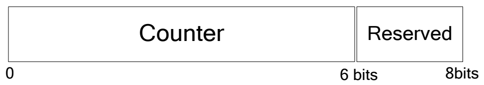
[Placeholder for TBC requirements associated to in-order transmission of LSDU fragments]

### 8.6.1.2 ARQ protocol

#### 8.6.1.2.1 ARQ header and ACK format

**CSREQ-6496** (preliminary, integration with encapsulation is pending)

The ARQ header shall include the following fields:




where

| Field | Length | Description |
|---|---|---|
| **Counter** | 6 bits | This field provides a sequence number for PSDU identification. |
| **Reserved** | 2 bits | TBD |

**Table 8-16: ARQ header fields**

**CSREQ-6498**

[Placeholder for ARQ ACK format]

#### 8.6.1.2.2 ARQ procedure

**CSREQ-6500**

An ARQ mechanism shall be integrated with each ALOHA state machine.

**CSREQ-6510**

ARQ for a single ALOHA state machine shall be based on a stop-and-wait strategy, with timeouts triggering retransmissions.

**CSREQ-6520**

One ARQ header management entity shall be active per CoS category and shall be common for the ALOHA state machine bank associated to the category.

**CSREQ-6525**

Retransmission timer shall be started when the PSDU is forwarded to the physical layer.

**CSREQ-6530**

Retransmission timer shall be set to PSDU frame transmission time plus RTT plus a configurable processing time plus a configurable margin.

### *8.6.1.3 Encapsulation*

**CSREQ-2260**

The return link encapsulation scheme shall support the integration, in the L2 header, of information optionally required for ARQ.

**CSREQ-2270**

The return link encapsulation scheme shall support the flexibility required in terms of addressing capabilities: i.e. 0, 2, 3 or 4 bytes addressing field.

**CSREQ-2280**

The UT shall support the encapsulation and fragmentation of L3 data units into L2 data units using the CS custom scheme for the return link.

**CSREQ-2290**

GS elements shall support the de-encapsulation and re-assembly of L3 packets from L2 fragments using the CS custom scheme for the return link.

**CSREQ-2310 (to be revised in B2)**

The return link encapsulation scheme used shall comply with the following:

Non Fragmented Custom Scheme Header

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S | E | AF | ARQ | Length | PT | C | R | (ARQ field) | (Source/Dest Address) | Payload | CRC-32 |

0 2 3 (+2) (+2 or +3 or +4) (+4)

First Fragment Custom Scheme Header

| S | E | AF | ARQ | Length | FID | PT | C | Total Length | (ARQ field) | (Source/Dest Address) | Payload |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2 | | | 4 | (+2) | (+2 or +3 or +4) | |

| S | E | AF | ARQ | Length | FID | (ARQ field) | (Source/Dest Address) | Payload |
|---|---|---|---|---|---|---|---|---|
| | | | | | 2 | (+2) | (+2 or +3 or +4) | |

| S | E | AF | ARQ | Length | FID | (ARQ field) | (Source/Dest Address) | Payload | Seq Number/ CRC-32 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2 | (+2) | (+2 or +3 or +4) | | +1 (or +4) |

where

| Field | Length | Description |
|---|---|---|
| **S** and **E** flags:<br>Start and End bits | 1 bit each | These fields indicate if the packet is non-fragmented (11), if it is the first fragment (10), the last fragment (01) or an intermediate fragment (00) of a fragmented packet. |
| **AF** field:<br>Address Format | 2 bits | This field indicates the address format that will be contained in the encapsulation header. It can take the following values:<br>**00**: No address field/label re-use<br>**01**: 2 bytes address field: UT source address<br>**10**: 3 bytes address field: 2 bytes source UT address + 1 byte destination GS element address<br>**11**: 4 bytes address field: 3 bytes source UT ICAO address + 1 byte destination GS element address |
| **ARQ** flag | 1 bits | This field indicates whether the ARQ process is used, implying an additional 2 bytes field for un-fragmented packet, and for every fragment when fragmented. |
| **Length** field | 11 bits not fragmented/<br>8 bits fragmented | This field indicates the length of the L2 payload size for the current fragment (for fragmented packet) or the total length of the payload for non-fragmented packet. This length enables physical payload sizes up to 259 bytes (this length is sufficient in regards to the considered physical burst size over the return link, which is below 200 bytes). |
| **PT** field:<br>Payload Type | 3 bits | This field indicates the type of the contained payload that can be ATN/IPS, ATN/OSI, Signalling, compressed data, etc. |
| **C** flag:<br>CRC Presence | 1 bits | This field indicates if a 4 bytes CRC field is present as a trailer in the current packet (when un-fragmented). |
| **R** field:<br>Reserved | 4 bits | This field is reserved for future use. |
| **ARQ** field:<br>ARQ Information | 2 bytes | This optional field contains the information required for the ARQ process when the ARQ bit is set to 1. It shall comply with §8.6.1.1. When fragmented, the ARQ mechanism reuses the Flow ID field already present in the encapsulation header. Thus only the Packet Count and the fragment count fields are present within this ARQ field. When non fragmented, the three fields of the ARQ are required (FID, PC and FC). |
| **Source/Dest Address** field | optional field of 2, 3 or 4 bytes | This field is optional and contains the source and destination addresses as indicated by the Address Format (AF) field. |

| Field | Length | Description |
|---|---|---|
| **FID** field:<br>Flow ID | 3 bits | This field identifies the Class of Service (or the flow) of the current packet (it permits to differentiate interleaving of various CoS or MODCODs). This field is used by re-assembly process when the packet is fragmented and by ARQ process when activated. |
| **Total Length** field | 12 bits | This field indicates the total length of the L3 payload when fragmented. This length enables L3 packet sizes up to 4096 bytes. |
| **Seq Number/CRC-32** field | 1 or 4 bytes | When indicated by the C bit or by system design, a 4 bytes trailer is added after the payload when un-fragmented or at the end of the last fragment when fragmented. When fragmented, if this option is set by system design, a 1-byte sequence number is added and used by re-assembly process to identify the fragment having the same PID in case of fragment loss. |

**Table 8-17: Return link encapsulation fields**

#### *8.6.1.4 Security*

Refer to 8.3.

### *8.6.2 Physical layer specification*

#### *8.6.2.1 Burst types*

**CSREQ-2320**

On the return link the following burst types shall be implemented:

- RACH burst (Random Access Channel)

#### *8.6.2.2 Burst waveform generation*

**CSREQ-2321**

The burst waveform generation shall be applied to the RTN_PSDU and shall be composed of a sequence of functional modules as represented in Figure 8-20: Return link burst waveform generation. The functional blocks shall be:

- Physical Layer Adaption
- Error Detection
- Base Band scrambling
- FEC Encoding, which includes the inner encoding and the bit interleaver
- Auxiliary channel generation
- Bit Mapping into Constellation
- Spreading
- Physical Layer Framing
- Base-band Pulse Shaping and Quadrature Modulation

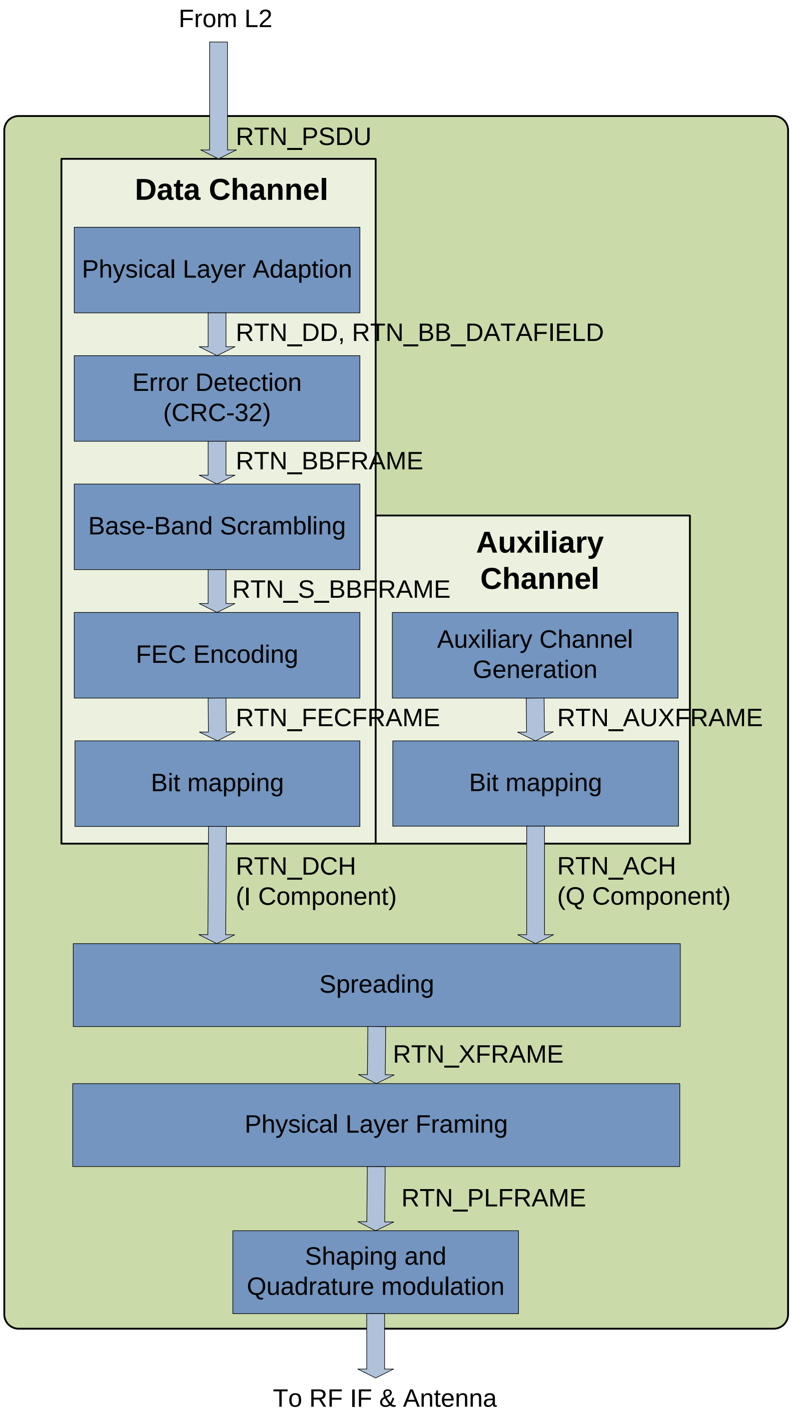



**Figure 8-20: Return link burst waveform generation**

**CSREQ-2640**

The RTN Link bursts shall follow the frame format presented in the following figure:

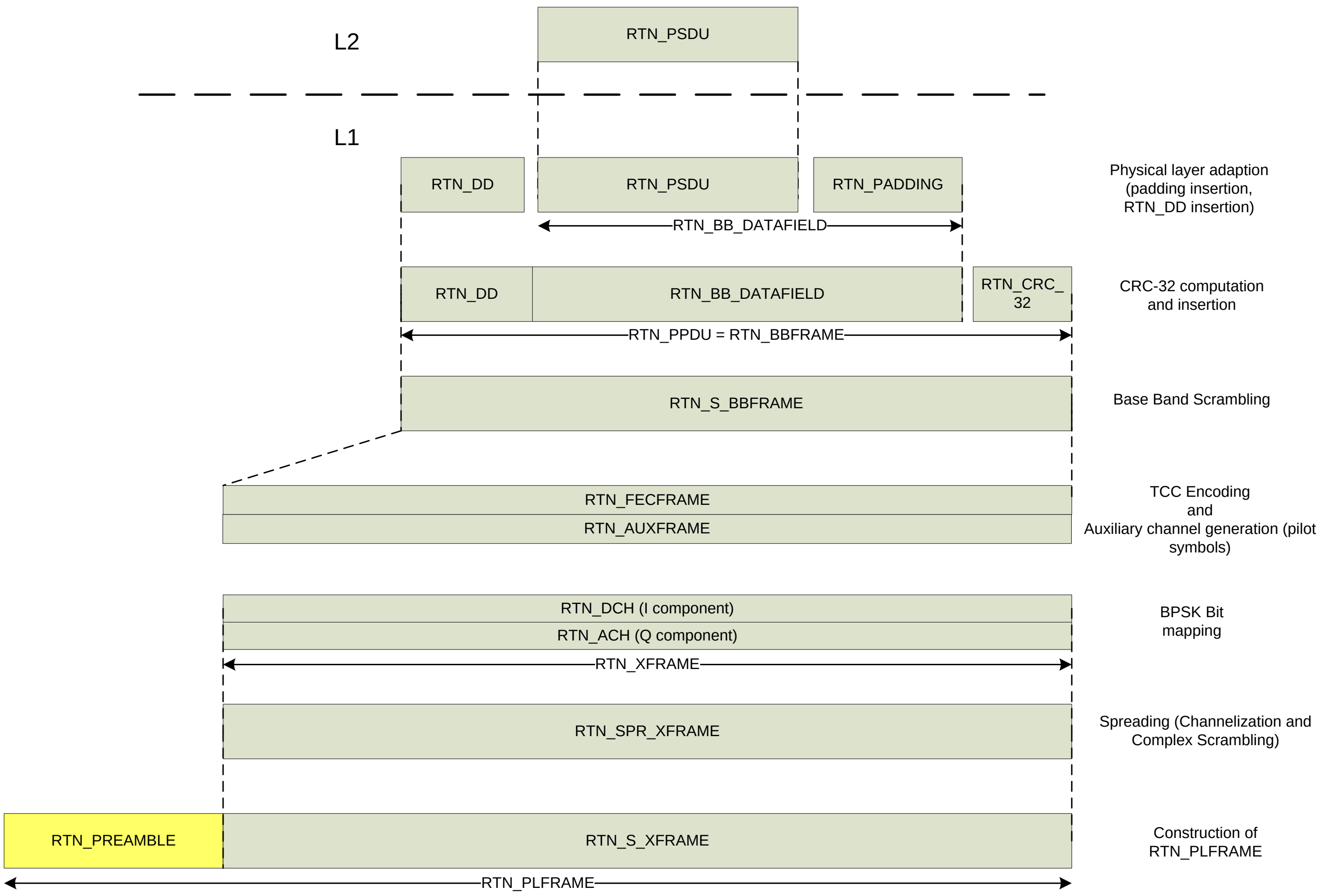



**Figure 8-21: RTN Link burst frame structure**

### CSREQ-6540

The RACH burst shall support the following configurations.

| RACH Configuration ID | Chip rate (kchip/s) | SF length | Mod | Code rate | Data Word Size (bits) - BBFRAME |
|---|---|---|---|---|---|
| $RACH\_CR_{160}\_SF_{16}\_DB_{512}$ | 160 (TBC) | 16 | BPSK | 1/3 | 512 (TBC) |
| $RACH\_CR_{160}\_SF_{4}\_DB_{2048}$ | 160 (TBC) | 4 | BPSK | 1/3 | 2048 (TBC) |
| $RACH\_CR_{160}\_SF_{4}\_DB_{288}$ | 160 (TBC) | 4 | BPSK | 1/3 | 288 (TBC) |

**Table 8-18: Allowed RACH burst configurations**

(Note: these configurations correspond to the Data Channel)

### *8.6.2.3 Physical Layer Adaption*

**CSREQ-2661**

The Physical Layer Adaption module shall perform:

- Interface with Layer 2
- Padding insertion
- RTN_DD (RTN Data Descriptor) insertion

**CSREQ-2662**

The input stream of the Physical Layer Adaption module shall be a RTN_PSDU and the output stream shall be a RTN_DD Header followed by a BB_DATAFIELD, as detailed in Figure 8-22.

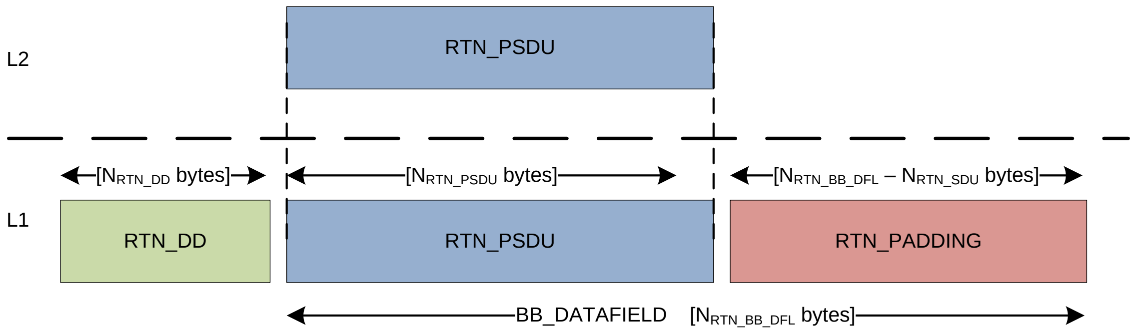



**Figure 8-22: Data format at the output of the RTN Physical Layer Adaption module**

**CSREQ-2660**

A single RTN PSDU shall be mapped onto a single burst.

#### *8.6.2.3.1 Interface with Layer 2*

**CSREQ-2650**

The Physical Layer Adaption module shall map RTN_PSDU of 3 types of layer 2 entities (or protocols):

- RLE
- Protocol 2 TBD
- Protocol 3 TBD

**CSREQ-2680**

The RTN_PSDU size (in bytes) shall be variable in the range depending on the selected RACH configuration. The maximum RTN_PSDU size (Max. $N_{RTN\_PSDU}$) shall be as follows:

| RACH Configuration ID | Max. $N_{RTN\_PSDU}$ [Maximum PSDU size (bytes)] |
|---|---|
| $RACH\_CR_{160}\_SF_{16}\_DB_{512}$ | 58 bytes (TBC) |
| $RACH\_CR_{160}\_SF_{4}\_DB_{2048}$ | 250 bytes (TBC) |
| $RACH\_CR_{160}\_SF_{4}\_DB_{288}$ | 30 bytes (TBC) |

**Table 8-19: Maximum PSDU size**

*8.6.2.3.2 Padding insertion*

**CSREQ-2691**

($N_{RTN\_BB\_DFL}$ - $N_{RTN\_PSDU}$) bytes shall be appended after the RTN_PSDU according to Figure 8-22. The contents of the padding bytes shall be “0x00”.

*8.6.2.3.3 RTN_DD (RTN Data Descriptor) insertion*

**CSREQ-2692**

A fixed length header (RTN_DD) of $N_{RTN\_DD}$= 2 bytes (bits $I_0$-$I_{15}$) shall be inserted in front of the RTN_BB_DATAFIELD according to Figure 8-22.

**CSREQ-2690**

The RTN_DD header shall contain the following fields:

| Bits | Field | Field size | Description |
|---|---|---|---|
| $I_0$ | RTN_PSDU Size Flag | 1 bit | It indicates if the PSDU Size is present in the RTN_DD header |
| $I_1$ | Alternate Descriptor Flag | 1 bit | It indicates if the Alternate Descriptor is present in the RTN_DD header |
| $I_2$-$I_3$ | L2 Protocol Type | 2 bits | It indicates the L2 protocol used in the RTN_PSDU |
| $I_4$-$I_{11}$ | Contents field | 8 bits | It contains the PSDU size or the Alternate Descriptor (see **CSREQ-6550**) |

| | | | |
|---|---|---|---|
| $I_{11}$-$I_{15}$ | Reserved field | 4 bits | Reserved for future use |

**Table 8-20: RTN_DD header fields**

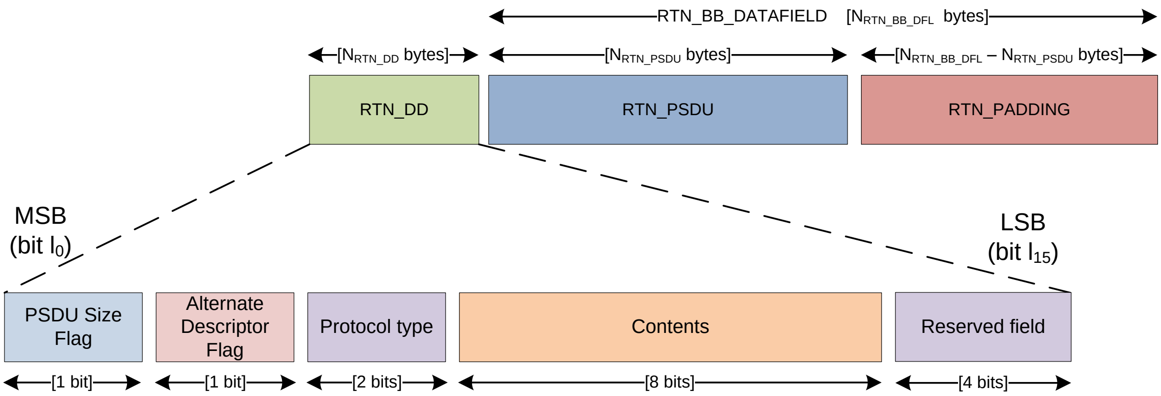



**Figure 8-23: FWD_DD Header fields**

### CSREQ-6550

The mapping of RTN_PSDU Size Flag, the Alternate Descriptor Flag and the Contents field shall be as detailed in Table 8-6.

| $I_0$ (RTN_PSDU Size Flag) | $I_1$ (RTN Alternate Descriptor Flag) | $I_4$-$I_{11}$ (RTN Contents Field) |
|---|---|---|
| 1 | 0 | "Contents" field is filled with the PSDU size, in bytes |
| 0 | 1 | "Contents" field is filled with the Alternate Descriptor<br>Note: Alternate Descriptor field is reserved for future use |
| 0 | 0 | N.A |
| 1 | 1 | N.A |

**Table 8-21: Contents field mapping**

### CSREQ-2730

The Protocol Type shall indicate which L2 entity is the client of the burst. It is a 2-bit field coded as follows:

| $I_2$ $I_3$ (RTN Protocol Type) | Description |
|---|---|
| 00 | Reserved |
| 01 | RLE |
| 10 | TBD |
| 11 | TBD |

**Table 8-22: RTN Link Protocol Type field mapping**

#### 8.6.2.4 *Error detection (CRC-32)*

**CSREQ-2741**

The RTN Error Detection module shall compute the CRC parity bits in order to detect erroneous packets in the receiver side and to provide a packet quality indicator.

**CSREQ-2742**

The input stream of the RTN Error Detection module shall be a RTN_DD header followed by a RTN_BB_DATAFIELD and the output stream shall be a RTN_PPDU (or a RTN_BBFRAME), as illustrated in Figure 8-24.

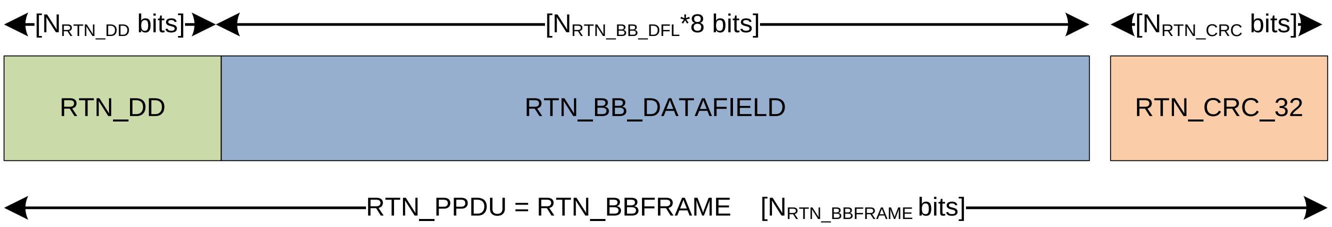



**Figure 8-24: Data format at the output of the RTN Error Detection module**

**CSREQ-2740**

The 32-bit CRC (RTN_CRC_32 field) shall be appended after the RTN_BB_DATAFIELD, as illustrated in Figure 8-24.

**CSREQ-2750**

The CRC_32 shall be computed over:

- The RTN_DD header
- The RTN_BB_DATAFIELD

**CSREQ-2760**

The content of the RTN_CRC_32 field shall be computed as it is described in **CSREQ-2030**, **CSREQ-2040** and **CSREQ-2041**.

#### *8.6.2.5 Base-band scrambling*

**CSREQ-2911**

The RTN Base-band scrambling module shall perform data randomisation in order to ensure adequate binary transitions.

**CSREQ-2912**

The input stream of the RTN Base-band scrambling module shall be a RTN_BBFRAME (or a RTN_PPDU) and the output stream shall be a RTN_S_BBFRAME (RTN Scrambled BBFRAME).

(Note: the length of the input and output data stream (RTN_BBFRAME and RTN_S _BBFRAME) is the same, as the Base-band scrambling does not add redundancy)

**CSREQ-2910**

The Base-band scrambling sequence shall be synchronous with the RTN_BBFRAME.

**CSREQ-2920**

The output stream (RTN_S_BBFRAME) shall be generated by the following feed-back shift register: TBD

#### *8.6.2.6 FEC encoding*

**CSREQ-2781**

The FEC Encoding module shall perform the following functions:

- Inner channel coding (TCC)
- Bit interleaving

**CSREQ-2782**

The input stream of the FEC encoding module shall be a RTN_S_BBFRAME and the output stream shall be a RTN_FECFRAME, as illustrated in the following figure.

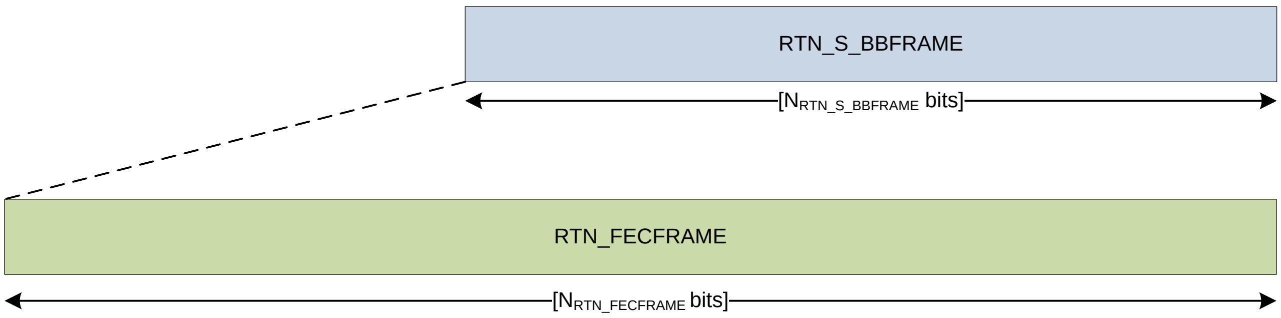



**Figure 8-25: Output stream of the FEC Encoding**

**CSREQ-2780**

The BBFRAME shall be encoded with 1/3 code rate using the inner coding described in section 8.6.2.6.1

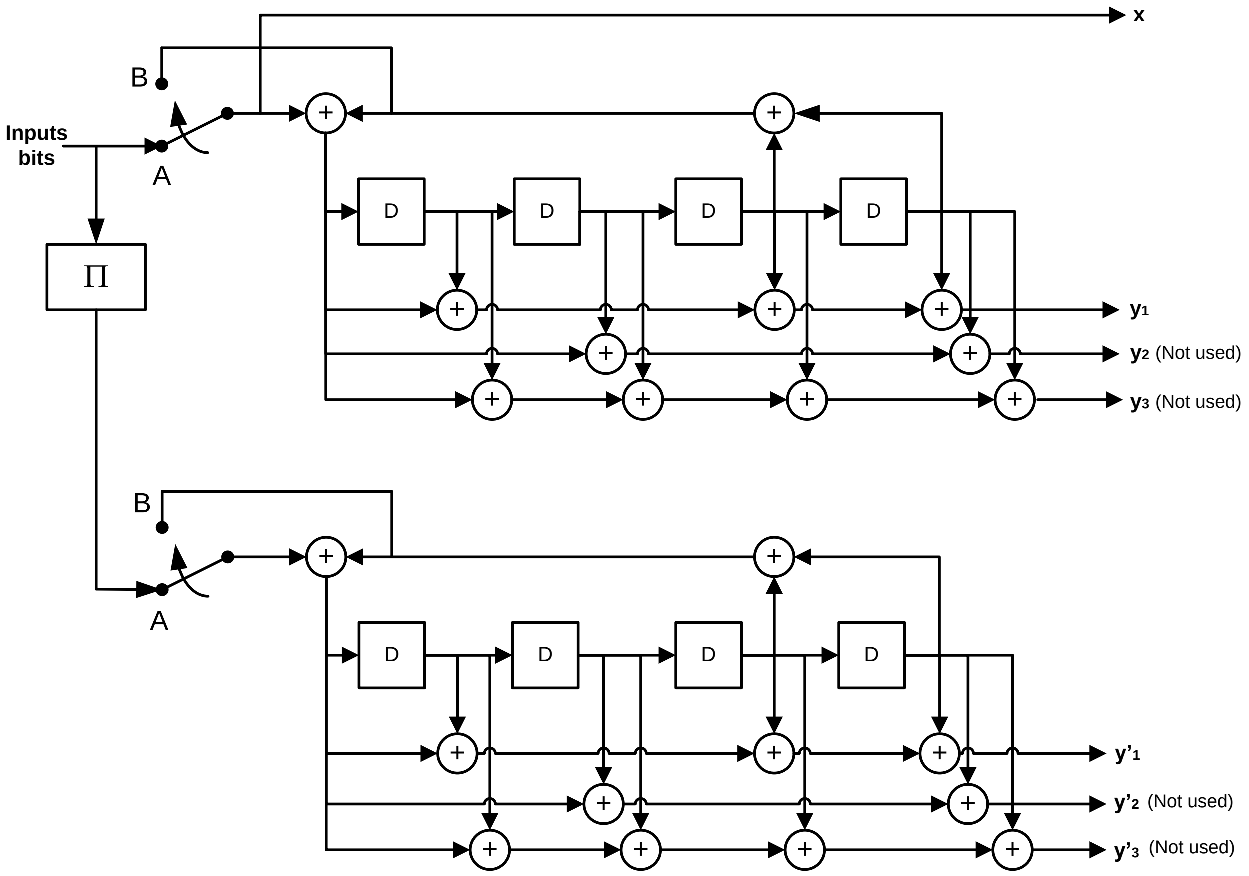
*8.6.2.6.1 Inner encoding (TCC)*

**CSREQ-2940**

The Forward Error correction scheme on the return link shall be Turbo Convolutional Codes.

**CSREQ-2960**

The Turbo code architecture shall be a Parallel Concatenated Convolutional Code (PCCC) with two identical 16-state binary, recursive and systematic convolutional encoders and a Turbo code internal interleaver, as it is depicted in the following figure.




(Note: $y_2$, $y_3$, $y'_2$, and $y'_3$ are not used for the code rate 1/3)

**Figure 8-26: PCCC 16-states binary architecture**

The Turbo encoder output shall be computed according to the following procedure (code rate 1/3):

1. Both 16-state constituent encoders shall be initialised with 0 in all the shift registers before coding a block (initial state).
2. All switches shall be set in the A position.
3. The encoded data shall be generated by clocking the constituent encoders $N_{RTN\_S\_BBFRAME}$ times. MSB of RTN_S_BBFRAME shall be inserted first in the TCC encoder. The constituent encoder outputs for each bit period k (k< $N_{RTN\_S\_BBFRAME}$) shall be the output sequence (k represents the ):

$$x(k),\ y_1(k),\ y'_1(k)$$

4. Once the last input bit has been inserted in the constituent encoders (LSB of RTN_S_BBFRAME), the switches shall be set to position B.
5. Then the tail (trellis termination) bits are generated by clocking 4 times the constituent encoders. The tail bits shall be appended after the encoded information block.The tail bits are transmitted in the same order as in step 3 and shall be:

*x*($N_{RTN\_S\_BBFRAME}$), $y_1$($N_{RTN\_S\_BBFRAME}$), $y'_1$($N_{RTN\_S\_BBFRAME}$), …, *x*($N_{RTN\_S\_BBFRAME+3}$), $y_1$($N_{RTN\_S\_BBFRAME+3}$), $y'_1$($N_{RTN\_S\_BBFRAME+3}$)

6. The transmitted sequence shall be:

*x*(0), $y_1$(0), $y'_1$(0), *x*(1), $y_1$(1), $y'_1$(1), …., *x*($N_{RTN\_S\_BBFRAME-1}$), $y_1$($N_{RTN\_S\_BBFRAME-1}$), $y'_1$($N_{RTN\_S\_BBFRAME-1}$), *x*($N_{RTN\_S\_BBFRAME}$), $y_1$($N_{RTN\_S\_BBFRAME}$), $y'_1$($N_{RTN\_S\_BBFRAME}$), …, *x*($N_{RTN\_S\_BBFRAME+3}$), $y_1$($N_{RTN\_S\_BBFRAME+3}$), $y'_1$($N_{RTN\_S\_BBFRAME+3}$)

**CSREQ-2970**

The transfer function of the 16-state constituent code for shall be:

$$G(D) = \left[ 1 \quad \frac{n_0(D)}{d(D)} \quad \frac{n_1(D)}{d(D)} \quad \frac{n_2(D)}{d(D)} \right],$$

where

$$d(D) = 1 + D^3 + D^4$$

$$n_0(D) = 1 + D + D^3 + D^4$$

$$n_1(D) = 1 + D^2 + D^4$$

$$n_2(D) = 1 + D + D^2 + D^3 + D^4$$

(Note: for code rate 1/3 only *d(D)* and $n_0(D)$ are required)

**CSREQ-3010**

The internal turbo interleaver shall be implemented as detailed in the algorithm provided in section 16.

**CSREQ-6660**

The TCC coding shall support the following RACH block sizes reported in the following table

| RACH Configuration ID | Code rate | RTN_S_BBFRAME (bits) | Tail bits | RTN_FECFRAME (bits) |
|---|---|---|---|---|
| RACH_CR$_{160}$_SF$_{16}$_DB$_{512}$ | 1/3 | 512 bits | 12 bits | 1548 bits |
| RACH_CR$_{160}$_SF$_4$_DB$_{2048}$ | 1/3 | 2048 bits | 12 bits | 6156 bits |
| RACH_CR$_{160}$_SF$_4$_DB$_{288}$ | 1/3 | 288 bits | 12 bits | 876 bits |

**Table 8-23: RACH TCC coding parameters**

#### *8.6.2.6.2 Bit interleaving*

**CSREQ-3030**

The output of the TCC encoder shall be bit interleaved using a block interleaver (row/column) with the parameters defined in the following table

| RACH Configuration ID | RTN_FECFRAME size (bits) | Bit interleaver specification | |
|---|---|---|---|
| | | $N_{RTN}$ | $M_{RTN}$ |
| RACH_SF$_{16}$_DB$_{512}$ | 1548 | 36 | 43 |
| RACH_SF$_{4}$_DB$_{2048}$ | 6156 | 36 | 171 |
| RACH_SF$_{4}$_DB$_{288}$ | 876 | 12 | 73 |
| Note:<br>– N stands for the number of rows<br>– M stands for the number of columns | | | |

**Table 8-24: RACH burst bit interleaver parameters**

**CSREQ-6670**

The bit interleaver depth shall be 1 RTN_FECFRAME (1 Code Word)

**CSREQ-6680**

On the transmitter side, the encoded bits shall be serially written in column-wise and shall be serially read out row-wise. MSB of RTN_FECFRAME shall be written and read out first.

