AX.25 Telemetry and Telecommand Transfer Frames Format

Prepared by:

Florian George

Stephane Billeter

Checked by:

Muriel Richard

Approved by:

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Swiss Space Center EPFL

Lausanne

Switzerland

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swiss space center

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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REFERENCES

Applicable Documents

[A1] AX.25 Protocol Specification http://www.tapr.org/pdf/AX25.2.2.pdf

[A2] QB50 System Requirements and Recommendations, Issue 5, 11 October 2013

References Documents

[R1] ESA-PSS-04-106 Packet Telemetry Standard

[R2] ESA-PSS-04-107 Packet Telecommand Standard

[R3] CubeSat program http://cubesat.calpoly.edu/

[R4] Cyclic Redundancy Check http://en.wikipedia.org/wiki/Cyclic_redundancy_check

LIST OF ACRONYMS

CCSDS	Consultative Committee for Space Data Systems
CRC	Cyclic Redundancy Check [R4]
EGSE	Electrical Ground-Support Equipment
EPFL	Ecole Polytechnique Fédérale de Lausanne (Swiss Federal Institute of Technology in Lausanne)
ESA	European Space Agency
ESOC	European Space Operations Centre
ESTEC	European Space Research and Technology Centre
FCS	Frame-Check Sequence
GS	Ground Station
ICD	Interface Control Document
LMTS	Microsystems for space technologies laboratory
MSB	Most Significant Bit
SSID	Secondary Station Identifier
TBD	To Be Defined
TC	Telecommand
TM	Telemetry
UI-Frame	Unnumbered Information Frame (see [A1])
VC	Virtual Channel

1 INTRODUCTION

This document describes the format of the AX.25 Transfer Frames, a simple Data Layer (layer 2)[1] protocol based on the Unnumbered Information Frames (UI-Frames) of the AX.25 protocol [A1] and adapted for space applications. It was initially designed for the SwissCube project, while not being specific to it.

The reason it is based on the AX.25 protocol is for compatibility. As with most others CubeSat projects [R3], the project makes use of the amateur radio network using amateur radio frequencies on amateur radio equipment, which uses AX.25 for "high data-rate" digital transmissions. The transfer frames must therefore be compliant with the format defined in the AX.25 protocol to be able to use the existing amateur radio equipment.

Only the Unnumbered Information Frames (UI-Frames) of the protocol are used to allow for easy implementation on-board the spacecraft, which have limited resources. But to provide the necessary functionalities of space-to-ground transportation in the Transfer Frames (e.g. frame loss detection, on-board arrival detection, time correlation, etc.), a Secondary Header has been added to the Telemetry Transfer Frame. The fields of this Secondary Header are adapted from the Packet Telemetry Standard [R1]. Moreover in order to allow the Transfer Frames to carry telecommands larger than the maximal size of their Information Field, an optional Secondary Header has been added to manage the segmentation of telecommands over multiple Transfer Frames. The fields of this Secondary Header are adapted from the Packet Telecommand Standard [R2].

In result, the hereby-defined protocol is asymmetric, which is a property common to space-to-ground protocols. This is due to the fact that resources are very unbalanced between the spacecraft hardware and ground hardware.

[1] OSI model: http://en.wikipedia.org/wiki/OSI_model

2 TRANSFER FRAMES FORMAT

All the data communication is done with the use of Unnumbered Information Frame (UI-Frame) from the AX.25 protocol [A1]. The term AX.25 Transfer Frame therefore refers to an AX.25 UI-Frame.

If not specified otherwise, all sizes are in bits.

2.1 AX.25 Transfer Frame Format

2.1.1 Unnumbered Information Frame

As described in the protocol, the unnumbered frame (U frame) is structured as follows:

Flag	Address	Control	Info	FCS	Flag
01111110	112	16	N*8	16	01111110

The Transfer Frames are compliant AX.25 Unnumbered Information Frame (UI-Frame) [A1], detailed below.