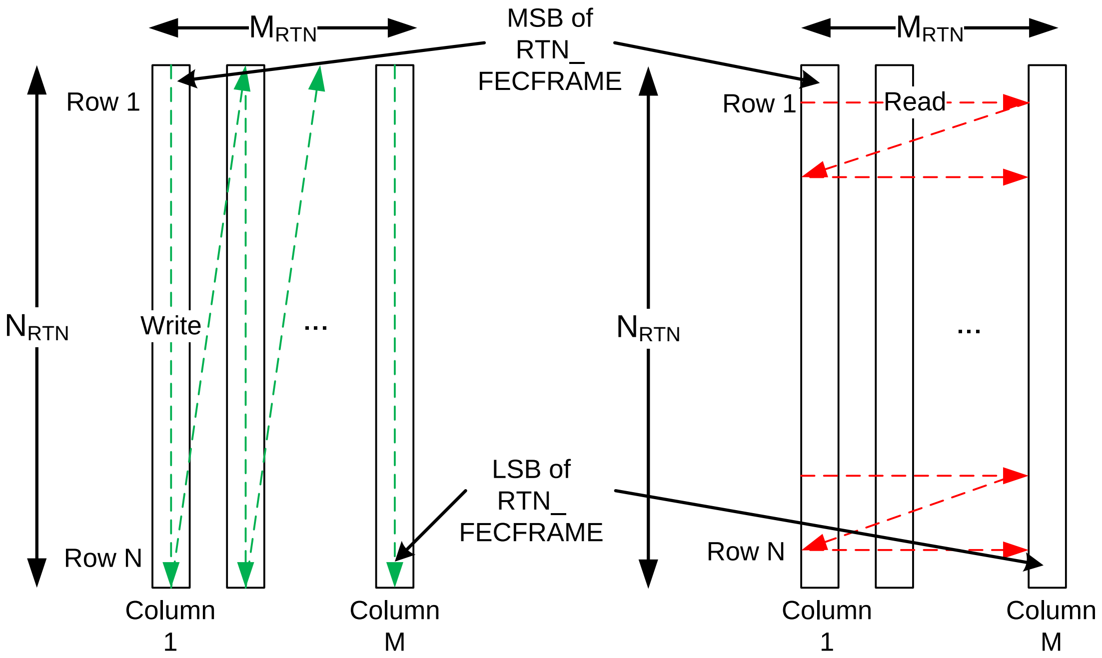



**Figure 8-27: Bit interleaving scheme**

**CSREQ-6690**

On the receiver side, the encoded bits shall be serially written in row-wise and shall be serially read out column-wise. MSB of RTN_FECFRAME shall be written and read out first.

*8.6.2.7 Auxiliary channel generation*

**CSREQ-6601**

The Auxiliary Channel Generation module shall generate the Pilot symbols to support the channel estimation for coherent detection

**CSREQ-6600**

The output stream of the Auxiliary Channel Generation shall be RTN_AUXFRAME. The RTN_AUXFRAME shall consist of $N_{RTN\_PS}$ known pilot symbols.

**CSREQ-6610**

The number of pilot symbols ($N_{RTN\_PS}$) of the Auxiliary channel shall depend on the RTN burst configuration and shall be as reported in Table 8-25.

| RACH Configuration ID | $N_{RTN\_PS}$ (symbols) | Pilot symbol sequence |
|---|---|---|
| RACH_CR$_{160}$_SF$_{16}$_DB$_{512}$ | 1548 symbols (TBC) | TBD |
| RACH_CR$_{160}$_SF$_{4}$_DB$_{2048}$ | 6156 symbols (TBC) | TBD |
| RACH_CR$_{160}$_SF$_{4}$_DB$_{288}$ | 876 symbols (TBC) | TBD |

**Table 8-25: Number of Pilot symbols ($N_{RTN\_PS}$) of the Auxiliary Channel for allowed RTN burst configurations**

**CSREQ-6611**

The contents of the Auxiliary channel (RTN_AUXFRAME) shall be generated using the following ML PN generator: TBD

#### *8.6.2.8 Bit mapping into constellation*

**CSREQ-6701**

The bit mapping module shall perform the mapping of the incoming bits into symbols according to the specified constellation order.

**CSREQ-6702**

The input stream of the Bit mapping module shall be a RTN_FECFRAME and a RTN_AUXFRAME and the output stream shall be a RTN_DCH (Return Data Channel) and a RTN_ACH (Auxiliary Channel) respectively.

Both inputs (RTN_FECFRAME and RTN_AUXFRAME) are bit mapped independently.

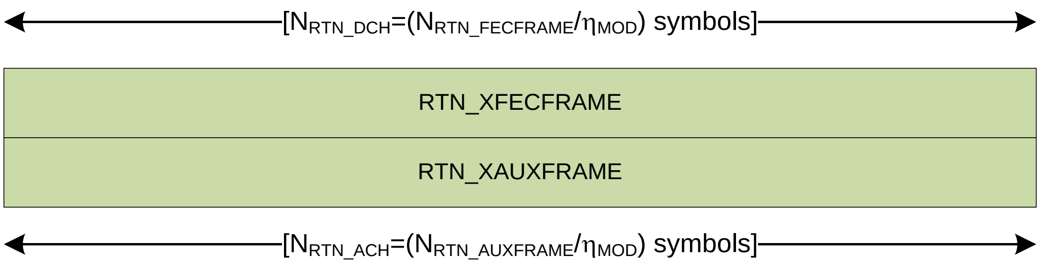



**Figure 8-28: Data format at the output of the Bit mapping module**

**CSREQ-6703**

The RTN_FECFRAME and the RTN_AUXFRAME shall be bit mapped independently into BPSK modulation ($\eta_{MOD}$=1) according to the **CSREQ-6700**.

**CSREQ-6700**

The bit mapping into BPSK constellation shall be compliant with Table 8-26.

One bit of the RTN_FECFRAME shall be mapped to a 1 BPSK symbol. One bit of the RTN_AUXFRAME shall be mapped to a 1 BPDK symbol.

| Bits | Symbol |
|---|---|
| 0 | 1 |
| 1 | -1 |

**Table 8-26: BPSK bit mapping**

### *8.6.2.9 Spreading*

**CSREQ-6711**

The Spreading module shall perform

- the channelization of both channels (Data and Auxiliary channel)
- the complex scrambling

**CSREQ-6712**

The input stream of the Spreading module shall be a RTN_DCH (I component) and a RTN_ACH (Q component) and the output stream a RTN_XFRAME (RTN complex FRAME).

**CSREQ-6710**

The spreading of RTN_CDH and RTN_ACH shall be applied as illustrated in the following figure and shall consist of two operations:

1. The channelization operation, which transforms every symbol into a number of chips, increasing the bandwidth of the signal ($C_{ch,d}$ and $C_{ch,c}$ channelization codes).
2. The scrambling operation, where a complex scrambling code is applied to the spread signal ($C_{Scram}$ scrambling code)

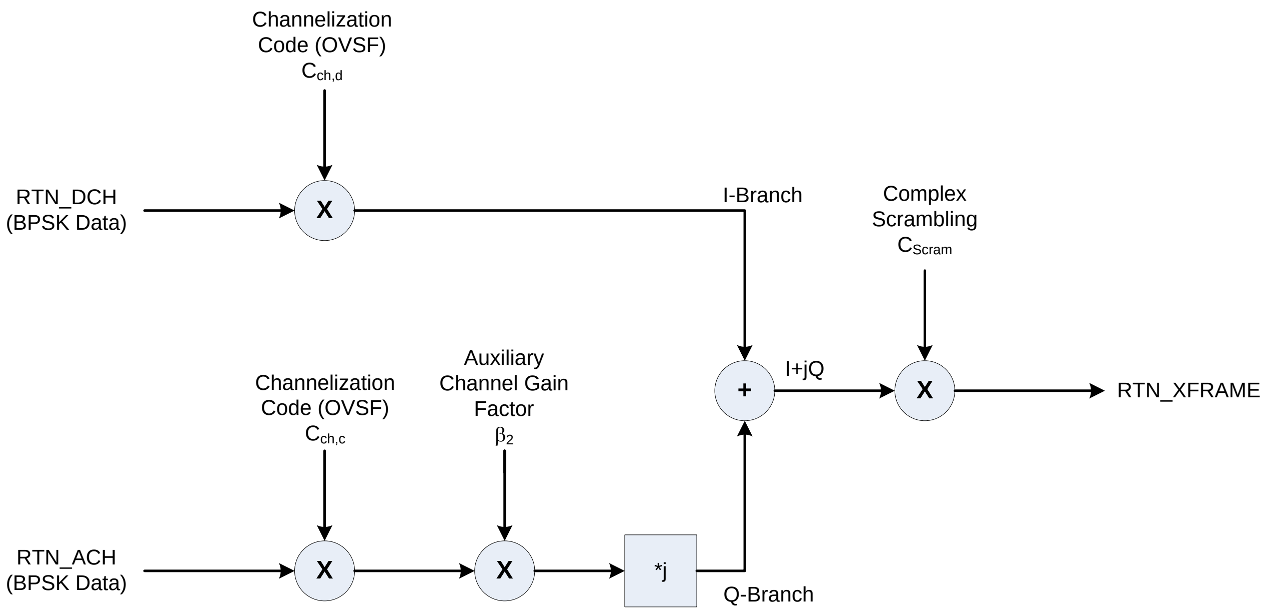



**Figure 8-29: Spreading operation**

**CSREQ-6720**

The RTN_CDH shall be spread to the chip rate by the channelization code $C_{ch,d}$ and the RTN_ACH shall be spread to the chip rate by the channelization code $C_{ch,c}$. The channelization codes used shall be OVSF codes following the specification described in section 8.6.2.9.1

**CSREQ-6730**

After the channelization, the Auxiliary part (RTN_ACH) shall be weighted by the gain factor $\beta_2$=sqrt(0.1) (TBC)

**CSREQ-6740**

The stream of the real-valued chips on the I-branch (RTN_CDH) and Q-branch (RTN_ACH) shall be treated as a complex-valued stream of chips, being the RTN_CDH (I component) the real part and the RTN_ACH (Q component) the imaginary part.

**CSREQ-6750**

The complex-valued stream (I+jQ) shall be scrambled by the complex valued scrambling code $C_{scramb}$, (complex product). The scrambling code is specified in section 8.6.2.9.2

*8.6.2.9.1 Channelization*

**CSREQ-6770**

The channelization codes ($C_{ch,d}$, $C_{ch,c}$) shall be Orthogonal Variable Spreading Factor (OVSF) codes. The channelization codes shall be used to distinguish the RTN_CDH and the RTN_ACH.

**CSREQ-6780**

The OVSF codes shall be generated using the code tree of Figure 8-30.

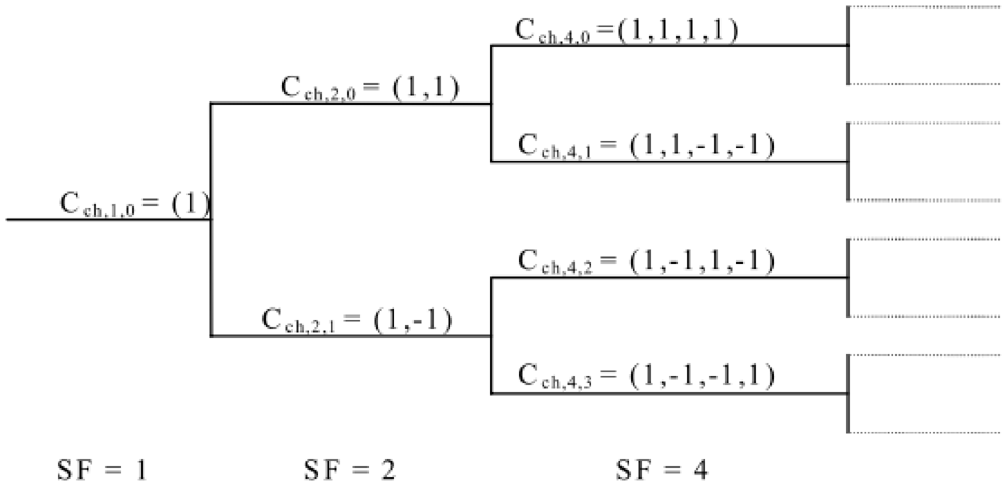



**Figure 8-30: Code-tree for generation of Orthogonal Variable Spreading Factor (OVSF) codes**

Channelization codes are uniquely described as $C_{ch,SF,k}$, where SF is the spreading factor of the code and $k$ is the code number, $0 \le k \le SF-1$.

The generation method for the channelization code is defined as:

$$C_{ch,1,0} = 1$$

$$\begin{bmatrix} C_{ch,2,0} \\ C_{ch,2,1} \end{bmatrix} = \begin{bmatrix} C_{ch,1,0} & C_{ch,1,0} \\ C_{ch,1,0} & -C_{ch,1,0} \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$\begin{bmatrix} C_{ch,2^{(n+1)},0} \\ C_{ch,2^{(n+1)},1} \\ C_{ch,2^{(n+1)},2} \\ C_{ch,2^{(n+1)},3} \\ \vdots \\ C_{ch,2^{(n+1)},2^{(n+1)}-2} \\ C_{ch,2^{(n+1)},2^{(n+1)}-1} \end{bmatrix} = \begin{bmatrix} C_{ch,2^n,0} & C_{ch,2^n,0} \\ C_{ch,2^n,0} & -C_{ch,2^n,0} \\ C_{ch,2^n,1} & C_{ch,2^n,1} \\ C_{ch,2^n,1} & -C_{ch,2^n,1} \\ \vdots & \vdots \\ C_{ch,2^n,2^n-1} & C_{ch,2^n,2^n-1} \\ C_{ch,2^n,2^n-1} & -C_{ch,2^n,2^n-1} \end{bmatrix}$$

**CSREQ-6790**

The RTN_DCH shall always be spread by the following channelization codes ($C_{ch,d}$), depending on the Burst Configuration ID. All the UT shall use the same channelization codes reported in Table 8-27.

| Configuration ID | Channelization code length | Channelization code allocation ($C_{ch,d}$) |
|---|---|---|
| $RACH\_CR_{160}\_SF_{16}\_DB_{512}$ | 16 chips | TBD |
| $RACH\_CR_{160}\_SF_{4}\_DB_{2048}$ | 4 chips | TBD |
| $RACH\_CR_{160}\_SF_{4}\_DB_{288}$ | 4 chips | TBD |

**Table 8-27: Channelization code allocation for $C_{ch,d}$**

**CSREQ-6800**

The RTN_ACH shall always be spread by the following channelization codes ($C_{ch,c}$) , depending on the Burst Configuration ID. All the UT shall use the same channelization codes reported in Table 8-28.

| Configuration ID | Channelization code length | Channelization code allocation ($C_{ch,c}$) |
|---|---|---|
| $RACH\_CR_{160}\_SF_{16}\_DB_{512}$ | 16 chips | TBD |
| $RACH\_CR_{160}\_SF_{4}\_DB_{2048}$ | 4 chips | TBD |
| $RACH\_CR_{160}\_SF_{4}\_DB_{288}$ | 4 chips | TBD |

**Table 8-28: Channelization code allocation for $C_{ch,c}$**

Note: the RTN_ACH always use the same SF as the RTN_DCH

*8.6.2.9.2 Complex Scrambling*

**CSREQ-6810**

The scrambling code shall be a complex-valued sequence.

**CSREQ-6820**

The scrambling code shall be generated according to the following procedure: TBD.

**CSREQ-6830**

All the UT shall use the same scrambling codes reported in Table 8-29.

| RACH Configuration ID | Scrambling code allocation ($C_{scramb}$) |
|---|---|
| $RACH\_CR_{160}\_SF_{16}\_DB_{512}$ | TBD |
| $RACH\_CR_{160}\_SF_{4}\_DB_{2048}$ | TBD |
| $RACH\_CR_{160}\_SF_{4}\_DB_{288}$ | TBD |

**Table 8-29: Scrambling code allocation**

**CSREQ-6840**

The scrambling sequence shall be truncated to the data channel size in chips. The size of the scrambling sequence shall be:

| RACH Configuration ID | Scrambling code length (chips) |
|---|---|
| $RACH\_CR_{160}\_SF_{16}\_DB_{512}$ | 24,768 |
| $RACH\_CR_{160}\_SF_{4}\_DB_{2048}$ | 24,624 |
| $RACH\_CR_{160}\_SF_{4}\_DB_{288}$ | 3,504 |

**Table 8-30: Scrambling code length**

*8.6.2.10 Physical layer framing*

**CSREQ-2801**

The Physical layer framing module shall perform the RTN_PREAMBLE insertion.

**CSREQ-2802**

The input stream of the Physical Layer Framing sub-system shall be a RTN_XFRAME and the output a RTN_PLFRAME.

**CSREQ-6570**

The PREAMBLE shall consist of $N_{RTN\_P}$ known complex symbols. The preamble length shall be as reported in Table 8-31.

| RACH Configuration ID | $N_{pre}$ (symbols) |
|---|---|
| $RACH\_CR_{160}\_SF_{16}\_DB_{512}$ | 96 symbols (TBC) |
| $RACH\_CR_{160}\_SF_{4}\_DB_{2048}$ | 96 symbols (TBC) |
| $RACH\_CR_{160}\_SF_{4}\_DB_{288}$ | 96 symbols (TBC) |

**Table 8-31: RACH Preamble length (in symbols)**

**CSREQ-6590**

The preamble sequence shall be spread according to the following procedure: TBD

*8.6.2.11 Base-band pulse shaping and quadrature modulation*

**CSREQ-3070**

I and Q signals shall be shaped using a Square Root Raised Cosine with a roll-off factor $\alpha$=0.2.

**CSREQ-3080**

The baseband SRRC filter shall have a theoretical function defined by the following expression.

$$H(f) = 1 \qquad \text{for } |f| < f_N(1-\alpha)$$

$$H(f) = \left\{ \frac{1}{2} + \frac{1}{2} \sin \frac{\pi}{2 f_N} \left[ \frac{f_N - |f|}{\alpha} \right] \right\}^{1/2} \qquad \text{for } f_N(1-\alpha)$$

$$H(f) = 0 \text{ for } |f| > f_N(1+\alpha),$$

where $f_N = \frac{R_S}{2}$ is the Nyquist frequency and $\alpha$ is the roll-off factor.

**CSREQ-3090**

The quadrature modulation shall be performed by multiplying the In-phase component (I) by $\cos(2\pi f_0 t)$ and the quadrature component (Q) by $-\sin(2\pi f_0 t)$. The resulting I and Q components shall be added to conform the modulator output signal.

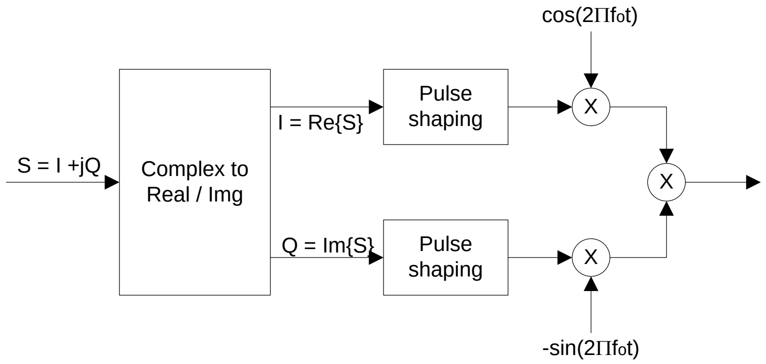



**Figure 8-31: Return link modulation**

### 8.6.3 Splitting traffic policies

**CSREQ-7270**

The messages shall be mapped to the RACH burst Configurations based on message service requirements as detailed in Table 8-32 (TBC).

| RACH Configuration ID | Service | Splitting policy |
|---|---|---|
| RACH_CR$_{160}$_SF$_{16}$_DB$_{512}$ | Data | All except the data messages transmitted through RACH_CR$_{160}$_SF$_4$_DB$_{2048}$ (TBC) |
| RACH_CR$_{160}$_SF$_4$_DB$_{2048}$ | Data | TD95 ≤ 2.4 & Message size ≥ 1000 bytes (TBC) |
| RACH_CR$_{160}$_SF$_4$_DB$_{288}$ | Voice | -- |

**Table 8-32: Mapping between services and RACH bursts Configuration**

(Note: this requirement has been included to provide a evidence of a preliminary mapping between messages and RACH bursts configurations. In a future, this requirement will be updated mapping CoS and RACH burst configurations.)

(Note: This requirement will also address mapping of L2 signalling messages to RACH burst configurations).

# 9. CONTROL PLANE SPECIFICATION

## 9.1 Control plane description

The Control plane deals with real-time control functionality that is required in order for the communication system to function including:

- terminal registration
- handover
- multicast control
- synchronisation
- radio resource management
- redundancy
- security control

Refer to section 5.2 for details on the control plane.

## 9.2 Control procedures

### *9.2.1 Terminal registration procedure (log-on)*

**(To be revised in B2)**

#### *9.2.1.1 Terminal logon-on procedure*

**CSREQ-3100**

The GS shall broadcast the System Information tables periodically to allow UTs to logon, containing at least the following information:

- A description of the structuring of the communication
- a description of the division of the communication resources
- a table that specifies the content and characteristics (e.g. symbol rate, code rate, etc.) of each available communication resource

**CSREQ-3110**

The UT shall be capable of listening to the System Information tables broadcasted by the GS.

**CSREQ-3120**

Once the System Information tables have been correctly received, the UT shall perform an initial synchronisation procedure.

**CSREQ-3130**

The UT shall send a logon request burst through the RACH channel, including the following parameters:

- L2 address address as identifier of the UT
- CS capabilities (e.g. support for ACM, frequency range admitted by the UT, etc.) TBC
- L3 capabilities (e.g., preferred address configuration method, support of ROHC compression, etc.) TBC
- Application level capabilities (voice support, support for ATC services only or AOC services only, etc.) TBC

**CSREQ-3135**

[Placeholder for logon confirm message].

**CSREQ-3140**

The UT shall re-attempt to logon for TBD times if no confirmation is received after an internal timeout expires.

**CSREQ-3150**

Upon GS terminal registration internal checks (e.g. admission analysis based on the system status), the GS shall notify the UT of the assigned GES by a logon response.

**CSREQ-6250**

The CS shall not perform authentication of UTs during the log-on procedure.

**CSREQ-6255 (TBC)**

The CS shall support a logon INFO message to inform backup GS Element about logged on UTs.

#### *9.2.1.2 Terminal log-off procedure*

**CSREQ-3160**

The UT shall be able to forward log-off messages to the GS.

**CSREQ-3180**

Upon the reception of a valid log-off message, the GS shall stop accounting procedures for that aircraft and release any resource reservation.

**CSREQ-3190**

The GS shall be able to forward log-off confirmation messages to the UT as a response to a log-off message.

**CSREQ-3210**

The GS shall be able to trigger the log-off of a UT (TBC). The UT shall log-off at the request of the GS.

*Note: This requirement needs feedback from the safety case.*

### *9.2.2 Handover procedures*

(To be revised for B2)

Note: This topic has not been addressed during the BP, only from the synchro point of view. This section will be updated at Phase B2.

#### *9.2.2.1 Handover sequence*

##### *9.2.2.1.1 Handover detection*

**CSREQ-3220**

The handover detection process shall be able to rely only on signal measurements.

**CSREQ-3230**

The UT shall constantly monitor the signal strength of neighbour/alternative channels and compare the measurements with its current link quality in order to detect potential HO candidates.

**CSREQ-3225**

The UT shall use a second receiver specifically devoted to handover purposes (handover detection and support to handover execution).

**CSREQ-3240**

The handover detection process shall implement a hysteresis cycle to avoid continuous handovers on coverage transition areas.

**CSREQ-3250**

The UT shall send a HO_RECOMMENDATION message to the GS including the following information:

- Signal power measurements (identifying current and neighbour carriers)
- Position information (if available) (TBC)
- Administrative, political and business related preferences

**CSREQ-3260**

The GS shall be able to receive and process HO_RECOMMENDATION messages from UTs or triggered by other GS subsystems (e.g., management module, redundancy module).

*9.2.2.1.2 Handover decision*

**CSREQ-3270**

After overall system status analysis, the GS shall send a HO_COMMAND message to the UT including at least the following information:

- Reference frequencies of transmission and reception
- GES to be connected to

**CSREQ-3280**

If a handover is determined to a different satellite and information of overall system status of candidate GSs is available, the previous GS shall send to the UT information about the new GS that shall be in charge of the new connection.

**CSREQ-3290**

If a handover to a different satellite is being performed and the HO request has been accepted by the new GS, the UT shall send a HO_COMMAND to the previous GS to inform it about the HO status.

#### 9.2.2.1.3 Handover execution

**CSREQ-3300**

A UT shall be capable of receiving two sets of FWD link MF-TDMA carriers (associated to different beams or to different satellites).

**CSREQ-3310**

A UT shall be capable of transmitting not simultaneously to different sets of RTN link A-CDMA carriers.

**CSREQ-3320**

The GS shall give priority to terminals in a HO process with a risk of signal loss (beam and satellite HOs).

### 9.2.2.2 Handover procedure specification

Note: The term "multicast responsible" refers to the GS element in charge of forwarding a multicast group over a certain satellite link beam.

#### 9.2.2.2.1 Procedure "Satellite Change. Same LAN"

**CSREQ-3330**

Upon HO recommendation, the previous GS shall send information of the new GS to the UT.

**CSREQ-3340**

Upon the reception of new GS information, the UT shall relay the recommendation to the new GS.

**CSREQ-3350**

At the reception of a HO recommendation at the new GS, the previous GS shall issue a HO COMMAND to the UT, which shall relay it also to other affected GS elements, if required.

**CSREQ-3360**

After the HO COMMAND, the UT shall perform an initial synchronisation procedure and send a HO COMMAND to the new GES, maintaining the communication with the previous GES.

**CSREQ-3370**

In parallel with the initial synchronisation procedure with the new GS, the UT shall request a Multicast join to the new multicast responsible and leave the previous multicast responsible before the previous connection is closed.

**CSREQ-3380**

While performing the HO, in case of pending traffic and imminent previous link loss or timeout, the UT shall perform the following:

- For the forward link, the UT shall inform of imminent connection loss to the previous GES, which shall send pending traffic to the new GES for relay to the UT.

**CSREQ-3390**

When buffers are empty, either the UT or the previous GES shall issue a CONNECTION CLOSE to the other entity. When confirmed, a HO FINISHED shall be sent to both NCCs.

##### *9.2.2.2.2 Procedure "Satellite Change. Different LAN"*

**CSREQ-3400**

Upon HO recommendation, the previous GS shall send information of the new GS to the UT.

**CSREQ-3410**

Upon the reception of new GS information, the UT shall relay the recommendation to the new GS.

**CSREQ-3420**

At the reception of a HO recommendation at the new GS, the previous GS shall issue a HO COMMAND to the UT, which shall relay it also to other affected GS elements, if required.

**CSREQ-3430**

After the HO COMMAND, the UT shall perform an initial synchronisation procedure with the new GS and send a HO COMMAND to the new GES, maintaining the communication with the previous GES.

**CSREQ-3440**

In parallel with the initial synchronisation procedure with the new GS, the UT shall request a Multicast join to the new multicast responsible and leave the previous multicast responsible before the previous connection is closed.

**CSREQ-3450**

After the synchronisation procedure, the L3 network update procedure shall be executed between the new GES and the UT while communication is initially maintained with both GES.

**CSREQ-3460**

While performing the HO, in case of pending traffic and imminent previous link loss or timeout, the UT shall perform the following:

- For the forward link, the UT shall inform of imminent connection loss to the previous GES, which shall send pending traffic to the new GES for relay to the UT.

**CSREQ-3470**

When buffers are empty, either the UT or the previous GES shall issue a CONNECTION CLOSE to the other entity. When confirmed, a HO FINISHED shall be sent to both NCCs.

*9.2.2.2.3 Procedure "SSP Change"*

**CSREQ-3480**

Upon HO recommendation, the previous GS shall send information of the new GS to the UT.

**CSREQ-3490**

Upon the reception of new GS information, the UT shall perform the LOGON to the new GS, which shall issue a HO COMMAND to the UT. The UT shall relay it also to the previous GS.

**CSREQ-3500**

Upon the relay of the HO COMMAND to the previous GS from the UT, the UT shall perform the initial synchronisation with the new GS, send a HO COMMAND to the new GES and perform the LOGON NEGOTIATION with the new GS.

**CSREQ-3510**

In parallel with the initial synchronisation procedure with the new GS, the UT shall request a Multicast join to the new multicast responsible and leave the previous multicast responsible before the previous connection is closed.

**CSREQ-3520**

After the synchronisation procedure, the L3 network update procedure shall be executed between the new GES and the UT while communication is initially maintained with both GES.

**CSREQ-3530**

While performing the HO, in case of pending traffic and imminent previous link loss or timeout, the UT shall perform the following:

- For the forward link, the UT shall inform of imminent connection loss to the previous GES, which shall send pending traffic to the new GES for relay to the UT.

**CSREQ-3540**

When buffers are empty, either the UT or the previous GES shall issue a CONNECTION CLOSE to the other entity. When confirmed, a HO FINISHED shall be sent to both GSs.

##### *9.2.2.2.4 Procedure "Beam Change. Same GES"*

**CSREQ-3550**

Upon HO recommendation, the GS shall issue a HO COMMAND to the UT, which shall relay it also to other affected GS elements, if required.

**CSREQ-3560**

After the HO COMMAND, the UT shall perform the synchronisation for the new beam while communication is maintained with both links.

**CSREQ-3570**

In parallel with the initial synchronisation procedure, the UT shall request a Multicast join to the new multicast responsible and leave the previous multicast responsible before the previous connection is closed.

**CSREQ-3580**

While performing the HO, in case of pending traffic and imminent previous link loss or timeout, the UT shall perform the following:

- For the forward link, the UT shall inform of imminent connection loss to the GES, which shall send pending traffic through the new link (keeping two sessions).

**CSREQ-3590**

When buffers are empty, either the UT or the GES shall issue a CONNECTION CLOSE to the other entity. When confirmed, a HO FINISHED shall be sent to the NCC.

##### *9.2.2.2.5 Procedure "Beam Change. Same LAN"*

**CSREQ-3600**

Upon HO recommendation, the GS shall issue a HO COMMAND to the UT, which shall relay it also to other affected GS elements, if required.

**CSREQ-3610**

After HO COMMAND, the UT shall perform the synchronisation for the new beam and shall issue a HO COMMAND to the new GES while communication is maintained with both links.

**CSREQ-3620**

In parallel with the initial synchronisation procedure, the UT shall request a Multicast join to the new multicast responsible and leave the previous multicast responsible before the previous connection is closed.

**CSREQ-3630**

While performing the HO, in case of pending traffic and imminent previous link loss or timeout, the UT shall perform the following:

- For the forward link, the UT shall inform of imminent connection loss to the previous GES, which shall send pending traffic to the new GES for relay to the UT.

**CSREQ-3640**

When buffers are empty, either the UT or the previous GES shall issue a CONNECTION CLOSE to the other entity. When confirmed, a HO FINISHED shall be sent to the NCC.

*9.2.2.2.6 Procedure "Beam Change. Different LAN"*

**CSREQ-3650**

Upon HO recommendation, the GS shall issue a HO COMMAND to the UT, which shall relay it also to other affected GS elements, if required.

**CSREQ-3660**

After the HO COMMAND, the UT shall perform the synchronisation for the new beam and issue a HO COMMAND to the new GES while communication is maintained with both links.

**CSREQ-3670**

In parallel with the initial synchronisation procedure, the UT shall request a Multicast join to the new multicast responsible and leave the previous multicast responsible before the previous connection is closed.

**CSREQ-3680**

After the synchronisation procedure, the L3 network update procedure shall be executed between the new GES and the UT while communication is initially maintained with both GES.

**CSREQ-3690**

While performing the HO, in case of pending traffic and imminent previous link loss or timeout, the UT shall perform the following:

- For the forward link, the UT shall inform of imminent connection loss to the previous GES, which shall send pending traffic to the new GES for relay to the UT.

**CSREQ-3700**

When buffers are empty, either the UT or the previous GES shall issue a CONNECTION CLOSE to the other entity. When confirmed, a HO FINISHED shall be sent to the NCC.

*9.2.2.2.7 Procedure "GES Change. Same LAN"*

**CSREQ-3710**

Upon HO recommendation, the GS shall issue a HO COMMAND to the UT, which shall relay it also to the previous and new GES (if required) while communication is maintained with both GES.

**CSREQ-3720**

When buffers are empty, either the UT or the previous GES shall issue a CONNECTION CLOSE to the other entity. When confirmed, a HO FINISHED shall be sent to the NCC.

###### *9.2.2.2.8 Procedure "GES Change. Different LAN"*

**CSREQ-3730**

Upon HO recommendation, the GS shall issue a HO COMMAND to the UT, which shall relay it also to the previous and new GES, if required.

**CSREQ-3740**

After the HO COMMAND, the L3 network update procedure shall be executed between the new GES and the UT while communication is initially maintained with both GES.

**CSREQ-3750**

When buffers are empty, either the UT or the previous GES shall issue a CONNECTION CLOSE to the other entity. When confirmed, a HO FINISHED shall be sent to the NCC.

###### *9.2.2.2.9 Procedure "Bulk Handover"*

[Placeholder. To be completed in B2]

### *9.2.3 Multicast control procedures*

**(To be revised in B2)**

#### *9.2.3.1 Overview of multicast membership management methods*

Three different types of memberships are defined: static, GES-based and dynamic memberships for the CS.

- The concept of static group memberships involves that an aircraft is a member of a predefined set of multicast groups. The membership management scheme does not allow change of group subscriptions during the flight.
- The concept of dynamic memberships entails that hosts would be capable of joining and leaving multicast groups during the flight. Thus, subscriptions to multicast groups would change dynamically.
- GES-based memberships involves that the GES, and not the UT, subscribe to multicast groups and act as multicast members (or listeners). Then, the GES broadcasts all the multicast data received over the beam. This option is rather static and may fit with multicast groups linked with geographical areas.

At this point, as no information about the expected characteristics of multicast services and applications is provided, it is proposed to retain all the membership methods.

**CSREQ-3760**

The following membership management methods shall be supported:

- Static group membership
- GES-based group membership
- Dynamic group membership

*Note: This requirement has been considered as no information was available about the detailed nature of multicast services. Hence, it is not possible to select the most suitable membership management method at this point.*

#### *9.2.3.2 Multicast membership management procedures*

**CSREQ-3770**

Mechanisms such as re-broadcasting and answer suppression shall be supported in order to minimise the amount of resources used for multicast signalling in the satellite.

*Note: How to perform these techniques will be indicated by the ANTARES-GMP protocol and how to implement and configure timers will be stated in the guidelines.*

#### *9.2.3.3 Multicast forwarding procedures*

Dynamic selective forwarding is proposed for the CS.

**CSREQ-3780**

A CS-compliant system should be able to forward multicast traffic only over those specific beams with active members (if this information is available).

### 9.2.4 Network synchronisation procedures

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.
- ATM links: GS-Satellite-UT or UT-Satellite-GS links that go through Satellite ATM transceivers.

#### 9.2.4.1 General synchronisation aspects

**CSREQ-3790**

The NCC reference clock long term instability shall be better than 0.01 ppm per year.

**CSREQ-3800**

The GES reference clock long term instability shall be better than 0.01 ppm per year.

**CSREQ-3810**

The Satellite reference clock long term instability shall be better than 0.05 ppm over a period of 15 years.

**CSREQ-6860**

The UT reference clock long term instability shall be better than 1 ppm per year.

**CSREQ-3820**

The ATM transceivers belonging to the same satellite shall use the same reference clock.

**CSREQ-6880**

UT and GS elements shall guarantee operate under significant UT movement:

- UT speed up to Mach 2.5, i.e. up to 850 m/s at nominal atmospheric conditions at sea level
- UT acceleration up to 50 $m/s^2$

UT angular velocity up to 3.33, 1.67 and 2 º/s (roll, pitch and yaw)

**CSREQ-6260**

All GS elements shall compensate the Feeder link Doppler Effect with a normalised residual error lower than $10^{-3}$ by:

- Computing the Doppler Effect from
  - GS element location
  - Satellite location and speed derived from satellite ephemerides
  - Nominal carrier and symbol frequencies
- Compensating Feeder link Doppler Effect on
  - Transmitter frequency and time.
  - Receiver frequency and time

**CSREQ-3860**

The NCC may estimate the satellite clock error and distribute it to all associated GS elements.

**CSREQ-6270**

All GS elements shall compensate the satellite translation error affecting all ATM transceivers by:

- Receiving the estimated satellite clock error distributed by the NCC (if available) or estimating it.
- Computing the satellite translation error affecting each ATM transceiver they are transmitting to or receiving from.
- Compensating the satellite translation error on all transmitted and received carriers.

#### *9.2.4.2 Forward Link synchronisation*

**CSREQ-3830**

The maximum difference between the delays introduced by any satellite ATM transceivers shall be low enough in order not to impact the forward link time synchronisation:

- Maximum delay difference lower than 1% of the symbol period in the forward link.

**CSREQ-3870**

Forward link initial synchronisation and synchronisation maintenance procedures shall be implemented

- either by means of Feeder-to-Feeder links,

- or through the Forward Link Carrier.

**CSREQ-3840**

The NCC shall distribute to all GS elements the Network Clock Reference (NCR)

- either by broadcasting NCR packets through the FCH physical channel, if the forward link network synchronisation is implemented through ATM links, i.e. the Forward Link Carrier;
- or by broadcasting NCR packets (or any alternative time stamp) through specific channels, if the forward link network synchronisation is implemented through Feeder-to-Feeder links.

**CSREQ-3841**

The Network Clock Reference shall have a frequency of 27 MHz.

**CSREQ-3842**

The NCR packet shall contain the value of a 40-bit counter provided in tics of the Network Clock Reference. The value shall correspond to the time at which the last preamble symbol of the FCH burst containing the NCR packet is transmitted.

**CSREQ-3850**

NCR packets shall be inserted with a periodicity that guarantees a proper recovery of the NCR to be used as a system time reference by any GS element.

- The minimum NCR packets periodicity shall be 2 packet/s.

**CSREQ-6890**

GS elements shall recover the system time reference from the processing of NCR packets (or any alternative time stamp). An NCR loop shall be implemented to locally recover the system NCR.

**CSREQ-6900**

Forward link initial synchronisation and synchronisation maintenance procedures shall be implemented

- either by means of GS elements auto-synchronisation through reception of their own transmission;
- or by means of a remote closed loop between all GS elements and the NCC.

**CSREQ-3875**

If forward link network synchronisation procedures are implemented through Feeder-to-Feeder links, Feeder-to-Feeder and ATM transceivers shall belong to the same satellite.

**CSREQ-3880**

If forward link network synchronisation procedures are implemented through Feeder-to-Feeder links, the Satellite Feeder-to-Feeder and ATM transceivers shall use the same reference clock.

**CSREQ-3890**

If forward link network synchronisation procedures are implemented through Feeder-to-Feeder links, the maximum difference between the delays introduced by any satellite Feeder-to-Feeder and ATM transceivers shall be low enough in order not to impact the forward link time synchronisation:

- Maximum delay difference lower than 1% of the symbol period in the forward link.

**CSREQ-6290**

If forward link network synchronisation procedures are implemented through the Forward Link Carrier, GS elements shall be equipped with an L-band RF front-end (reception in L-band, apart from Ku, Ka or C-band, is required).

**CSREQ-3900**

The forward link network synchronisation maintenance procedure shall guarantee that GS transmissions to the Forward Link Carrier at the satellite front-end are

- Synchronised in time: maximum time error lower than half the guard time.
- Synchronised in carrier frequency: maximum frequency error lower than 10 Hz.
- Power balanced: uplink fades shall be compensated in order to guarantee a maximum power unbalance of 2 (TBC) dB.

**CSREQ-3910**

If forward link network synchronisation procedures are implemented through Feeder-to-Feeder links, GS elements shall not transmit any bursts to the Forward Link Carrier until the forward link synchronisation maintenance stage is reached.

**CSREQ-3920**

If forward link network synchronisation procedures are implemented through Feeder-to-Feeder links, GS elements shall stop transmission to the Forward Link Carrier if synchronisation is lost. Transmission shall not be allowed until the forward link synchronisation is recovered.

### *9.2.4.3 Return Link synchronisation*

The return link synchronisation procedures are depicted in Figure 9-1 and Figure 9-2 and covered in the requirements in subsequent sections.

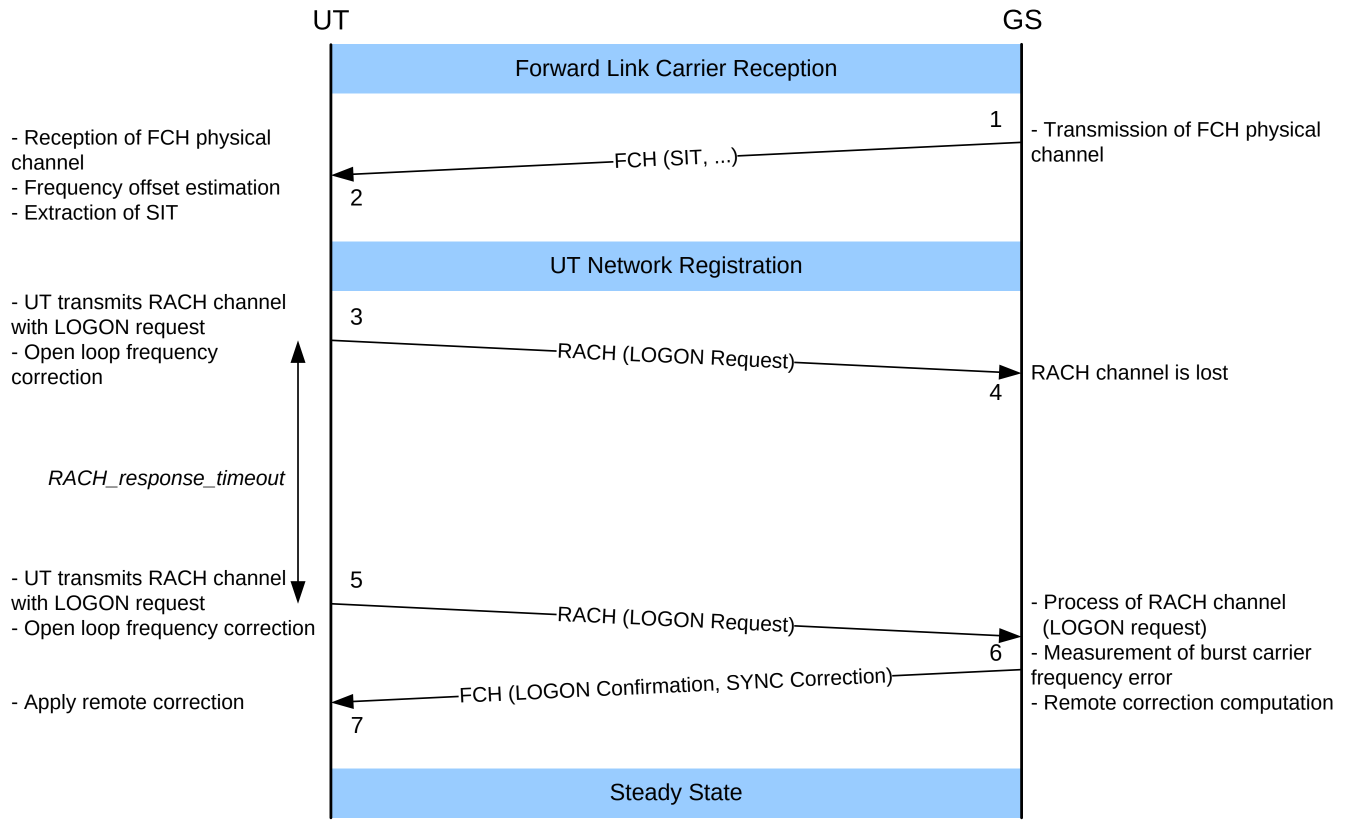



**Figure 9-1: Return link synchronisation procedure (FLC Reception and UT Network Registration)**

#### *9.2.4.3.1 UT Forward link carrier reception*

**CSREQ-3930**

The UT shall be able to detect and demodulate Forward Link Carrier bursts affected by significant carrier frequency offsets. The sources of carrier frequency error are:

- GS (NCC or GES) reference clock instability
- Satellite reference clock instability (residual error after the compensation implemented by GS elements – CSREQ-6270)
- UT reference clock instability

- Satellite motion (residual error after the Feeder link Doppler compensation implemented by GS elements – CSREQ-6260)
- UT motion

The maximum carrier frequency offsets are:

- 6.5 kHz for GEO constellations (Feeder link operation in Ku-band is assumed)
- 22.5 kHz for MEO constellations (Feeder link operation in C-band is assumed)
- 35 kHz for HEO constellations (Feeder link operation in Ka-band is assumed)

**CSREQ-3940**

The UT shall be able to detect and demodulate Forward Link Carrier bursts affected by significant time drifts. The sources of time drifts are:

- GS (NCC or GES) reference clock instability
- UT reference clock instability
- Satellite motion (residual error after the Feeder link Doppler compensation implemented by GS elements – CSREQ-6260)
- UT motion

The maximum time drifts are:

- 3.9 us/s for GEO constellations (Feeder link operation in Ku-band is assumed)
- 14.2 us/s for MEO constellations (Feeder link operation in C-band is assumed)
- 21.2 us/s for HEO constellations (Feeder link operation in Ka-band is assumed)

**CSREQ-3950**

The UT shall be able to detect and demodulate Forward Link Carrier bursts affected by significant carrier frequency drifts. The sources of carrier frequency drifts are:

- Satellite acceleration (residual error after the Feeder link Doppler compensation implemented by GS elements – CSREQ-6260)
- UT acceleration and angular movement

The maximum carrier frequency drift is 350 Hz/s.

**CSREQ-3960**

The UT shall be able to detect and demodulate Forward Link Carrier bursts affected by significant time drift variations. The sources of time drift variations are:

- Satellite acceleration (residual error after the Feeder link Doppler compensation implemented by GS elements – CSREQ-6260)

- UT acceleration and angular movement

The maximum time drift variation is 0.22 us/$s^2$.

#### *9.2.4.3.2 UT network registration procedure*

**CSREQ-4000**

The UT shall implement a transmitter Doppler pre-compensation mechanism aimed at:

- Minimising the initial frequency errors in the logon request bursts (first access to the system)
- Estimating and compensating the Doppler dynamics to reduce synchronisation errors

**CSREQ-4005**

The UT transmitter Doppler pre-compensation mechanism shall be based on the receiver carrier frequency offsets estimated by the UT demodulator upon reception of the Forward Link Carrier.

**CSREQ-6910**

The UT shall initiate the network registration procedure by means of a logon request sent through a RACH burst.

**CSREQ-4010**

The UT shall guarantee that RACH bursts implementing a logon request are received at the GS in the appropriate contention channel with a carrier frequency error lower than half the RACH guard band (see CSREQ-0980).

**CSREQ-4025**

The UT shall guarantee that RACH bursts implementing a logon request, once received at the GS, are affected by a maximum carrier frequency drift of 50 Hz/s.

**CSREQ-4030**

The UT shall guarantee that RACH bursts implementing a logon request, once received at the GS, are affected by a time drift during the burst duration lower than $T_c/8$, being $T_c$ the chip period.

**CSREQ-4040**

Upon reception of a RACH burst with a UT logon request, the GS shall:

- Estimate the carrier frequency error and compute the corresponding synchronisation correction.
- Send to the UT the required synchronisation correction through the Forward Link Carrier (SYNC correction message).

**CSREQ-6920**

Upon reception of a synchronisation correction (SYNC correction message) through the Forward Link Carrier after a logon request, the UT shall adjust its transmitter accordingly.

**CSREQ-6930**

The UT shall restart the network registration procedure if no answer is received after an internal timeout (*RACH_response_timeout*) expires. *RACH_response_timeout* = TBD.

#### *9.2.4.3.3 Steady state procedures (after UT registration)*

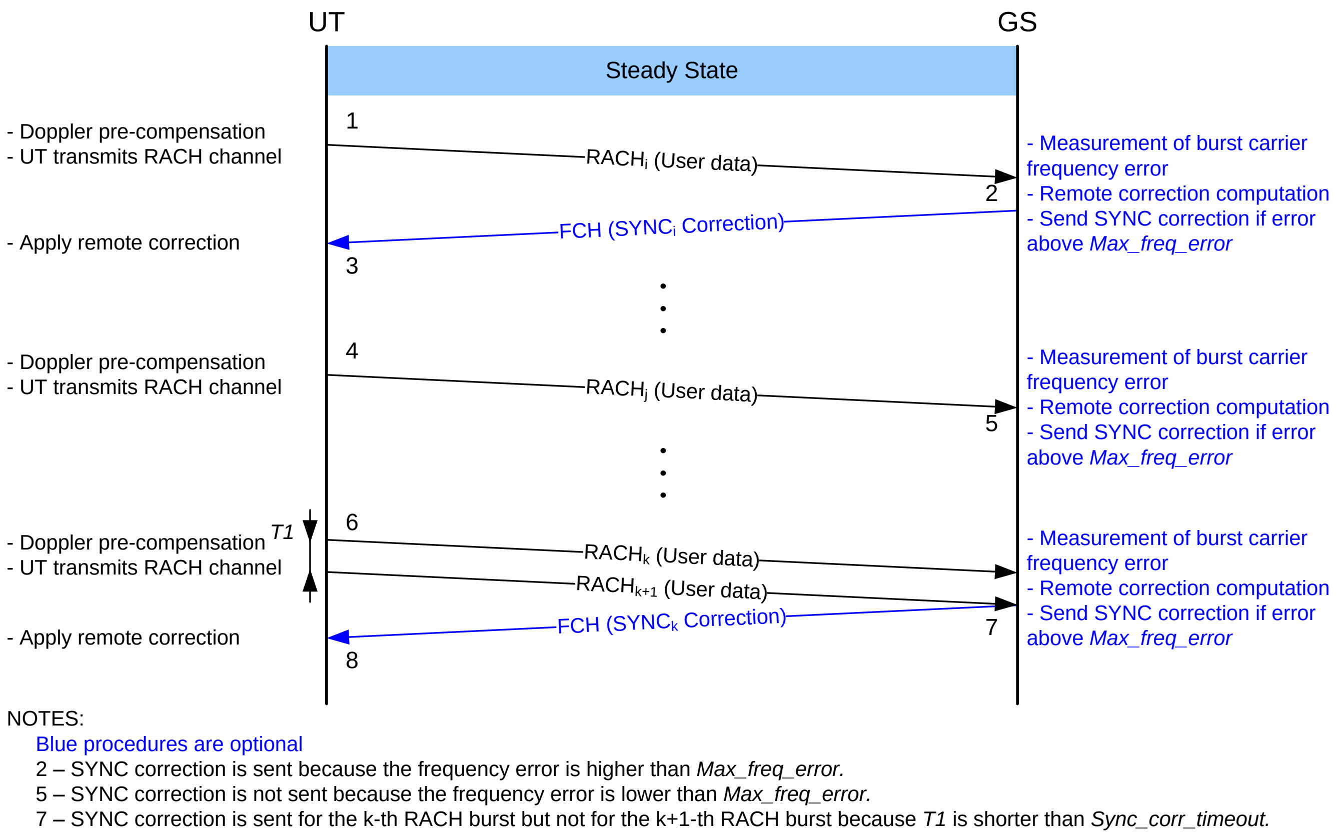



**Figure 9-2: Return link synchronisation procedure (Steady state)**

**CSREQ-4115**

The UT shall guarantee that RACH bursts, once received at the GS, are affected by a maximum carrier frequency drift of 50 Hz/s.

**CSREQ-4120**

The UT shall guarantee that RACH bursts, once received at the GS, are affected by a time drift during the burst duration lower than $T_c/8$, being $T_c$ the chip period.

**CSREQ-4130**

The UT shall adjust its transmitter according to

- the corrections received through the Forward Link Carrier (SYNC correction message),
- the corrections computed locally by the transmitter Doppler pre-compensation mechanism, which is focussed on compensating Doppler dynamics.

**CSREQ-4135**

The GS shall be able to receive RACH bursts with a maximum carrier frequency error of half the RACH guard band (see CSREQ-0980).

**CSREQ-4140 (Optional)**

Upon reception of a RACH burst, the GS shall:

- Estimate the carrier frequency error and compute the corresponding synchronisation correction.
- If required, send to the UT the required synchronisation correction, through the Forward Link Carrier (SYNC correction message).

**CSREQ-4160 (Applicable only if CSREQ-4140 is implemented)**

Upon reception of a new RACH burst of a given UT, the GS shall only send a synchronisation correction if the following conditions are met at the same time:

- The carrier frequency error is higher than a certain threshold *Max_freq_error*, where *Max_freq_error* = RACH guard band / 8.
- The time elapsed since the last correction generated (to the same UT) is longer than *Sync_corr_timeout*, where *Sync_corr_timeout* = 300 ms + 2 x (Round Trip Time).

**CSREQ-4170**

The UT shall interrupt transmissions in any of the following circumstances:

- When required to do so by the GS.
- When the Forward Link Carrier is lost, i.e. no FCH bursts are received for *FLC_loss_timeout* seconds; *FLC_loss_timeout* = 2 (TBC) seconds.

### *9.2.5 ACM procedures*

#### *9.2.5.1 Forward link general requirements*

**CSREQ-5590**

The user plane shall support adaptive waveforms (code rate and modulation order) on the Forward link. The following MODCODs shall be supported:

- QPSK 1/3, 1/2, 2/3
- 8-PSK 1/2, 2/3
- 16-APSK 2/3

(Note: in the future, the list of supported MODCODs can be expanded if deemed necessary (e.g. by including robust MODCODs)

**CSREQ-5600**

The GS shall be able to change the modulation and coding rate of the packets it transmits towards the different UTs.

**CSREQ-6940**

The UT shall implement two mechanisms to adapt the coding and modulation scheme used by the GS to communicate with it:

- A Fast ACM mechanism, which is used to react in the case of fast degradation of the link due to banking situation. A fast mechanism is defined as the mechanism that acts in a time window of less than TBD seconds.
- Slow ACM mechanism, which is used to better adapt the coding and modulation to slow variation of the propagation channel. A slow mechanism is defined as the mechanism that acts in a time window higher than TBD seconds.

**CSREQ-6950**

The Fast ACM mechanism shall prevail in front of the Slow ACM mechanism.

**CSREQ-6960**

At the UT power up, the GS shall use the most robust MODCOD to communicate with the UT.

*9.2.5.2 Fast ACM mechanism*

**(To be revised in B2)**

**CSREQ-6970**

The Fast ACM mechanism shall be based on monitoring the PER[3] for each MODCOD of the burst received in the FWD Link Carriers to detect fast link degradations.

**CSREQ-6980**

In the case that the Fast ACM mechanism detects fast signal degradation, the MODCOD shall be switched to the most robust one.

**CSREQ-6990**

The UT shall continuously measure the PER of all the bursts transmitted with different MODCODs able to be received in its assigned FLC.

**CSREQ-7000**

The PER monitoring performance for the Fast ACM mechanism shall guarantees that the PER will not be worse than $10^{-3}$ (TBC) for a time window longer than TBD.

**CSREQ-7030**

Based on the PER monitoring, the UT

- shall detect negative banking situation to trigger a switch of MODCOD to the most robust one to reduce PER during manoeuvre situations.
- shall detect positive banking situation to prevent misinterpreting a degradation of the SNIR when the aircraft recover normal non-banking attitude after manoeuvre.

Note: the terms negative and positive banking refer to (see also the following figure):

- Negative banking: situation where the received signal strength improves rapidly during the manoeuvre.
- Positive banking: situation where the received signal strength deteriorates rapidly during the manoeuvre.

[3] The PER is computed as the number of PPDU received erroneous divided by the total number of received PPDU.

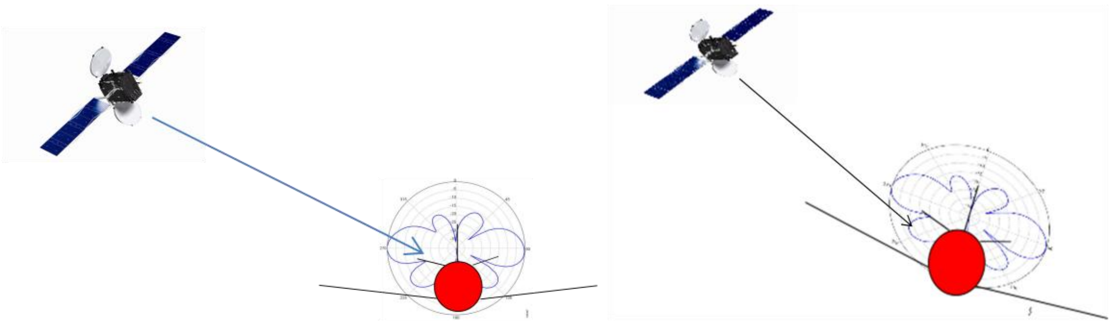


**Figure 9-3: Aircraft received signal variation due to antenna lobe pointing resulting from banking manoeuvres**

**CSREQ-7050**

When the monitored PER exceeds the *PER_fast_Thr* threshold ($10^{-1}$ TBC), the UT shall indicate to the GS that the most robust MODCOD shall be used.

**CSREQ-7060**

When a banking condition is detected (the monitored PER exceeds the *PER_fast_Thr* threshod), the UT shall initiate a timer (*Banking_timer*) to be used as a watchodog for banking termination detection.

The *Banking_timer* can be set to 90 (TBC) seconds.

**CSREQ-7080**

When the banking termination is detected (the monitored PER is less than *PER_fast_Thr* threshold again or if *Banking_timer* expires), the UT shall re-start the Slow ACM mechanism as it were at the power up stage.

**CSREQ-7320**

In order to prevent rapid switch back and forth between slow and fast mechanism, an Hysteresis mechanism shall be put in place.

#### *9.2.5.3 Slow ACM mechanism*

**CSREQ-7090**

The Slow ACM mechanism shall be based on monitoring the PER for each MODCOD of the burst received in the FWD Link Carriers.

**CSREQ-7120**

For a given MODCOD, the threshold shall be unique over the coverage area.

**CSREQ-7330**

The PER monitoring performance for the Slow ACM mechanism shall guarantees that the PER will not be worse than $10^{-3}$ (TBC) for a time window of TBD seconds.

**CSREQ-7140**

The UT shall monitor the PER for each MODCOD and for each GES using its assigned forward link carrier.

**CSREQ-7160**

The MODCOD selection mechanism shall be as follows:

- MODCOD downgrade: when the monitored PER for the current MODCOD increases above the PER threshold, the UT shall request the GES to send further packets with the next more robust MODCOD available on the forward link.
- MODCOD upgrade: when the PER for the next less robust MODCOD decreases below the PER threshold, the UT shall request the GES to send further packets with the next less robust MODCOD available on the forward link.

**CSREQ-7170**

In order to prevent rapid switch back and forth between 2 MODCOD, a Hysteresis mechanism shall be put in place.

**CSREQ-7180**

The GS shall ensure that all the MODCODs used by all the UT assigned to a FLC and the next less robust MODCOD are transmitted in a regular way. The minimum periodicity shall be TBD seconds.

(Note: for instance, if the less robust MODCOD in a FLC is MODCOD3, the GS shall ensure that MODCOD1, MODCOD2, MODCOD3 and MODCOD4 are transmitted in a regular way)

**CSREQ-7190**

When banking condition is detected (Fast ACM mechanism), the Slow ACM mechanism is disabled.

### *9.2.6 Radio resource management procedures*

This section addresses:

- Congestion of the RACH (data and signalling)

#### *9.2.6.1 Congestion control*

The purpose of congestion control (CC) mechanisms is to control the amount of traffic entering in the communications network in order to avoid a collapse caused by oversubscription of either processing abilities or link capabilities of the networks and, furthermore, to ensure network stability, throughput efficiency and a fair allocation of resources.

CC mechanisms are based on A-CDMA channel noise rise measurements by the GS receiver. The problem is the satellite propagation delay, since actions enforced by the CC to the terminals arrive one full RTT later (540 ms).

Meaning of congestion control parameters indicated in this section is defined in section 8.6.1.1 (CSREQ-6470) and section 8.6.1.2 (CSREQ-6530)

##### *9.2.6.1.1 Return Link congestion control protocol for data channel*

**CSREQ-4280**

The UT shall support the congestion control mechanism indicated by the FLC through a CC_CONFIG message, with the following parameters for each supported CoS:

| Congestion control mechanism | Parameter |
|---|---|
| Backoff | tx_backoff<br>Persistence<br>Timeout margin (TBC) |

**Table 9-1: Congestion control signalling message (CC_CONFIG msg)**

Note: Exact format of the CC_CONFIG message will be defined in B2.

**CSREQ-4282**

The GS shall set congestion control parameters included in the CC_CONFIG message adaptively according to the system load status (low traffic, medium traffic, high traffic, congested).

**CSREQ-4284**

The system load status shall be estimated based on the measured noise rise and its evolution (details TBD).

**CSREQ-4286**

Congestion control parameters shall be set as follows according to load status:

- Low traffic: TBD
- Medium traffic: TBD
- High traffic: TBD
- Congested: TBD

**CSREQ-4288**

A CC_CONFIG message shall be sent when there is a change in the system load status and with a periodicity not less than TBD seconds.

**CSREQ-4290**

The CC_CONFIG message can be sent either as a standalone message or be integrated as a part of signalling framework (details TBD).

##### *9.2.6.1.2 Return Link contention resolution protocol for signalling channel*

**To be revised in B2**.

### *9.2.7 Redundancy and failure detection procedures*

Redundancy and failure detection procedures are basically transparent to the CS. Whenever a failure event happens, the communication system will reconfigure itself to use the backup entities, making the UT basically unaware of the event, except for any possible handover procedures execution.

**CSREQ-4380**

Upon total loss of reception from any GS element, the UT shall allow TBD s for GS redundancy procedures to restore communications before activating failure procedures.

*Note: RAMS analysis to provide values for the requirement above.*

### *9.2.8 Security control procedures*

Refer to 8.3.

### *9.2.9 Network interface procedures*

#### *9.2.9.1 ATN/OSI*

**CSREQ-4500**

At the time the interface between the airborne router and the UT becomes enabled, the airborne router shall send a PARAM.request message to the UT.

**CSREQ-4510**

Upon the reception of a PARAM.request message from an airborne router at the UT, the UT shall respond with a PARAM.confirm towards the airborne router.

**CSREQ-4520**

At the time an L3 handover or a logoff is performed, the GES shall send a LOGOFF.indication towards the A/G-R.

*9.2.9.1.1 Legacy Mode*

**CSREQ-4530**

At the time the interface between the GES and the A/G-R becomes enabled, the A/G-R shall provide its own network address to the GES.

**CSREQ-4540**

Upon the reception of a JOIN.indication message from the UT at the airborne router, the airborne router shall start an ISH 8208 call establishment procedure towards the GES.

**CSREQ-4550**

Upon the reception of an ISH 8208 call establishment procedure from an airborne router at the GES, the GES shall start an ISH 8208 call establishment procedure towards the A/G-R.

**CSREQ-4560**

Upon the establishment of an 8208 connection between the GES and the A/G-R, the A/G-R shall perform an IDRP Connection Establishment towards the airborne router.

**CSREQ-4570**

Upon the establishment of an IDRP Connection between an airborne router and an A/G-R, the airborne router shall perform an IDRP routing information exchange towards the A/G-R.

**CSREQ-4580**

Upon the establishment of an IDRP Connection between an airborne router and an A/G-R, the A/G-R shall perform an IDRP routing information exchange towards the airborne router.

*9.2.9.1.2 Iris Mode*

**CSREQ-4590**

At the time the interface between the GES and the A/G-R becomes enabled, the A/G-R shall provide the following information to the GES:

- Its own network address
- Network prefixes for which the A/G-R has access

**CSREQ-4600**

Upon the L2 logon procedure is finished, the GES shall forward to the A/G-R a LOGON.indication with the following parameters:

- Airborne router address
- Classes of Service supported

**CSREQ-4610**

Upon the L2 logon procedure is finished, the UT shall forward to the airborne router a JOIN.indication.

*9.2.9.1.3 Legacy Conversion Mode*

**CSREQ-4620**

At the time the interface between the GES and the A/G-R becomes enabled, the A/G-R shall provide the following information to the GES:

- Its own network address
- Network prefixes for which the A/G-R has access

**CSREQ-4630**

Upon the L2 logon procedure is finished, the GES shall forward to the A/G-R a LOGON.indication with the following parameters:

- Airborne router address
- Classes of Service supported

**CSREQ-4640**

Upon the reception of a JOIN.indication message from the UT at the airborne router, the airborne router shall start an ISH 8208 call establishment procedure towards the UT.

**CSREQ-4650**

Upon the establishment of an 8208 connection between the UT and the A/G-R, the UT shall perform an IDRP Connection Establishment towards the airborne router.

**CSREQ-4660**

Upon the establishment of an IDRP Connection between an airborne router and the UT, the airborne router shall perform an IDRP routing information exchange towards the UT.

**CSREQ-4670**

Upon the establishment of an IDRP Connection between an airborne router and the UT, the UT shall perform an IDRP routing information exchange towards the airborne router.

## 9.3 Security

**CSREQ-6300**

The CS shall not support any mechanism for control plane data encryption.

**CSREQ-6310**

The CS shall not support any mechanism for control plane data authentication.

**CSREQ-6320**

CS control procedures shall not require authentication of UTs or GS elements.

## 9.4 Control plane forward link specification

### *9.4.1 Link layer specification*

#### *9.4.1.1 ARQ protocol*

Refer to User plane (section 8.5.1.1).

#### *9.4.1.2 Encapsulation*

Refer to User plane (section 8.5.1.1).

#### *9.4.1.3 Security*

Refer to 8.3.

### *9.4.2 Physical layer specification*

**CSREQ-4700**

The forward link control shall use the following burst types:

- FCH burst (DAMA burst)

**CSREQ-7210**

The FWD Link Control Plane shall use the Physical layer specification detailed in section 8.5.2 for the FWD Link User Plane with the exception that ACM is not supported for signalling purposes.

The signalling bursts shall use QPSK 1/3.

## 9.5 Control plane return link specification

### *9.5.1 Link layer specification*

#### *9.5.1.1 ARQ protocol*

Refer to User plane (section 8.6.1.1).

#### *9.5.1.2 Encapsulation*

Refer to section 8.6.1.3.

#### *9.5.1.3 Security*

Refer to 8.3.

### *9.5.2 Physical layer specification*

**CSREQ-4990**

The return link control plane shall use the following burst types:

- RACH burst (Random Access burst)

**CSREQ-4991**

The RTN Link Control Plane shall use the Physical layer specification detailed in section 8.6.2 for the RTN Link User Plane

# 10. MANAGEMENT PLANE SPECIFICATION

## 10.1 Management plane description

The term management plane refers to a subset of functions related to management of the satellite network from a communication standard point of view. The management plane aims at supporting non-real time functions, such as FCAPS (Fault, Configuration, Accounting, Performance, and Security), network resources operation planning (frequency allocation, network reconfiguration, maintenance phases planning, etc.) as well as user database management.

It is noted that only a small subset of these functions are proposed hereafter for standardisation in the CS.

## 10.2 Management procedures

### *10.2.1 General management procedures*

**CSREQ-5800**

Management of elements shall be based on SNMP version 3 (SNMPv3) as in [RD-18].

**CSREQ-5460**

All management elements definition shall be compatible with SMIv2 [RD-01] defined structures.