Flag	AX.25 Transfer Frame Header (128 bits)				Information Field	Frame-Check Sequence	Flag
	Destination Address	Source Address	Control Bits	Protocol Identifier			
8	56	56	8	8	0-2048	16	8

2.1.2 Flag (8 bits)

The flag field is one octet long. Because the flag delimits frames, it occurs at both the beginning and end of each frame. Two frames may share one flag, which would denote the end of the first frame and the start of the next frame. A flag consists of a zero followed by six ones followed by another zero, or 01111110 (0x7E). In order to ensure that the flag bit sequence mentioned above does not appear accidentally anywhere else in a frame, bit stuffing is applied. The sender monitors the bit sequence for a group of five or more contiguous '1' bits. Any time five contiguous '1' bits are sent, the sending station inserts a '0' bit after the fifth '1' bit. During frame reception, any time five contiguous '1' bits are received, a '0' bit immediately following five '1' bits is discarded.

2.1.3 AX.25 Transfer Frame Header (128 bits)

Destination Address (56 bits)

Callsign (48 bits)																SSID							
C1 (8 bits)								C2 to C5	C6 (8 bits)								8 bits							
X	X	X	X	X	X	X	0	…	X	X	X	X	X	X	X	0	0	1	1	S	S	I	D	0

The destination address consists of the callsign and the Secondary Station Identifier (SSID) of the destination. The callsign is made up of 6 upper-case letters, numbers or space ASCII characters only (7 bits). The SSID is a four-bit integer that uniquely identifies multiple stations using the same amateur callsign.

The 6 characters of the callsign are placed in the first 6 octets of the field (C1 to C6). Each character bits are shifted one bit on the left and the least significant bit is set to '0'.

The SSID is placed in the bits 3-6. The other bits of the field have a fixed value.

Remark: The destination address field is fixed as the CubeSat is paired with one University.

Remark: In QB50, the SSID in the destination of a Telemetry Transfer Frame (downlink) is used to identify the type of date as defined in QB50-SYS-1.5.13 [A2].

Source Address (56 bits)

Callsign (48 bits)																SSID							
C1 (8 bits)								…	C6 (8 bits)								8 bits							
X	X	X	X	X	X	X	0		X	X	X	X	X	X	X	0	0	1	1	S	S	I	D	1

The source address consists of the callsign and the Secondary Station Identifier (SSID) of the source. It is the callsign of the satellite on the downlink and the callsign of the Ground station on the uplink.

The callsign is made up of upper-case alpha and numeric ASCII characters only (7 bits). The SSID is a four-bit integer that uniquely identifies multiple stations using the same amateur callsign.

The 6 characters of the callsign are placed in the first 6 octets of the field. Each character bits are shifted one bit on the left and the least significant bit is set to '0'.

The SSID is placed in the bits 3-6. The other bits of the field have a fixed value. Note that the last bit differs from the Destination Address field. It indicates that the octet to which it belongs is the last octet of the address fields.

Control Bits (8 bits)

The control field identifies the type of frame being passed and controls several attributes of the Layer 2 connection. For an AX.25 Unnumbered Information Frame, its value is always 00000011 (0x03).

Protocol Identifier (8 bits)

Shall be 11110000 (0xF0).

2.1.4 Information Field (0 to 2048 bits)

The Information Field contains the data specific to the usage of the AX.25 Transfer Frame. The maximum size of the Information Field is 2048 bits.

2.1.5 Frame-Check Sequence (16 bits)

The Frame-Check Sequence is a 16-bit number calculated by both the sender and the receiver of a frame. It ensures that the frame was not corrupted by the transmission medium. The

Frame-Check Sequence is a CRC calculated using polynomial $x^{16} + x^{12} + x^5 + 1$ (also called CRC-CITT).

2.2 Telemetry Information Field Usage

When the Transfer Frame is used as a Telemetry Transfer Frame, a Secondary Header shall be present at the start of the Information Field before the transported data. An optional Time field shall also be appended at the end.