**CSREQ-5470**

The following SMIv2 defined MIBs will be implemented by all system elements:

- SNMP MIB defined in [RD-02] which allows to characterise the SNMP entity itself
- IF-MIB defined in [RD-03] for technology independent interface management
- ALARM-MIB defined in [RD-04] for all alarm related management

### *10.2.2 Monitoring and configuration*

**CSREQ-5480**

At least the following monitoring parameters shall be accessible (read-only) by a Ground Segment management entity from Ground Segment elements about all their interfaces:

| Parameter | Description | Type |
|---|---|---|
| Interface status | Indicates the status of the interface. The status can be either “down” (0), “up” (1), or “standby” (2). The “standby” state being used for interface redundancy purposes. | Octet |
| List of logged on UT* | Provides a list of the ID of all the aircraft currently under the responsibility of the element | Octet String |

| Parameter | Description | Type |
|---|---|---|
| Traffic Log* | Indicates the location of the traffic log files on the local file system for retrieval. | Octet String |
| Tx bytes | Provides the number of bytes transmitted on the interface since system startup. This value is used by monitoring entities to compute average throughput. | Counter |
| Rx bytes | Provides the number of bytes received on the interface since system startup. This value is used by monitoring entities to compute average throughput. | Counter |
| Rx Power* | Indicates the received signal power level (0.1 dBm units). | Integer |
| SNIR* | Indicates the received Signal-to-(Noise+Interference) Ratio (0.1 dB units). | Integer |
| BER* | Indicates the current average bit error rate on the air interface (1E-9 units). | Integer |
| PER | Indicates the current Packet Error rate on a given interface (1E-9 units). | Integer |
| ModCod list* | Provides a list of the ModCod currently in use for each of the user terminals currently under this elements responsibility. | Octet String |
| Last context replication timestamp | Indicates the timestamp of the last context replication towards the redundant element in case the element is currently the active primary. Otherwise, the value indicates the timestamp of the last received context replication from the primary. | Timestamp |
| Random Access collision rate | Indicates the current rate of collisions for the random access channel (return carrier(s)). | Integer |
| Fault History | Lists the fault IDs of all the faults that have been recorded since system startup indicating, for each fault, the timestamp at which it has occurred. | Octet String |
| Current Fault Status | Provides informative access to the current fault status for the ground segment element. | Octet String |

*(*) For air interfaces only*

**Table 10-1: GS monitored parameters**

**CSREQ-5490**

At least the following configurable parameters shall be accessible (read-write) by a Ground Segment management entity from Ground Segment elements about all their interfaces:

| Parameter | Description | Type |
|---|---|---|
| L2 addresses | For each of the element interfaces, provides access to the layer 2 address. | Octet String |
| L3 addresses | For each of the element interfaces, provides access to the layer 3 addresses configured on the interface. | Octet String |
| Carrier Frequency Allocation | List of parameters that characterise the carriers to be used by the element both for transmission and reception of traffic and signalling data. | Octet String |
| Redundancy Role | Indicates the role of the element in the redundancy architecture. This role can either be “primary” or “redundant” depending on the value that is set. | Octet |
| Redundancy peer address | Indicates the address of the peer element in the redundancy architecture. | Octet String |
| Context replication periodicity | Indicates the frequency, in milliseconds, of the context replication from the active primary towards the redundant standby in the redundancy architecture. This value is also used by failure detection mechanisms to dimension the timers. | Integer |

| Parameter | Description | Type |
|---|---|---|
| Adjacent systems information | Provides system information for each of the systems to which inter-system handover can be performed. | Octet String |

**Table 10-2: GS configurable parameters**

### *10.2.3 Security aspects*

Refer to 8.3.

# 11. PHYSICAL LAYER COUNTERMEASURES

## 11.1 Channel impairment countermeasures

### *11.1.1 Forward link channel impairments countermeasures*

#### *11.1.1.1 Diversity*

**CSREQ-5540**

Forward Diversity techniques shall be applicable for user and control plane.

**CSREQ-5550**

If Ku-band frequencies are used for the fixed uplink, transmission site diversity may be implemented.

**CSREQ-5560**

If Ka-band frequencies are used for the fixed uplink, transmission site diversity shall be implemented.

**CSREQ-5570**

In case of implementing site diversity, the distance between GS element shall be compliant with [RD-17] for a given availability.

**CSREQ-5580**

Only one link shall be active at any time (best link selection)

### *11.1.2 Return link channel impairments countermeasures*

#### *11.1.2.1 Diversity*

**CSREQ-5640**

Return Diversity techniques shall be applicable for user and control plane.

**CSREQ-5650**

If Ku-band frequencies are used for the fixed uplink, reception site diversity may be implemented.

**CSREQ-5660**

If Ka-band frequencies are used for the fixed uplink, reception site diversity shall be implemented.

**CSREQ-5670**

In case of implementing site diversity, the distance between GS element shall be compliant with [RD-17] for a given availability.

**CSREQ-5680**

The return link site diversity algorithm shall be based on selection of the best link.

# 12. SIGNALLING STRUCTURES

**(To be revised in B2)**

This section provides detailed information about the PDUs of the signalling structures to be used for several control procedures.

**CSREQ-5770**

The exchanged signalling messages shall comply with the structures shown in the following subsections.

## 12.1 System information tables

TBD

## 12.2 Handover

Note: see section 9.2.2 note.

By now, eight different types of HO are defined, each of them requiring a specific signalling exchange between the involved entities. Below, the set of PDUs available for HO control functions are detailed.

### *12.2.1 HO Recommendation*

| HO Recommendation | | |
|---|---|---|
| **Content of message** | **size (Bytes)** | **comments** |
| Message type | 1 | |
| HO type | 1 | |
| UT ID (optional) | 2 | |
| Signal power measurements | 64 | 8 neighbour information |
| Position Coordinates | 24 | 3 position coordinates (trajectory) |
| APB Preferences | 20 | 10 preferences of 2 Bytes |
| new GES ID (optional) | 1 | |
| **TOTAL SIZE (Bytes)** | **113** | |

### *12.2.2 New NCC information*

| New NCC Information | | |
|---|---|---|
| **Content of message** | **size (Bytes)** | **comments** |
| Message type | 1 | |
| New NCC ID | 1 | |
| **TOTAL SIZE (Bytes)** | **2** | |

### 12.2.3 HO Command

| HO Command | | |
|---|---|---|
| Content of message | size (Bytes) | comments |
| Message type | 1 | |
| previous GES ID (optional) | 1 | |
| new GES ID (optional) | 1 | |
| Physical layer parameters | 64 | |
| TOTAL SIZE (Bytes) | 67 | |

### 12.2.4 Connection close

| Connection close | | |
|---|---|---|
| Content of message | size (Bytes) | comments |
| Message type | 1 | |
| TOTAL SIZE (Bytes) | 1 | |

### 12.2.5 ACK Connection close

| ACK Connection close | | |
|---|---|---|
| Content of message | size (Bytes) | comments |
| Message type | 1 | |
| TOTAL SIZE (Bytes) | 1 | |

### 12.2.6 HO finished

| HO Finished | | |
|---|---|---|
| Content of message | size (Bytes) | comments |
| Message type | 1 | |
| previous GES ID | 1 | |
| new GES ID | 1 | |
| TOTAL SIZE (Bytes) | 3 | |

## 12.3 Multicast

One multicast signalling message can contain reports for multiple multicast groups. In this sense, the size of multicast join messages is variable and depends on the number of multicast groups reported.

### 12.3.1 Multicast join

| Multicast join | | |
|---|---|---|
| Content of message | size (Bytes) | comments |
| Message type | 1 | |
| Number of Mcast address records (N) | 1 | Multicast groups reported |
| Filter mode | 1 | Include/Exclude |
| Multicast address record | >34 | Multicast address + N source addresses |
| TOTAL SIZE (Bytes) | >36 | |

### 12.3.2 Multicast join ACK

| Multicast join ACK | | |
|---|---|---|
| **Content of message** | **size (Bytes)** | **comments** |
| Message type | 1 | |
| Number of Mcast address records (N) | 1 | Multicast groups reported |
| Filter mode | 1 | Include/Exclude |
| Multicast address record | >34 | Depends on the number of source addresses |
| **TOTAL SIZE (Bytes)** | **>36** | |

### 12.3.3 Multicast leave

| Multicast leave | | |
|---|---|---|
| **Content of message** | **size (Bytes)** | **comments** |
| Message type | 1 | |
| Number of Mcast address records (N) | 1 | Multicast groups reported |
| Filter mode | 1 | Include/Exclude |
| Multicast address record | >34 | Depends on the number of source addresses |
| **TOTAL SIZE (Bytes)** | **>36** | |

### 12.3.4 Multicast change state report

| Multicast change report | | |
|---|---|---|
| **Content of message** | **size (Bytes)** | **comments** |
| Message type | 1 | |
| Number of Mcast address records (N) | 1 | Multicast groups reported |
| Filter mode | 1 | Include/Exclude |
| Multicast address record | >34 | Depends on the number of source addresses |
| **TOTAL SIZE (Bytes)** | **>36** | |

## 12.4 Logon

Two operation modes are proposed for logon, the transparent mode and the ANTARES integrated mode. In transparent mode, L2 logon opens an interface which is used for finalizing the logon procedure at L3. Otherwise, the ANTARES integrated mode translates several L3 logon fields to L2 so that logon can be entirely performed at L2 level. (TBD)

### 12.4.1 Logon request

| LOGON Request | | |
|---|---|---|
| **Content of message** | **size (Bytes)** | **comments** |
| Message type | 1 | |
| UT/System capabilities & configuration | 32 | (TBC) UT CS parameters and capabilities |
| **TOTAL SIZE (Bytes)** | **33** | |

The content of a logon request may vary in function if in ATN/OSI or ATN/IPS mode.

### *12.4.2 Logon confirmation*

| LOGON Confirmation | | |
|---|---|---|
| **Content of message** | **size (Bytes)** | **comments** |
| Message type | 1 | |
| UT/System admission | 16 | (TBC) |
| UT/System configuration | 16 | (TBC) |
| **TOTAL SIZE (Bytes)** | **33** | |

The content of a logon confirmation may vary in function if in ATN/OSI or ATN/IPS mode.

## 12.5 RRM

TBD

## 12.6 Random Access

The signalling structures used for RA are mainly involved with congestion control functions and control checks. This section details the used PDUs.

### *12.6.1 RACH Congestion control*

| RACH Congestion control | | |
|---|---|---|
| **Content of message** | **size (bytes)** | **comments** |
| Message type | 1 | |
| CC method type<br>CC parameters | 1 | |
| **TOTAL SIZE (Bytes)** | **2** | |

## 12.7 Voice Control

The signalling structures used for voice are mainly involved with specific CBR channel reservation and admission notification. They are encapsulated over IP and used in the interfaces number 4 and 6 of Figure 4-2.

### *12.7.1 cbr on*

| cbr on | | |
|---|---|---|
| **Content of message** | **size (Bytes)** | **comments** |
| Message type | 1 | |
| Notification ID | 2 | (TBC) |
| Connection ID | 2 | (TBC) |
| Interlocutor ID | 2 | (TBC) |
| **TOTAL SIZE (Bytes)** | **7** | |

### *12.7.2 cbr off*

The structure of the message is the same as the one presented for the “cbr on” message in section 12.7.1.

### 12.7.3 cbr req

| cbr req | | |
|---|---|---|
| **Content of message** | **size (Bytes)** | **comments** |
| Message type | 1 | |
| Notification ID | 2 | (TBC) |
| Interlocutor ID | 2 | (TBC) |
| **TOTAL SIZE (Bytes)** | **5** | |

### 12.7.4 cbr rel

The structure of the message is the same as the one presented for the “cbr on” message in section 12.7.1.

### 12.7.5 req cbr

The structure of the message is the same as the one presented for the “cbr req” message in section 12.7.3.

### 12.7.6 rel cbr

The structure of the message is the same as the one presented for the “cbr on” message in section 12.7.1.

### 12.7.7 ack

The structure of the message is the same as the one presented for the “cbr req” message in section 12.7.3.

## 12.8 Network synchronisation

### 12.8.1 SYNC correction

| SYNC Corrections Message | | | | | |
|---|---|---|---|---|---|
| **Message content** | **Size [bits]** | **Step** | **Range** | **Units** | **Comments** |
| Message type | 8 | NA | 0 - 256 | NA | |
| UT identifier | 16 | NA | 0 - 65535 | NA | |
| Carrier frequency correction | 11 | 10 | +/-10240 | Hz | |
| RFU | 5 | NA | NA | NA | Reserved for future use |
| Total size | 40 | | | bits | |
| **Total size** | **5** | | | **bytes** | |

### 12.8.2 NCR field

| NCR Packet | | | | | |
|---|---|---|---|---|---|
| **Message content** | **Size [bits]** | **Step** | **Range** | **Units** | **Comments** |
| Message type | 8 | NA | 0 - 256 | NA | |
| NCR counter | 40 | NA | - | Hz | Tics of the 27 MHz Netw ork Clock Reference |
| Total size | 48 | | | bits | |
| **Total size** | **6** | | | **bytes** | |

## 12.9 ACM

TBD

# 13. ANNEX A: AERONAUTICAL CHANNEL AND CODING PERFORMANCES

## 13.1 Aeronautical channel scenarios

The propagation conditions have been categorised in a set of relevant scenarios. The following table summarises the aeronautical propagation scenarios

| Scenario Id | Aircraft type | Region | Latitude | Surface | Banking | Scintillation | Elevation angle range | Aircraft Speed (km/h) | Aircraft Altitude (km) | LS parameters | | GR parameters | | | Periodic fades | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | K_LS (dB) | Doppler Spread (Hz) | K_GR (dB) | Doppler Spread (Hz) | Delay LoS-GR (μs) | Fade Depth (dB) | Fade duration (ms) | Fading period (ms) |
| 1 | Fixed wing | ECAC | Medium | Ground | No | No | [10º, 35º] | 900 | 10 | 14 | 1 | 20 | 32.8 | 11.5 | N.A | N.A | N.A |
| 2a | Fixed wing | ECAC | Medium | Sea | No | No | [10º, 35º] | 900 | 10 | 14 | 1 | 10 | 32.8 | 11.5 | N.A | N.A | N.A |
| 2b | Fixed wing | ECAC | Medium | Sea | No | Yes | [10º, 35º] | 900 | 10 | 14 | 1 | 10 | 32.8 | 11.5 | N.A | N.A | N.A |
| 4 | Fixed wing | ECAC | High | Sea | No | No | [5º, 10º] | 900 | 10 | 14 | 1 | 5 | 18.4 | 5.8 | N.A | N.A | N.A |
| 7 | Fixed wing | ECAC | Low | Sea | No | No | > 35º | 900 | 10 | 14 | 1 | 15 | 103.65 | 38.28 | N.A | N.A | N.A |
| 6a | Fixed wing | Global | Medium | Sea | No | No | [10º, 35º] | 900 | 10 | 14 | 1 | 10 | 32.8 | 11.5 | N.A | N.A | N.A |
| 6b | Fixed wing | Global | Low | Sea | No | Yes | > 35º | 900 | 10 | 14 | 1 | 15 | 103.65 | 38.28 | N.A | N.A | N.A |
| 9 | Rotary wing | ECAC | Medium | Ground | No | No | [10º, 35º] | 315 | 5.5 | 14 | 1 | 20 | 11.24 | 6.37 | 7 | 10.8 | 54 |

**Table 13-1: Aeronautical propagation scenarios**

It should be noted that the Doppler Spread corresponding to Scenario #9 is different from the one reported for Scenario #1, #2a, #2b and #6a due to the aircraft speed is different: Scenario #9 corresponds to a rotary-wing aircraft while the others to a fixed-wing aircrafts.

### 13.2 Forward Link FEC Error Performance

The input stream to the LDPC encoder shall be a BBFRAME and the output stream a FECFRAME. Each BBFRAME ($k_{ldpc}$ bits) shall be processed by the FEC coding subsystem, to generate a FECFRAME ($n_{ldpc}$ bits).

The following table illustrates the turbo coding configurations.

| MODCOD Id | Mode | LDPC Uncoded Block $k_{ldpc}$ (bits) | LDPC Coded Block $n_{ldpc}$ (bits) |
|---|---|---|---|
| MODCOD 1 | QPSK 1/3 | 2048 | 6144 |
| MODCOD 2 | QPSK 1/2 | 3072 [4096] | 6144 [8192] |
| MODCOD 3 | QPSK 2/3 | 4096 | 6144 |
| MODCOD 4 | 8-PSK 1/2 | 4608 [4096] | 9216 [8192] |
| MODCOD 5 | 8-PSK 2/3 | 6144 | 9216 |
| MODCOD 6 | 16-APSK 2/3 | 8192 | 1288 |

**Table 13-2: FWD Link FEC parameters**

Note: MODCOD 2 and MODCOD 4 PER curves reported in this section correspond to a Data Word of 4096 bits in each case instead of 3072 for MODCOD2 and 4608 for MODCOD4.

The results presented in this section have been obtained considering the following configuration parameters:

- Channel estimation / sampling: ideal over the LOS component.[4]
- Monte Carlo method: 100 block errors.
- Roll-off: 0.2
- Interleaving: L=4 (with exception of Channel 6, where L=1).
- Baud rate: 150 ksps (with exception of Channel 6, where it is close to 18 ksps)
- Nominal number of LDPC Decoder iterations: **50**.

[4] We sample the received signal at the optimum sampling time for the LOS component. Additionally, the channel coefficient used for soft-demodulation has been assumed to be coefficient of the LOS component. The approach provided to be accurate, due to the relatively-large C/M factors, and for the relatively large delay of the reflected component. In the worst case scenario (4), the C/M=5dB, and the delay is roughly 0.87*Ts (being Ts the symbol time). The filter response pulse at t=0.87*Ts more than 15 dB lower than the peak value. Thus, the ratio between the LOS component power and the useful contribution coming from the ground reflection in Scenario 4 is more than 20 dB, which does not visibly affect the decoder performance. For Scenario 6, where the baud rate is reduced, the reflection is between 10 and 15 dB below the LOS component, hence the channel estimation can be still assumed accurate.

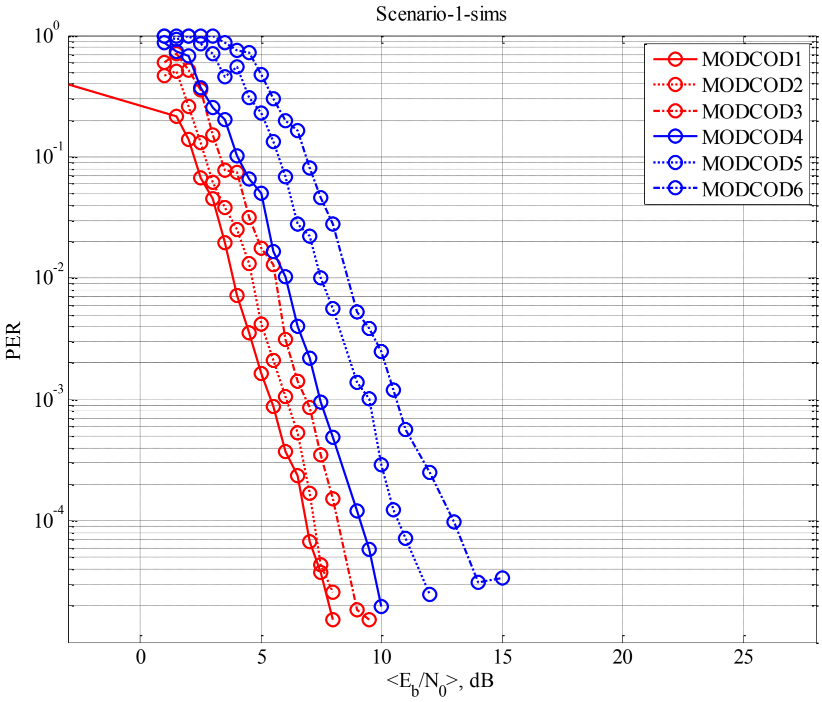



**Figure 13-1: PER vs. Eb/N0 for Scenario 1.**

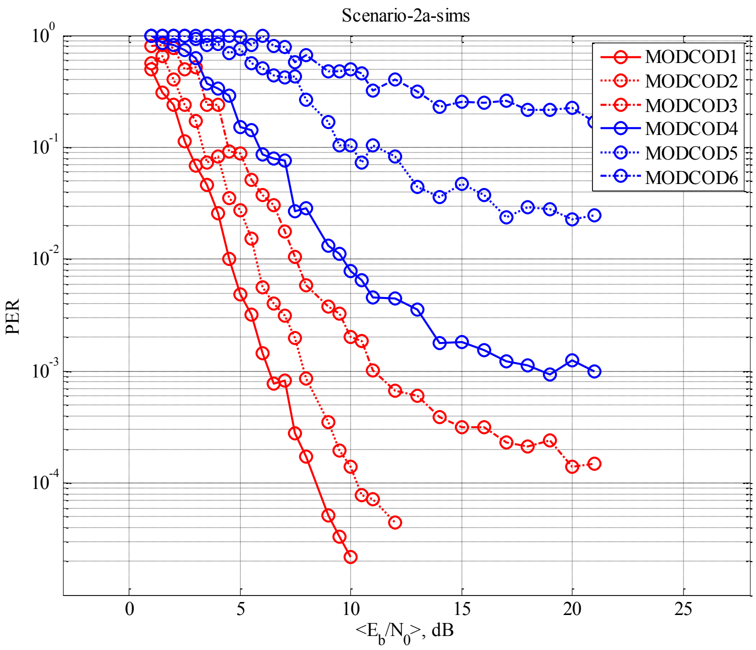



**Figure 13-2: PER vs. Eb/N0 for Scenario 2a.**

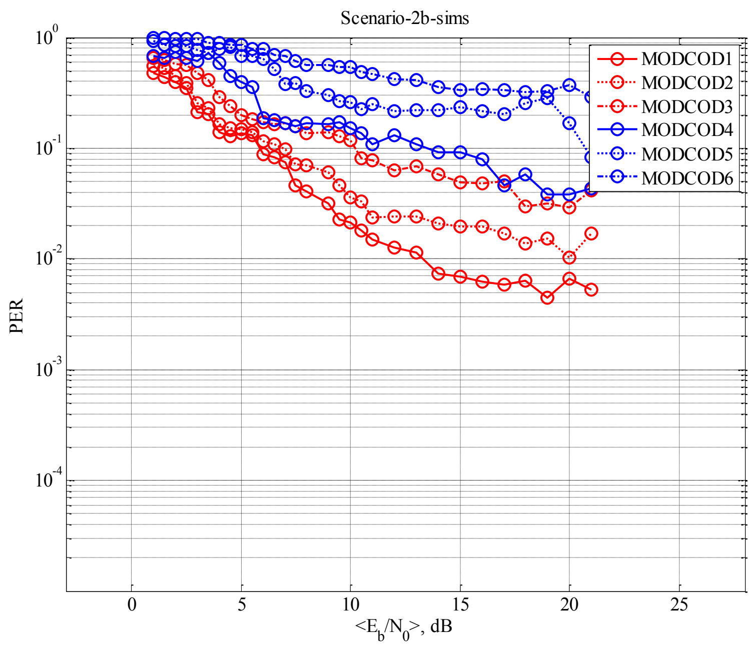



**Figure 13-3: PER vs. Eb/N0 for Scenario 2b.**

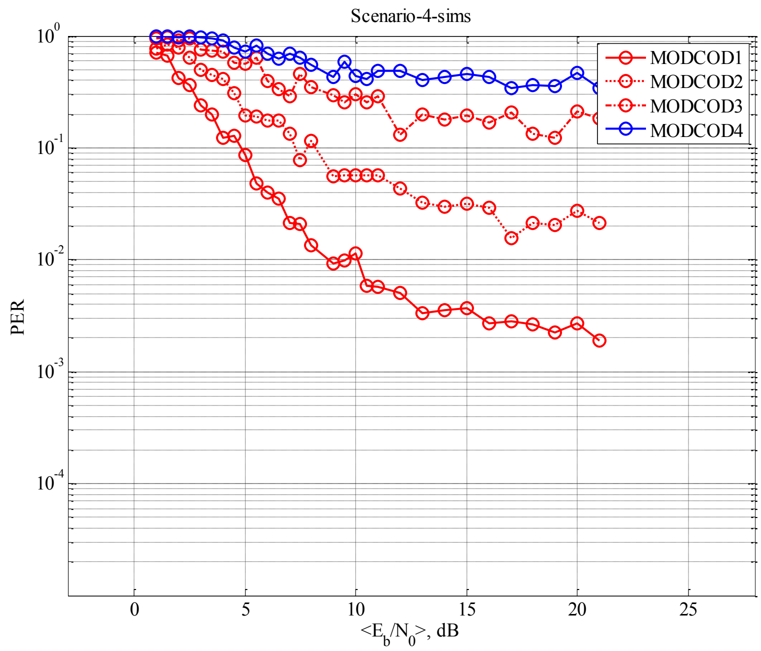



**Figure 13-4: PER vs. Eb/N0 for Scenario 4.**

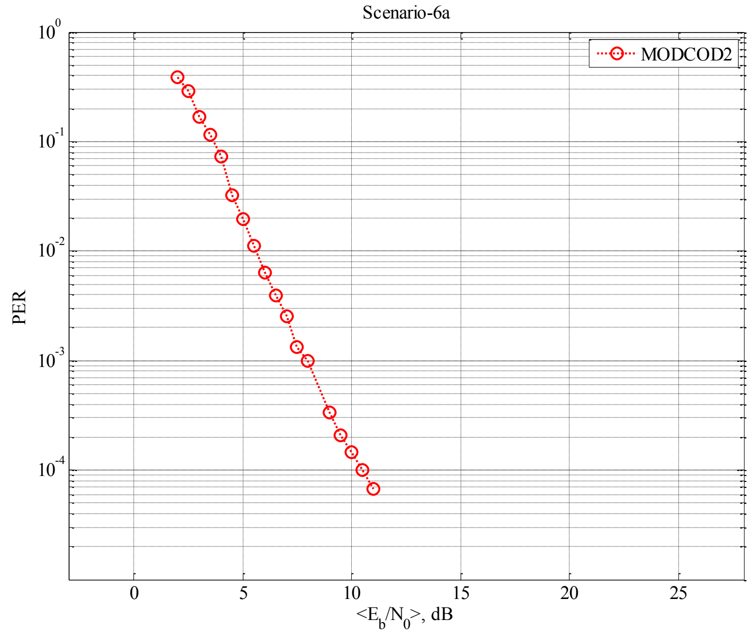



**Figure 13-5: PER vs. Eb/N0 for Scenario 6a.**

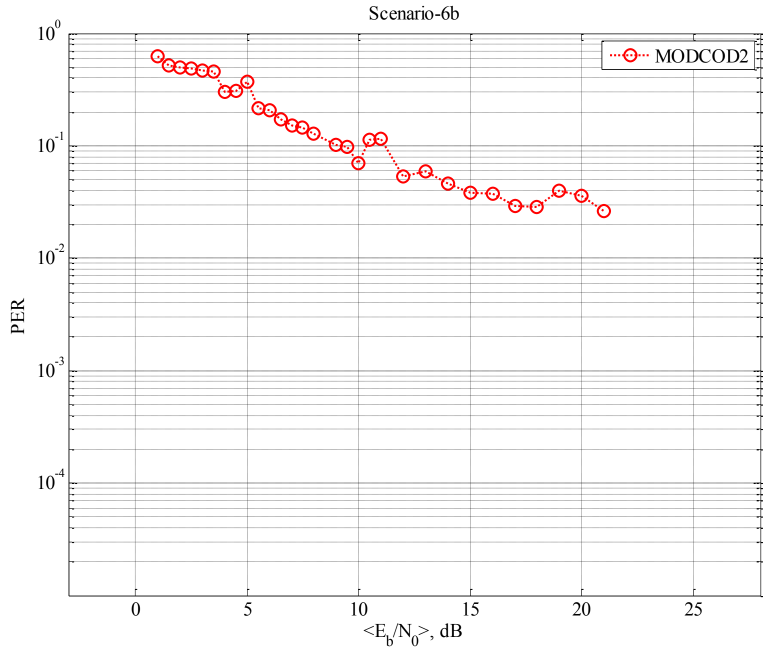



**Figure 13-6: PER vs. Eb/N0 for Scenario 6b.**

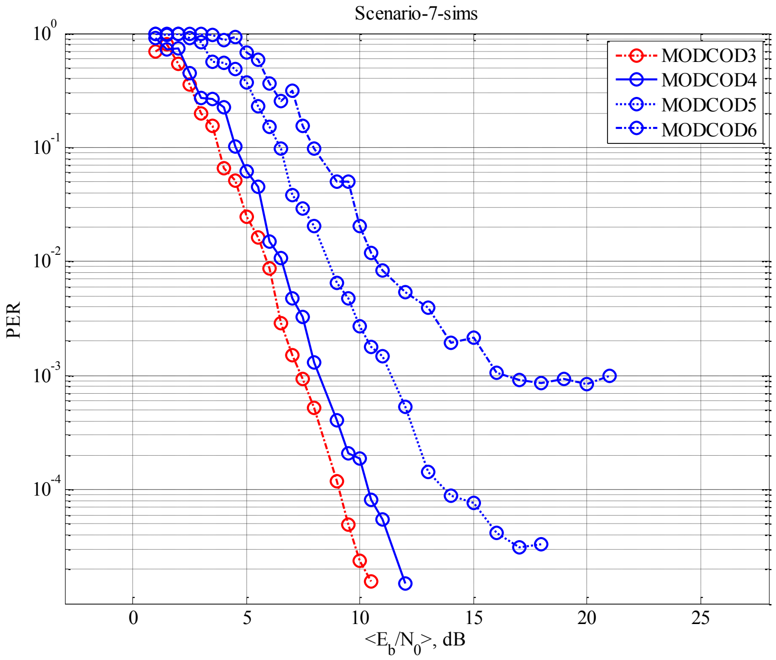



**Figure 13-7: PER vs. Es/N0 for Scenario 7.**

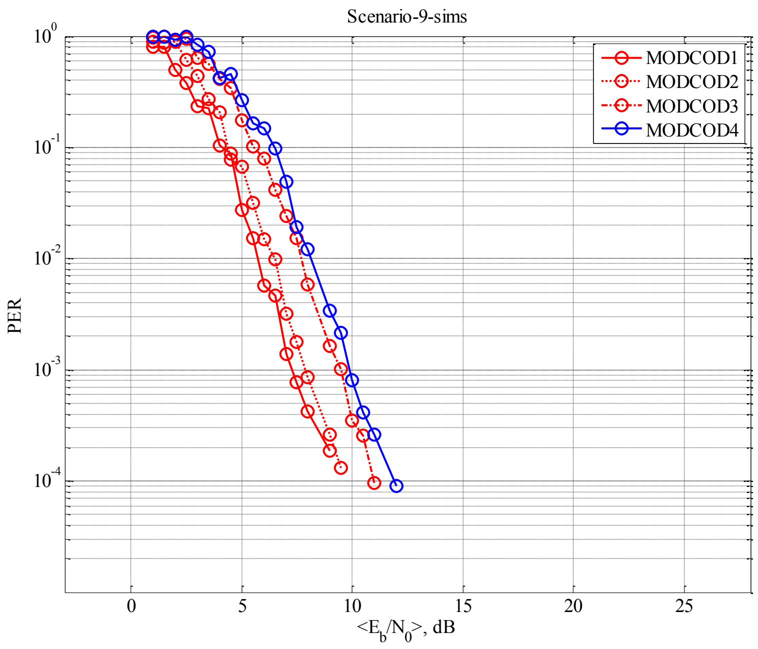



**Figure 13-8: PER vs. Eb/N0 for Scenario 9 (rotary-wing).**

## 13.3 Return Link FEC Error Performance

The input stream to the Turbo encoder shall be a BBFRAME and the output stream a FECFRAME. Each BBFRAME ($k_{TCC}$ bits) shall be processed by the FEC coding subsystem, to generate a FECFRAME ($n_{TCC}$ bits).

The following table illustrates the turbo coding configurations:

| RACH Configuration ID | Code rate | TCC Uncoded Block $k_{TCC}$ (bits) | Tail bits | TCC Coded Block $n_{TCC}$ (bits) |
|---|---|---|---|---|
| RACH_CR$_{160}$_SF$_{16}$_DB$_{512}$ | 1/3 | 512 bits | 12 bits | 1548 bits |
| RACH_CR$_{160}$_SF$_{4}$_DB$_{2048}$ | 1/3 | 2048 bits [4096 bits] | 12 bits | 6156 bits [8204 bits] |
| RACH_CR$_{160}$_SF$_{4}$_DB$_{288}$ | 1/3 | 288 bits [-] | 12 bits | 876 bits [-] |

**Table 13-3: RACH TCC coding configurations**

The results presented in the following sub-sections have been obtained with the following configuration parameters:

| Parameters | Value |
|---|---|
| UT HPA | No (lineal HPA) |
| TCC type | Binary 16-states |
| Decoder Algotithm | Log-MAP |
| Number of iterations | 10 |
| Block interleaver | Yes, as specified in the CS Technical specification |

**Table 13-4: RTN Link PER simulation parameters**

Note: PER curves for RACH_CR$_{160}$_SF$_{4}$_DB$_{2048}$ and RACH_CR$_{160}$_SF$_{4}$_DB$_{288}$ are not available. Instead of these results, PER curves for a BBFRAME of 4096 are provided.

The following figures present the PER curves with:

– Ideal channel estimation (perfect knowledge of the channel coefficients)

– Real channel estimation: the channel is estimated from the Control channel, which is 10 dB below the Data Channel and using a sliding window of 250 symbols.