<table>
<tr><td colspan="11">AX.25 Transfer Frame Information Field (0-2048)</td></tr>
<tr><td colspan="6">Telemetry Transfer Frame Secondary Header (32 bits)</td><td rowspan="3">Data</td><td colspan="4">Telemetry Transfer Frame Trailer (8-72 bits)</td></tr>
<tr><td colspan="3">Frame Identification (8 bits)</td><td rowspan="2">Master Frame Count</td><td rowspan="2">Virtual Channel Frame Count</td><td rowspan="2">First Header Pointer</td><td colspan="3">Frame Status (8 bits)</td><td rowspan="2">Time</td></tr>
<tr><td>Version Number</td><td>Virtual Channel ID</td><td>Spare</td><td>Time Flag</td><td>Spare</td><td>TC Count</td></tr>
<tr><td>2</td><td>3</td><td>3</td><td>8</td><td>8</td><td>8</td><td>0-2008</td><td>4</td><td>2</td><td>2</td><td>0-64</td></tr>
</table>

2.2.1 Telemetry Transfer Frame Secondary Header (32 bits)

The Telemetry Transfer Frame Secondary Header is located at the beginning of the Information Field. It adds supplementary information needed for proper communication with the spacecraft.

Frame Identification (8 bits)

Version Number (2 bits)

These two bits (which occupy the two most significant bits of the 16-bit field) are reserved for potential evolution of the Transfer Frame structure. In this standard, only one version number (version 1) is recognized, which specifies the Transfer Frame structure described herein. This number is '00'.

Virtual Channel ID (3 bits)

This 3-bit field enables up to eight Virtual Channels to be run concurrently by a particular spacecraft on a particular physical data channel.

When only one Virtual Channel is foreseen to be on the physical data channel, the number of the Virtual Channel shall be '0'. When more than one Virtual Channel exists, Channel '0' shall always be transmitted whenever spacecraft time correlation is required.

Channel '0' is coded '000', Channel '1' is coded '001' and so forth, the last channel ('7') being coded '111'.

The use of Virtual Channels enables the separation of the transmission flows of multiple sources so for example the telecommands acknowledgements don't have to wait for the payload to end filling up the Telemetry Transfer Frame.

Spare (3 bits)

This 3-bit field is reserved for future application. It is required that the field be set to the value '000'.

Master Frame Count (8 bits)

The purpose of the Master Channel Frame Count field is to provide an 8-bit sequential up-count (modulo 256) of each Transfer Frame generated by the spacecraft on a given physical data channel (the Master Channel). It allows the ground to detect the loss of a frame during the transmission.

The counter must be left free-running, i.e. it shall not be short-cycled.

Virtual Channel Frame Count (8 bits)

The purpose of the Virtual Channel Frame Count field is to provide individual accountability for each of the Virtual Channels. The 8-bit field represents a sequential up-count (modulo 256) of the frames assigned to each of the Virtual Channels. It is used in association with the Virtual Channel ID field to maintain a separate counter for each of up to eight separate Virtual Channels. Together with the Master Frame Count, it allows the ground to detect from which Virtual Channel the lost frame was. Note that there is no mechanism for the retransmission of lost frames; actions shall be taken at the application level if the contained packets were to have to be retransmitted.

The counter must be left free-running, i.e. it shall not be short-cycled.

First Header Pointer (8 bits)

The First Header Pointer specifies the octet number within the data field (starting at octet 0, which is the first octet of the frame data field) that contains the first octet of the first packet header. It allows knowing where the first packets header is in the frame even if the previous frame(s) were lost.

If no packet header starts in the data field, the First Header Pointer shall be set to '11111111' (all ones, 0xFF).

If the frame doesn't contains any packet fragment, i.e. raw payload data, the First Header Pointer shall be set to '11111110' (all ones minus one, 0xFE).

2.2.2 Data (0 to 2008 bits)

This field, which must exist as an integral number of octets, contains user application data (e.g. Telemetry Packets) to be transferred from the spacecraft to the ground.

Telemetry Packets shall be inserted contiguously into the data field on octet boundaries, the location of the octet containing the first header being indicated by the First Header Pointer in the frame header. Subsequent headers are located by examining the 'length' field in each packet.

When the Virtual Channel is active and no data are available for transmission from any source, a Telemetry Transfer Frame with only the headers (AX.25 and Secondary), the Time field and an empty Data field shall be sent by the spacecraft data system for the purpose of keeping the packet extraction process on ground synchronized. The First Header Pointer field shall be set to 0xFF.