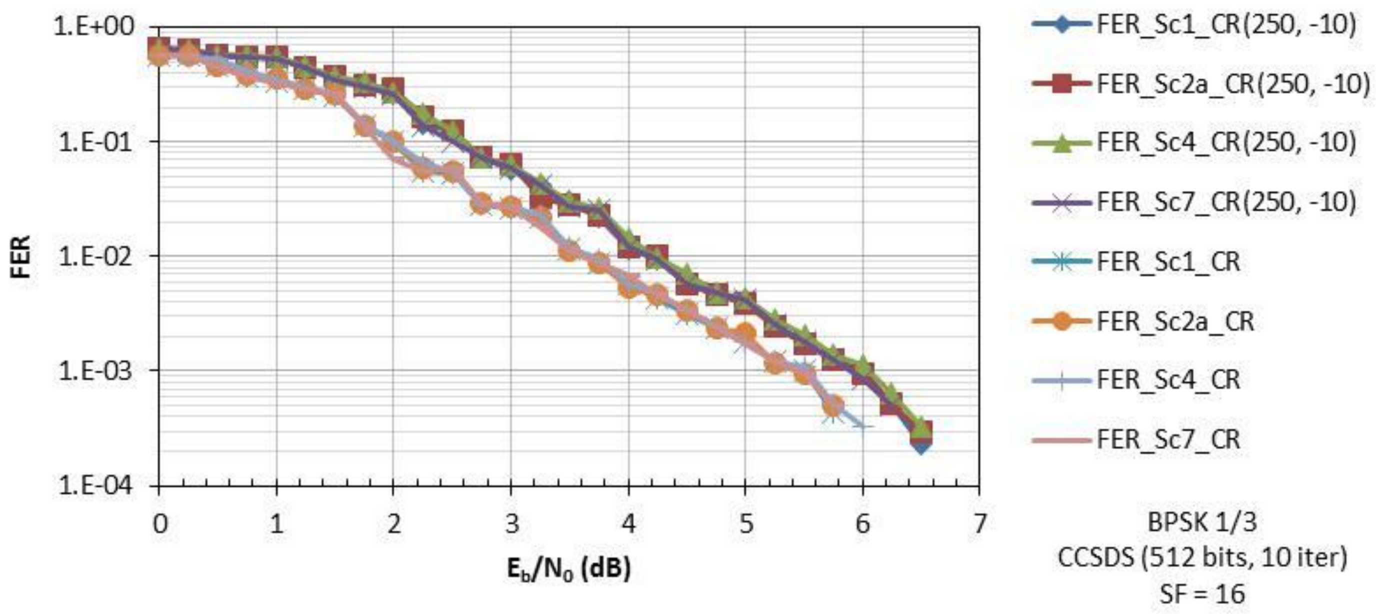



**Figure 13-9: PER curves in aeronautical channel for configuration RACH_$CR_{160}$_$SF_{16}$_$DB_{512}$ with ideal channel estimation and with channel estimation**

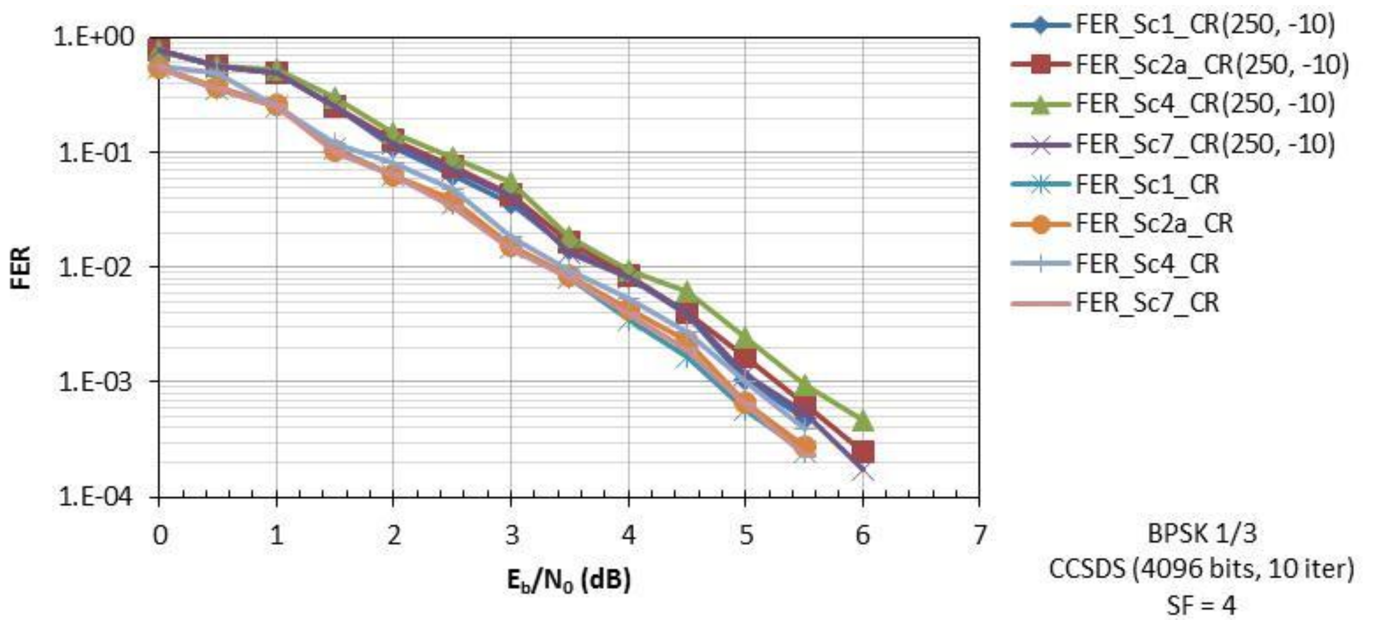



**Figure 13-10: PER curves in aeronautical channel BBFRAME = 4096 bits with ideal channel estimation and with channel estimation**

# 14. ANNEX B: LDPC ENCODING PROCEDURE AND ADDRESSES OF PARITY BIT ACCUMULATORS FOR IRA LDPC

## 14.1 LDPC encoding procedure

LDPC encoder systematically encodes an information block of size $k$, $\boldsymbol{i}=(i_0,i_1,...,i_{k-1})$ onto a codeword of size $n$, $\boldsymbol{c}=(i_0,i_1,...,i_{k-1},p_0,p_1,...p_{n-k-1})$ The transmission of the codeword starts in the given order from $i_0$ and ends with $p_{n-k-1}$.

The task of the encoder is to determine $n-k$ parity bits $(p_0,p_1,...,p_{n-k-1})$ for every block of $k$ information bits, $(i_0,i_1,...,i_{k-1})$. The procedure is follows:

- Initialise $p_0=p_1=p_2=...=p_{n-k-1}=0$
- Accumulate the first information bit, $i_0$, at parity bit addresses specified in the first row of parity bit addresses. For example, for r=1/2 and $k_{ldpc}$=4096 bits code (section 14.2.7), (All additions are in GF(2))

$$p_{383}=p_{383}\oplus i_0$$

$$p_{1836}=p_{1836}\oplus i_0$$

$$p_{2903}=p_{2903}\oplus i_0$$

$$p_{3461}=p_{3461}\oplus i_0$$

- For the next c-1 information bits (c=128 for the 2k, 4k and 6k codes, c=256 for the 8k code), $i_m, m=1,2,...,c-1$ accumulate $i_m$ at parity bit addresses $\{x+m \bmod c\times q\}\bmod(n-k)$ where $x$ denotes the address of the parity bit of the accumulator corresponding to the first bit $i_0$, and $q$ is specified in Table 14-1. Continuing with the example, $q=32$. So for example for information bit $i_1$, the following operations are performed,

$$p_{415}=p_{415}\oplus i_1$$

$$p_{1868}=p_{1868}\oplus i_1$$

$$p_{2935}=p_{2935}\oplus i_1$$

$$p_{3493}=p_{3493}\oplus i_1$$

- For the (c+1)$^{th}$ information bit $i_c$, the addresses of the parity bit accumulators are given in the second row the table presented in section 14.2.7. In a similar manner the addresses of the parity bit accumulators for the following c-1 information bits $i_m, m=c+1,...,2c-1$ are obtained using the formula $\{x+m \bmod c\times q\}\bmod(n-k)$ where $x$ denotes the address of the parity bit accumulator corresponding to the information bit $i_c$, i.e. the entries in the second row of the table in section 14.2.7.

- In a similar manner, for every group of c new information bits, a new row from the table in section 14.2.7 is used to find the addresses of the parity bit accumulators.

After all of the information bits are exhausted, the final parity bits are obtained as follows,

- Sequentially perform the following operations starting with $i=1$

$$p_i = p_i \oplus p_{i-1}, \qquad i = 1,2,...,n-k-1$$

- Final content of $p_i$, $i = 0,1,..,n-k-1$ is equal to the parity bit $p_i$.

| Block Size | q/c |
|---|---|
| 2048 | 32/128 |
| 3072 | TBD |
| 4096 | 16/128 |
| 4608 | TBD |
| 6144 | 24/128 |
| 8192 | 16/256 |

**Table 14-1: q/c values.**

## 14.2 Addresses of parity bit accumulator for IRA LDPC

### *14.2.1 MODCOD1 parity bit accumulator (r=1/3 and $k_{ldpc}$ = 2048)*

469 962 2940 3752
2173 2953 3587 3894
202 1796 2110 4023
299 997 2431 3568
536 550 1676 2513
313 711 2157 3730
115 1710 2074 3040
463 673 2011 3828
1446 2093 2396 2839
592 846 1021 2279
672 1150 1873 4015
1522 2184 2687 3649
184 809 3234 3859
842 1716 3171 4057
171 533 1380 2234

172 1659 1974 2373

**Table 14-2: MODCOD1 parity bit accumulator addresses (r=1/3 and kldpc = 2048)**

### *14.2.2 MODCOD2 parity bit accumulator (r=1/2 and $k_{ldpc}$ = 3072)*

TBD

### *14.2.3 MODCOD3 parity bit accumulator (r=2/3 and $k_{ldpc}$ = 4096)*

1400 1564 2615 2773
446 989 1593 2298
399 672 1219 2410
40 827 1369 1700
1025 1226 2454 2541
963 1198 1639 1788
263 472 2090 2263
185 507 944 3066
1356 1497 2155 2764
1066 1397 2029 2252
1392 1526 1619 2253
687 1662 2545 2830
574 2747 2797 2954
182 1035 1535 2694
220 1098 2503 2871
440 1963 2069 3016
2040 2225 2564 2673
490 1173 2172 2977
417 541 1196 1417
1082 1094 2733 2938
238 255 747 1331
1703 1924 2152 2718
173 209 631 1194
504 948 1520 2851
453 1827 2147 2244
1822 2029 2430 2956
974 1133 2311 2399
320 1146 3015 3024
619 1504 1681 3009
730 1145 2666 2876
990 1048 1847 3051
127 412 426 1121
1304 1421 1675 2580
609 648 1628 2821
405 806 1345 2770
303 770 1318 2699
569 652 656 2202
365 1089 1404 2083

476 1117 2338 2712
73 717 1454 2867
118 1239 1566 1898
1720 1827 2335 2783
825 1250 2293 2300
734 2098 2181 2283
803 2758 2991 3028
280 342 2549 2615
1553 1962 2568 2599
636 2360 2545 2995

**Table 14-3: MODCOD3 parity bit accumulator (r=2/3 and kldpc = 4096)**

### *14.2.4 MODCOD4 parity bit accumulator (r=1/2 and $k_{ldpc}$ = 4608)*

TBD

### *14.2.5 MODCOD5 parity bit accumulator (r=2/3 and $k_{ldpc}$ = 6144)*

1400 1564 2615 2773
446 989 1593 2298
399 672 1219 2410
40 827 1369 1700
1025 1226 2454 2541
963 1198 1639 1788
263 472 2090 2263
185 507 944 3066
1356 1497 2155 2764
1066 1397 2029 2252
1392 1526 1619 2253
687 1662 2545 2830
574 2747 2797 2954
182 1035 1535 2694
220 1098 2503 2871
440 1963 2069 3016
2040 2225 2564 2673
490 1173 2172 2977
417 541 1196 1417
1082 1094 2733 2938
238 255 747 1331
1703 1924 2152 2718
173 209 631 1194
504 948 1520 2851
453 1827 2147 2244
1822 2029 2430 2956
974 1133 2311 2399
320 1146 3015 3024
619 1504 1681 3009

730 1145 2666 2876
990 1048 1847 3051
127 412 426 1121
1304 1421 1675 2580
609 648 1628 2821
405 806 1345 2770
303 770 1318 2699
569 652 656 2202
365 1089 1404 2083
476 1117 2338 2712
73 717 1454 2867
118 1239 1566 1898
1720 1827 2335 2783
825 1250 2293 2300
734 2098 2181 2283
803 2758 2991 3028
280 342 2549 2615
1553 1962 2568 2599
636 2360 2545 2995

**Table 14-4: MODCOD5 parity bit accumulator (r=2/3 and kldpc = 6144)**

### *14.2.6 MODCOD6 parity bit accumulator (r=2/3 and $k_{ldpc}$ = 8192)*

763 2006 2831 3202
1772 2035 2424 3062
359 2867 3640 3676
32 781 2359 2809
512 900 905 2237
1822 2436 2538 3329
990 1649 1738 2869
351 1138 3013 3531
403 1318 1902 4041
618 675 1398 3071
192 1495 3695 3994
155 800 1143 2172
321 2276 3099 4092
1633 2932 2952 2973
61 1848 2533 3394
85 649 2542 2738
1623 1793 1900 2137
82 2332 2586 3943
957 1780 1978 2594
811 2669 3811 4004
963 2565 3259 3982
992 1550 1560 1893
159 1112 2310 3264

166 1103 1785 3905

547 1757 3157 3658

1488 1782 1806 3035

1451 1456 1470 2982

15 2552 2855 4001

727 2577 2696 2879

18 2132 2345 3564

1385 2306 2892 3940

2021 2451 2618 2813

**Table 14-5: MODCOD6 parity bit accumulator (r=2/3 and kldpc = 8192)**

### *14.2.7 Additional parity bit accumulator (r=1/2 and $k_{ldpc}$ = 4096)*

383 1836 2903 3461

56 653 1254 2544

337 878 1191 3033

3392 3503 3802 3922

179 2651 3144 3425

1020 2754 2793 3092

2147 2250 3389 3605

107 214 932 1566

509 614 2675 3724

2413 3134 3220 3527

469 832 2350 3903

120 1537 1590 1935

599 2137 2216 3106

122 547 2857 4016

452 571 977 2090

293 907 2172 3666

931 2195 2350 3896

431 2388 2564 3481

250 533 613 3752

70 1883 3465 3894

727 3207 3388 3626

299 304 608 1405

1105 1516 1662 2049

482 2221 2898 3135

1095 2491 3125 3723

2252 3964 4054 4064

225 471 1645 2717

962 1200 1694 3822

255 431 2769 3235

2532 2962 3784 3896

549 659 1177 2633

810 1722 2182 2836

**Table 14-6: Additional parity bit accumulator (r=1/2 and kldpc = 4096)**

# 15. ANNEX C: FORWARD LINK BIT INTERLEAVING MATRIX

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# 16. ANNEX D: TURBO CODE INTERNAL INTERLEAVER ALGORITHM

The turbo interleaver functionality shall be such that the input bits are readdressed following a certain mapping sequence, in position *i* of which the new address of input bit *i* can be read. This mapping sequence is generated following the process defined in the 3GPP2 standard and described below.

An (n+5)-bit counter, initialised to 0 and where n is the smallest integer such that $N_{turbo} \leq 2^{n+5}$ ($N_{turbo}$ is input bit sequence length), is used as input to the algorithm detailed in Figure 16-1, in such a way that the output is the new address for each *i* generated by the counter.

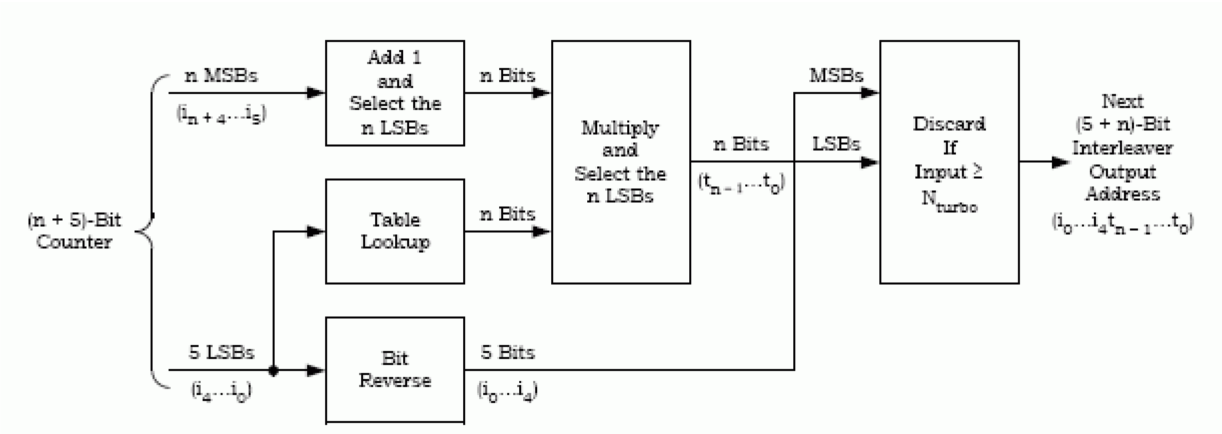


**Figure 16-1: Turbo interleaver output address calculation algorithm.**

The lookup table included in algorithm is depicted in the following table.

| Table index | n=3 | n=4 | n=5 | n=6 | n=7 | n=8 | n=9 | n=10 |
|---|---|---|---|---|---|---|---|---|
| **0** | 1 | 5 | 27 | 3 | 15 | 3 | 13 | 1 |
| **1** | 1 | 15 | 3 | 27 | 127 | 1 | 335 | 349 |
| **2** | 3 | 5 | 1 | 15 | 89 | 2 | 87 | 303 |
| **3** | 5 | 15 | 15 | 13 | 1 | 83 | 15 | 721 |
| **4** | 1 | 1 | 13 | 29 | 31 | 19 | 15 | 973 |
| **5** | 5 | 9 | 17 | 5 | 15 | 179 | 1 | 703 |
| **6** | 1 | 9 | 23 | 1 | 61 | 19 | 333 | 761 |
| **7** | 5 | 15 | 13 | 31 | 47 | 99 | 11 | 327 |
| **8** | 3 | 13 | 9 | 3 | 127 | 23 | 13 | 453 |
| **9** | 5 | 15 | 3 | 9 | 17 | 1 | 1 | 95 |
| **10** | 3 | 7 | 15 | 15 | 119 | 3 | 121 | 241 |
| **11** | 5 | 11 | 3 | 31 | 15 | 13 | 155 | 187 |
| **12** | 3 | 15 | 13 | 17 | 57 | 13 | 1 | 497 |
| **13** | 5 | 3 | 1 | 5 | 123 | 3 | 175 | 909 |
| **14** | 5 | 15 | 13 | 39 | 95 | 17 | 421 | 769 |
| **15** | 1 | 5 | 29 | 1 | 5 | 1 | 5 | 349 |
| **16** | 3 | 13 | 21 | 19 | 85 | 63 | 509 | 71 |
| **17** | 5 | 15 | 19 | 27 | 17 | 131 | 215 | 557 |
| **18** | 3 | 9 | 1 | 15 | 55 | 17 | 47 | 197 |
| **19** | 5 | 3 | 3 | 13 | 57 | 131 | 425 | 499 |
| **20** | 3 | 1 | 29 | 45 | 15 | 211 | 295 | 409 |
| **21** | 5 | 3 | 17 | 5 | 41 | 173 | 229 | 259 |
| **22** | 5 | 15 | 25 | 33 | 93 | 231 | 427 | 335 |
| **23** | 5 | 1 | 29 | 15 | 87 | 171 | 83 | 253 |
| **24** | 1 | 13 | 9 | 13 | 63 | 23 | 409 | 677 |
| **25** | 5 | 1 | 13 | 9 | 15 | 147 | 387 | 717 |
| **26** | 1 | 9 | 23 | 15 | 13 | 243 | 193 | 313 |
| **27** | 5 | 15 | 13 | 31 | 15 | 213 | 57 | 757 |
| **28** | 3 | 11 | 13 | 17 | 81 | 189 | 501 | 189 |
| **29** | 5 | 3 | 1 | 5 | 57 | 51 | 313 | 15 |
| **30** | 5 | 15 | 13 | 15 | 31 | 15 | 489 | 75 |
| **31** | 3 | 5 | 13 | 33 | 69 | 67 | 391 | 163 |

**Table 16-1: Turbo interleaver lookup table definition**

## 17. ANNEX E: RETURN LINK BIT INTERLEAVING MATRIX

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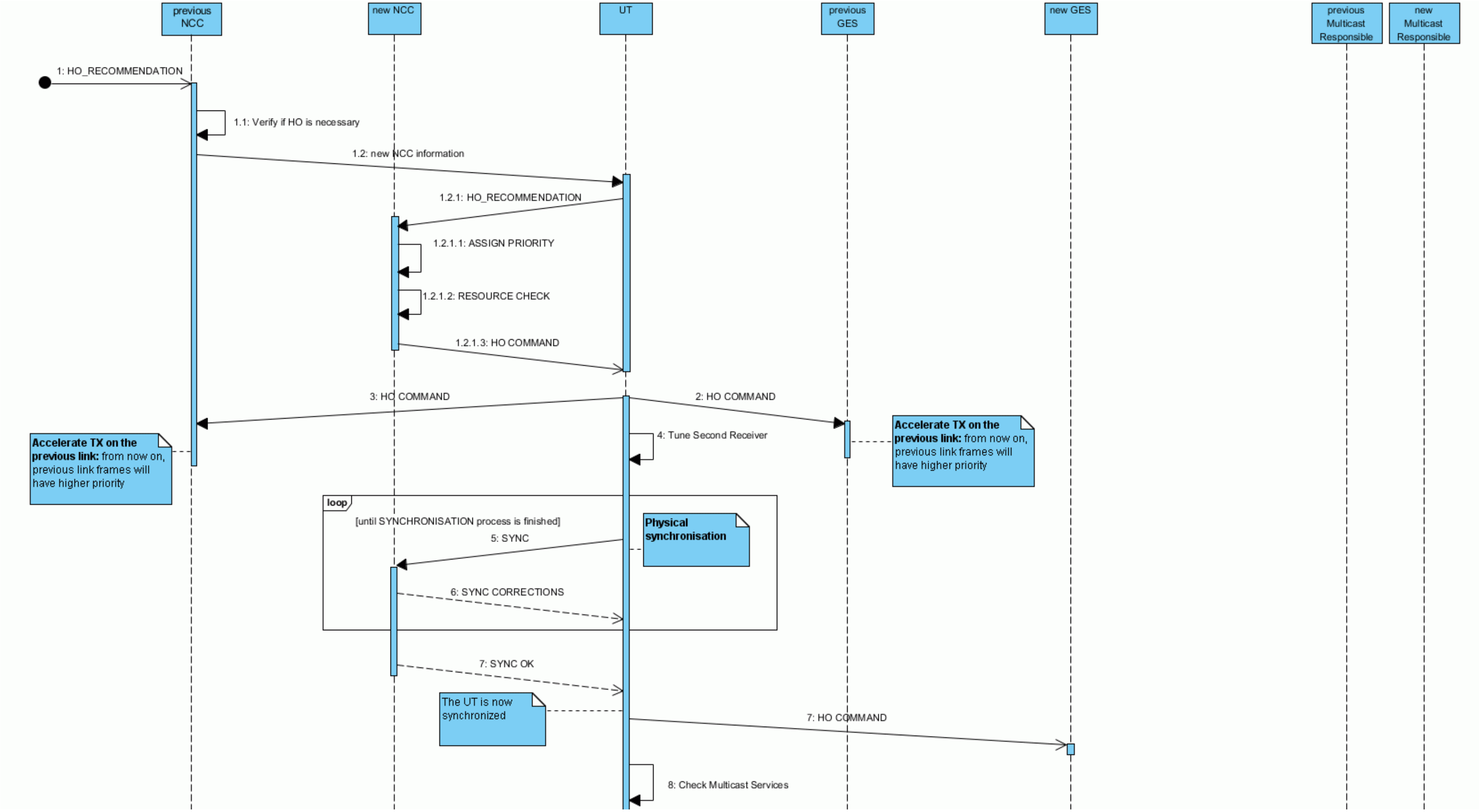
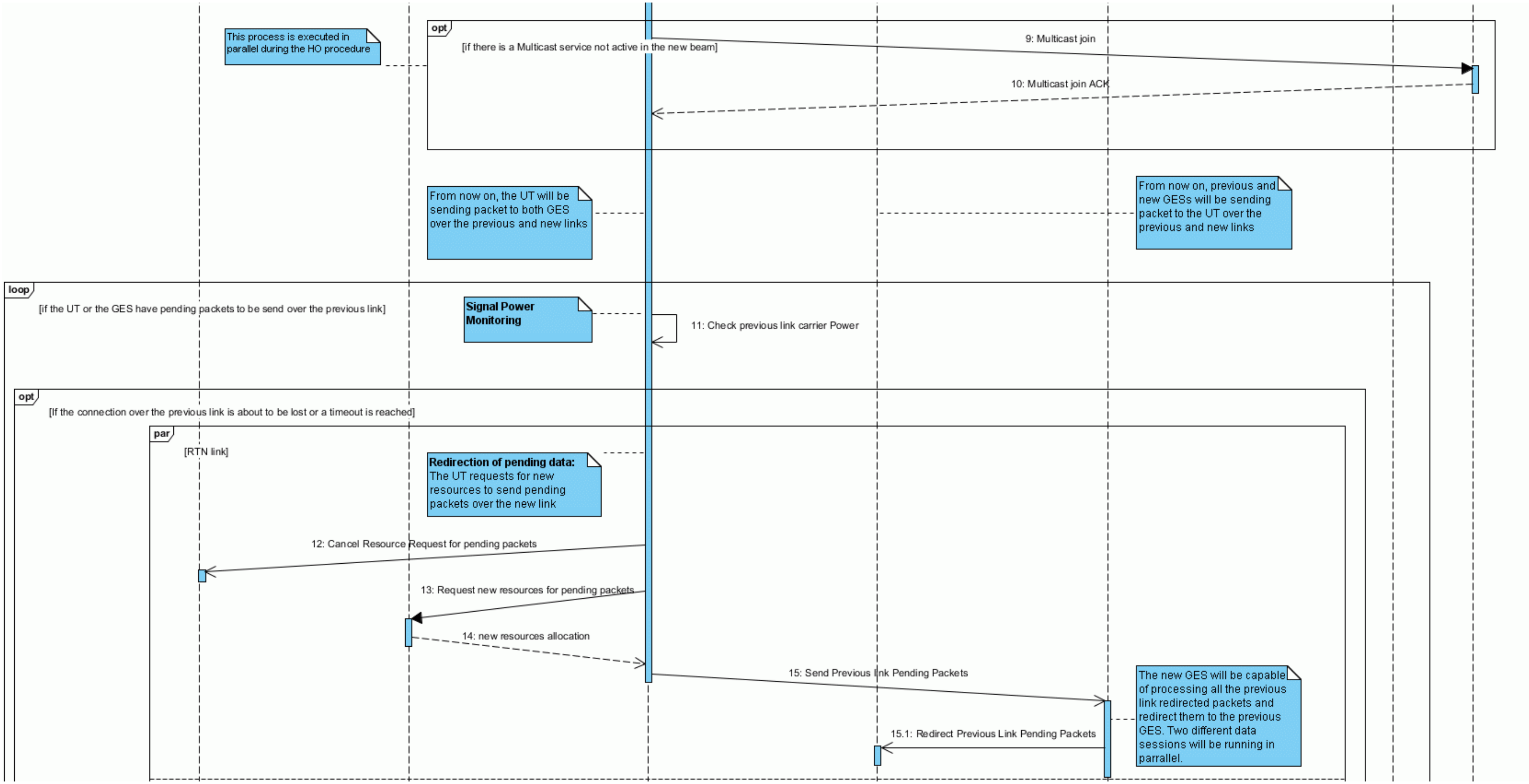
# 18. ANNEX F: INDIVIDUAL HO PROCEDURE SEQUENCE DIAGRAMS

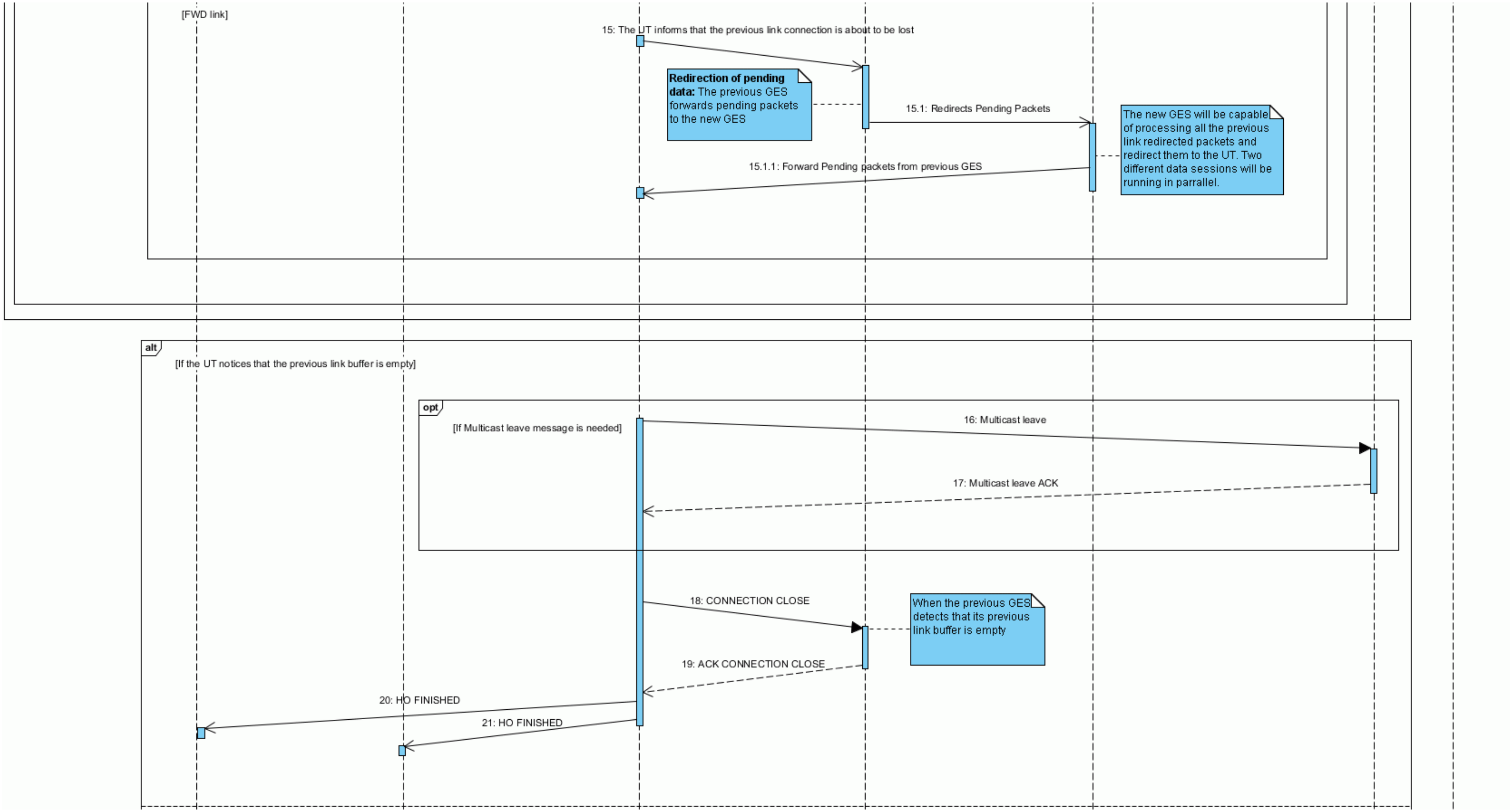
**(To be revised in B2**

See note at section 9.2.2. In this section, the sequence diagram for nominal conditions of each type of HO procedure is shown.

## 18.1 Satellite change, same LAN




This process is executed in parallel during the HO procedure
opt
[if there is a Multicast service not active in the new beam]
9: Multicast join
10: Multicast join ACK
From now on, the UT will be sending packet to both GES over the previous and new links
From now on, previous and new GESs will be sending packet to the UT over the previous and new links
loop
[if the UT or the GES have pending packets to be send over the previous link]
Signal Power Monitoring
11: Check previous link carrier Power
opt
[If the connection over the previous link is about to be lost or a timeout is reached]
par
[RTN link]
Redirection of pending data: The UT requests for new resources to send pending packets over the new link
12: Cancel Resource Request for pending packets
13: Request new resources for pending packets
14: new resources allocation
15: Send Previous link Pending Packets
15.1: Redirect Previous Link Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the previous GES. Two different data sessions will be running in parrallel.


[FWD link]
15: The UT informs that the previous link connection is about to be lost
Redirection of pending data: The previous GES forwards pending packets to the new GES
15.1: Redirects Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the UT. Two different data sessions will be running in parralel.
15.1.1: Forward Pending packets from previous GES
alt
[If the UT notices that the previous link buffer is empty]
opt
[If Multicast leave message is needed]
16: Multicast leave
17: Multicast leave ACK
18: CONNECTION CLOSE
When the previous GES detects that its previous link buffer is empty
19: ACK CONNECTION CLOSE
20: HO FINISHED
21: HO FINISHED

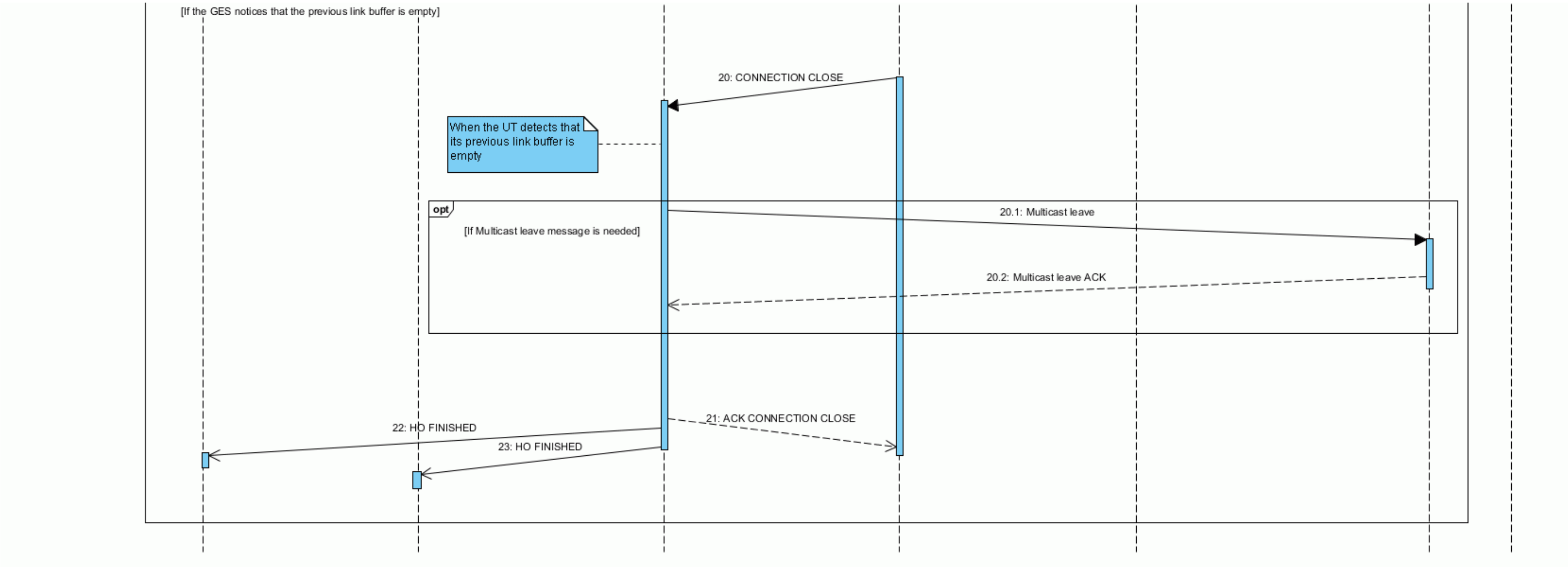
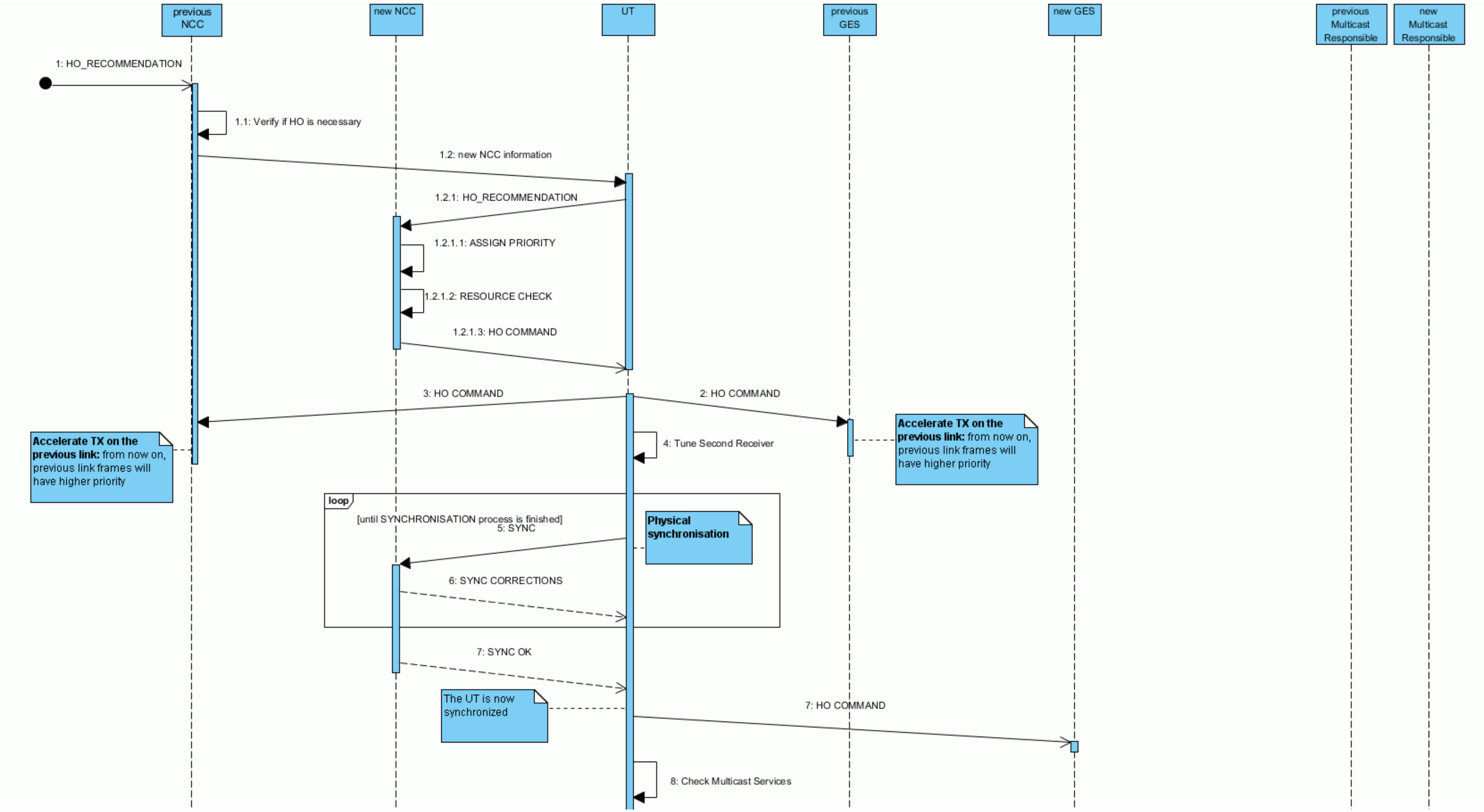
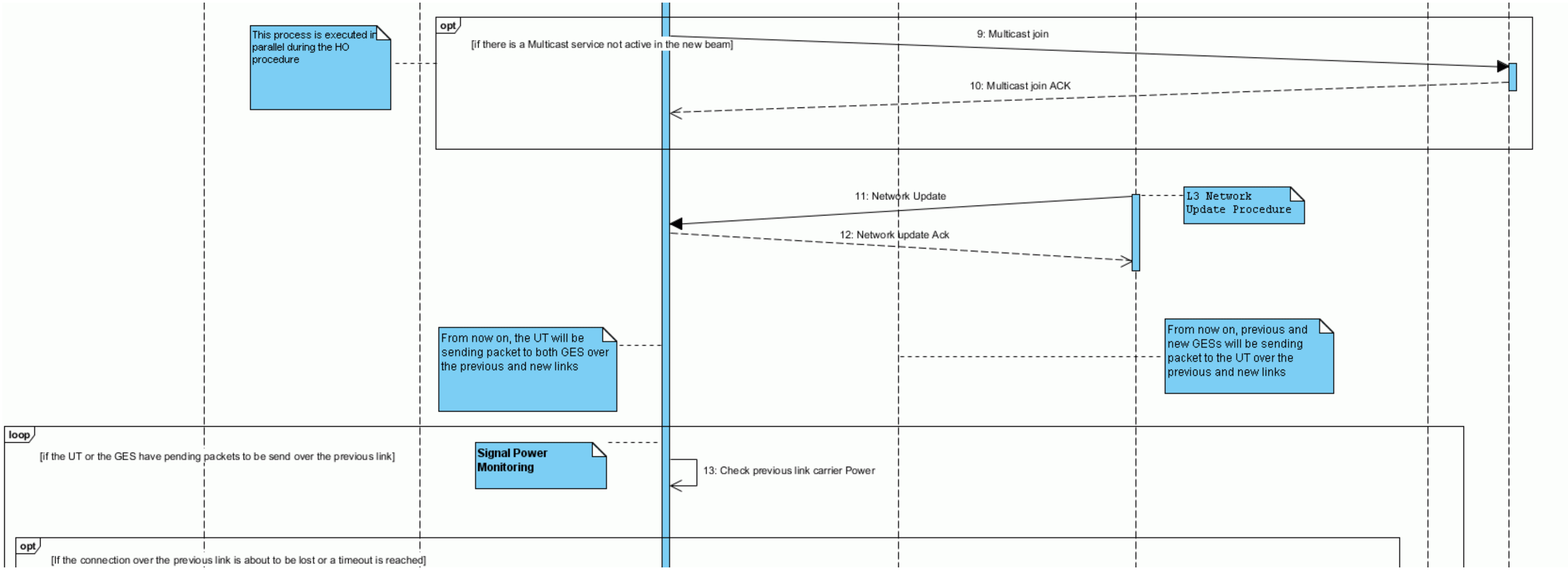
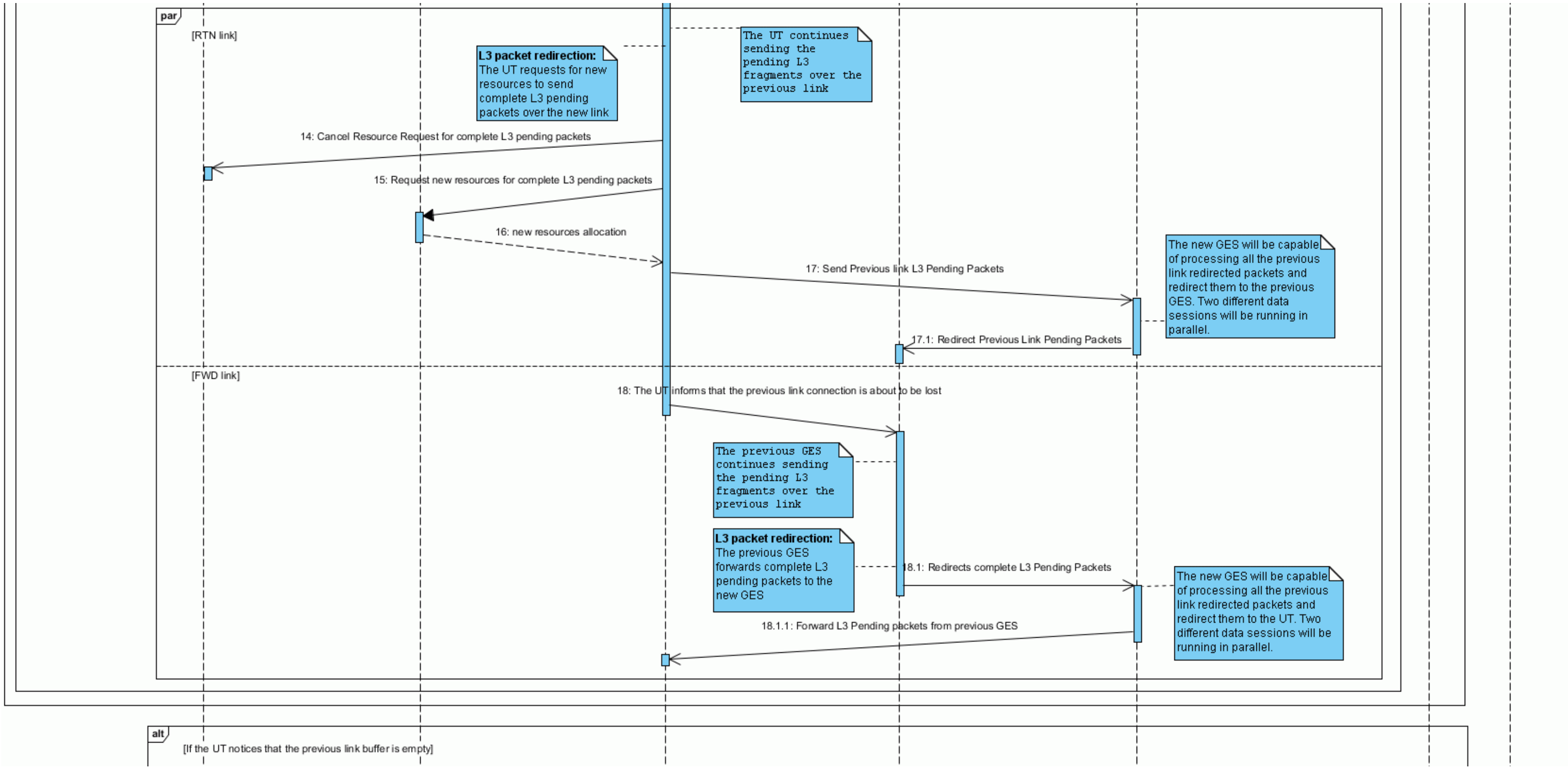



**Figure 18-1: Satellite change with previous & new GES connected to the same LAN**

## 18.2 Satellite change, different LAN




This process is executed in parallel during the HO procedure
opt
[if there is a Multicast service not active in the new beam]
9: Multicast join
10: Multicast join ACK
11: Network Update
L3 Network Update Procedure
12: Network update Ack
From now on, the UT will be sending packet to both GES over the previous and new links
From now on, previous and new GESs will be sending packet to the UT over the previous and new links
loop
[if the UT or the GES have pending packets to be send over the previous link]
Signal Power Monitoring
13: Check previous link carrier Power
opt
[If the connection over the previous link is about to be lost or a timeout is reached]


par
[RTN link]
L3 packet redirection: The UT requests for new resources to send complete L3 pending packets over the new link
The UT continues sending the pending L3 fragments over the previous link
14: Cancel Resource Request for complete L3 pending packets
15: Request new resources for complete L3 pending packets
16: new resources allocation
17: Send Previous link L3 Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the previous GES. Two different data sessions will be running in parallel.
17.1: Redirect Previous Link Pending Packets
[FWD link]
18: The UT informs that the previous link connection is about to be lost
The previous GES continues sending the pending L3 fragments over the previous link
L3 packet redirection: The previous GES forwards complete L3 pending packets to the new GES
18.1: Redirects complete L3 Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the UT. Two different data sessions will be running in parallel.
18.1.1: Forward L3 Pending packets from previous GES
alt
[If the UT notices that the previous link buffer is empty]

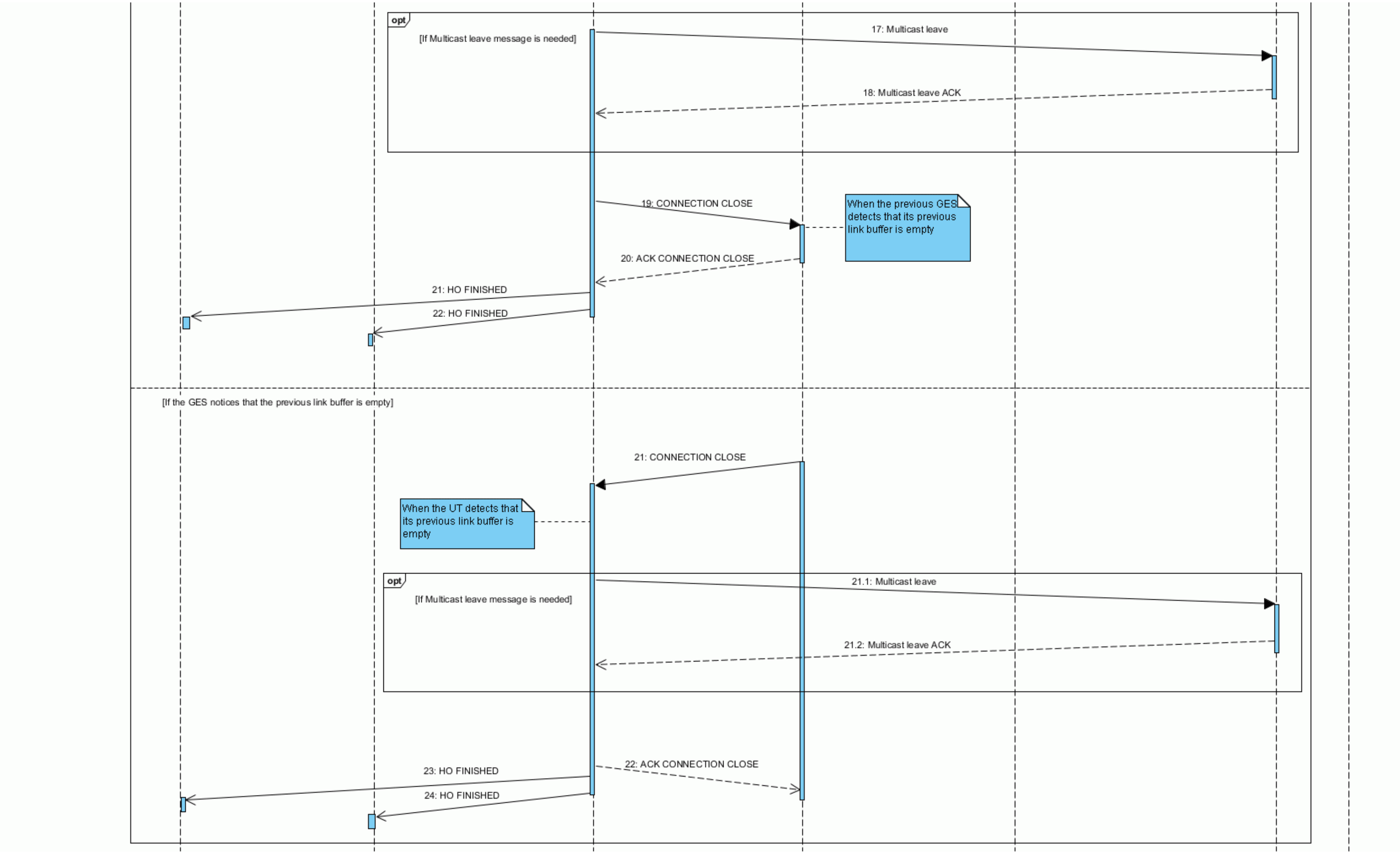
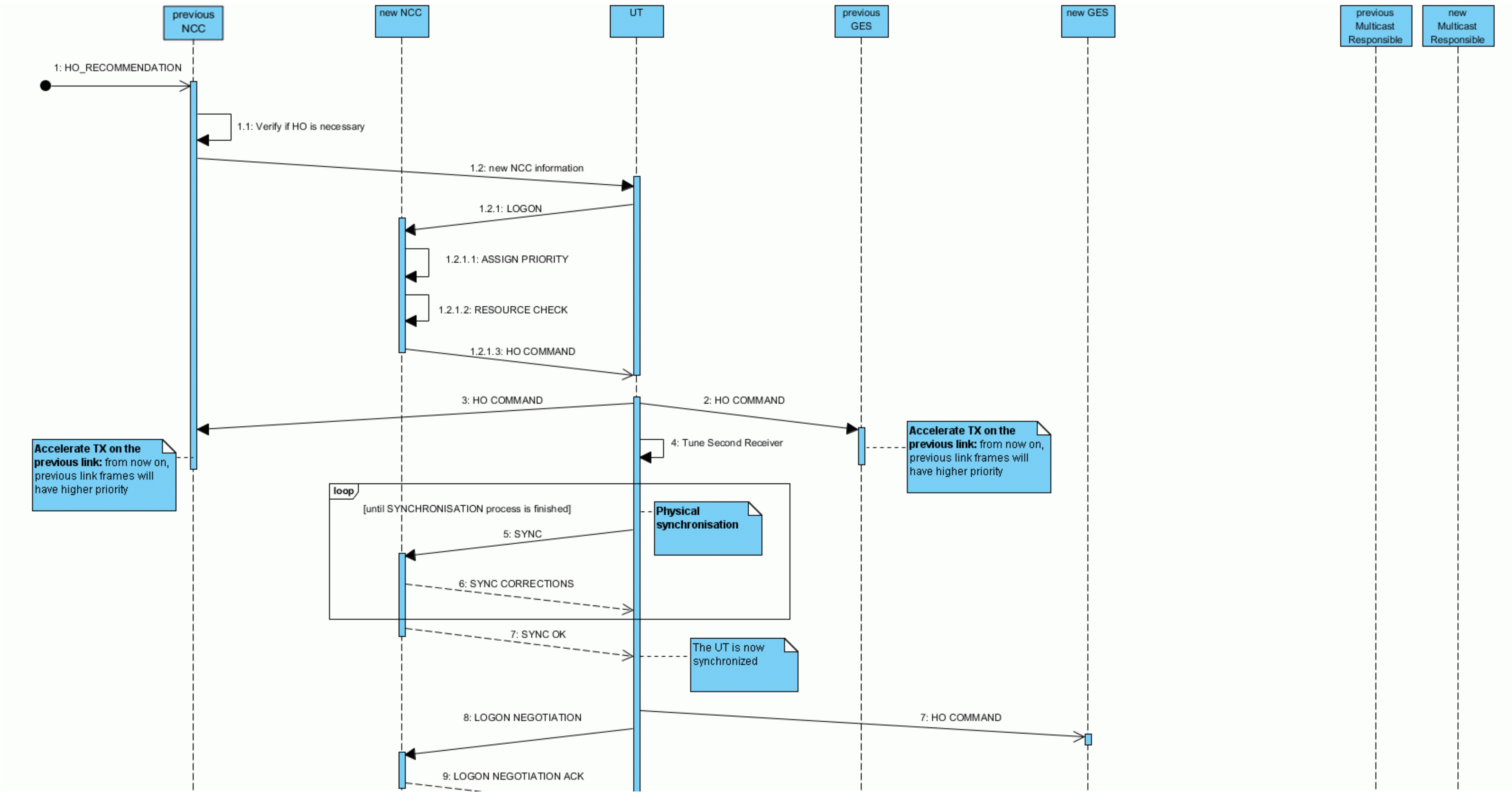
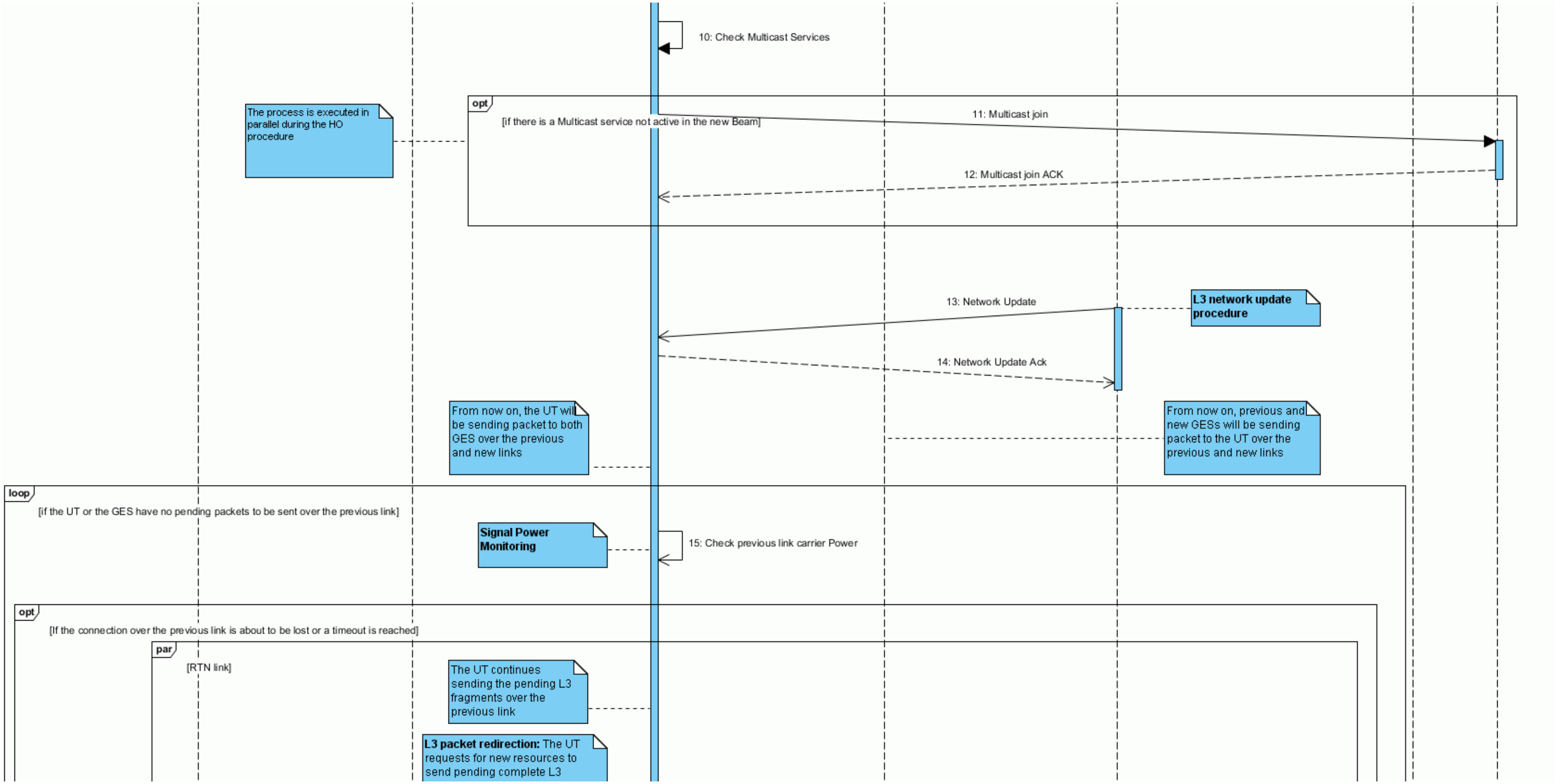


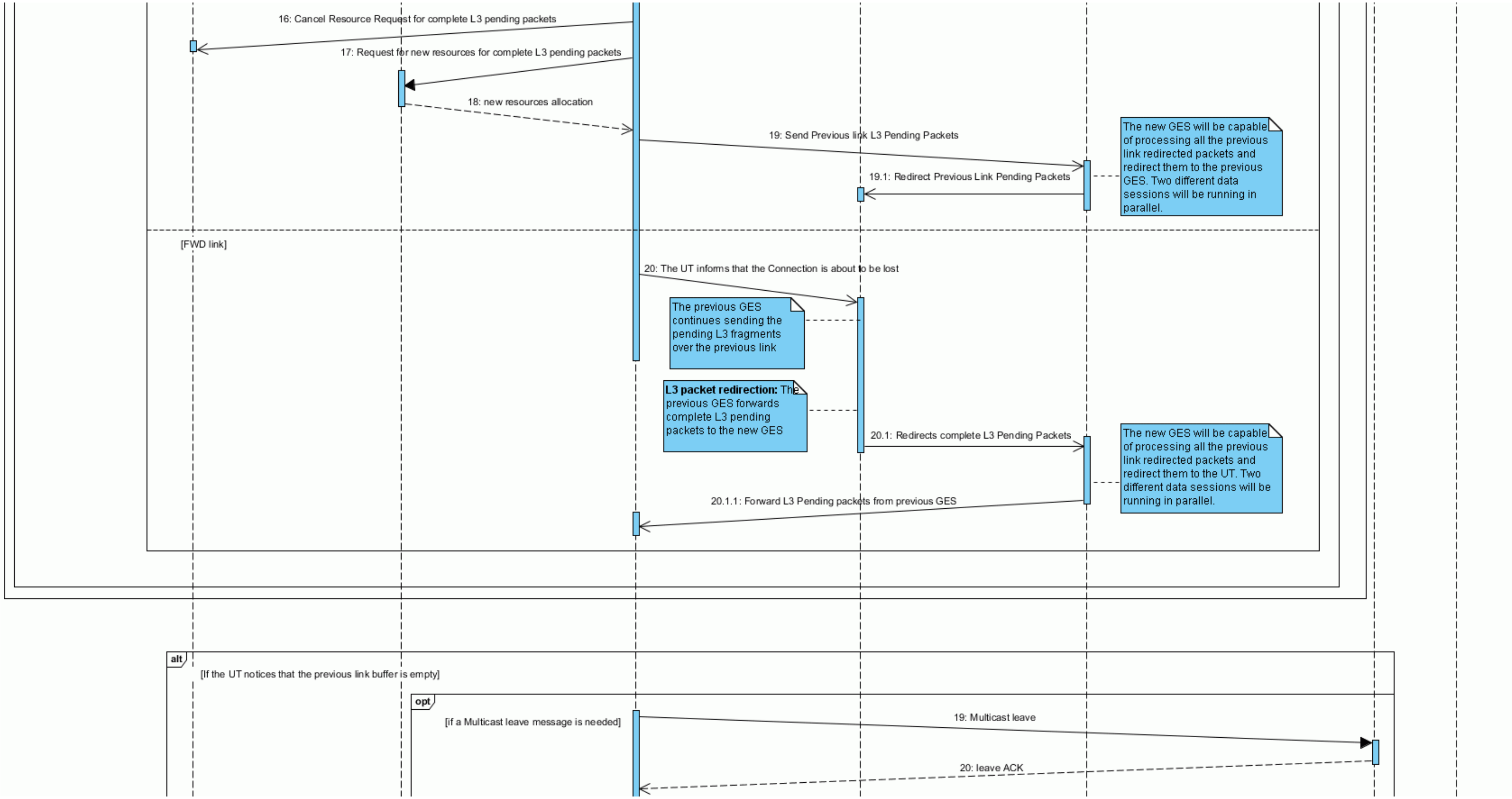

**Figure 18-2: Satellite change with previous & new GES connected to different LANs**

Note: The L3 network update procedure of this diagram and subsequent ones is a logical representation of the L3 HO procedures for ATN/OSI and ATN/IPS described in Annex XIV of D021.

## 18.3 SSP change




10: Check Multicast Services
opt
[if there is a Multicast service not active in the new Beam]
The process is executed in parallel during the HO procedure
11: Multicast join
12: Multicast join ACK
13: Network Update
L3 network update procedure
14: Network Update Ack
From now on, the UT will be sending packet to both GES over the previous and new links
From now on, previous and new GESs will be sending packet to the UT over the previous and new links
loop
[if the UT or the GES have no pending packets to be sent over the previous link]
Signal Power Monitoring
15: Check previous link carrier Power
opt
[If the connection over the previous link is about to be lost or a timeout is reached]
par
[RTN link]
The UT continues sending the pending L3 fragments over the previous link
L3 packet redirection: The UT requests for new resources to send pending complete L3


16: Cancel Resource Request for complete L3 pending packets
17: Request for new resources for complete L3 pending packets
18: new resources allocation
19: Send Previous link L3 Pending Packets
19.1: Redirect Previous Link Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the previous GES. Two different data sessions will be running in parallel.
[FWD link]
20: The UT informs that the Connection is about to be lost
The previous GES continues sending the pending L3 fragments over the previous link
L3 packet redirection: The previous GES forwards complete L3 pending packets to the new GES
20.1: Redirects complete L3 Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the UT. Two different data sessions will be running in parallel.
20.1.1: Forward L3 Pending packets from previous GES
alt
[If the UT notices that the previous link buffer is empty]
opt
[if a Multicast leave message is needed]
19: Multicast leave
20: leave ACK