The maximum length of the frame data field is the maximum size of the I-Field (2048 bits) minus the length of the header and trailer fields, therefore 1952 to 2008 bits (244 to 251 octets) depending of the value of Time Flag.

2.2.3 Telemetry Transfer Frame Trailer (0 to 72 bits)

Frame Status (8 bits)

Time Flag (4 bits)

This 4-bit field gives the size of the Time Field located there after at the end of the Information Field. The following values are applicable (bit 0 is the MSB):

Bit 0	Meaning
'0'	No Time field (bits 1-3 shall be set to '000').
'1'	Bits 1-3 provide the size of the Time field in octets + 1. E.g.: '1000' means a Time field of 1 octet (8 bits). '1111' means a Time field of 8 octets (64 bits).

Spare (2 bits)

This 2-bit field is reserved for future application. It is required that the field be set to the value '00'.

Ideas: Last TC Frame Corrupted Flag, Safe-Mode Enabled Flag

TC Counter (2 bits)

This 2-bit field contains a sequential up-count (modulo 4) of each Telecommand Transfer Frame received and declared valid. It allows the ground to detect if a Telecommand Transfer Frame was received on-board or lost/corrupted during transmission. For the detection to work properly, the Telemetry Transfer Frame generation rate must be greater than the Telecommand Transfer Frame generation rate.

Time (0 to 64 bits)

This field contains the onboard time that correspond to moment the End Flag of the previous frame was transmitted across all Virtual Channels (previous frame in the Master Frame Count). The presence and size of this field depend of the value in the Time Flag field.

2.3 Telecommand Information Field Usage

When the Transfer Frame is used as a Telecomand Transfer Frame, a Secondary Header can be present at the start of the Information Field before the transported data in order to support large telecommands, i.e. more than 256 octets. This secondary header is optional, see 2.3.3, but its use is recommended and should be consistent throughout the whole mission.

Remark: In the QB50 SCS, this can be configured in the TM/TC Front End settings.

There can be only one complete Telecommand Packet or one segment from a single Telecommand Packet per Telecomand Transfer Frame.

The Telecommand Transfer Frame Format has no support for Virtual Channels or multiplexing.

AX.25 Transfer Frame Information Field (0-2048)		
Telecommand Transfer Frame Secondary Header (8 bits)		Data
Segment Header (8 bits)		
Sequence Flag	Spare	
2	6	0-2040

2.3.1 Telecommand Transfer Frame Secondary Header (8 bits)

The Telecomand Transfer Frame Secondary Header is located at the beginning of the Information Field. It adds supplementary information needed for the segmentation of large telecommands.

Segment Header (8 bits)

Sequence Flag (2 bits)

These two bits (which occupy the two most significant bits of the 8-bit field) indicate the type of frame in a sequence of segments.

Bit 0	Bit 1	Meaning
'0'	**'1'**	First Segment: the frame contains the first segment of a telecommand
‘0’	**‘0’**	Continuing Segment: the frame contains an intermediate segment of a telecommand
‘1’	**‘0’**	Last Segment: the frame contains the last segment of a telecommand
‘1’	**‘1’**	No Segmentation: the frame contains one complete telecommand without segmentation

Spare (6 bits)

This 6-bit field is reserved for future application. It is required that the field be set to the value '000000'.

2.3.2 Data (0 to 2040 bits)

This field, which must exist as an integral number of octets, contains user application data (e.g. Telecommand Packets) to be transferred from the ground to the spacecraft.

The maximum length of the frame data field is the maximum size of the I-Field (2048 bits) minus the length of the header fields, therefore 2040 bits (255 octets).

2.3.3 Without the Telecommand Transfer Frame Secondary Header

If the secondary header is not used in Telecommand Transfer Frames, there can be only one Telecommand Packet per Telecommand Transfer Frame and it must fit in the Information Field of one frame. Therefore the maximum size of a Telecommand Packet is 2048 bits (256 octets). In this configuration, the Telecommand Transfer Frame does not contain any additional field. Instead the telecommand data is put directly inside the Information Field of the AX.25 Transfer Frame.