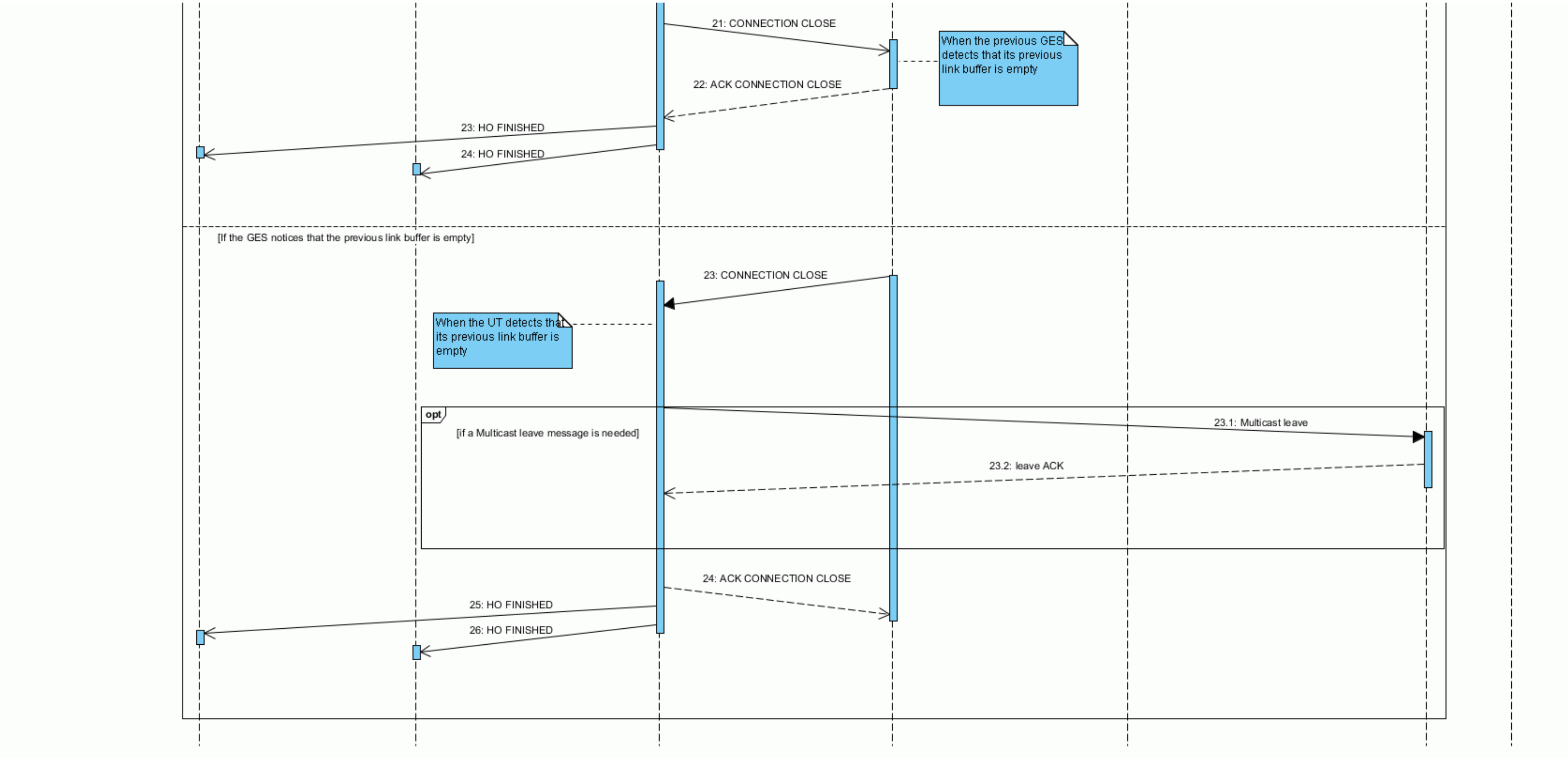
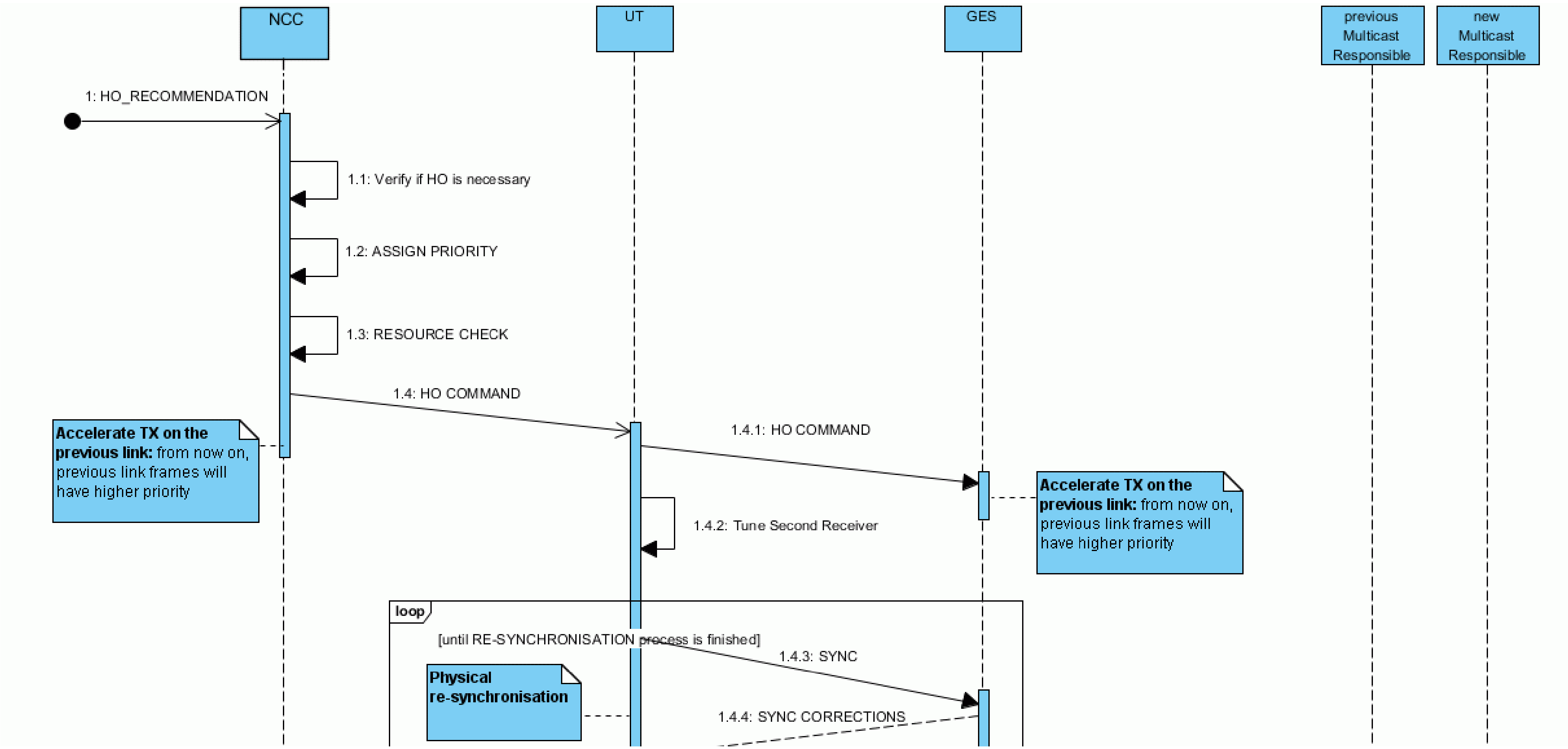
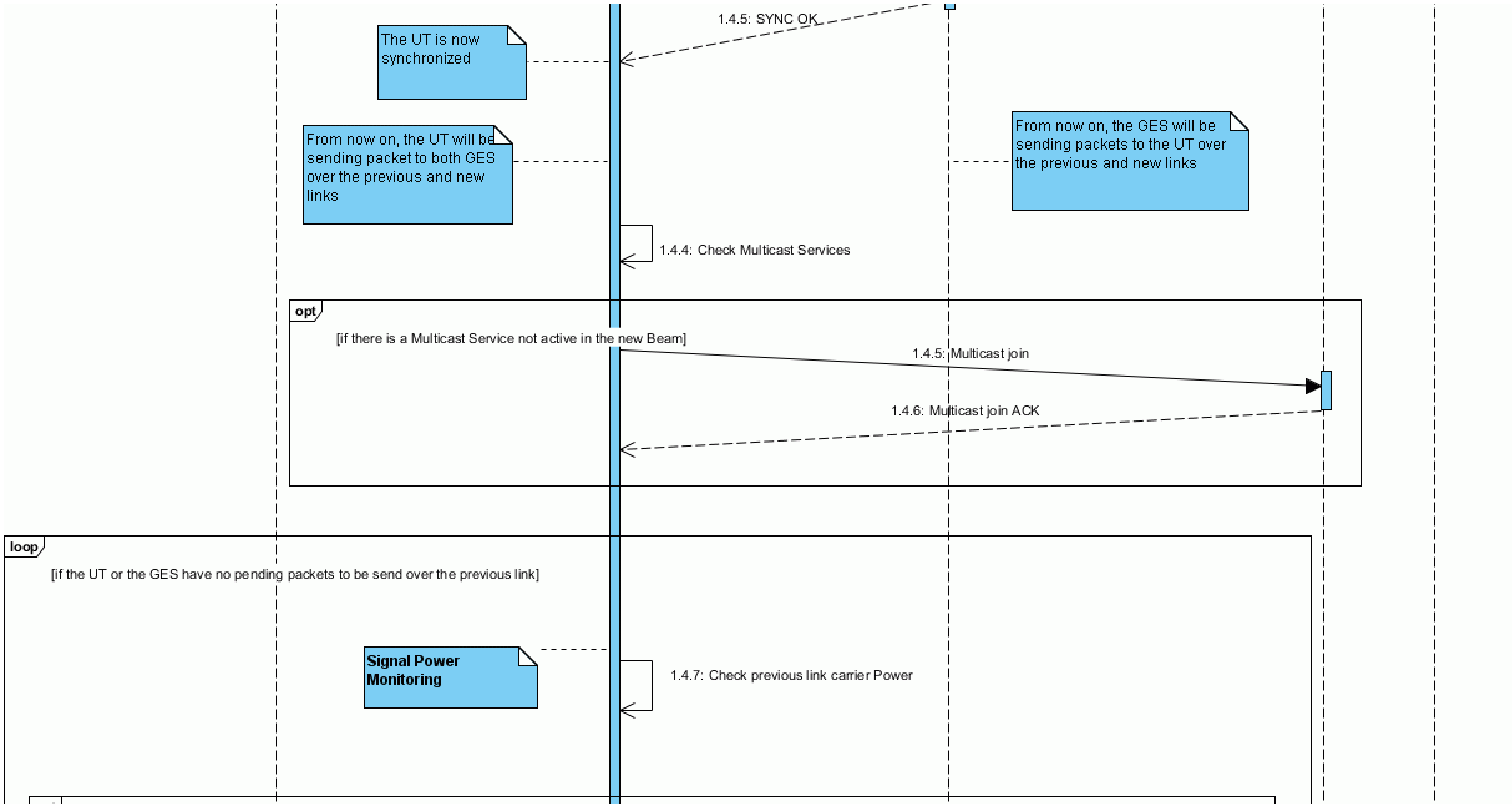
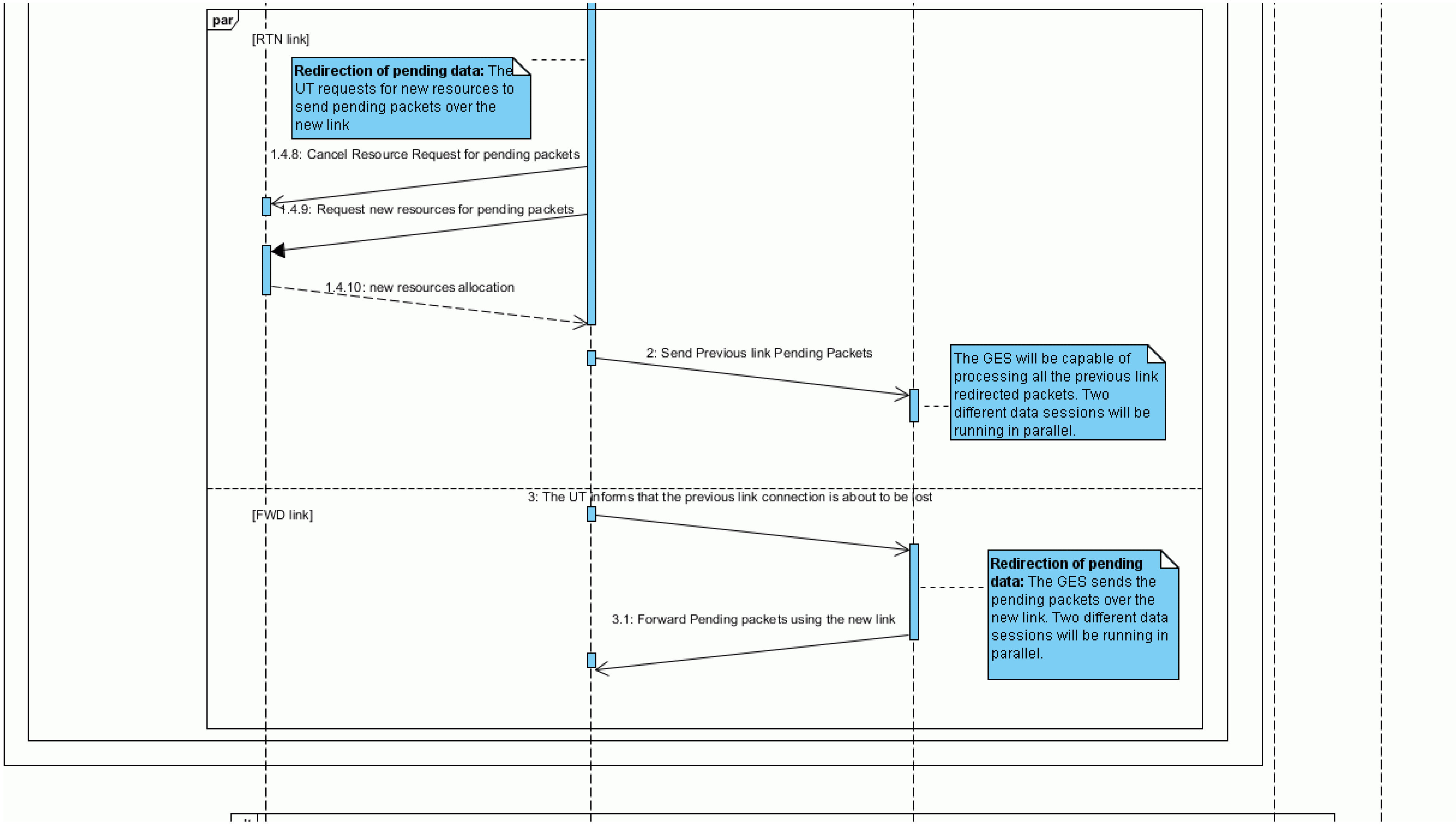


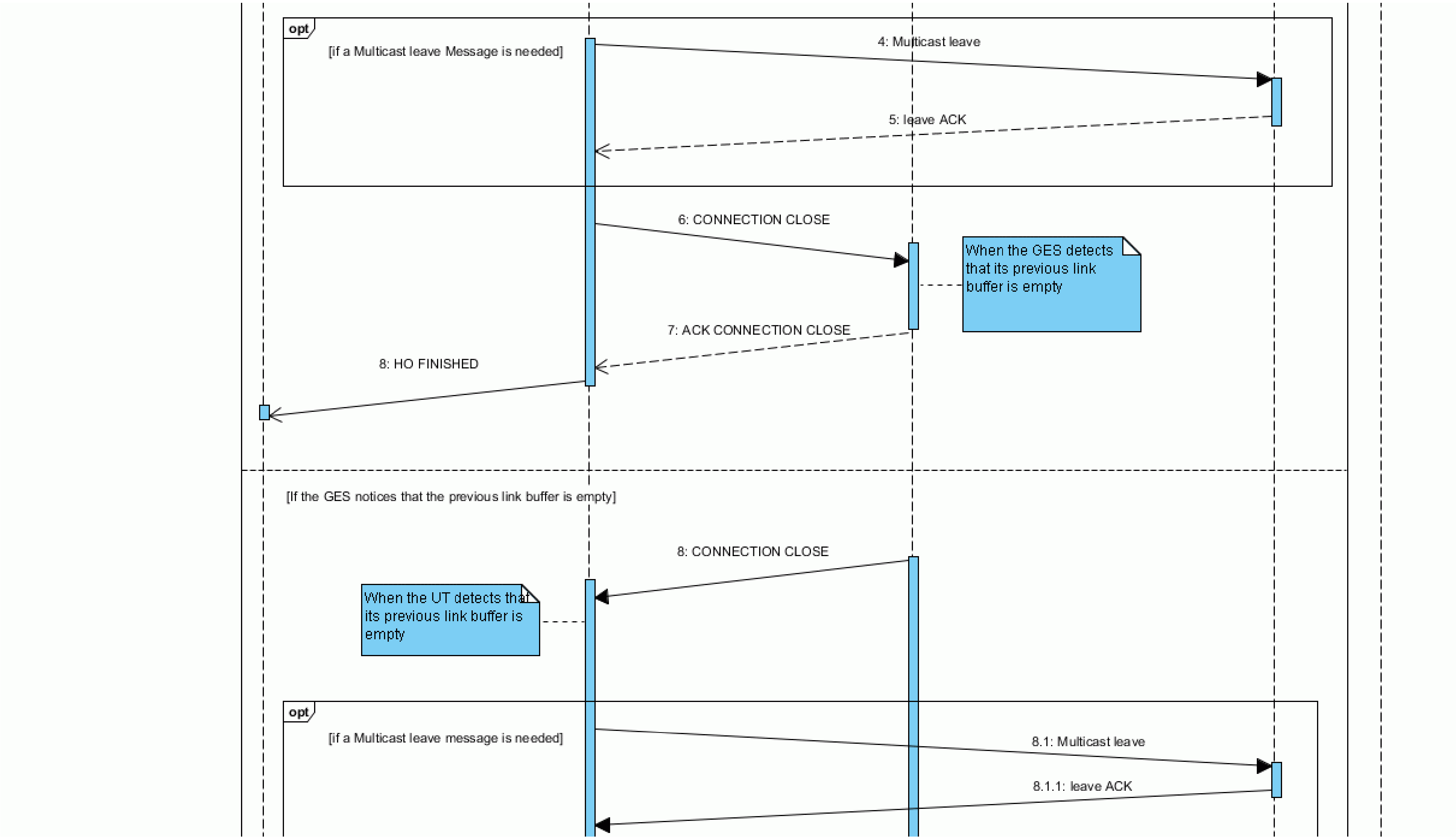

**Figure 18-3: SSP change. Previous & new GES connected to different LANs**

## 18.4 Beam change, same entity




1.4.5: SYNC OK
The UT is now synchronized
From now on, the UT will be sending packet to both GES over the previous and new links
From now on, the GES will be sending packets to the UT over the previous and new links
1.4.4: Check Multicast Services
opt
[if there is a Multicast Service not active in the new Beam]
1.4.5: Multicast join
1.4.6: Multicast join ACK
loop
[if the UT or the GES have no pending packets to be send over the previous link]
Signal Power Monitoring
1.4.7: Check previous link carrier Power


par
[RTN link]
**Redirection of pending data:** The UT requests for new resources to send pending packets over the new link
1.4.8: Cancel Resource Request for pending packets
1.4.9: Request new resources for pending packets
1.4.10: new resources allocation
2: Send Previous link Pending Packets
The GES will be capable of processing all the previous link redirected packets. Two different data sessions will be running in parallel.
3: The UT informs that the previous link connection is about to be lost
[FWD link]
**Redirection of pending data:** The GES sends the pending packets over the new link. Two different data sessions will be running in parallel.
3.1: Forward Pending packets using the new link


opt
[if a Multicast leave Message is needed]
4: Multicast leave
5: leave ACK
6: CONNECTION CLOSE
When the GES detects that its previous link buffer is empty
7: ACK CONNECTION CLOSE
8: HO FINISHED
[If the GES notices that the previous link buffer is empty]
8: CONNECTION CLOSE
When the UT detects that its previous link buffer is empty
opt
[if a Multicast leave message is needed]
8.1: Multicast leave
8.1.1: leave ACK

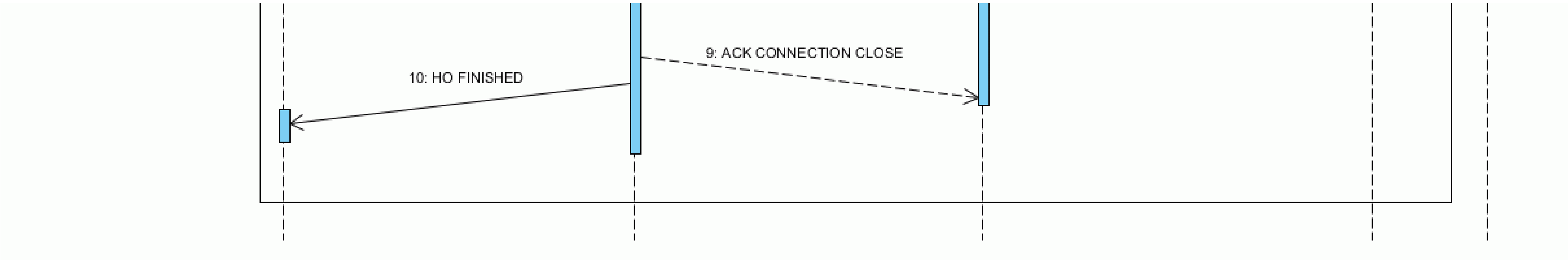
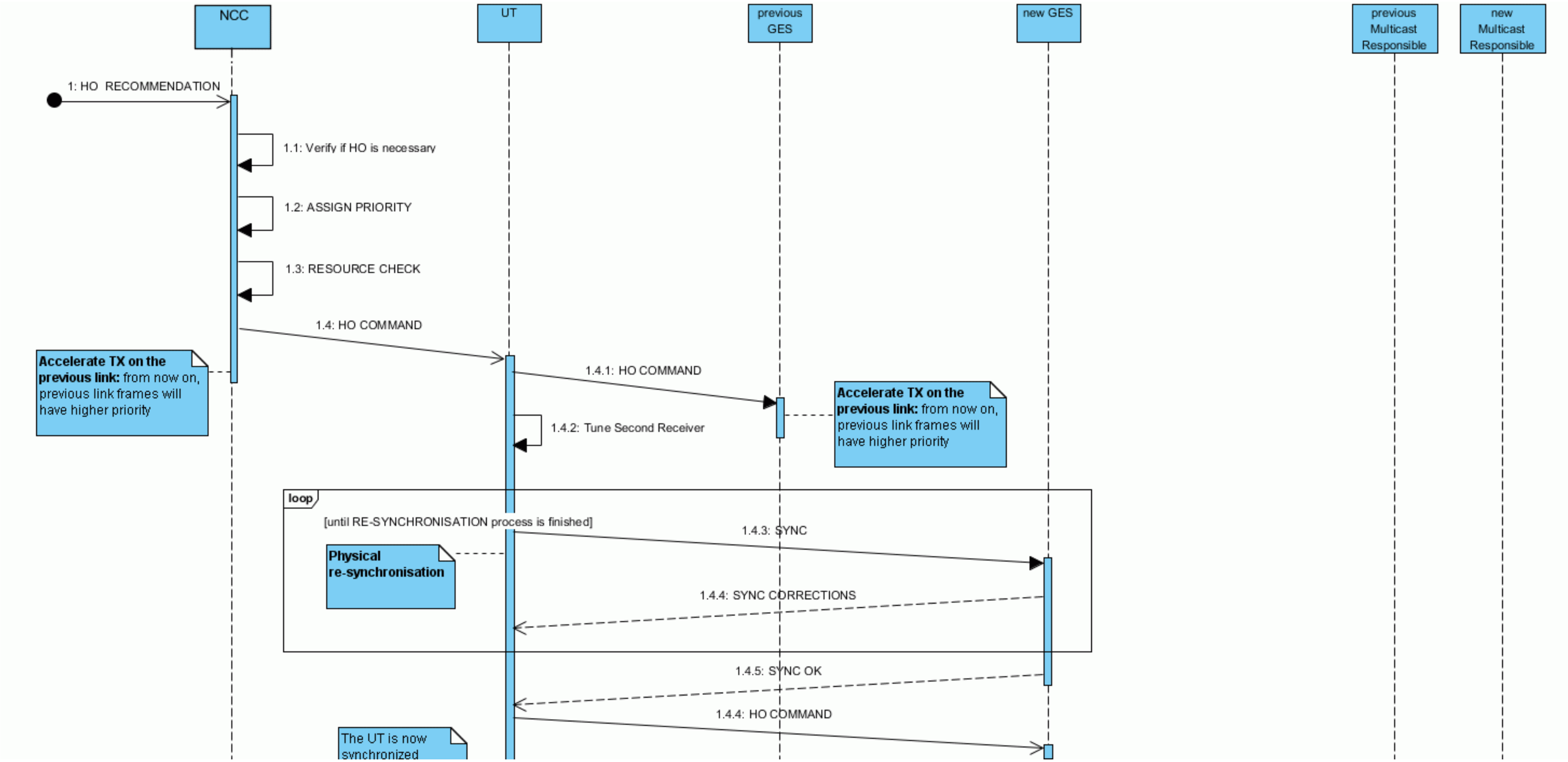
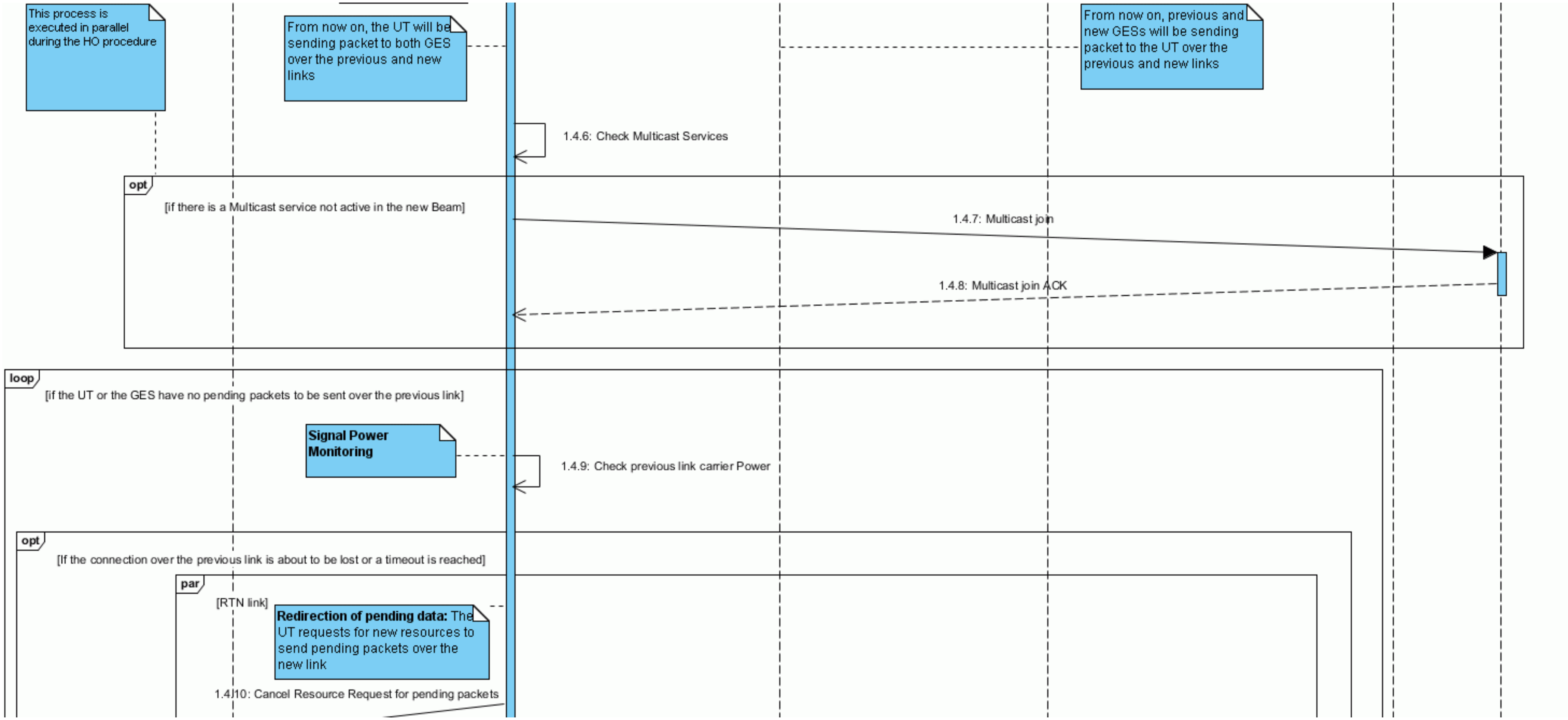
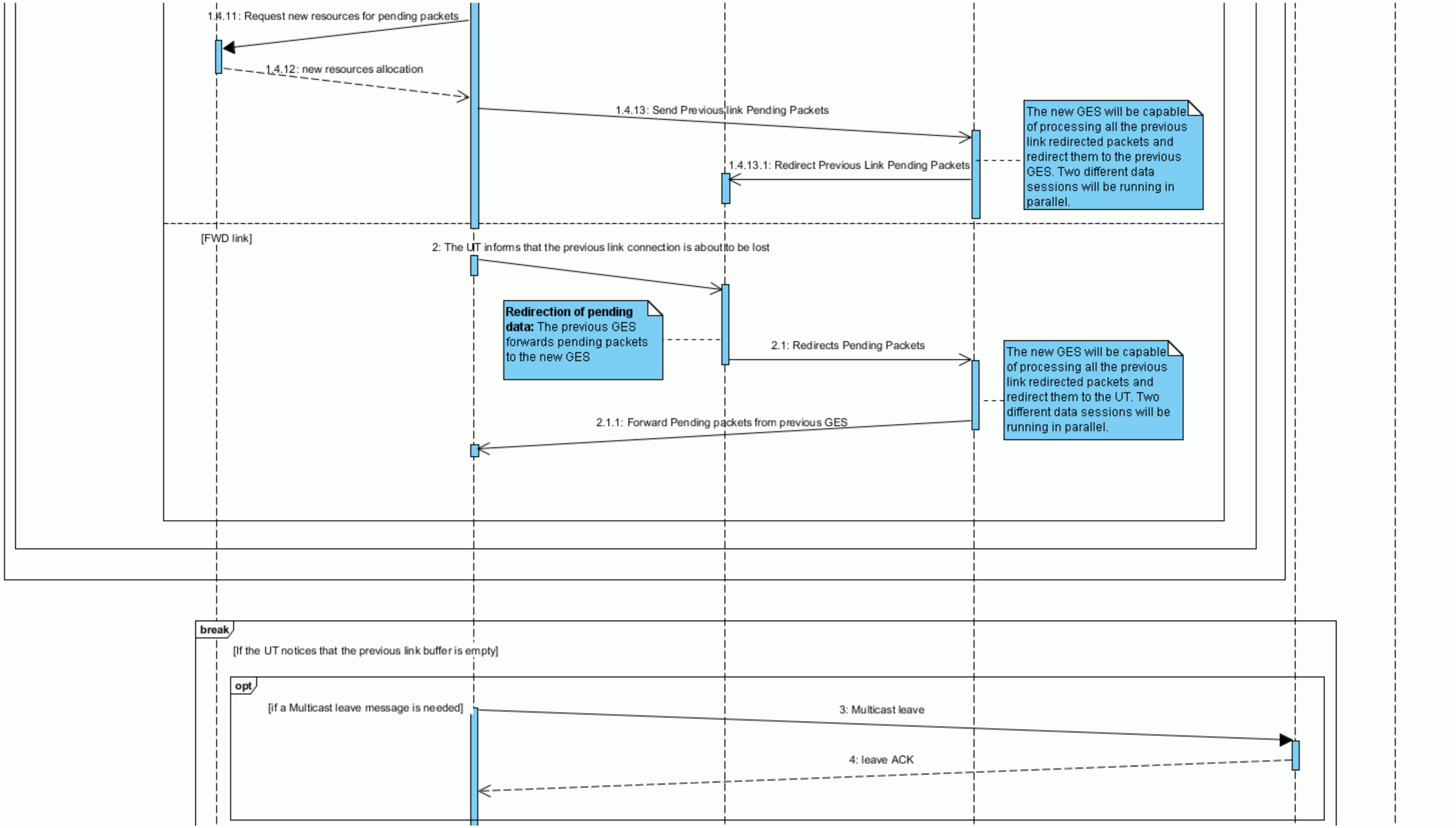



**Figure 18-4: Beam change in which previous GES and new GES are the same entity**

## 18.5 Beam change, same LAN




This process is executed in parallel during the HO procedure
From now on, the UT will be sending packet to both GES over the previous and new links
From now on, previous and new GESs will be sending packet to the UT over the previous and new links
1.4.6: Check Multicast Services
opt
[if there is a Multicast service not active in the new Beam]
1.4.7: Multicast join
1.4.8: Multicast join ACK
loop
[if the UT or the GES have no pending packets to be sent over the previous link]
Signal Power Monitoring
1.4.9: Check previous link carrier Power
opt
[If the connection over the previous link is about to be lost or a timeout is reached]
par
[RTN link]
Redirection of pending data: The UT requests for new resources to send pending packets over the new link
1.4.10: Cancel Resource Request for pending packets


1.4.11: Request new resources for pending packets
1.4.12: new resources allocation
1.4.13: Send Previous link Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the previous GES. Two different data sessions will be running in parallel.
1.4.13.1: Redirect Previous Link Pending Packets
[FWD link]
2: The UT informs that the previous link connection is about to be lost
**Redirection of pending data:** The previous GES forwards pending packets to the new GES
2.1: Redirects Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the UT. Two different data sessions will be running in parallel.
2.1.1: Forward Pending packets from previous GES
break
[If the UT notices that the previous link buffer is empty]
opt
[if a Multicast leave message is needed]
3: Multicast leave
4: leave ACK

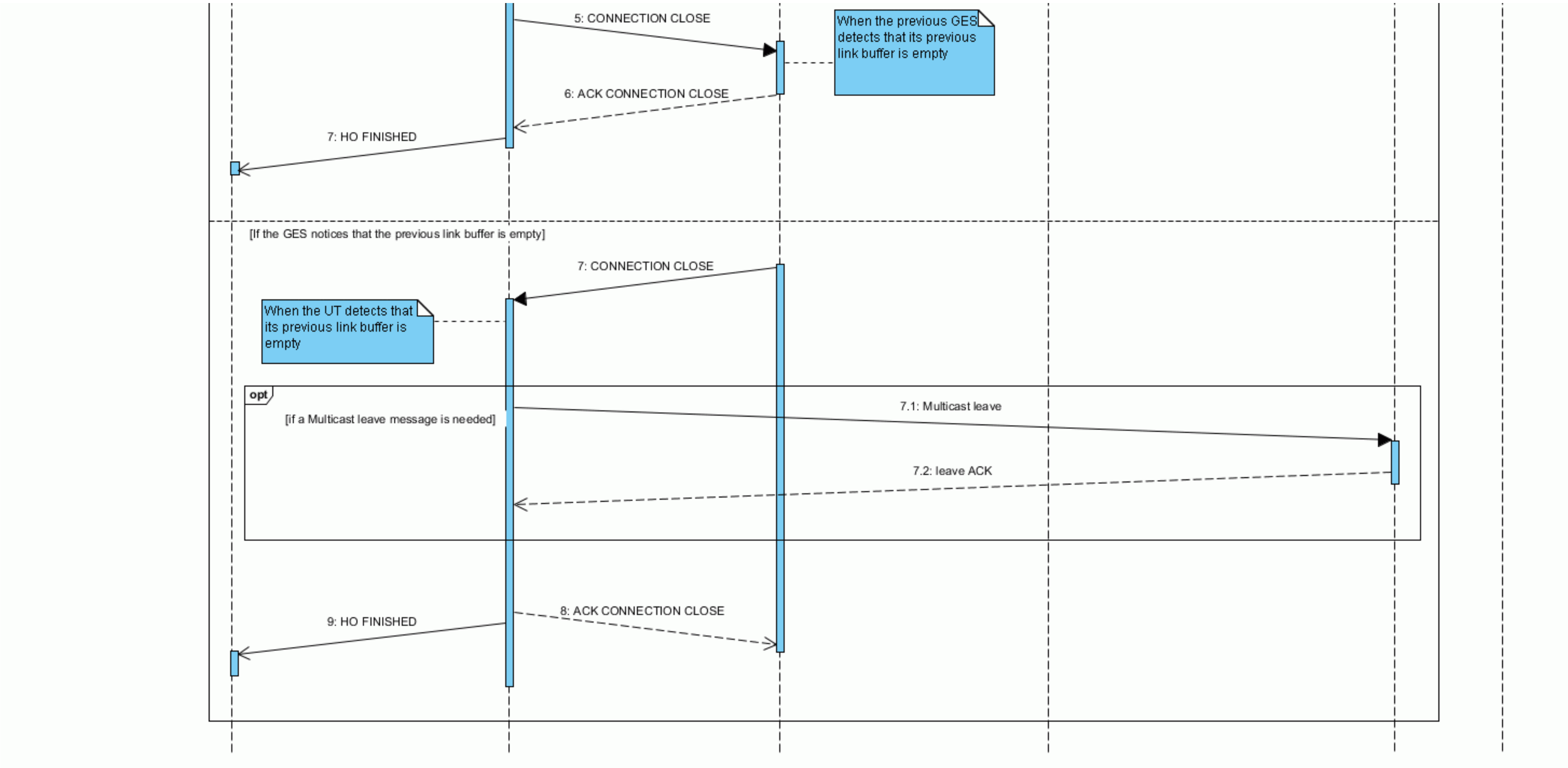
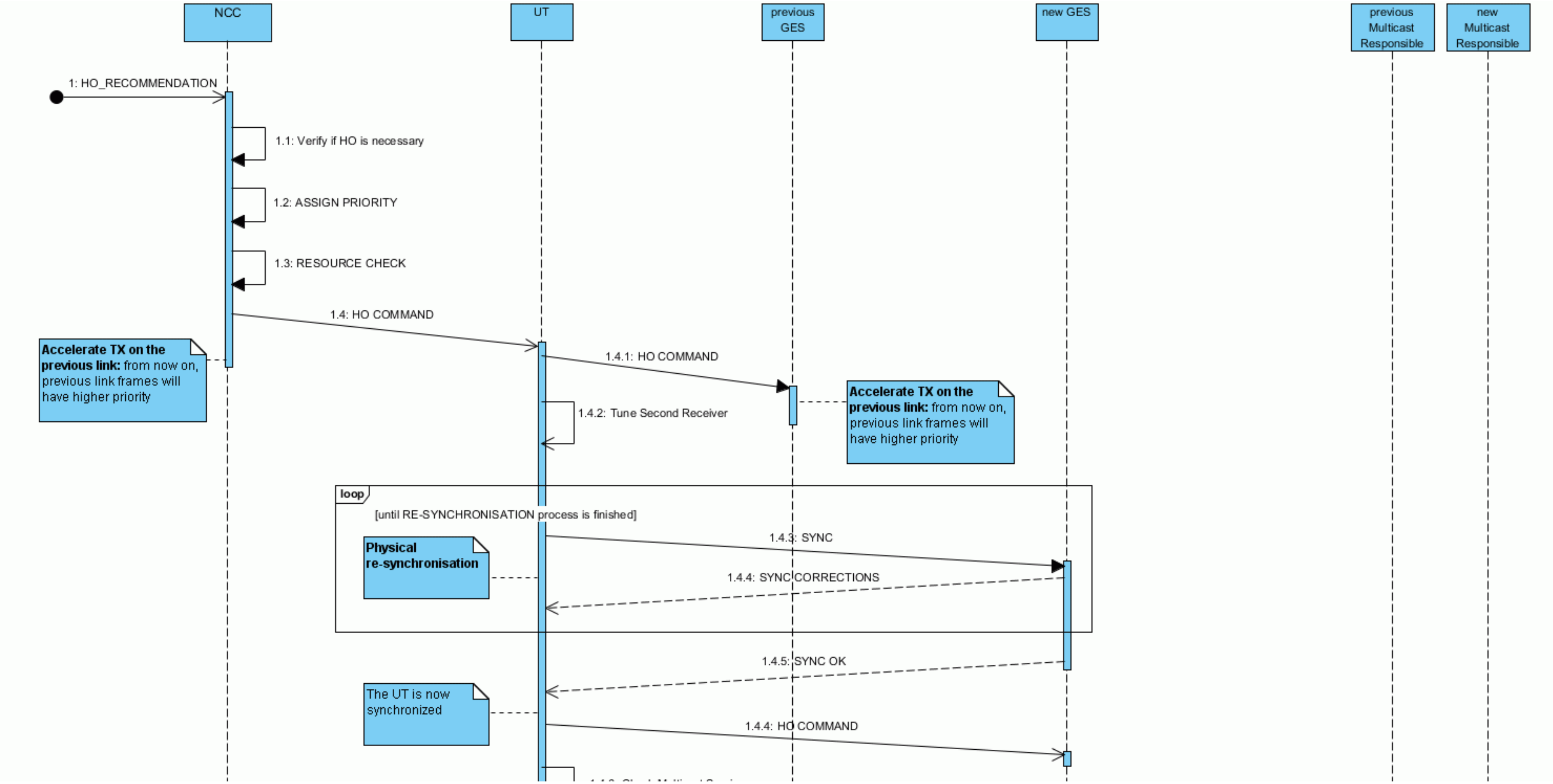
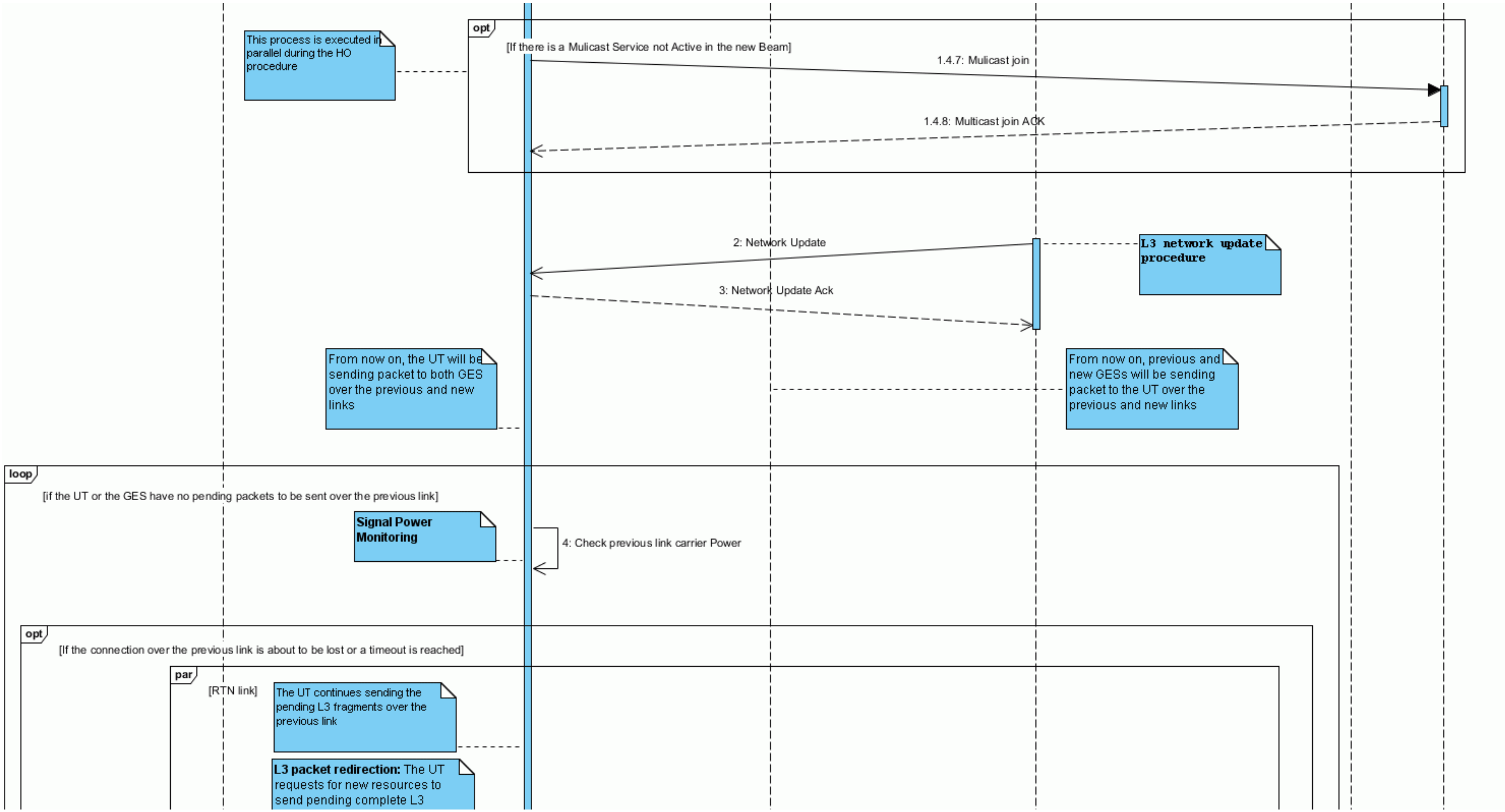
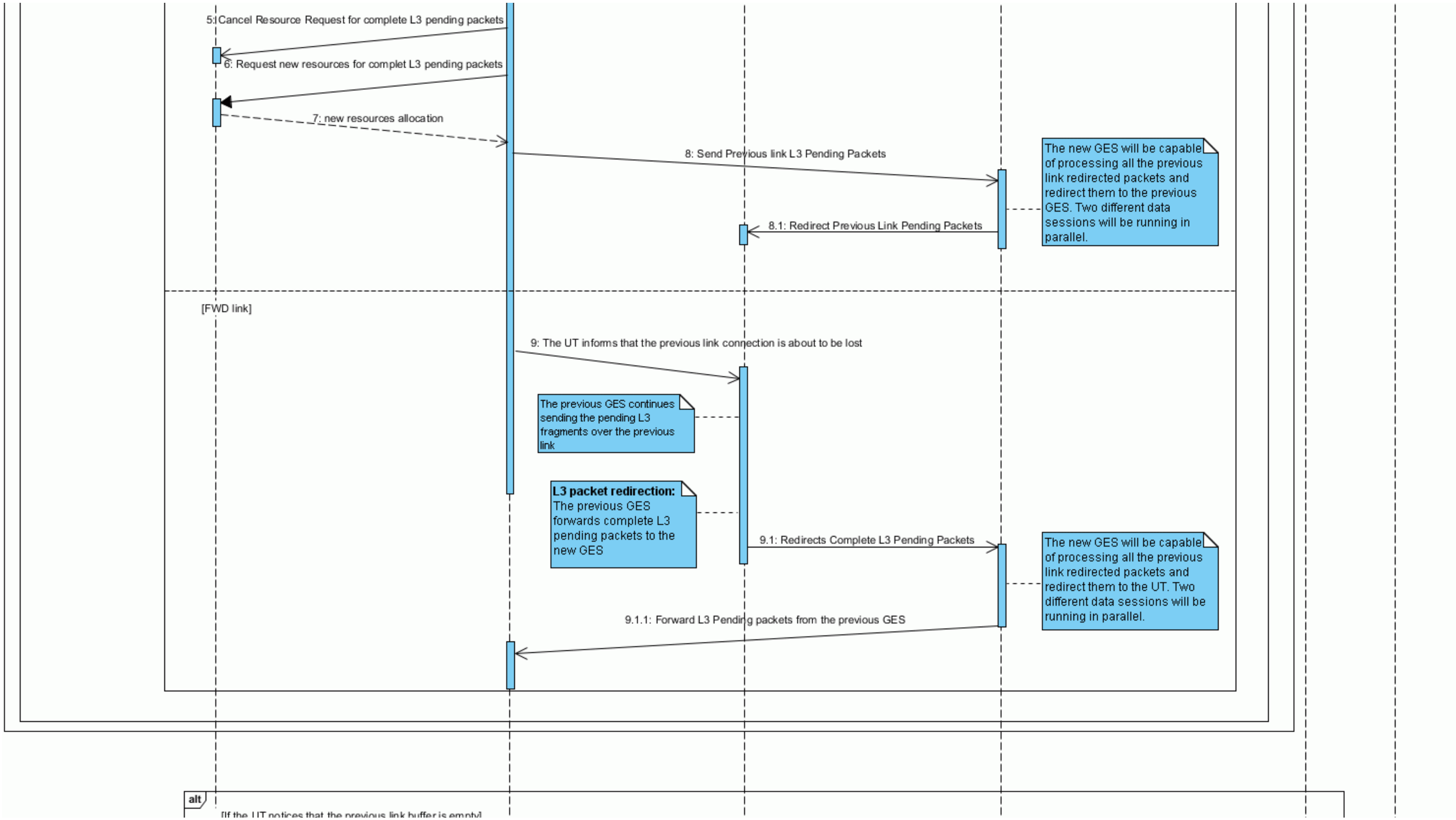



**Figure 18-5: Beam change with previous & new GES connected to the same LAN**

## 18.6 Beam change, different LAN




opt
[If there is a Mulicast Service not Active in the new Beam]
This process is executed in parallel during the HO procedure
1.4.7: Mulicast join
1.4.8: Multicast join ACK
2: Network Update
3: Network Update Ack
L3 network update procedure
From now on, the UT will be sending packet to both GES over the previous and new links
From now on, previous and new GESs will be sending packet to the UT over the previous and new links
loop
[if the UT or the GES have no pending packets to be sent over the previous link]
Signal Power Monitoring
4: Check previous link carrier Power
opt
[If the connection over the previous link is about to be lost or a timeout is reached]
par
[RTN link]
The UT continues sending the pending L3 fragments over the previous link
L3 packet redirection: The UT requests for new resources to send pending complete L3


5: Cancel Resource Request for complete L3 pending packets
6: Request new resources for complet L3 pending packets
7: new resources allocation
8: Send Previous link L3 Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the previous GES. Two different data sessions will be running in parallel.
8.1: Redirect Previous Link Pending Packets
[FWD link]
9: The UT informs that the previous link connection is about to be lost
The previous GES continues sending the pending L3 fragments over the previous link
L3 packet redirection:
The previous GES forwards complete L3 pending packets to the new GES
9.1: Redirects Complete L3 Pending Packets
The new GES will be capable of processing all the previous link redirected packets and redirect them to the UT. Two different data sessions will be running in parallel.
9.1.1: Forward L3 Pending packets from the previous GES
alt

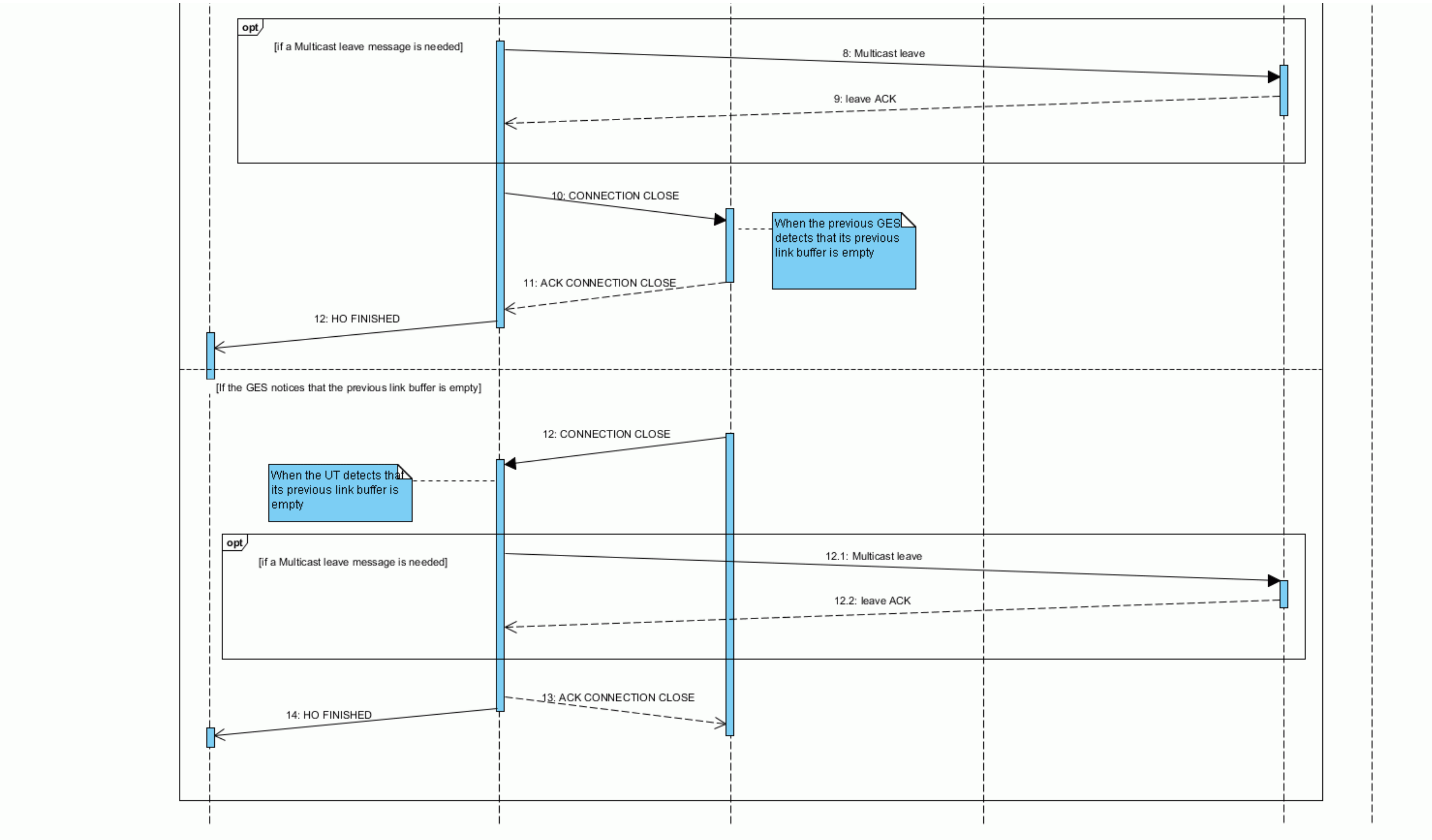
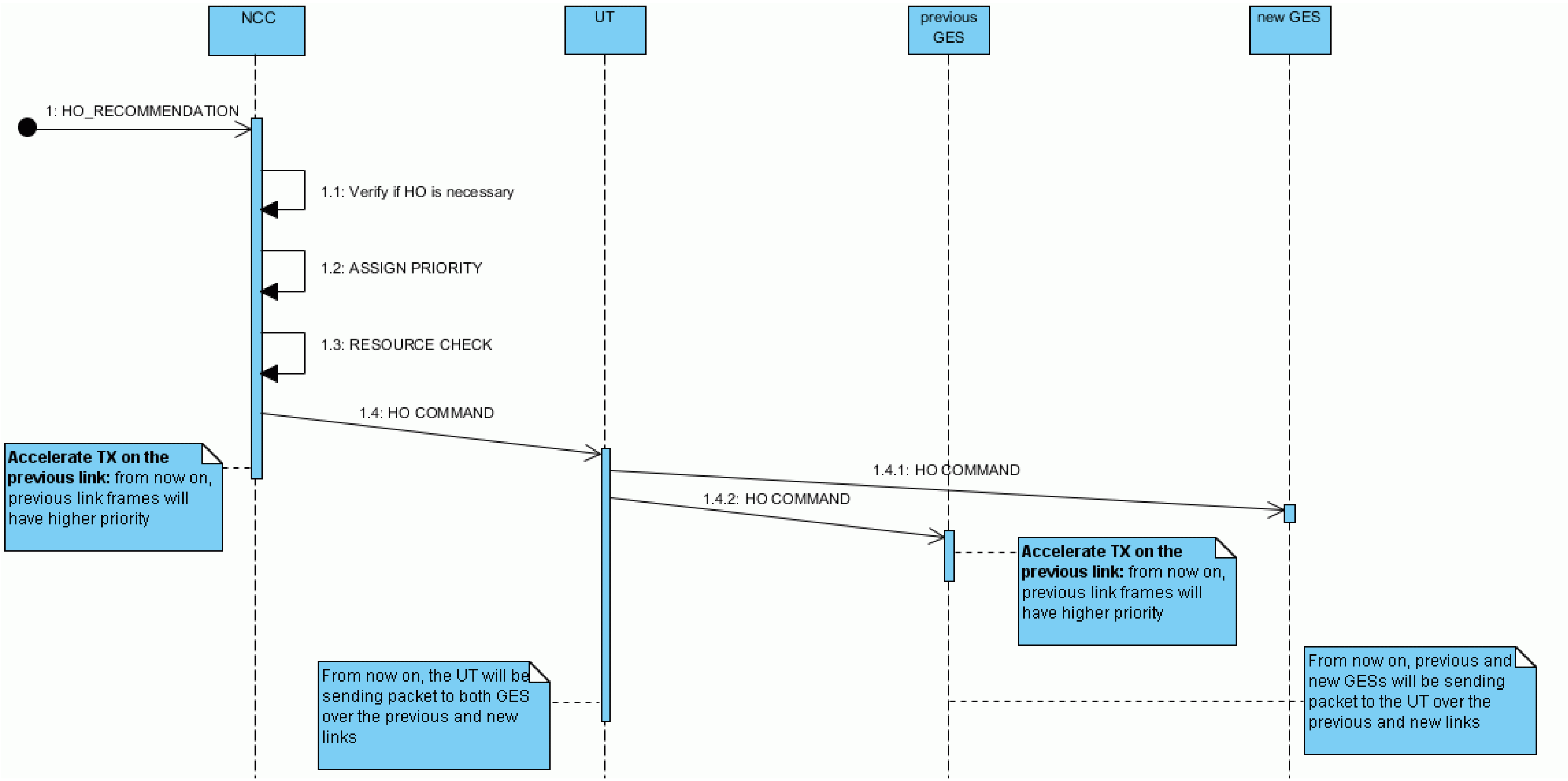



**Figure 18-6: Beam change with previous & new GES connected to different LANs**

## 18.7 GES change, same LAN



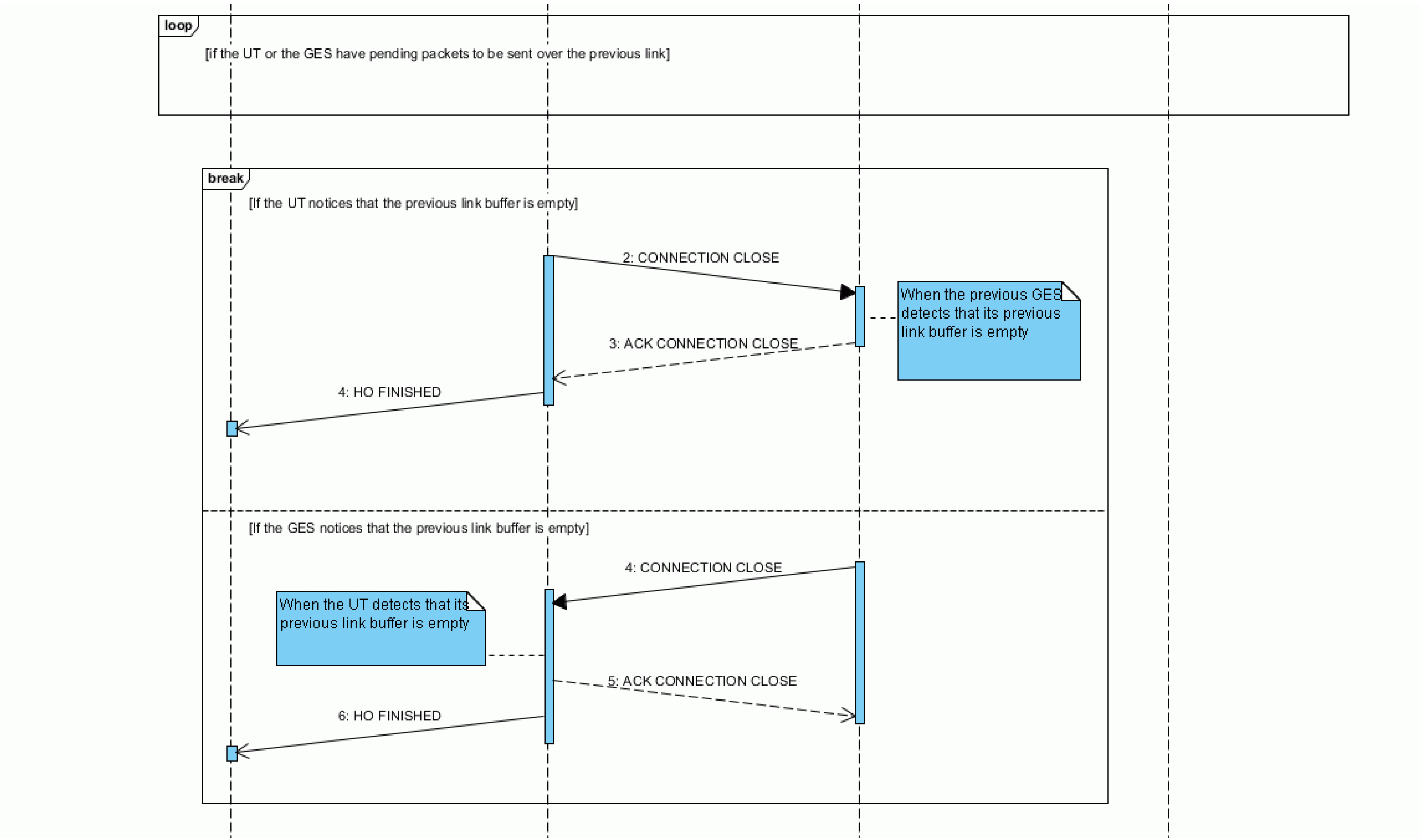
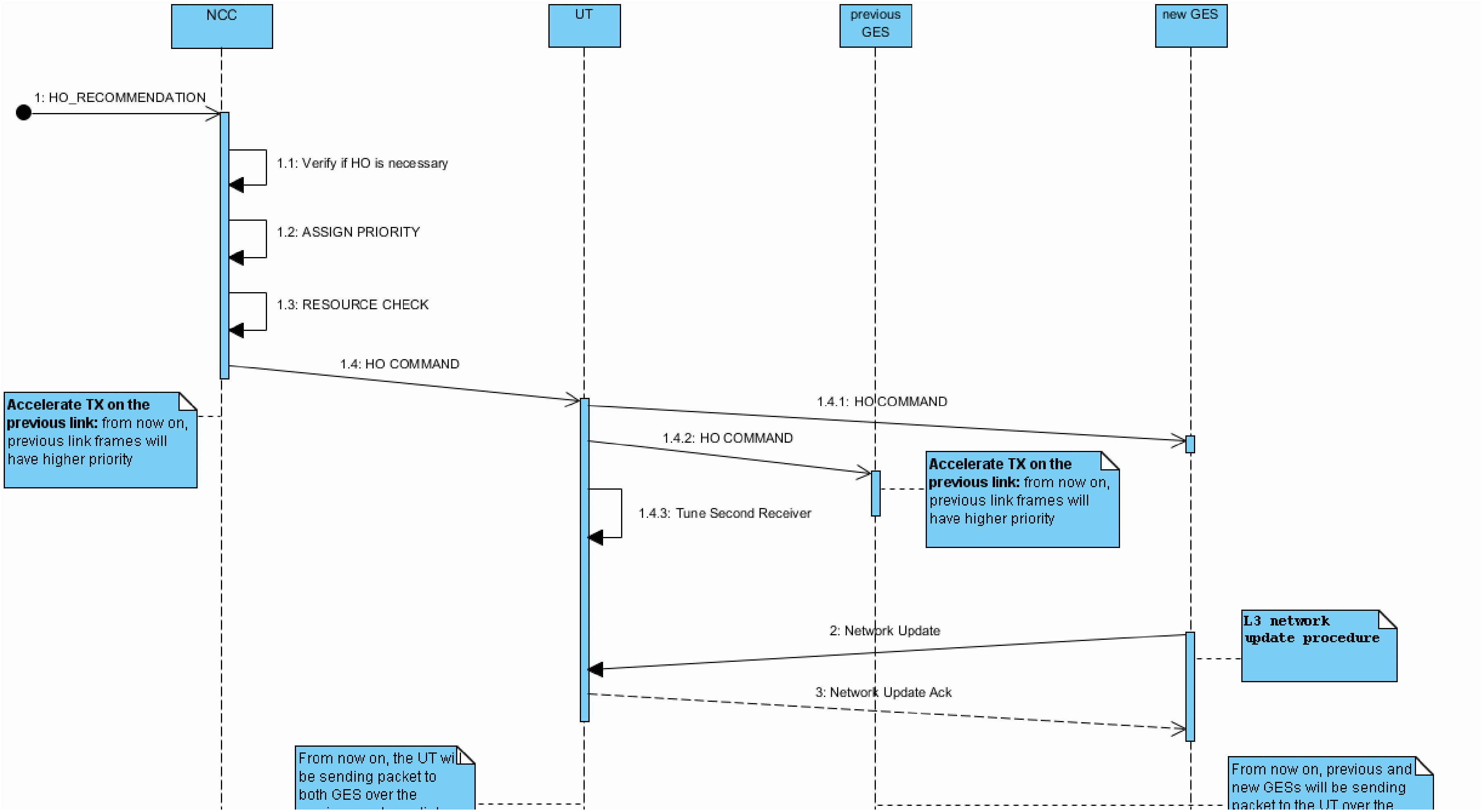



**Figure 18-7: GES change with previous & new GES connected to the same LAN**

## 18.8 GES change, different LAN



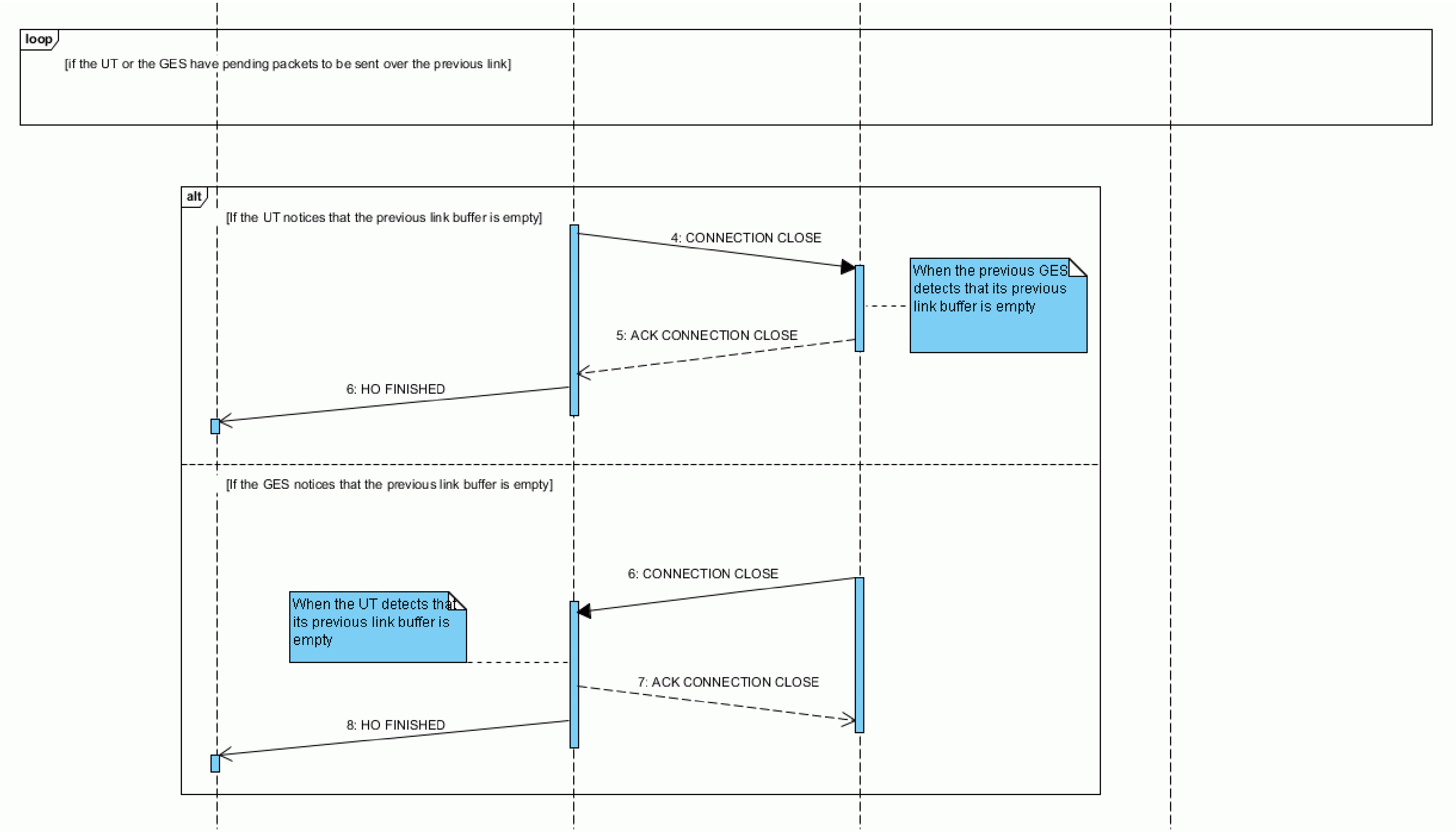



**Figure 18-8: GES change with previous & new GES connected to different LAN**

# 19. ANNEX G: GROUND TO GROUND SIGNALLING SPECIFICATION

[To be specified after system architecture consolidation]

# 20. ANNEX H: ACM MECHANISM IMPLEMENTATION GUIDELINES

This Annex presents some guidelines for the ACM mechanism implkementation.

**Previous CSREQ-6460**

The LDPC decoder shall be able to provide the BBFRAME at $N_{reduced}$ number of iterations. The $N_{reduced}$ number of iterations shall be configurable depending on the MODCOD.

## 20.1 Fast ACM mechanism

**Related to CSREQ-7320**

The Hysteresis mechanism between slow and fast mechanism can be based on the following strategy:

- A “Prevent MODCOD upgrade” timer shall be started each time a switch to the most robust MODCOD is decided using the Fast ACM Mechanism.
- While the “Prevent MODCOD upgrade” timer is running, any switch to a less robust MODCOD shall be prevented.
- The “Prevent MODCOD upgrade” timer duration should be around 90 seconds. This hysteresis mechanism would allow to reduce the signalling required when the aircraft evolves at high latitude where banking false detection are occurring more often due to the highest variability of the SNIR.

## 20.2 Slow ACM mechanism

**Related to CSREQ-7090**

The Slow ACM mechanism can monitor the PER for each MODCOD getting the decoded packet at a reduced number of LDPC decoder iterations ($N_{reduced}$).

**Previous CSREQ-7100**

The Slow ACM mechanism can implement the transitions as follows: to the next more robust MODCOD (downgrade) or to the next best available less robust MODCOD (upgrade).

(Note: for instance, assuming that the current MODCOD used by the UT is MODCOD3, the slow mechanism only allow the transitions to MODCOD2, in case of downgrade, or MODCOD4 or higher in case of upgrade)

**Previous CSREQ-7110**

For each MODCOD, a PER threshold at a reduced number of decoder iteration ($N_{reduced}$) shall be defined so that when the measured PER at this reduced number of decoder iteration is below the PER threshold it would guarantee that the PER after a nominal number of iterations ($N_{nominal}$) is below the target PER. The threshold shall be defined by two parameters:

- $N_{reduced}$ decoder iterations value
- The PER threshold al Nreduced iterations

**Related to CSREQ-7280**

The PER threshold at a reduced number of decoder iteration shall be measurable over less than 1000 Code Word. As a consequence, the PER threshold at a reduced number of decoder iterations shall be above $10^{-1}$

**Previous CSREQ-7130**

The $N_{reduced}$ interations and the PER threshold at $N_{reduced}$ decoder iterations may be the ones reported in Table 20-1: Recommended $N_{reduced}$ decoder iterations and PER threshold at $N_{reduced}$ decoder iterations for the FWD Link MODCODs.

| MODCOD Id | Modulation | Code rate | $N_{reduced}$ decoder itetarions | PER threshold at $N_{reduced}$ decoder iterations |
|---|---|---|---|---|
| MODCOD1 | QPSK | 0.33 | | |
| MODCOD2 | QPSK | 0.50 | 3 | 0.1 |
| MODCOD3 | QPSK | 0.67 | 2 | 0.142 |
| MODCOD4 | 8PSK | 0.50 | 4 | 0.272 |
| MODCOD5 | 8PSK | 0.67 | 3 | 0.0845 |
| MODCOD6 | 16APSK | 0.67 | 3 | 0.121 |

**Table 20-1: Recommended $N_{reduced}$ decoder iterations and PER threshold at $N_{reduced}$ decoder iterations for the FWD Link MODCODs**

**Related to CSREQ-7140**

The UT can monitor the PER using $N_{reduced}$ decoder iterations for each MODCOD and for each GES using its assigned forward link carrier.

(Note: it has been assumed that the UT uses the bursts transmitted by its assigned GES to compute the PER at $N_{reduced}$ decoder iterations despite of an Uplink Power control is put in place.)

**Previous CSREQ-7150**

The PER at $N_{reduced}$ decoder iterations for each MODCOD may be computed over a sliding window of 1000 consecutive Code Words (TBC).

**Related to CSREQ-7160**

The recommened MODCOD selection mechanism is as follows:

- MODCOD downgrade: When the PER after $N_{reduced}$ decoder iterations for the current MODCOD increases above PER threshold at $N_{reduced}$ decoder iteration, the UT shall request the GES to send further packets with the next more robust MODCOD available on the forward link.
- MODCOD upgrade: When the PER after $N_{reduced}$ decoder iterations for the next less robust MODCOD decreases below PER threshold at $N_{reduced}$ decoder iteration, the UT shall request the GES to send further packets with the next less robust MODCOD available on the forward link.

**Related to CSREQ-7170**

The recommended Hysteresis mechanism is as follows:

- A "*Prevent_MODCOD_upgrade*" timer shall be started each time a switch to a more robust MODCOD is done.
- While the "*Prevent_MODCOD_upgrade*" timer is running, any switch to a less robust MODCOD shall be prevented.

The "*Prevent_MODCOD_upgrade*" timer duration should be around 90 s (TBC).

**END OF DOCUMENT**